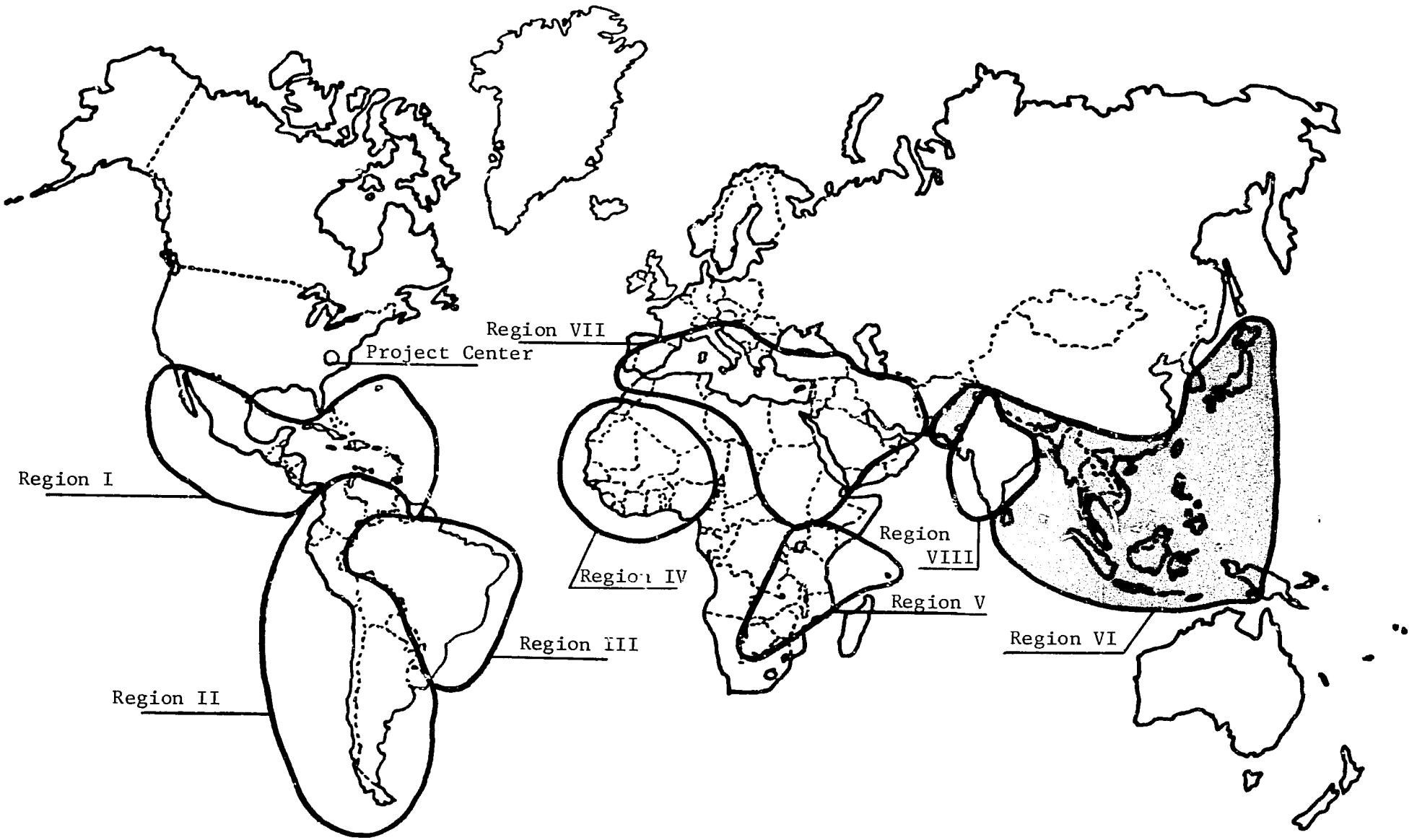

THE EIGHT INTERNATIONAL MELOIDOGYNE PROJECT REGIONS

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INTERNATIONAL MELOIDOGYNE PROJECT

IMP

Contract No. AID/ta-c-1234

Proceedings of The Third Research Planning Conference on Root-Knot Nematodes, Meloidogyne spp.

Bangladesh
Burma
Indonesia
Japan
Korea
Malaysia

REGION VI

Nepal
Pakistan
Philippines
Sri Lanka
Taiwan
Thailand

July 20-24, 1981
Jakarta, Indonesia

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PREFACE

The third Asian regional research and planning conference on root-knot nematodes, July 20-24, 1981, Jakarta, Indonesia, owes its organization jointly to the Agency for Agricultural Research and Development, Central Research Institute for Food Crops (AARD, CRIFC) in Bogor, Indonesia, and to the International Meloidogyne Project headquartered at North Carolina State University, Raleigh, N.C., U.S.A. Scientists from 12 countries representing Region VI of the International Meloidogyne Project (Bangladesh, Burma, Indonesia, Japan, Korea, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, and Thailand) have contributed progress reports to this conference proceedings. Of these, Bangladesh, Burma, Nepal, and Pakistan are new to Region VI and are heartily welcomed. Region VI is one of eight regions forming a network of approximately 100 scientists from 60 nations working toward a better understanding of the biology of root-knot nematodes.

Scientists from the participating Asian countries are affiliated with nematology research units at universities, agricultural experiment stations, and research institutes. As in the two earlier conferences, the aim of this gathering is to report on studies made, evaluate overall progress, and discuss common constraints. The information acquired adds substantially to the framework established by earlier region conferences. The continued accumulation of information on root-knot nematodes promises to promote increased food production and a better standard of living in developing nations.

Though increased food crop production through control of root-knot nematodes is still our major objective, emphasis in the accomplishment of this goal is shifting to three primary areas: breeding for resistance, cropping systems research, and technology transfer. The first two areas of research provide specific control methods: resistant cultivars, effective rotations, and favorable cultural practices. Technology transfer involves the dissemination of the acquired control information from the researcher to the grower. The reports of work groups assigned to discuss these pertinent topics appear in this volume.

Gratitude and appreciation are extended to all conference participants for their dedicated efforts through which significant knowledge is being compiled on local and regional root-knot nematode research.

Special thanks are also due to the members of the steering and local organization committees (listed below), headed by Sadikin Sumintawikarta and Dewa Made Tantera, respectively. Their efforts in making this a successful conference and an enjoyable visit are heartily appreciated.

J. N. Sasser, Principal Investigator

Steering Committee

Mr. Sadikin Sumintawikarta	Director General AARD
Dr. Marah Rusli Hakim	Director CRIFC-AARD
Dr. J. N. Sasser	Principal Investigator, IMP

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Mr. Mahyuddin Syam	Announcer
Mrs. Atiek Sri Duriat	Announcer

OPENING REMARKS

D. M. Tantera
Chairman of the Organizing Committee

Distinguished scientists from abroad, my dear colleagues from Indonesia, ladies and gentlemen:

We are happy to see all of you here this morning. Some of you have circled half the globe to come to this city of Jakarta; some of you have come from places closer to this region; some of you are our dear friends from Asian countries. We are extremely grateful to have here representatives from Thailand, Malaysia and Philippines.

Some of you I have never even met before, particularly Drs. Sasser, Triantaphyllou, and Smith. I have known you only by name before this conference; now we have the honor of knowing you personally. We welcome you to this part of the world.

My first encounter with Meloidogyne spp. dates back to the summer of 1968 when I took a post-graduate nematology course in Wageningen under Dr. Oostenbrink in which Drs. Weinhorst, Coomans, de Conink, and Loof taught how to look at, inspect and identify nematodes. These small creatures were so interesting to look at, and in those days, when I was a little bit younger, there was much interest in them. Our teachers were all great scientists, great motivators for young scientists like us at that time.

I have here Dr. Y. E. Choi from Korea. We were in the same course in Wageningen, thirteen years ago. During that course, we heard a lot about research done by Dr. Sasser and Dr. Triantaphyllou who are here today. I sincerely hope that both of you can further stimulate ideas and assurance to our younger nematologists who are gathered here.

As the organizer of this conference, I once again welcome all of you to this country, to Jakarta and its surrounding city of Bogor, and later on in a field trip to the country side of West Java. We again thank you for taking your valuable time to visit us here.

To our colleagues from Indonesia which are included here, to some scientists from other countries such as Japan and the United States who work with us, and to our friends from the agrochemical companies, I herewith extend our appreciation for your being here with us today and the next several days.

The Organizing Committee, as you see, is composed mainly of young scientists in pathology. Including the typists, there are 12 of us out of about 150 plant pathologists in this country. We have no more than 10 nematologists. They are extremely scarce for a country as big as Indonesia.

The main reason we agreed to organize this conference in Indonesia at this time was somewhat related to the scarcity of nematologists. We organized this conference here to stimulate interest in nematology. Because we have only a few plant pathologists, there has been a tendency for most of us to work on the most pressing disease problem, and nematode diseases have been somewhat neglected. I was supposed to work in nematodes after the course in 1968, but when I returned, I worked on rice pathology, especially diseases, because in 1969 and the early seventies, we had an outbreak of tungro virus. Now we have younger pathologists such as Wijaja Hadisoeganda and his colleagues, young nematologists. We are now motivated to continue stimulating nematode research in this country.

Therefore, in the future, we hope to participate more in nematode research, especially on Meloidogyne and some other important species such as Tylenchulus, Radopholus, Aphelenchoides, and others. As for Meloidogyne spp., as you know from old literature, M. javanica was identified in 1885 by Treub as Heterodera marioni on a sugarcane plantation at Cirebon, West Java. Now we have M. javanica, M. incognita on the solanaceous crops potato and tomato, and M. arenaria on legumes.

On citrus we have Tylenchulus semipemetrosus; on pepper we have Radopholus similis and Meloidogyne spp.; and on rice we have Aphelenchoides besey.

Our nematology research is relatively very young. In late 1965, one researcher at University of Gajah Mada in Jogyakarta, Central Java, started a preliminary research survey on plant-parasitic nematodes of several crops. In 1970, a small nematology laboratory was established at Segunung, West Java, by the Research Institute for Horticulture. Their young staff member (Mr. Wijaja Hadisoeganda) began to work on Meloidogyne spp. In late 1970, the Central Research Institute for Agriculture in Bogor hired a young nematologist (Mr. M. Herman). He started to work on parasitic nematodes on legumes, mainly with Meloidogyne javanica and M. incognita. The work

of these men has actually produced some significant findings related to the role of Meloidogyne in tropical crops.

Much more work needs to be done in order to document the terrible damage done by these species on our food crops and to study intensively the biology of Meloidogyne spp. in the tropical regions and how they differ from those in the temperate regions. This is the main reason we organized the Third Region VI Congress of IMP in Jakarta.

The organization of the sessions in this conference is entirely based on what Dr. Sasser had requested of us. This includes 4 days of solid sessions, which I have broken into two parts by inserting a one-day field trip in the middle. Otherwise it will be rather tiring for the delegates. On the field trip, which will be on the third day, we will travel through the maintained areas of West Java, and visit two research laboratories, two botanical gardens and one presidential palace. I hope these arrangements satisfy both the scientific curiosity and exploratory interests of our delegates. Since I first mentioned the delegates, I probably should also report here that according to our list, we have delegates from 12 countries in this particular meeting: Bangladesh, Burma, Japan, Malaysia, Philippines, Pakistan, Sri Lanka, Taiwan, Korea, Peru, Thailand, and USA. The Indonesian delegates in this conference have the status as observer. Aside from the delegates I just mentioned, we have observers from other institutions, universities and agrochemical companies. Some of them have in one way or another significantly contributed to the success of this conference. I therefore thank all parties concerned who have made a contribution to the success of this conference. Among others, I would like to mention here that we have support from PT. Parama Bina Tani, FMC-International, PT. Du Pont, PT. Rohm and Haas of Indonesia, PT. Bayer Agrochemicals, and The Central Research Institute for Food Crops at Bogor.

Finally, I would like to express my sincere gratitude to Dr. Sasser and Dr. Smith who have trusted us to organize the conference this time in Jakarta. Furthermore, I would like to thank all my colleagues in the Organizing Committee for their enthusiasm in the preparation of this conference and also the Hotel Indonesia Sheraton which has arranged for such a nice Madura room in which to hold this opening ceremony and conference.

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A.I.D. AGRICULTURE RESEARCH PROGRAMS

Mark A. Smith
Agricultural Production Division
Bureau for Science and Technology
Agency for International Development (A.I.D.)
Washington, D.C.

Introduction

Before I discuss the agricultural research programs of the United States Agency for International Development (A.I.D.), I would like to discuss in general terms why agricultural research and development programs are vitally needed by all countries, and particularly in developing countries with large and rapidly expanding populations.

A recent report commissioned during the administration of former U.S. President Jimmy Carter, entitled "Global 2000," gives us some insight into population trends and agriculture production needs in the year 2000 as compared to 1975 (Table 1). The data contained in Table 1 are projections and thus not precise. However, they are considered to be well-formed estimates of general population trends that will be encountered by the year 2000.

The developing countries in Africa, Asia and Latin America will have far greater demands placed on their agricultural production capabilities because of rapidly expanding populations than the developed countries of North America and Western Europe, as well as Australia, Japan and New Zealand where the population growth is not as rapid. Not only will many countries of Africa, particularly Sub-Saharan Africa, Asia and Latin America, need to dramatically increase their food production capabilities, but they will need to produce this food on not very much more land. Land under cultivation is projected to increase only 4 percent by 2000, primarily because most good agricultural land is already in use. In 1970 the food from one hectare of land supported 2.7 people, but by 2000 that same hectare must produce sufficient food to support 4.0 people.

These projections present a tremendous challenge and opportunity to those of us involved in plant protection research. Estimates indicate that plant pests reduce production of basic food crops worldwide 20 to 40 percent

annually. Dr. Sasser and his cooperators in the International Meloidogyne Project (IMP) have estimated that root-knot nematodes alone and in combination with other pests and diseases cause a 10 to 12 percent loss annually among a broad range of crops, particularly in the tropics and subtropics. If we, as plant protectionists, can significantly reduce losses due to plant pests, we can make a major contribution to stabilizing and ultimately increasing world food supplies.

Thus, the need to increase agricultural productivity through research and development is vitally important to future generations and is why A.I.D. and many other bi-lateral and international organizations are heavily involved in improving agriculture research capabilities in developing countries. In fact, the U.S. Government in creating A.I.D. in 1961 provided a method to establish partnerships with developing countries in the broad field of agricultural processes related to the production of crops and the rural income generation.

A.I.D. Agriculture Research Programs

A.I.D., organizationally, is divided into a number of Offices and Bureaus located in Washington, D.C. Four Regional Bureaus (Africa, Asia, Latin America and the Caribbean, and Near East) coordinate the work of nearly 60 A.I.D. Missions located around the world. The Bureau for Science and Technology, also located in Washington, D.C., is a Bureau organized to supply technical input into the major interests of the Regional Bureaus and their associated Missions. Consequently, Regional Bureaus and the Bureau for Science and Technology work to assure that agriculture and other development projects reflect Mission and host country needs. The Bureau for Science and Technology maintains a permanent technical staff. However, the Bureau's principal source of technical expertise for agricultural projects is U.S. Land-Grant and 1890 universities and institutions.

A.I.D. agriculture research activities are sponsored through:

1. The International Agriculture Research Centers (IARCs), as one of the principle donors in the Consultative Group on International Agriculture Research (CGIAR),

2. Collaborative Research Support Programs (CRSPs) with U.S. colleges and universities working in cooperation with developing country institutions,

3. Other projects and contracts with U.S. Institutions,

4. Individual Mission/Host Country projects.

The CGIAR-IARC research and training activities deal with crops and livestock that encompass three-quarters of the food supply to developing countries. Table 2 lists the CGIAR-IARCs and their major research areas. A.I.D. also assists in the financial support of other non-CGIAR/IARCs, including the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, the International Fertilizer Development Center (IFDC) in Alabama, U.S.A., and the International Soybean Program (INTSOY) in Illinois, U.S.A.

The CRSPs are a mechanism set up under Title XII of the amended Foreign Assistance Act which provides ". . . support for long-term collaborative university research (in the developing countries to the maximum extent possible) on food production, distribution, storage, marketing and consumption." Four CRSPs have been established at this time. The subject matter areas and the Management Entities of these CRSPs are: Small Ruminants, University of California-Davis; Sorghum/Millet, University of Nebraska; Beans and Cowpeas, Michigan State University; Soil Management, North Carolina State University.

Other research projects with U.S. institutions provide a linkage through Regional Bureaus and Missions to furnish technical assistance, training and important research capabilities in developing countries. Examples of these research project areas are: irrigation water use, biological nitrogen fixation, control of vertebrate pests, tissue culture, seed industry and development, food grain storage and marketing, and pest management. Projects in pest management include weed control, control of barley diseases, pest management and related environmental protection, postharvest food losses, and the subject of this workshop--root-knot nematodes.

The Regional Bureaus and associated Missions worldwide place major emphasis on agricultural improvement efforts in developing countries, and, consequently, fund a large number of projects in agriculture research and development. It would be impractical to enumerate all these projects here since they number in the hundreds. However, some of the new or planned projects that may be of interest to the participants at this conference, because of their pest management aspects, are:

1. Central American coffee rust control project,

2. Jordan Valley Agriculture Services Project, with a major pest management control component,

3. ASEAN Plant Quarantine Training Project, headquartered in Kuala Lumpur, Malaysia, to serve all ASEAN countries,

4. Indonesia Comprehensive Pest Management Project.

Summary

Projections indicate populations will double in Africa and Latin America between 1975 and 2000. In Asia and Oceania, the most populous region of the world, a 60 percent increase is anticipated during this time. Most countries in these regions will have to greatly improve their agriculture production capabilities to meet only the minimal nutritional needs of their people by the year 2000. Consequently, A.I.D. and other bi-lateral and international assistance organizations have placed major emphasis on improving food production capabilities of developing countries through agriculture research and development activities.

A.I.D.'s Bureau for Science and Technology works closely with the Regional Bureaus in Washington, D.C., who in turn work with A.I.D. Missions worldwide to develop agriculture research projects relevant to the needs of host countries. Through this working partnership, agricultural research projects that will have a long range impact on increasing food production capabilities of the developing world are implemented.

Table 1. Population Projections for World, Major Regions

Area	Population 1975	Population 2000	% Increase by 2000	Average Annual Increase %
	--in millions--			
World	4090	6351	55	1.8
More developed regions	1131	1323	17	0.6
Less developed regions	2959	5023	70	2.1
Major Regions				
Africa	399	814	104	2.9
Asia/Oceania	2274	3630	60	1.9
Latin America	325	637	96	2.7
North America/Western Europe/ Australia/New Zealand/Japan	708	809	14	0.5

Table 2. International Agriculture Research Centers (IARCs) of the Consultative Group on International Agriculture Research (CGIAR)

IARC Names/Locations	Principal Research Programs
International Center for Tropical Agriculture (CIAT) Cali, Colombia	Cassava, field beans, rice, tropical pastures
International Center for Maize and Wheat Improvement (CIMMYT) Mexico D. F., Mexico	Maize, wheat
International Potato Center (CIP) Lima, Peru	Potatoes
International Board for Plant Genetic Resources (IBPGR) Rome, Italy	Collection, evaluation, utilization of genetic resources of important species
International Center for Agriculture Research in the Dry Areas (ICARDA) Beirut, Lebanon	Farming systems, cereals, food legumes (broad beans, lentils, chickpeas), forage crops
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Hyderabad, India	Chickpeas, pigeon peas, pearl millet, sorghum, groundnuts, farming systems
International Livestock Center for Africa (ILCA) Addis Ababa, Ethiopia	Livestock production systems
International Laboratory for Research on Animal Diseases (ILRAD) Nairobi, Kenya	Trypanosomiasis, Theileriosis
International Rice Research Institute (IRRI) Los Banos, Philippines	Rice
International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria	Farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), food legumes (cowpeas, lima beans, soybeans)
West Africa Rice Development Association (WARDA) Monrovia, Liberia	Rice
International Service for National Agricultural Research (ISNAR) The Hague, Netherlands	Provides assistance to developing countries to plan and manage research effectively
International Food Policy Research Institute (IFPRI) Washington, D.C., U.S.A.	Provide analysis of world food problems and actions to increase food supplies

RATIONALE FOR THE INTERNATIONAL *MELOIDOGYNE* PROJECT--PRINCIPAL GOALS, OBJECTIVES, AND IMPLEMENTATION

J. N. Sasser, Principal Investigator,
International *Meloidogyne* Project Headquarters
Raleigh, N.C.

The Problem

One of the major obstacles to the production of adequate supplies of food in developing nations is the damage caused by plant-parasitic nematodes, especially the "root-knot group," *Meloidogyne* species. Their world-wide distribution, extensive host ranges and involvement with fungi, bacteria and viruses in disease complexes rank them high on the list of disease agents affecting the world's food supply. Collectively, the various species of root-knot nematode attack nearly every crop that is grown. Not only are yields greatly affected, but quality is also reduced, especially for root crops such as potato, yams and peanuts.

Principal Goals

1) Increase production of economic food crops in developing nations.

2) Upgrade crop protection capabilities of developing nations.

3) Advance knowledge about one of the world's most important groups of plant-parasitic nematodes.

Specific Objectives

1) Identify species and biotypes of root-knot nematodes present within each of the eight geographical regions.

2) Determine susceptibility and/or resistance of food crops in each region to the root-knot nematodes present, and identify sources of resistant germ plasm.

3) Evaluate crop response information for the development and implementation of effective rotation schemes for control of root-knot nematodes in each region.

4) Study variability within species and populations with reference to host reaction, morphology, cytogenetics, and biochemistry, as a basis for species identification and understanding pathogenic behavior and phylogenetic relationships.

5) Evaluate various factors of the environment (past cropping history, soil type, moisture, temperature, weed hosts, and type of agriculture) with reference to distribution and survival.

6) Use the information obtained from these cooperative international studies to develop, on a regional basis, effective integrated crop protection systems for the control of root-knot nematodes.

Approach

Variations in root-knot nematode biology lead to differences in pathogenic behavior from one region of the world to another. As a result, concerted efforts on the part of scientists from various regions of the world are required if information vital for the control of these pests is to be obtained. A network of about 60 countries from eight, broad geographical regions, plus a research unit in Raleigh, N.C., U.S.A., is now cooperating on the problem. Through this network approach, it is possible to develop integrated crop protection systems based on control methods uniquely effective in each region.

The worldwide effort has the double effect of not only increasing knowledge on the biology of root-knot nematodes but also facilitating greater communication among world scientists working on the problem. Important, additional benefits of the IMP include improvement of nematode research capabilities in many developing countries and enhancement of the nematode research efforts at the various cooperating international agricultural centers. Research in each of the regions is concentrated on collection of nematode species, screening plants for resistance, recording ecological data, evaluation of nematicides, etc. The project center in Raleigh is responsible for much research on identification, morphology, taxonomy, biochemistry and cytology.

REPORT FROM SRI LANKA

P. Sivapalan
Tea Research Institute of Sri Lanka

Introduction

The crops cultivated in Sri Lanka could be broadly classified into three major groups: (a) the major plantation crops, including tea, rubber and coconut; (b) the minor export crops, including cardamom, cinchona, cloves, pepper and nutmeg; and (c) industrial field crops, including tobacco, sugarcane and pineapple.

The small-scale seasonal cultivation of crops by subsistence farmers include (a) various species of field crops like blackgram, greengram, cowpea, wingbean, groundnut (peanut), etc.; and (b) various species of vegetable crops. Rice is the staple diet of the people in this country and is cultivated by subsistence farmers in various parts of the country, other than in the highlands of the intermediate and wet zones.

On the basis of rainfall distribution and the duration of periods of dry weather, the island is broadly classified into three zones: the wet, intermediate and dry zones. These zones are in turn subdivided, in accordance with elevation, major soil groups and related climatic features, into 21 agro-ecological regions (Fig. 1).

The cultivation of the major plantation crops and the minor export crops are confined to the wet and intermediate zones. The bulk of the field and vegetable crop cultivation is concentrated in the dry zone and in the lowlands of the intermediate zone. Besides the plantation crop tea, vegetable crop cultivation dominates in the highlands of the wet and intermediate zones.

The greatest diversity of cropping systems is encountered mainly in the dry zone and, to a lesser extent, in the low and midlands of the intermediate zone.

Results of extensive surveys carried out in all agro-ecological zones of Sri Lanka have revealed that there are five species of root-knot nematodes: *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, *M. hapla* and *M. brevicauda*.

IMPORTANCE OF ROOT-KNOT NEMATODES IN SRI LANKA

Species Distribution

The most common species of root-knot nematode encountered in every agro-ecological regime is M. incognita, followed by M. javanica (Fig. 2). The latter is encountered more often in the intermediate and dry zones. M. arenaria is encountered less frequently and is limited to the mid and high elevation ranges of the wet zone and the high elevation of the intermediate zone. M. hapla is found rarely and is confined only to the highlands of the wet and intermediate zones.

M. brevicauda is a very rare species reported from only Sri Lanka and described first by Gadd & Loos in 1946. It is encountered only in a few mature old tea fields and highly localized to only one ecological zone in the wet highlands (above 1,800 m amsl). No alternate hosts have yet been found.

Economic Importance

The results of surveys carried out in the major plantation crops and in the minor export crops have revealed that these pests are very rare and are of no economic importance.

Rice, which is cultivated in most parts of the island, is also free of this pest problem.

Among the industrial crops cultivated on a large-scale, only tobacco was found to be significantly affected by this pest.

It is in the relatively small-scale subsistence type of farming of various field and vegetable crops that these pests were encountered most often and to varying degrees (Fig. 3). Details of such extensive surveys carried out in all the agro-ecological zones of Sri Lanka were presented at the last conference in Bangkok held in February 1978.

For the purpose of such an extensive survey, we necessarily had to select certain species of field and vegetable crops that are likely to be encountered in the different agro-ecological regions of this country. However, it is only a few of these field and vegetable crops that are cultivated to any significantly large extent. Consequently, if we are to assess realistically the importance of these pests as limiting factors to crop productivity, we would have to assess their occurrence and pathogenicity among this latter category of crops.

Root-knot nematodes have been encountered to the extent of causing anxiety to farmers in the tobacco-growing areas of Sri Lanka. Severe attacks have been observed and definite stunting of growth was evident. Local cultivars are available that are moderately resistant. A system of crop rotation and treatment of nursery beds is being followed at present.

Influence of Crop Rotation

During our investigations we found it very interesting to note that in the case of field crops that are cultivated in reasonably large extents, like the legumes blackgram, greengram, cowpea and the solanaceous crops red pepper, potato, tomato, etc., certain rotation sequences have been followed by the farmers. In most cases, the damage caused by root-knot nematodes to such susceptible crops was assessed to be minimal. The reason for such a situation is that, unknowingly (unknowingly as far as nematodes are concerned), a proper rotation sequence has been followed. I have reported this observation in my earlier report.

The cultivation of onion, peanut (groundnut), and the legume Sunhemp (*Crotalaria juncea*) reduces the population of both *M. incognita* and *M. javanica* very drastically. One season of growth under any of the above drastically reduces the population level of these pests. Even the most highly susceptible crops in areas that have been under any one of the above crops have shown hardly any signs of galling, even at the time of harvest.

The only two instances of crop failure observed during the entire survey were clearly on account of a crop rotation sequence not usually followed in these areas.

In the highlands of the wet zone, where intensive cultivation of vegetable crops is carried out, a similar type of rotation is followed. Root-knot nematode susceptible crops are rotated with a crop of leek, which is known to reduce the levels of both *M. incognita* and *M. javanica*.

Potential for Breeding Resistant Varieties

From the results of surveys and observations made in Sri Lanka, and the discussions I have had with the Plant Breeders of the Department of Agriculture, it has become clear that a program of breeding for resistance to root-knot nematodes would receive very low priority. On account of the fact that a proper cropping pattern is being followed in most instances,

there is hardly any demand for breeding special varieties that are tolerant or resistant to these pests. The scene may change, however, if the cultivation of such field and vegetable crops gets expanded to very large scales so as to ignore the old traditionally practiced rotation sequences and shift to high-yielding varieties that are highly susceptible to root-knot nematodes, as is the case with tobacco.

CURRENT RESEARCH ACTIVITIES

Meloidogyne brevicauda Investigations

Screening alternate hosts for susceptibility. Several species of plants have been checked for susceptibility to *M. brevicauda* during the past five years. No alternate hosts have yet been found. Since the observations made in tea seem to indicate that infestation sets in very slowly, over a protracted period, coffee and Tephrosia have continued to be grown in infested soil and are sampled periodically.

Susceptibility of tea clones to M. brevicauda. Five clones known to be either resistant or tolerant to the root-lesion nematode of tea, *Pratylenchus loosi*, and one susceptible clone were grown in an area very heavily infested with *M. brevicauda*. The plots, having 36 tea plants each, were replicated eight times in completely randomized blocks.

Regular sampling at 6-month intervals was carried out since 1969. No signs of infestation or galling were observed until 1973, i.e., five years from planting. Further assessments were suspended until 1980 (12 years from planting). It was at this assessment carried out at the 12th year from planting that signs of galling were observed (Table 1).

As seen from Table 1, the clone TRI 2142, which is resistant to the root-lesion nematode of tea, seems to be very susceptible to this species of root-knot nematode, though infestation sets in very slowly and symptom manifestation is prolonged.

Larval eclosion studies. Egg masses were removed from mature females in galled tea roots and kept singly in individual BPI dishes in distilled water so hatching could be observed. Twenty replicates were maintained for each observation over a period of four to five weeks until hatching ceased. This daily observation of egg hatch was compared with that of other species of *Meloidogyne* found in the same elevation range. The results of these observations are presented in Table 2.

The extremely low hatch of eggs from M. brevicauda appears to support field observations of a very slow and prolonged infestation potential (10 to 12 years from planting for obvious signs of infestation to appear).

Further screening for alternate hosts was suspended until the minimum inoculum level was established using tomato (Rutgers var.). This variety of tomato, though yet not known to be a host, is one that is susceptible to most species of Meloidogyne. This variety of tomato was used as a test plant with inocula ranging from 10, 25 and 50 egg masses per plant. No infestation was observed on examination at the end of four months.

Experiments are planned to be carried out by collecting larvae from 500 to 1,000 egg masses and inoculating the following host plants with such high concentrations of active larvae:

1. Tea (Clone TRI 2142)
2. Tomato (Rutgers)
3. Spinach
4. Centella asiatica
5. Coffee
6. Tobacco (NC 95)
7. Watermelon
8. Peanut

Field selections of clonal lines for resistance & susceptibility to M. brevicauda. Twelve mature tea bushes were selected in an old field heavily attacked by this species of root-knot nematode, for extreme susceptibility and complete resistance. The criteria for extreme susceptibility were heavy galling and the presence of large numbers of mature females. These tea bushes (mother plants) were rested and allowed to grow freely to remove shoots as sources of cuttings for vegetative propagation. These cuttings from the respective sources are being now propagated in the nursery. Once grown they will be transplanted into a heavily infested area in a randomized block design.

Investigations On Other Species of Meloidogyne

Differential host studies. The tests carried out so far were inconclusive. Seventeen populations of different species of root-knot nematodes are presently being multiplied on tomato (Rutgers) and a new series of tests will commence in due course using different levels of inocula.

Maintenance of nematode cultures in the greenhouse. Seven distinct populations of *M. incognita* and eight distinct populations of *M. javanica* and one each of *M. hapla* and *M. arenaria*, isolated from infested crops from the different locations representing distinctly different agro-ecological regimes, are being maintained in the greenhouse.

Attempts are now being made to multiply one population of each species in large cement-lined beds, measuring 1.5 m x 1 m and 1 m deep.

TABLE 1

EXAMINATION OF TEA CLONES FOR GALLING BY *MELOIDOGYNE BREVICAUDA* AT 12th YEAR FROM PLANTING

CLONE	GALLING INDEX	DEGREE OF RESISTANCE TO *PRATYLENCHUS LOOSI*
DT1	NIL	HIGH
TC9	HEAVY	MODERATE
K 145	MODERATE	HIGH
TRI 2024	NIL	V. LOW
TRI 2025	NIL	MODERATE
TRI 2142	HEAVY	HIGH

Note: Regular Assessments made upto 5 years from planting did not reveal any galling in any of the clones.

TABLE 2

MEAN NUMBER OF LARVAL HATCH/EGG MASS

MELOIDOGYNE SPP.

SPECIES	MEAN NO. OF LARVAE
M. incognita	531.3 ± 181.6
M. javanica	570.3 ± 120.7
M. arenaria	214.5 ± 93.3
M. hapla	357.5 ± 135.9
M. brevicauda	10.1 ± 11.3

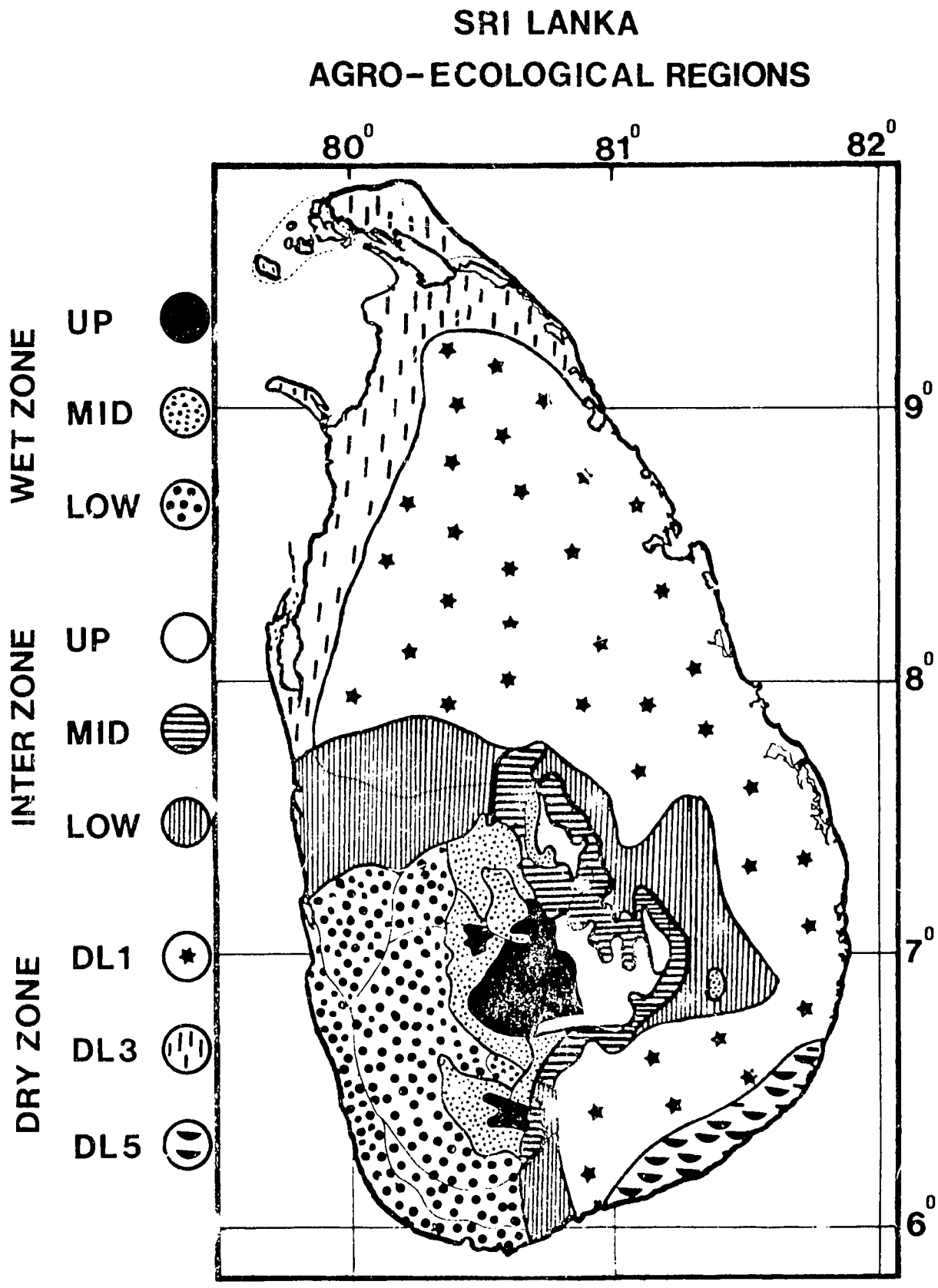
SRI LANKA
AGRO-ECOLOGICAL REGIONS
80°
81°
82°
9°
8°
7°
6°
WET ZONE
UP
MID
LOW
INTER ZONE
UP
MID
LOW
DRY ZONE
DL1
DL3
DL5

FIG. 1

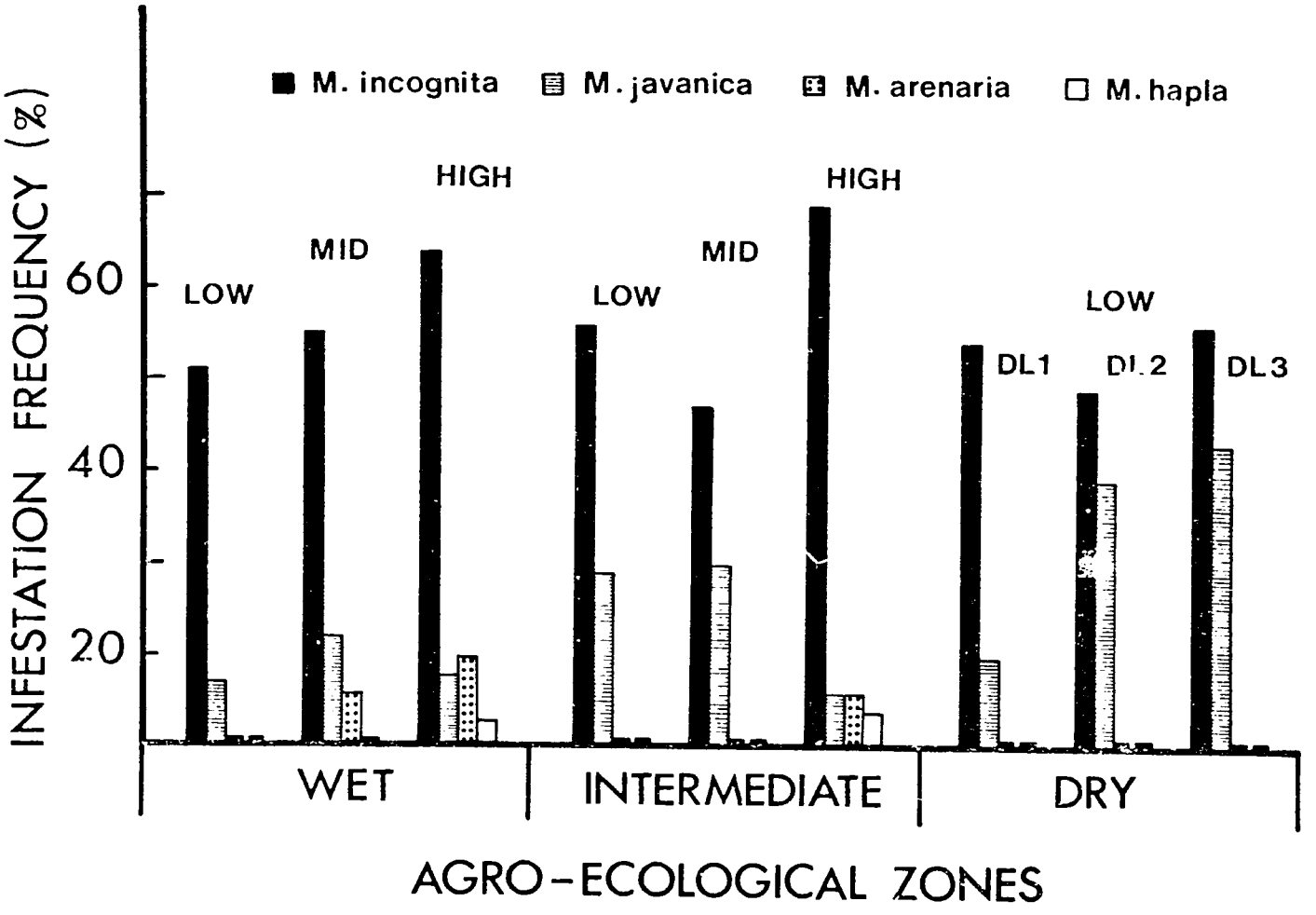

Fig. 2. Root-knot nematode species distribution in relation to agro-ecological regions and elevation.

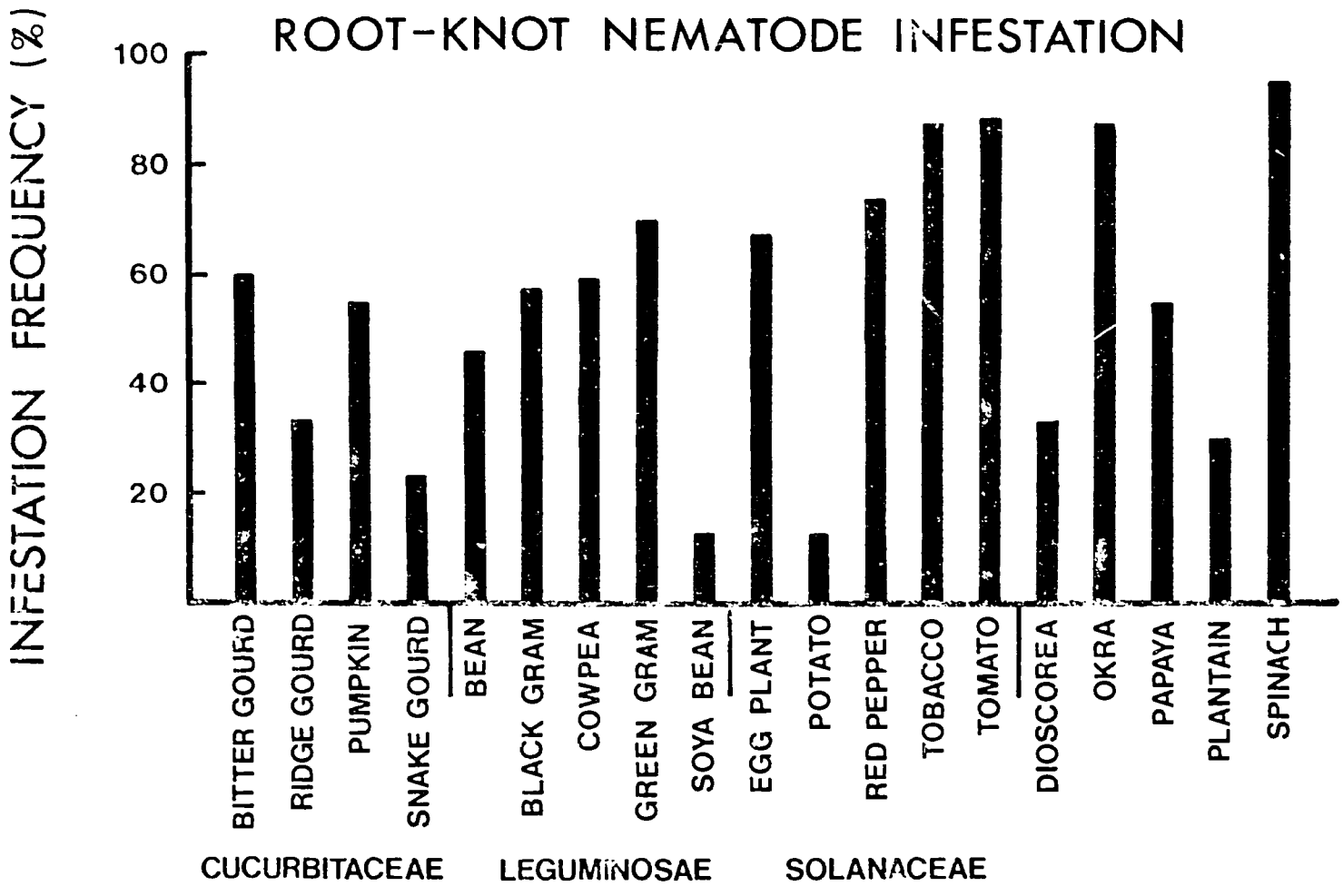

Fig. 3. Root-knot nematode infestation frequency amongst common cultivated crops.

THE ROOT-KNOT NEMATODES, MELOIDOGYNE SPP., IN KOREA

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Introduction

The status of the root-knot nematodes, Meloidogyne spp., in Korea was reported in the second Asian regional conference on the root-knot nematodes held in Bangkok, Thailand (Choi, 1978). This report will cover another portion of the work: the survey, ecology and control of Meloidogyne species carried out recently at Kyungpook National University.

Survey

Survey on the root-knot nematodes, Meloidogyne spp., is being conducted. A total of 87 soil-and-root samples were collected at different localities in 7 provinces. Four Meloidogyne species, M. arenaria, M. hapla, M. incognita and M. javanica, were identified. M. incognita was the only species found on Jaeju Island. The most dominant Meloidogyne species in Korea is M. hapla by 48.3%, M. incognita 38.0%, M. arenaria 8.0% and M. javanica 5.7% in decreasing order (Table 1).

Twenty-seven plants have been found to be attacked by root-knot nematodes; among them the most important economic crops are soybean, peanut, tomato, cucumber, carrot, watermelon, ginseng, red pepper, eggplant, tobacco, strawberry, cabbage, lettuce, edible burdock and ginger.

Differential Host Test

In order to know differential host responses of Meloidogyne species which are found in Korea, nine samples were tested. The results were as follows. Four samples responded as typical M. hapla type galls and two samples responded as M. arenaria Race 2. The remaining three samples responded as M. incognita Race 1 and Race 2 (Table 2).

Relationship Between the Yield of Peanut and Continuous Cropping Year

Field experiments were conducted to know the influence on growth and yield of peanut by M. hapla at continuous cropping field. Population of

M. hapla was increased considerably by continuous cropping of peanut at the same field (Table 3). Shoot length of peanut was shortened by continuous cropping years. Fresh weight of peanut was reduced more by continuous cropping for two years than for one year. Weight of pod showed little difference between two years of continuous cropping and one year of field cultivation by 123.5kg/10a and 127.5kg/10a. At continuous field cropping for five years, however, pod weight decreased 22.5% from first cultivation to 98.8kg/10a. Egg sac index was increased by continuous cropping of peanut, and pod weight showed negative correlation (Table 4).

Chemical Control Of Root-Knot Nematodes

Preplant chemical soil treatment was conducted in the peanut fields infested with M. hapla. The chemicals used were Telone c-17, Mocap and carbofuran. The effects of the nematicides on the root-knot nematodes M. hapla in the peanut field are shown in Table 5. At the harvesting time, population of nematodes in the soil was significantly reduced by Telone c-17, 10kg/10a as compared with the control; other treatments reduced soil population but had no significant effects. The other nematodes and other Tylenchida showed a little control effect. Growth and yield of peanuts grown in nematicide-treated soil are given in Table 6. Telone c-17 at 10kg/10a resulted in increased fresh weight and fresh pod weight significantly over the control, but Telone c-17 at 4kg/10a, carbofuran, and Mocap had no significant effect. Treatment with Telone c-17 greatly reduced the egg mass index which was 1.5 as compared to 4.7 for the control.

The Development - Temperature

There are four clear seasons in Korea. Average soil temperature for 10 years according to the latitude is shown in Fig. 1. Average soil temperature during winter (from November to March) at Seogwipo was 10.34^{o}C, Busan 7.35^{o}C and Suwon 2.64^{o}C. These temperatures, except in the Seogwipo district, are much lower than basal threshold temperature 10.11^{o}C for development of root-knot nematodes demonstrated by Milne and Duplessis (1964). Therefore, during winter season, root-knot nematodes cannot continue their development but can develop in agricultural crops during the growing season (from April to October). By the field observations it may be assumed that two or three generations are occurring during these

periods in Korea: the first generation in late June, the second in mid August and the third in late October. These investigations must be continued in the future, I believe.

Ecological Studies - Nematode Population

Results of the survey on root-knot nematode population under a controlled horticultural cropping system are shown in Table 7. Nematode populations were much higher in uplands than in paddy fields. Rice cultivated after potato, watermelon and red pepper was shown to have lower populations than either cabbage or cucumber cultivated after red pepper, or cucumber or strawberry cultivated after cucumber. As far as the soil type, silty loam showed higher populations than sandy clay and clay.

Future Plans and Activities

1. Survey and collection on root-knot nematodes will be continued all over the country.
2. Survey on distribution of *Meloidogyne* species according to latitude along the Nag Dong river will be undertaken.
3. Survey on root-knot nematode population according to cropping system at controlled horticulture will be continued.
4. Chemical soil treatments for root-knot nematode control on red pepper, cucumber and strawberry in controlled horticulture will be undertaken.
5. Work will be carried out to determine the resistance and susceptibility of various economic crops to root-knot nematode.
6. Crop rotation trials will be undertaken for control of the root-knot nematodes.

References

Bird, A. F., and H. R. Wallace. 1965. The influence of temperature on *Meloidogyne hapla* and *M. javanica*. Nematologica 11:581-589.

Choi, Y. E. 1978. Studies on root-knot nematodes in Korea. The Kasetsart Journal 12:31-35.

Milne, D. L., and D. P. Duplessis. 1964. Development of *Meloidogyne javanica* on tobacco under fluctuating soil temperatures. S. Afr. J. Agric. Sci. 7:673-680.

Sasser, J. N., K. R. Barker, and L. A. Nelson. 1975. Chemical soil treatments for nematode control on peanut and soybean. Plant Dis. Rep. 59:154-158.

Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (Meloidogyne species). A cooperative publication of the Department of Plant Pathology, North Carolina State University, and the United States Agency for International Development. North Carolina State University Graphics. 111 pp.

Table 1. Occurrence of Meloidogyne spp. according to locality in Korea

Meloidogyne species	Locality							Total	%
	Gyeong Gi	Gyeong Bug	Gyeong Nam	Jeon Nam	Jeon Bug	Chung Bug	Jaeju		
M. arenaria	4	2	1					7	8.0
M. hapla	15	15	8		1	3		42	48.3
M. incognita		4	10	3	1		15	33	38.0
M. javanica	1	2	1	1				5	5.7

Table 2. Response of the differential host plants to some root-knot nematodes

Population	Locality	Response of the differential host plant						Identified species and race
		Tobacco	Cotton	Pepper	Watermelon	Peanut	Tomato	
1	Gyeongsan	+	-	-	+	-	+	*M. arenaria* Race-2
2	Sangyeogdong Daegu	+	-	+	-	+	+	*M. hapla*
3	Namseongdong Sangju	+	-	+	-	+	+	*M. hapla*
4	Godongri Naju	+	-	-	+	-	+	*M. arenaria* Race-2
5	Shinhori Gimhae	+	-	+	+	-	+	*M. incognita* Race-2
6	Geomsadong Daegu	+	-	+	+	-	+	*M. incognita* Race-2
7	Changragdong Punggi	+	-	+	-	+	+	*M. hapla*
8	Sangmori Jaeju	-	-	+	+	-	+	*M. incognita* Race-1
9	Ibseogdong Daegu	+	-	+	-	+	+	*M. hapla*

Table 3. Nematode populations in the soil according to continuous cropping years of the peanut fields

Continuous cropping years	Number of nematodes/300 cm^3 soil		
	Meloidogyne hapla larvae	Other plant parasitic nem.*	Free living nematodes
1 year	305	124	890
2 years	1060	102	1049
5 years	1588**	78	968

* *Aphelenchoides* sp., *Aphelenchus avenae*, *Criconemoides informis*, *Helicotylenchus dihystera*, *Psilenchus hilarulus*, *Tylenchus* sp..

** Significantly different from first year at the 5% level.

Table 4. Influence on growth and yield of peanut by *Meloidogyne hapla* in continuous cropping fields

Continuous cropping years	Plant height (cm)	Fresh weight (g/plant)	Pod weight (kg/10a)	Egg sac index
1 year	58.0	325.0	127.5	2.8
2 years	45.5*	246.0	123.5	3.3
5 years	39.1**	172.9*	98.8*	4.2***

*, ** Significantly different from 1 year at the 5% and 1% level each

*** Values of r required for significance between egg sac index and pod weight, r = 0.97

Egg sac index scale: 0 = 0, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, 5 = more than 100 egg sac.

Table 5. Influence of chemical soil treatments on seasonal development of nematodes on peanuts

Treatment	Rate kg/10a	Nematodes/300 cm^3 of soil								
		Meloidogyne larva			Other Tylenchida			Other Nematoda		
		Apr.23	Aug.7	Oct.9	Apr.23	Aug.7	Oct.9	Apr.23	Aug.7	Oct.9
Telone c-17	10	301	3	242*	28	3	16	345	188	497
Telone c-17	4	337	4	833	22	8	9	404	130	841
carbofuran 10 G	6	218	70	979	61	4	33	429	285	1015
Mocap 10 G	6	379	24	953	69	9	88	389	333	840
Control		253	38	1515	15	12	21	485	296	690
L.S.D. 0.05				775.24			84.45			609.30
0.01				1127.89			122.86			886.47

Other Tylenchida: *Aphelenchoides* sp., *Aphelenchus* sp., *Criconemoides informis*, *Psilenchus hilarulus*, *Helicotylenchus dihystera*, *Tylenchus* sp..

Other Nematoda: *Dorylaimida* spp., Saparazoic nematodes.

*Different from control at 1% level.

Table 6. Effect of chemical treatments on nematode control, growth and yield of peanut.

Treatment	Rate kg/10a	Fresh weight*	Fresh pod weight	Egg mass index
Telone c-17	10	1824.9**	915.6**	1.5
Telone c-17	4	1456.1	751.2	1.5
carbofuran 10 G	6	949.1	547.8	4.3
Mocap 10 G	6	1065.7	558.5	4.2
Control		883.5	507.9	4.7
L.S.D. 0.05		660.51	318.12	
0.01		960.97	462.83	

*Top weight + Pod weight

**Different from control at 5% level.

Egg mass index: 0 = 0, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, 5 = more than 100 egg mass.

Table 7. Survey on root-knot nematode population according to cropping system in controlled horticulture (1981, Korea)

Field	Cropping system	Month/Year: Prior crop Pltd. start	Prior crop Harv. ended	Succed. Crop Pltd. start	Succed. Crop Harv. ended	Cult. years	Soil type	No. of *Meloidogyne* larvae/300 cm^3 soil*
	1. Potato - Rice	3^e/81	6^e/81	6^e/81	10^L/81	20	SC	0
Paddy	2. Watermelon-Rice	3^m/81	6^L/81	6^L/81	10^L/81	20	SC	10
field	3. Red pepper-Rice	3^m/81	6^L/81	6^L/81	10^L/81	5	C	61
	4. Red pepper-Cabbage	3^m/81	7^m/81	8^e/81	11^m/81	25	SiL	3487
Upland	5. Strawberry-fallow	8^m/81	5^L/81	8^m/81	5^L/82	10	SiL	2448
	6. Red pepper-cucumb.	12^e/80	6^L/81	8^m/81	12^m/81	15	SiL	3520
	7. Cucumber-Cucumber	1^e/81	3^e/81	8^m/81	12^L/81	4	SiL	3041

*All soil samples were collected at June 1981

1-5: Prior crops are grown in the plastic house

6-7: Prior crops and succeeding crops are growing in the plastic house with heating

e: Early

m: Middle

L: Late

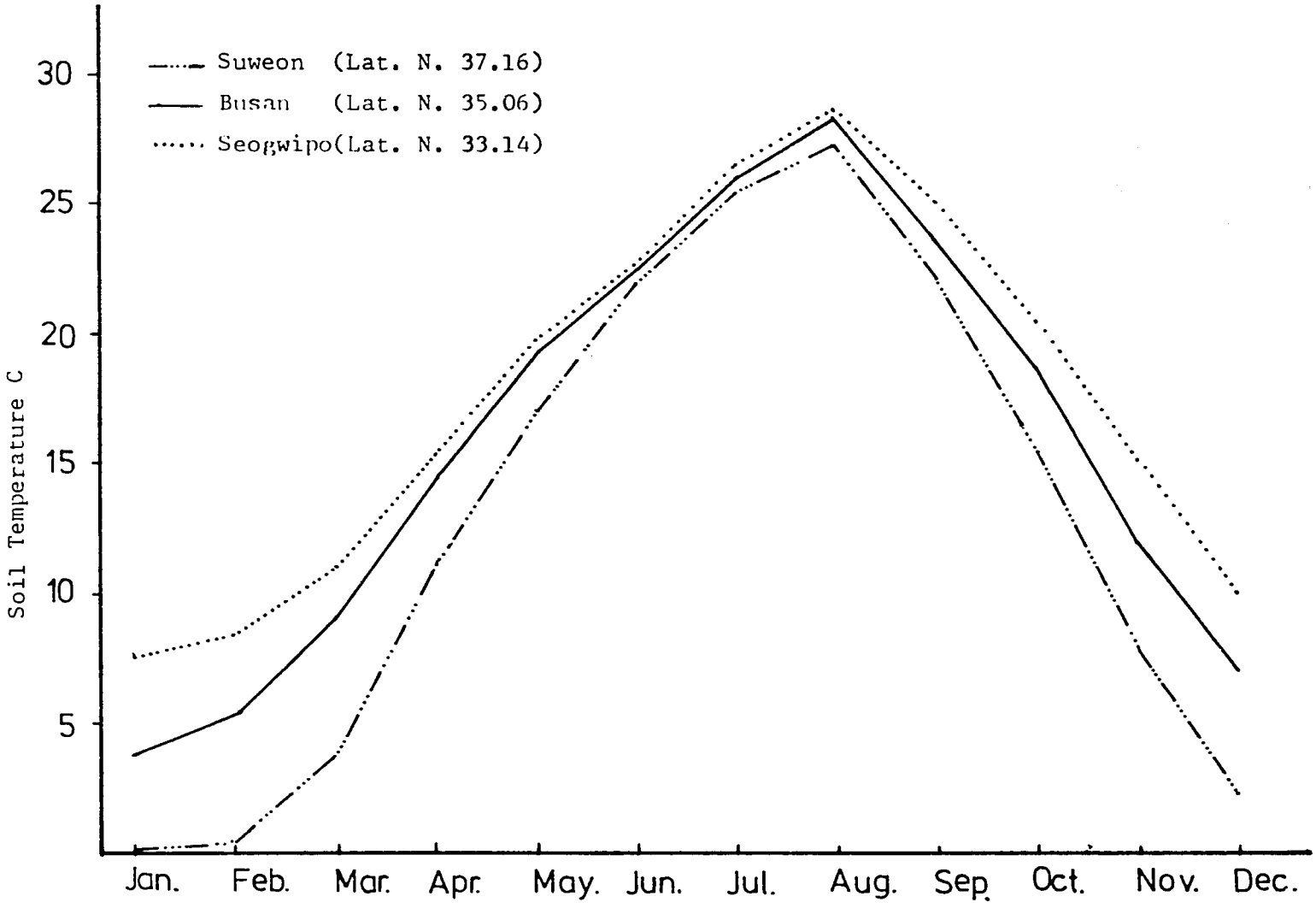
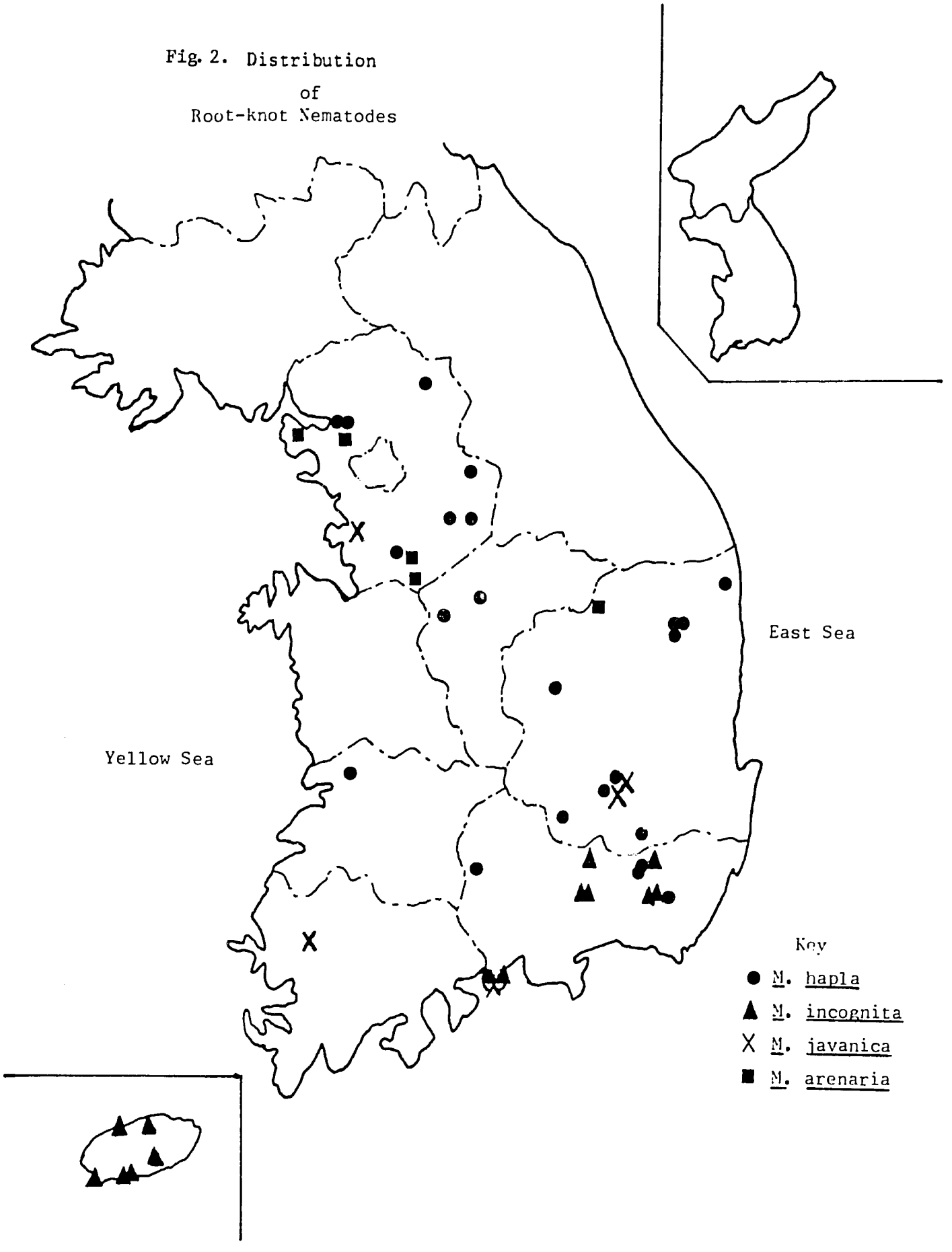


Fig. 1. Average monthly soil temperature at 10cm depth by latitude N. (Korea.1970-1979)

Fig. 2. Distribution of Root-knot Nematodes



THE ECONOMIC IMPORTANCE AND IDENTIFICATION OF ROOT-KNOT NEMATODE ISOLATES OF MALAYSIA

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Introduction

The agriculture industry in Malaysia has been traditionally associated with export crops such as rubber and oil palm. Oil palm is not harmed by root-knot nematode, though rubber is slightly affected at the early stage of growth (Razak, 1978). Hence, plant parasitic nematodes were never known to be pests of economic importance in Malaysia until the crop diversification policy of the country came into effect and new crops were introduced into the country for large scale cultivation. Land left idle for years was put into economic use. The land already under cultivation was exploited extensively for other crops which brought better income to the farmers. Over the years of the implementation of the policy, plant-parasitic nematodes began to manifest their importance. Loss of crop yield was experienced by the farmers.

Cocoa, black pepper, banana, sugarcane and tobacco are the five crops which became important and have been cultivated in large scale during the last 10 years. A study was carried out to identify the plant-parasitic nematodes associated with these crops under the International *Meloidogyne* Project since 1978. This paper reports on the overview of field performance of crops suspected to be infested by nematodes and identification of *Meloidogyne* species associated with them.

ECONOMIC IMPORTANCE OF MELOIDOGYNE ON COCOA, BLACK PEPPER, BANANA, SUGARCANE AND TOBACCO

Cocoa

The crop is generally planted in an old rubber area. *Meloidogyne*, *Pratylenchus brachyurus* and *Rotylenchulus reniformis* are ubiquitous and predominant (Razak, 1978). All three nematode genera are found to attack cocoa. *Meloidogyne* caused small, inconspicuous galls along the root. The

enlargement of the galls on the root caused a spindle-shaped, longitudinal split of the epidermal layer along the root axis. The mature female is imbedded in the cortical tissues of the woody root with the exposed posterior part of the nematode located at the widest split of the epidermal layer. Splitting the affected root into two longitudinal halves revealed the distorted stele region of the root where the giant cells were formed. Unlike with root-knot nematodes, a fluffy whitish substance concealed the presence of Rotylenchulus reniformis on cocoa root. The nematode usually attacked the root in groups of 6 to 15. Slight discoloration at the point of nematode attachment to the root was noted. Pratylenchus brachyurus caused lesions on the root. Under heavy nematode infestation a section of the root became discolored and black. In situ localization of the nematode in the root tissues by the normal staining and clearing process was not possible due to the opacity of the root tissue.

A pathogenicity study of Meloidogyne sp. and Pratylenchus brachyurus on cocoa seedlings resulted in 10 to 15% reduction on the vegetative growth of the plant (unpublished).

Black Pepper

Several abandoned pepper fields in Sarawak and Johore manifested general yellowing of leaves and unthrifty vines bearing sparsely distributed berries on the spike. New flushes of young leaves tended to show symptoms of iron deficiency. Vines arising from roots heavily galled by root-knot nematode died suddenly during the wet season. The entire canopy of leaves turned brown and dropped to the ground, leaving the bare vines standing. This malady is usually diagnosed as Phytophthora foot rot, thus overshadowing the long suffering of the vines from nematode infestation. Several dead plants in the field diagnosed as having Phytophthora foot rot, were never free from heavy galling of the roots. This observation concurred with the report of Holiday and Mowat (1963) though the role of nematodes in increasing the field susceptibility of the vines was doubted.

The young seedlings which germinate around the base of the vines are good indicators of nematode-infested vines. The galls are distinct with a pin-hole size opening on the apex. The roots are scanty and devoid of any lacerals. In contrast, galls on mature roots are usually accompanied by longitudinal cracks along the root axis. In both instances, the openings

on the root create an avenue for easy entry of fungal spores. Hence, field observation and the nature of galls produced on the root suggest that Phytophthora foot rot disease is more complex than just a simple direct infection of the fungus.

A nematicide experiment was carried out on a 7-year-old plant in a pepper field in Kulai, Johore. Treating the plant with 30 gm of Phenamiphos at 3-month intervals for 1½ years resulted in a significant increase in yield. Chemically treated plants produced 55% more berries than the untreated plants. The effectiveness of the chemical in maintaining the low field population lasted for 2 months.

Banana

Pratylenchus brachyurus, P. coffeae, Meloidogyne incognita, Helicotylenchus multicinctus and Radopholus similis have been collectively found associated with banana plants in the state of Selangor and Negeri Sembilan. Except for Meloidogyne, all the other nematodes caused root lesions which varied in intensity from a superficial, elliptical browning by Helicotylenchus multicinctus to a more extensive discoloration caused by Radopholus similis and P. coffeae. Galls induced by the root-knot nematode were distinct and confined to roots near the surface of the soil. Variety Nangka appeared to be tolerant to M. incognita. Despite the heavy galling on the roots, the plant appeared to perform well. Root-knot incidence on banana was not as common as Radopholus similis infestation. Varieties Restali and Embun appeared to be very susceptible to R. similis in the field. The sampling of nematodes on banana will be extended to the other states of Peninsular Malaya later.

Sugarcane

Sugarcane was introduced to Peninsular Malaya as a plantation crop about eleven years ago. Today only one plantation is doing successfully. However, the crop performance in the field does not reflect on the good agricultural management practiced by the company. The cane plants suffered from general stunting and unthrifty growth. The yield has dropped from about 28 tons per acre during the early years of cultivation to a current average of 15 tons per acre (per. communication with Mr. Yap, Perlis Plantation). The loose, friable Cuping Soil and continuous cultivation of the cane over the years could have possibly contributed to the progressive yield decline.

The plant survived on small clusters of badly discolored roots. Occasionally, galls produced on the terminal root distorted the root appearance. Samples from fourteen fields, collectively, revealed the presence of 12 genera of plant-parasitic nematodes (Table 1). Five genera, Hoplolaimus, Macroposthonia, Scutellonema, Longidorus and Rotylenchulus, are records on sugarcane, not listed by Loh Ting (1970). Pratylenchus was the dominant genus, consistently present in high numbers and constituting more than 60% of the plant parasitic nematodes recovered from the soil. Tylenchohynchus and Hoplolaimus, though ubiquitous, were present in low numbers. Other genera found less frequently were Helicotylenchus, Meloidogyne, Macroposthonia, Longidorus, Trichodorus, Paratylenchus, Xiphinema and Scutellonema. On the average, each field contained 5 nematode genera, with a range of 3 to 8 genera per field.

Meloidogyne was recovered from 35% of the field. The highest population was obtained on NCo 310 variety at the experimental station. All ten varieties of cane tested were susceptible to Meloidogyne infestation. Heavy galling was produced on the roots. Varieties Ragnar, L60-14, S-9 and CP 47-193 appeared to be most affected. The root systems were very much reduced with several large, terminal galls. The highest number of eggs per egg mass was obtained from variety S-9 though its gall rating of 6 was similar to that of the other nine varieties.

Tobacco

Tobacco cultivation in Malaysia was started on a 20-acre trial by a tobacco company twenty years ago. Today, the crop provides the major source of income to one-half million families, replacing the importance of the main traditional crop, rice. To prevent over-production of tobacco leaves in the limited Malaysian Market, a National Tobacco Board was formed. The function of the Board includes regulating the amount of plants planted by each farmer per season and providing technical advice on cultivation and marketing of the leaves.

Farmers were originally encouraged to plant tobacco on the idle rice land during the off season to supplement the low income from rice. Nematodes were never a problem then, mainly because of the small acreage involved, the use of only NC 95 variety, and the inundated condition of field during the rice season which makes it unsuitable for Meloidogyne. As the area of tobacco

cultivation extended to the poor sandy Bris Soil, Meloidogyne became a menace. Tobacco became the main crop and was planted in rotation with lowland cabbage and solanaceous plants. Farmers began to experience losses in yield, and field crop motality of up to 50% (personal communication En. Hassan of Kelantan Tobacco Industry).

A visit to several tobacco fields in Kelantan and Malacca, revealed that the nursery was the source of field inoculum. Left-over seedlings found in the nursery shed were all heavily infested by root-knot nematode. These plants were allowed to grow unchecked. The same nursery with the ready Meloidogyne culture would be used to grow seedlings of the next tobacco season. In areas where the seedlings were planted in rotation with rice, the nematode barely existed beyond more than one crop season. The heavy clay soil and frequent soil mounding around the base of the plant restricted root galling to seedling roots at transplanting. Subsequent roots produced by the plant with soil mounding were free of the root-knot nematode. Meloidogyne was never a problem to the crop. However, when the infected seedlings were transplanted to Bris Soil, nematodes posed problems to tobacco farmers. The situation was aggravated by poor choice of crop in the crop rotation program. Practically all samples collected from tobacco fields in the Bacok district of Kelantan contained Meloidogyne larvae. Areas where poor harvest was recorded in the preceeding tobacco crop gave high counts of Meloidogyne larvae.

Identification

Samples of soil and roots collected from the fields were brought back to Universiti Pertanian, Serdang for culturing. The Meloidogyne species in the field soil were baited with two-week-old tomato seedlings for subsequent single egg mass culture. The single egg mass culture of Meloidogyne species of the respective isolates were increased on tomato or coleus plants in the greenhouse.

For species identification, perineal patterns of the female were processed according to Taylor and Netscher's method (Taylor and Netscher, 1974). The second-stage larvae were extracted from the soil and fixed in F.A. for measurement. Egg masses on the root were used for host susceptibility tests on tobacco, cotton, pepper, watermelon, peanut and tomato as outlined by Taylor and Sasser (1978).

Results and Discussions

Table 2 shows the reaction of the test plants to the isolates of *Meloidogyne*. The original host plants from which the samples were collected are listed in brackets under the *Meloidogyne* isolates column. Likewise figures in brackets following host reaction indicate the gall index.

Host Susceptibility Test

All eleven isolates of root-knot nematode reacted positively to tomato and watermelon, with an average index of 7 or 8. The host reaction indicates that only two species were present in the Table 2 isolates: *Meloidogyne javanica* and *Meloidogyne incognita*. *M. incognita* is more widespread in distribution and has a wider host range. Of the 8 isolates of *M. incognita*, 6 isolates failed to reproduce on either cotton or tobacco (race 1). Populations from Sungai Buloh reacted positively on both test plants (race 4), while isolates from Serdang reproduced only on cotton (race 3). The three isolates of *M. javanica* were collected from tobacco soils at three different localities. The populations from Kampong Periok, Kelantan and Malacca gave similar reactions to the pest crop while the Bacok population failed to reproduce on pepper.

Microscopic Identification

The perineal patterns of the eight *M. incognita* isolates resemble *M. incognita* in having a distinct high dorsal arch composed of smooth to wavy lines and no lateral incisures. However, populations from Perlis appeared to be a mixture of *M. incognita* and *M. javanica*. Three perineal patterns resemble *M. javanica* in having a low dorsal arch and distinct lateral incisures, but the majority resemble *M. incognita*.

The larval measurements of all eight isolates fall within those of *M. incognita*, with an average length of 420 μm (363 to 526), stylet length of 12 μm (10 to 14), and tail length of 54 μm (38 to 69) from 20 specimens of each isolate.

The perineal pattern of the three *Meloidogyne* isolates from tobacco soil resembles *Meloidogyne javanica* with low dorsal arch and distinct perineal pattern. Larval measurements are not available.

References

Holliday, P., and W. P. Mowat. 1963. Foot-rot of Piper nigrum L. (Phytophthora palmivora). Phytopathological Paper No. 5. Commonwealth Mycological Institute, Kew, Surrey. 58 pp.

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

Razak, A. R. 1978. Variation in plant response, gall size and form induced by Meloidogyne on some Malaysian crops. The Kasetsart J. 12:43-45.

Taylor, A. L., and C. Netscher. 1974. An improved technique for preparing patterns in Meloidogyne spp. Nematologica 20:268-269.

Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (Meloidogyne species). A cooperative publication of the Department of Plant Pathology, North Carolina State University and United States Agency for International Development. North Carolina State Graphics, Raleigh, N.C. 111 pp.

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Table 1. The frequency of occurrence of the respective plant parasitic genera in the fields of Gula Perlis Plantation

Nematode Genera	Frequency of Occurrence (%)
Pratylenchus	100.00
Tylenchorhynchus	71.43
Hoplolaimus	71.43
Helicotylenchus	50.00
Meloidogyne	35.71
Criconemoides	35.71
Scutellonema	7.14
Trichodorus	14.29
Longidorus	42.86
Xiphinema	14.29
Paratylenchus	21.43
Rotylenchulus	0.0

Table 2. Result of differential host susceptibility test of isolates of *Meloidogyne*

Test Host / Meloidogyne Isolates (Host plant)	Tomato	Tobacco NC 95	Watermelon	Groundnut	Pepper	Cotton	Remarks
Serdang (Cover crops)	+ (8)		+ (7)	-	+ (3)	+ (2)	*M. incognita* race 3
Kelantan - Bacok (Tobacco)	+ (8)	+ (7)	+ (5)	-	-	-	*M. javanica*
Kelantan Kg Periok (Tobacco)	+ (8)	+ (7)	+ (9)	-	+ (4)	-	*M. javanica*
Sg. Buloh (Rubber)	+ (8)	(7)	+ (8)	-	+ (4)	+ (2)	*M. incognita* race 4
Perlis (Sugarcane)	+ (8)	-	+ (8)	-	+ (5)	-	*M. incognita* race 1
Kulai (Black pepper)	+ (8)	-	+ (8)	-	+ (5)	-	*M. incognita* race 1
Malacca (Tobacco)	+ (8)	+ (5)	+ (4)	-	+ (5)		*M. javanica*
Kuala Kangsar (Papaya)	+ (8)	-	+ (8)	-	+ (3)	-	*M. incognita* race 1
Kuala Pilah (Bitternut leaves plant)	+ (8)	-	+ (8)	-	+ (5)	-	*M. incognita* race 1
Kajang (Papaya)	+ (8)	-	+ (7)	-	+ (7)	-	*M. incognita* race 1
Pahang Chenor Lama (Black pepper)	+ (8)	-	+ (7)	-	+ (2)	-	*M. incognita* race 1

Figure in bracket indicates the gall rating

INTRODUCTORY REPORTS OF STUDIES ON MELOIDOGYNE SPP. IN JAPAN

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PART I. ON THE DAMAGE IN SWEET POTATOES BY MELOIDOGYNE INCOGNITA AND THE USEFULNESS OF RESISTANT VARIETY

Introduction

Sweet potato is one of the most important upland crops in the central and southern areas of Japan. Sweet potato is grown on a total of about 64,000 hectares in Japan, and the annual product is 1.36 million tons with an average yield of 21.3 tons per hectare in 1979. Sweet potato is used as a vegetable in daily dishes, and a large portion is processed to produce starch and alcohol.

In the case of starch potatoes, the yield is important, while in the case of marketable vegetable potatoes, it is the quality, that is, the shape and external appearance, which is important. So, the economic importance of the root-knot nematodes in sweet potato production differs according to the use of the crop.

Sweet potato as a whole is one of the most suitable hosts for *Meloidogyne incognita*, and the areas where most of the sweet potatoes are grown are more or less infested with *M. incognita*. So, the necessity of controlling the nematode has well been recognized by commercial sweet potato growers. Those people who grow vegetable sweet potatoes often treat their fields with soil fumigants because the return can compete with the chemicals in the price. However, those people who grow starch sweet potatoes cannot afford to use these expensive chemicals. Here, the nematode-resistant varieties become useful to escape the damage of the root-knot nematodes and to control them. There are some previous reports on these points (2, 3).

The present experiment was designed to provide information for good understanding of the actual damage of sweet potatoes by *M. incognita* and the usefulness of the root-knot resistant varieties.

Materials and Methods

An experimental field which had been heavily infested with *M. incognita* was treated with either chloropicrin (22 l/10a), D-D (20 l/10a), or EDB (25 l/10a). The soil surface of the chloropicrin plot was sealed with a thin, black vinyl sheet. The non-treated plot was set as the check.

About three weeks later the soil was plowed for aeration and another one month later seedlings of three sweet potato varieties were planted. These varieties were Kokei 14 (susceptible), Kanto 14 (susceptible), and Kanto 84 (resistant). One plot was 21.6 m^2 (2.4 m x 9 m) with two replicates.

The population level of the second-stage larvae in the soil was examined before chemical treatment, at planting, and after harvest. The root-knot severity of hairy roots, flesh root infection, plant growth, and yield were recorded.

Results and Discussion

Root-knot severity of the hairy roots was remarkably reduced by chemical treatment especially by EDB in both of two susceptible varieties, Kokei 14 and Kanto 14 (Fig. 1). No infection was found in Kanto 84, a resistant variety.

The plant growth (Fig. 2) and potato yield (Fig. 3) were remarkably increased in the treated plots in both the two susceptible varieties, while there was almost no change in the resistant variety. In the non-treated plots, the potato yield of the resistant variety was much higher than that of the two susceptible varieties (Table 1).

The nematode population after harvest was very high in the non-treated plots of two susceptible varieties (Table 2). It was fairly low in the treated plots of these varieties, but the level itself was high enough to induce damage on the next crop if it was susceptible. On the other hand, the number of the second-stage larvae in the soil was almost negligible after the resistant variety Kanto 84, even in the non-treated plot. In this case, the nematode-resistant sweet potato was considered to be a trap plant or cleaning crop against *M. incognita*.

As to the quality of the product, flesh roots of two susceptible varieties showed black spots and black cracks, while the nematode-resistant variety had no such symptoms at all (Fig. 4). These symptoms were lightened by chemical treatment remarkably in Kokei 14, but not so much in Kanto 14.

Black spots were observed mostly on the eye parts of potatoes. Female nematodes parasitizing within the basal portion of hairy roots were often found when cross sections of the flesh roots were made at the portion of the eye part which showed black spot. Therefore, the black spot symptom was considered to be caused by M. incognita.

Black cracks seemed to be a consequential case of developed black spots. In the symptom development, association of some soil-born fungi was thought to be likely.

In addition to black spot and black crack, browncoarse skin and brown crack symptoms were often observed. These latter symptoms were somewhat similar to those previously mentioned above, but were thought not to be caused by the nematodes, because the symptoms 1) were not reduced by nematicide treatment, 2) appeared individually and separately on plants, 3) appeared at high frequency in a root-knot free field, and 4) appeared even on the nematode-free potatoes grown in steam-sterilized soil in pots. The brown coarse skin and brown crack symptoms resemble those of russet crack caused by a strain of feathery mottle virus of sweet potatoes (5).

Thus, it was clear that M. incognita induced obvious damage on sweet potatoes quantitatively as well as qualitatively, and that the nematode-resistant variety was very effective in avoiding damage and in suppressing the nematode population in the soil.

PART II. HOST SUITABILITY TO MELOIDOGYNE INCOGNITA (6) AND M. JAVANICA (4)

Materials and Methods

Twenty-six kinds of crop plants were grown in steam-sterilized soil in 9-cm vinyl pots. In the case of M. incognita, 1,000 second-stage larvae and,of M. javanica, 700 larvae were introduced into each of the pots as water suspension. All pots were kept in an artificial growth chamber at 25°C.

Eleven weeks after inoculation for M. incognita and nine weeks for M. javanica, second-stage larvae were re-isolated from the soil. Multiplication rates were calculated by dividing the final population by the inoculum level.

Results

The multiplication rates of M. incognita and M. javanica are listed in Tables 3 and 4, respectively, in order of the rates. Those crops which

were used in both of the experiments are grouped according to the multiplication rates of M. incognita and M. javanica in combination (Table 5).

The crops on which both root-knot nematode species reproduced well were tomato, sweet potato, cucumber, and pumpkin. To the contrary, neither nematode reproduced on taro, Japanese radish, peanut, or trefoil.

Corn (Honey Bantum) was the only crop, among those tested, on which M. incognita reproduced moderately well, but M. javanica did not. In contrast, M. javanica reproduced on carrot, cauliflower, and broccoli, but M. incognita did not.

Since these data were from pot experiments in an artificial growth chamber, further investigations are necessary, especially under field conditions. Such results would help growers choose crops for rotation systems to control these species of root-knot nematodes.

Literature Cited

1. Inagaki, H., and Y. Momota. 1981. On the damage in three sweet potato varieties by Meloidogyne incognita. (Abstr.). Proc. 18th Ann. Meet. of App. Ent. Zool. Soc.:134.
2. Kondo, T. et al. 1972. Varietal difference of sweet potato in susceptibility to the root-knot nematode, Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949. Jap. J. Nematol. 1: 14-17.
3. Kondo, T. 1972. Varietal differences of sweet potatoes in reproduction of Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949. Jap. J. Nematol. 2:16-19.
4. Momota, Y., and A. Gotoh. 1980. Host suitability of some crops to the Javanese root-knot nematodes, Meloidogyne javanica. Proc. Kanto-Tosan Plant Prot. Soc. 27:165-166.
5. Moyer, J. W. et al. 1980. Identification of two sweet potato feathery mottle virus strains in North Carolina. Plant Dis. 64:762-764.
6. Shimizu, K., and A. Gotoh. 1979. Host suitability of some crops to the root-knot nematodes, Meloidogyne incognita and the root-lesion nematode, Pratylenchus penetrans. Proc. Kanto-Tosan Plant Prot. Soc. 26:139-140.

Table 1. Sweet potato yield in non-treated plot

Variety	Response	Yield (g)/plant
Kokei 14	Susceptible	167
Kanto 14	Suscpetible	118
Kanto 84	Resistant	202

Table 2. Number of the second-stage larvae of *M. incognita* in 100 ml of soil of an experimental sweet potato field

Variety	Treatment	Before Tmt	At planting	After harvest
Kokei 14 (suscept.)	Chloropicrin	537	0	384
	D-D	577	4	1,142
	EDB	770	4	225
	No Tmt	694	34	3,092
Kanto 14 (suscept.)	Chloropicrin	753	0	550
	D-D	900	4	984
	EDB	780	5	146
	No Tmt	1,100	41	3,750
Kanto 84 (resist.)	Chloropicrin	720	0	2
	D-D	1,017	4	1
	EDB	1,467	4	0
	No Tmt	923	37	10

Sieving (70-400 mesh)-Baermann method. Av. of 2 replicated plots.

Table 3. Multiplication of M. incognita on various crop plants in a pot experiment

Order	Crops	Varieties	Multiplication Rate
1	Eggplant	Gunko 2	107.4
2	Tomato	Kurihara	63.3
3	Sweet potato	Kokei 14	48.1
4	Cucumber	Aonaga-chihai	26.1
5	Pumpkin	Tokyo	24.6
6	Spinach	Seiyo-ohba	20.8
7	Melon	Prince	10.7
8	Chinese cabbage	Harumaki-gokuwase	9.6
9	Cabbage	Shiki-dori	9.0
10	Turnip	Hikari	8.9
11	Long onion	Ishikura-ippon-futonegi	5.3
12	Potato	Irish Cobbler	5.0
13	Corn	Honey Bantum	4.2
14	Chinese yam	------	4.0
15	Burdock	Takinogawa	2.2
16	Upland rice	Hata-sangoku	1.9
17	Lettuce	Great Lake	1.2
18	Watermelon	Asahi-miyako	1.1
19	Ginger	------	1.1
20	Carrot	Kokubu-senko-ohnaga	0.53
21	Cauliflower	Nozaki-wase	0.52
22	Taro	Dodare	0.06
23	Broccoli	------	0.04
24	Japanese radish	Mino-wase	0.03
25	Peanut	Chiba-handachi	0.02
26	Tefoil	Shiro-kuki	0.01

Average of 4 pots.

Table 4. Multiplication of *M. javanica* on various crop plants in a pot experiment

Order	Crops	Varieties	Multiplication rate
1	Tomato	Kurihara	63.0
2	Cucumber	Aonaga-chihai	48.7
3	Sweet potato	Kokei 14	23.2
4	Lettuce	Great Lake 366	20.2
5	Pumpkin	Tokyo	18.1
6	Cabbage	Shiki-dori	16.6
7	Cauliflower	Nozaki-wase	11.6
8	Long onion	Ishikura-ippon-futonegi	10.8
9	Carrot	Kokubu-senko-ohnaga	8.6
10	Turnip	Hikari	8.1
11	Chinese cabbage	Harumaki-gokuwase	7.8
12	Chinese yam	------	5.7
13	Burdock	Takinogawa	5.2
14	Broccoli	------	4.1
15	Italian ryegrass	Ohba-hikari	4.1
16	Tomato	Raiden	3.8
17	Ginger	------	3.1
18	Watermelon	Asahi-miyako	1.6
19	Upland rice	Hata-sangoku	1.1
20	Sorgo	Soldan	0.4
21	Fallow	------	0.3
22	Taro	Dodare	0.2
23	Japanese radish	Mino-wase	0.1
24	Corn	Honey Bantum	0.0
25	Peanut	Chiba-handachi	0
26	Trefoil	Shiro-kuki	0

Average of 3 pots.

Table 5. Grouping of crops according to combination of the multiplication rates of *M. incognita* and *M. javanica*.

M. incognita	*M. javanica*	Crops (varieties)
+++	+++	Tomato (Kurihara) Sweet potato (Kokei 14) Cucumber (Aonaga-chihai) Pumpkin (Tokyo)
++	++	Chinese cabbage (Harumaki-gokuwase) Cabbage (Shiki-dori) Turnip (Hikari) Long onion (Ishikura-ippon-futonegi) Chinese yam (---)
+	+	Burdock (Takinogawa) Upland rice (Hata-sangoku) Watermelon (Asahi-miyako) Ginger (---)
+	+++	Lettuce (Great Lake)
++	-	Corn (Honey Bantum)
-	++	Carrot (Kokubu-senko-ohnaga) Cauliflower (Nozaki-wase) Broccoli (---)
-	-	Taro (Dodare) Japanese radish (Mino-wase) Peanut (Chiba-handachi) Trefoil (Shiro-kuki)

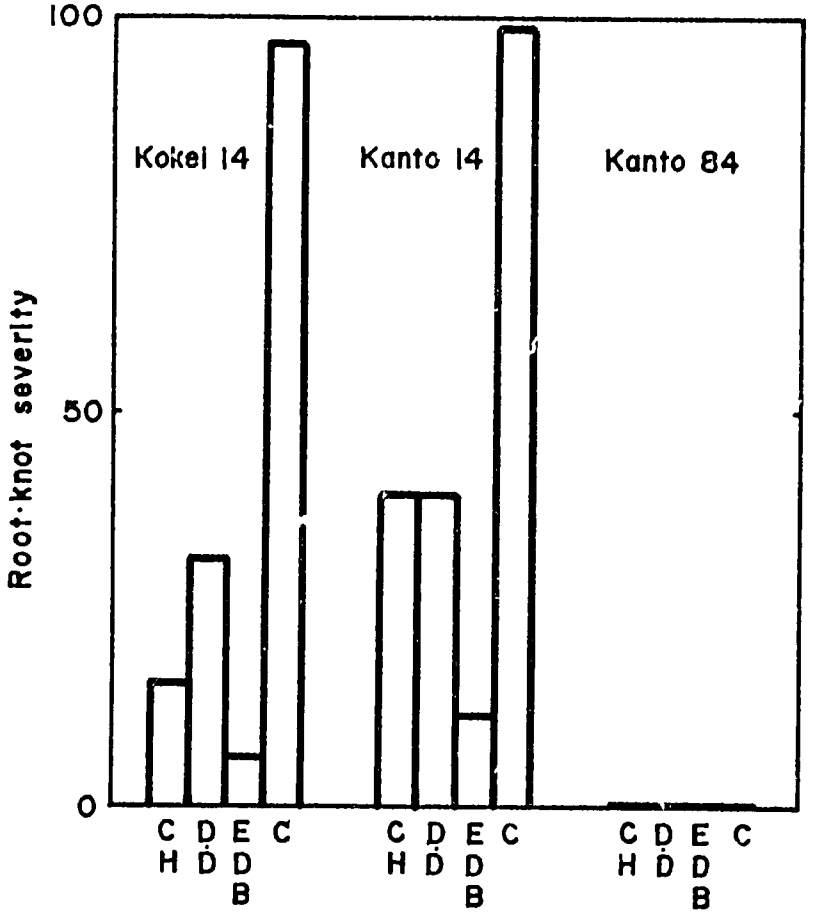

Fig. 1 Root-knot severity of the hairy roots of three varieties of sweet potato in an experimental field. (CH:chloropicrin, D-D:D-D, EDB:EDB, C:non-treated check)

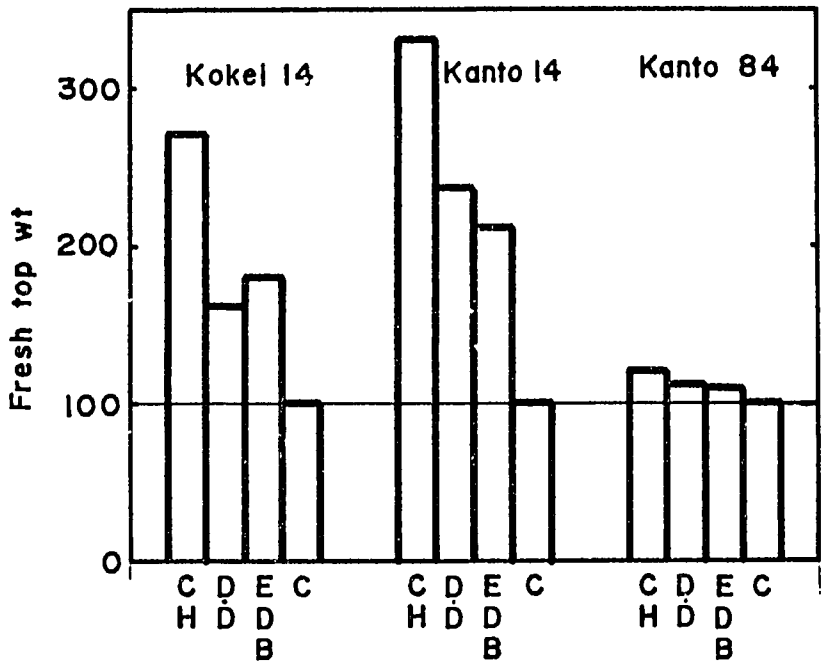

Fig. 2 Top growth of three varieties of sweet potato in an experimental field.

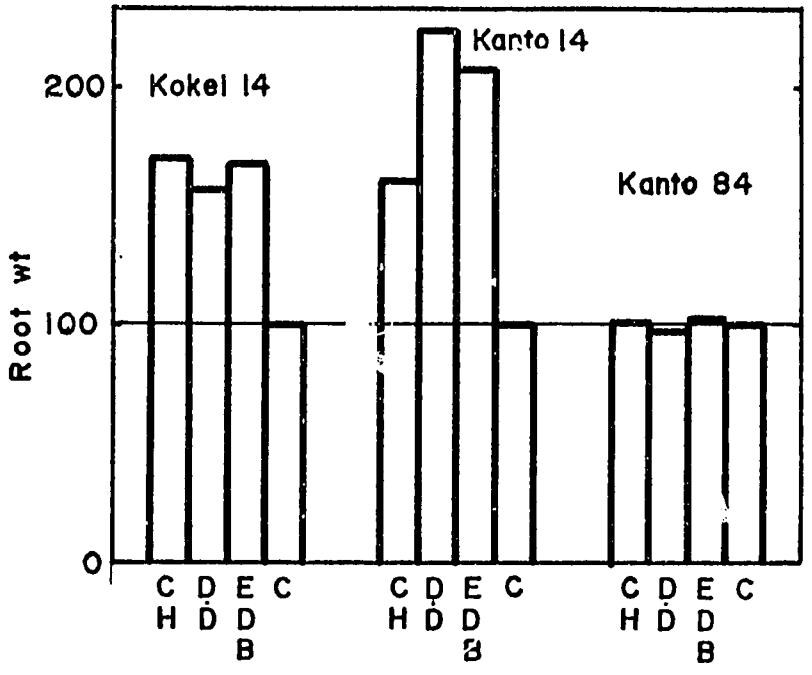

Fig. 3 Yield of three varieties of sweet potato in an experimental field.

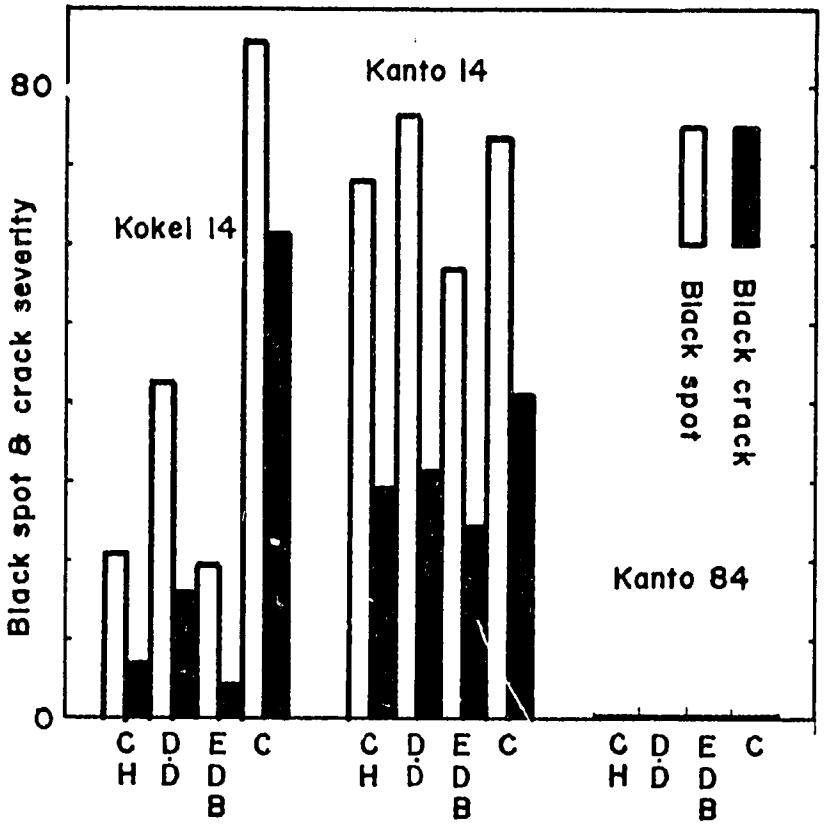

Fig. 4 Potato infection of three varieties of sweet potato in an experimental field.

PARASITISM OF THREE SPECIES OF *MELOIDOGYNE* TO LETTUCE VARIETIES

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The economic importance of lettuce as a cash crop is gradually increasing in Japan. Although it has long been recognized that lettuce is a host of *Meloidogyne hapla* (Gaskin and Crittenden, 1956) and of *M. arenaria*, *M. incognita acrita*, and *M. javanica* (Minz, 1956), little information is available, especially in this country, on actual root-knot nematode damage to plants. Therefore, a greenhouse pot test was undertaken to see whether or not there are varietal differences in reaction to root-knot nematodes and to compare the relative importance of the three most common *Meloidogyne* species attacking this crop in Japan.

Nematode species tested, their sources, and densities in the potted soil were presented in Table 1. Small plastic pots (h = 7 cm, d = 9 cm) were filled with 300 ml of the nematode-infested soils. Test plants were directly seeded in those pots and grown with about ten plants per pot in a temperature-controlled greenhouse (25 $\pm$ 5° C). Seeds of the forty lettuce varieties tested were obtained from several commercial seed suppliers, and tomato (var. Red Cherry) was included in the test as a standard check. Forty days after sowing, the roots of the plants were washed free of soil and rated for calculation of the root-knot index, according to the system presented by Smith and Taylor (1947).

The results obtained are presented in Table 2. From these figures, the following suppositions were made. 1) No lettuce varieties immune or highly resistant to *M. hapla*, *M. incognita*, and/or *M. javanica* were detected among the materials tested. It seems likely that some figures showing relatively small values of the indices are attributable to experimental error since this is an unreplicated experiment. 2) The majority of the varieties tested were recognized as highly susceptible or more susceptible than the standard (tomato) on which each of the nematode species was tested. It appears that there are no large species-specific differences among the nematodes tested regarding their pathogenicity to lettuce. 3) From these findings, it might be desirable to pay particular attention to root-knot nematode problems when cultivating lettuce.

Table 1. Sources of the root-knot nematodes and their densities in soil tested

Nematode species	Source		No. of larvae per 20 g soil*
	Locality	Host	
Meloidogyne hapla	Kukizaki, Ibaraki Pref.	Peanut	438 ± 18
M. incognita	Konosu, Saitama Pref.	Sweet potato	332 ± 20
M. javanica	Matsushiro, Nagano Pref.	Chinese yam	106 ± 4

*Extracted by a direct Baermann's funnel method for 10 days.

Table 2. Root-knot indices of lettuce varieties grown in soil infested with each of three *Meloidogyne* species for 40 days.

Lettuce varieties	*M. hapla*	*M. incognita*	*M. javanica*
"Aka-Kaki-Chisha"	88	88	83
Alpen	83	80	75
Baby Head	89	75	48
Carma	85	86	33
Cicoria Di Verona Invernale	69	31	-
Climax	83	94	75
Ever Green	87	71	48
Florida	96	89	89
Great Lakes B	69	63	69
Great Lakes OX	84	80	79
Great Lakes 54	88	71	79
Great Lakes 366	89	81	75
Green Bay	71	75	75
Green Curled	88	83	75
Ideal	83	84	80
Ithaca	60	65	78
King Crown	56	72	69
Lattuga riccia rossa d'America	66	44	83
May King	77	82	-
Mesa 659 MT	71	89	-
Minetto	64	26	75
My Lettuce	92	71	50
New York 515	66	100	88
"Nippon"	92	90	-
"Okayama-Saradana"	93	100	100
Olympia	92	75	100
Pen Lakes	100	77	95
Premier Great Lakes	64	50	-
Prince Head	100	88	88
Queen Crown	100	100	75
Simpson	100	81	92
Sun Blest No. 1	79	75	75
Sun Lettuce	80	82	81

Table 2. (continued)

Lettuce varieties	*M. hapla*	*M. incognita*	*M. javanica*
Top Mark	92	71	-
Vanguard	93	75	-
Veraviglia	100	94	96
Verister	100	86	87
Wear Head	83	84	75
Winter Green	100	95	100
Wit Roof	84	66	-
Tomato (var. Red Cherry)	74	83	84

PRELIMINARY EXPERIMENT ON VARIETAL REACTION OF CORN TO THREE *MELOIDOGYNE* SPECIES

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It appears that corn (*Zea mays* L.) is one of the important crops frequently used in several countries in crop rotations. In Japan, this plant has been called a "cleaning crop," because there is general recognition that the plant has capabilities of regulating plant nutrients in soil and of suppressing soil-borne diseases. The use of the plant in crop rotations is increasingly recommended by agronomists and soil chemists to maintain soil productivity as well as to overcome soil-sickness problems.

It has long been recognized that corn is a non-host of *Meloidogyne hapla* (1, 3, 5, 11, 16). In addition to this, it usually shows rather light symptoms and relatively high tolerance when infected with other species of root-knot nematodes. On account of these facts, it seems likely that the plant has occasionally been overestimated as an effective rotation crop which lowers soil densities of root-knot nematodes. In fact, there are some rotations with corn which increase *Meloidogyne* population densities instead of decreasing them (1, 2, 7, 12).

Although relatively little information is available on varietal differences in the reaction of corn to *Meloidogyne* spp., Nelson (1957), Dropkin (1959), Baldwin and Barker (1970), Tanveer and Saad (1971), Johnson (1975), and Ibrahim and Rezk (1978) reported differences among certain cultivars, which indicated some may be more effective than others against root-knot nematodes. On the other hand, differences in pathogenicity to corn were also reported among certain populations of some root-knot nematode species (1, 9, 10, 14).

This preliminary experiment was undertaken to reconfirm universality in immunity of corn to *Meloidogyne hapla* and to find effective cultivars, among a national collection of corn seeds, for cultural control of *M. incognita* and *M. javanica* through their use in crop rotations.

Materials and Methods

The root-knot nematodes used in this experiment are indicated with their sources and original hosts in Table 1. Each of these nematodes was previously propagated under greenhouse conditions in a bulk of steam-sterilized, loamy soil planted with susceptible tomato (var. Red Cherry). Plastic pots (equivalent to 1/10,000 a) were filled with 1 kg of the nematode-infested soil homogenized by passage through a coarse-mesh sieve and by thorough mixing. All of the plants to be tested were directly seeded in potted, nematode-infested soil, and grown at the rate of five plants per pot (without replications) for about 60 days under greenhouse conditions (average temperature: 25° C). Seventy-two corn cultivars, including 35 Japanese local flint varieties and 37 F_1 hybrids, were tested. All of these cultivars, except A-401 Minn which was supplied from the IMP Project Center, were supplied from the 2nd Laboratory of Genetics, National Institute of Agricultural Sciences. In addition to corn cultivars, tomato (var. Red Cherry) and kidney bean (var. Top Crop) were included as susceptible standard checks.

Root systems of uprooted plants were washed free of soil and rated for degree of infection based on the symbols and definitions presented by Sasser (1954). The roots were returned to the pots and tomato (Red Cherry) was sown as the indicator plant. About 20 plants per pot were grown under the above mentioned conditions. After about 60 days, the roots of the susceptible succeeding crops were examined for the root-knot indices according to the method of Smith and Taylor (1947).

Results and Discussion

All of the corn cultivars tested were perfectly immune to *M. hapla*. That is, no cultivars showed any signs of galling and egg-mass production even under conditions where heavy symptoms were observed on the susceptible check plants, tomato and kidney bean (Table 2). Therefore, corn is undoubtedly an effective rotation crop for use in soils infested with *M. hapla*, though the infestation levels on the succeeding susceptible crops in this experiment have not been examined yet. Whether or not biotypes of *M. hapla* pathogenic to corn (9, 10, 14) occur in this country is an unsolved problem.

Contrary to the above, no cultivars immune to *M. incognita* and *M. javanica* were detected among tested materials. Varietal differences in pathogenicities of the two nematode species were very small. No cultivars

showed such heavy symptoms as recorded by Baldwin and Barker (1970) and Divito et al. (1980). Slight or moderate galling and egg-mass production, however, were clearly detected on all of the cultivars tested (Table 2). Root-knot indices of the susceptible succeeding crop (tomato), grown in soil where corn cultivars were previously grown for two months, are presented in Table 3. From these figures, it has been concluded that there are no corn cultivars, among the materials tested here, effective in rotations for the control of M. incognita and/or M. javanica.

References

Baldwin, J. G., and K. R. Barker. 1970. Host suitability of selected hybrids, varieties and inbreds of corn to populations of Meloidogyne spp. J. Nematol. 2:345-350.

Divito, M., N. Vovlas, and R. N. Inserra. 1980. Influence of Meloidogyne incognita on growth of corn in pots. Plant Dis. 64:1025-1026.

Dropkin, V. H. 1959. Varietal response of soybeans to Meloidogyne - A bioassay system for separating races of root-knot nematodes. Phytopathology 49:18-23.

Ibrahim, I. K. A., and M. A. Rezk. 1978. Reaction of corn to Meloidogyne javanica and M. incognita. J. Nematol. 10:289-290.

Ichinohe, M. 1955. Two species of the root-knot nematodes in Japan. Jap. J. Appl. Zool. 20:75-82. (In Japanese with English summary.)

Johnson, A. W. 1975. Resistance of sweet corn cultivars to plant-parasitic nematodes. Plant Dis. Rep. 59:373-376.

Koga, S., and T. Koga. 1980. Effects of cropping systems on population densities of the root-knot nematode (Meloidogyne incognita) in vegetable gardening under vinyl greenhouses. Proc. Assoc. Plant Prot. Kyushu 26:153-155. (In Japanese.)

Nelson, R. R. 1957. Resistance in corn to Meloidogyne incognita. Phytopathology 47:25-26.

Ogbuji, R. O., and H. J. Jensen. 1972. Pacific northwest biotypes of Meloidogyne hapla. Plant Dis. Rep. 56:520-523.

Ogbuji, R. O., and J. J. Jensen. 1974. Two Pacific Northwest biotypes of Meloidogyne hapla reproduce on corn and oat. Plant Dis. Rep. 58:128-129.

Sasser, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (Meloidogyne spp.). Univ. Maryland Agr. Exp. Sta. Tech. Bull. A-77. 31 pp.

Sasser, J. N., and C. J. Nusbaum. 1955. Seasonal fluctuations and host specificity of root-knot nematode populations in two-year tobacco rotation plots. Phytopathology 45:540-545.

Smith, A. L., and A. L. Taylor. 1947. Field methods of testing for root-knot infestation. Phytopathology 37:85-93.

Stoyanov, D. 1979. Pathogenicity variations of three species of root-knot nematodes, pp. 307-310. In Root-knot nematodes (Meloidogyne species), F. Lamberti and C. E. Taylor (ed.). Academic Press, London.

Tanveer, M., and A. T. Saad. 1971. Reaction of some cultivated crops to two species of root-knot nematodes. Plant Dis. Rep. 55:1082-1084.

Van Der Linde, W. J., J. G. Clemitson, and M. E. Crous. 1959. Host-parasite relationships of South African root-knot eelworms (Meloidogyne spp.). S. Afr. Dep. Agr. Tech. Serv. Sci. Bull. 385. 16 pp.

Table 1. Root-knot nematodes and their densities in soil tested

Nematode species	Origin		No. of larvae per 20 g soil*
	Locality	Host	
Meloidogyne hapla	Kukizaki, Ibaraki Pref.	Peanut	117 ± 18
M. incognita	Konosu, Saitama Pref.	Sweet potato	213 ± 11
M. javanica	Matsushiro, Nagano Pref.	Chinese yam	252 ± 24

*Extracted by a direct Baermann's funnel method for 10 days.

Table 2. Susceptibility of corn cultivars to attack by root-knot nematodes

Code No.	Cultivars	Susceptibility ratings*		
		M. hapla	*M. incognita*	*M. javanica*
	Japanese local flint varieties			
1	Abetto	0	2	1
2	Doushi Takenomoto	0	2	1
3	Egari 1	0	2	1 - 2
4	Gojou	0	2	2
5	Heinai 1	0	1	2
6	Hirano Zairai	0	2	1
7	Honna 2	0	1 - 2	1
8	Irareko	0	1	1
9	Iwanai Zairai	0	1	1
10	Kamigane Kamigane 1	0	1	1
11	Kandachi	0	1 - 2	1
12	Kijiyama	0	1 - 2	1
13	Ki Wase	0	1 - 2	1
14	Koushuu	0	1	2
15	Kuni 5	0	1	1
16	Kushiro Zairai	0	1 - 2	1
17	Manba 2	0	1 - 2	1

Table 2. (continued)

Code No.	Cultivars	Susceptibility ratings*		
		M. hapla	*M. incognita*	*M. javanica*
18	Miyanoshita	0	1 - 2	1 - 2
19	Mizuhiki 3	0	1	1 - 2
20	Naganohara 4	0	1	1
21	Nunosawa 3	0	1	1
22	Okuzuru Wase	0	1	1
23	Oomomo	0	2	1
24	Oozuku	0	1 - 2	1
25	Sakashita	0	1	1
26	Shimizu	0	1	1
27	Shinboso	0	1	1 - 2
28	Suyama Inno 1	0	1 - 2	1
29	Tonegawa	0	1 - 2	2
30	Tone 3	0	1	1
31	Toyomaki 1	0	1	1
32	Ueno 3	0	1	1
33	Wada	0	1	1
34	Yamamotoshu	0	1	1
35	Yama Kibi	0	1	1
	F_1 hybrids			
36	Heigen Wase	0	1	2
37	Wase Homare	0	1	1
38	Hokuyuu	0	1	1
39	Koo 8	0	1	1
40	Takane Wase	0	1	1
41	Koo 3	0	1	2
42	Azuma Yellow	0	1	1
43	Chookoo B411	0	1	1
44	Mutsu Midori	0	1	1
45	oh 545 x 704	0	1	1
46	Suji Shirazu	0	1	1
47	Hyuuga Corn	0	1	1
48	Snow Dent A	0	1	2
49	Pioneer A	0	1	1 - 2

Table 2 (Continued)

Code No.	Cultivars	Susceptibility ratings*		
		M. hapla	*M. incognita*	*M. javanica*
50	Snow Dent 1	0	1	1
51	Pioneer 1	0	1	1 - 2
52	Snow Dent 2	0	1 - 2	1
53	Pioneer 2	0	2	1
54	Snow Dent 3	0	1	1
55	Pioneer 3	0	1	1
56	MTC 4	0	1	1
57	MTC 6	0	2	1
58	MTC 8	0	1 - 2	1
59	MTC 8A	0	1	1 - 2
60	MTC 10A	0	1	1 - 2
61	MTC 11	0	2	1 - 2
62	MTC 12	0	1	1
63	Gold Dent 901	0	2	1
64	Gold Dent 1001	0	1 - 2	1
65	Gold Dent 1101	0	2	1
66	Gold Dent 1102	0	1	1
67	Gold Dent 1201	0	1 - 2	1
68	Galion	0	1	1
69	DK 24	0	2	1
70	3B	0	2	1 - 2
71	XR 44	0	1 - 2	1
72	A-401 Minn	0	1	1
	Susceptible standard checks			
73	Tomato	4	4	4
74	Kidney bean	4	4	4
75	(Fallow)			

*Refers to Sasser (1954)

Table 3. Root-knot indices of susceptible succeeding crop (tomato) grown for 2 months in soil previously planted with corn cultivars for 2 months

Code No. of cultivars	Root-knot indices*		Code No. of cultivars	Root-knot indices	
	M. incognita	*M. javanica*		*M. incognita*	*M. javanica*
1	76	53	33	79	54
2	83	60	34	67	46
3	87	65	35	95	44
4	74	54	36	80	71
5	84	54	37	91	67
6	83	73	38	84	50
7	88	61	39	87	45
8	85	65	40	68	70
9	90	82	41	85	71
10	84	63	42	74	71
11	76	68	43	69	79
12	87	71	44	71	74
13	76	85	45	59	66
14	80	69	46	83	78
15	79	58	47	94	59
16	96	73	48	86	59
17	96	61	49	92	58
18	89	67	50	83	67
19	76	73	51	89	81
20	82	50	52	59	53
21	90	67	53	76	51
22	88	68	54	65	55
23	90	55	55	83	46
24	87	52	56	71	59
25	76	48	57	93	63
26	83	54	58	81	42
27	88	71	59	83	63
28	79	56	60	66	65
29	66	52	61	73	45
30	63	51	62	75	54
31	93	55	63	93	52
32	78	64	64	94	53

Table 3 (continued)

Code No. of cultivars	*M. incognita*	*M. javanica*
65	93	55
66	71	58
67	69	48
68	70	43
69	68	53
70	65	55
71	56	50
A-401 Minn	61	42
Tomato	76	52
Kidney Bean	85	71
Fallow	45	26

*Refers to Smith and Taylor (1947)

DISTRIBUTION OF SWEET POTATO CLONES WITH RESISTANCE TO ROOT-KNOT NEMATODE IN THE PACIFIC ISLANDS

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A sweet potato collection consisting of 617 clones which had been collected from Pacific islands by Dr. D. E. Yen at the Crop Research Division, Department of Scientific and Industrial Research, New Zealand, was introduced into Japan by Agriculture, Foresty and Fishery Research Council, M.A.F., in the summer of 1969. After a quarantine of several months, terrestrial stems of 574 clones were delivered to our Breeding Center and the characters of these clones were examined. Now, 373 clones among them have been successfully maintained in the field or greenhouse.

Field trials for the collection were carried out to determine agronomic characters in Japan. Screening tests for resistance to black rot, *Ceratocystis fimbriata* Elliot, and root-knot nematode, *Meloidogyne incognita* var. *acrita* Chitwood, were done for four years until 1973. A report of the investigation was published by T. Takemata and K. Sakai in 1975 in Japanese with English summary. This paper deals with the distribution of root-knot resistant sweet potato clones of the collection in the Pacific islands.

Methods

The screening test was conducted in a field heavily infested with the root-knot nematode at our Breeding Center. Out of 574 clones, 408 clones were examined in the test. To increase the nematode population a susceptible sweet potato cultivar, Kanto 14, was planted in the preceding year and garden balsam was grown promptly before the test in the spring. Early in July, five vines of each clone were transplanted 15 cm apart in 30-cm rows in duplicate plots. Early in September, visual root-knot readings of the test plants were made and the degree of gall formation was classified into the following five classes: Class 0, all roots without visible galls; Class 1, 1 to 25%; Class 2, 26 to 50%; Class 3, 51 to 75%; and Class 4, 76 to 100% of roots with galls.

Results and Discussion

Out of 408 clones tested, 67 clones possessed high resistance to root-knot nematode and another 66 clones showed some resistance. Table 1 shows distribution of sweet potato clones with resistance to root-knot nematode in the Yen collection gathered from the Pacific islands. Highly resistant and resistant clones were frequently those collected from Papua New Guinea and neighboring islands. The ratio of highly resistant and resistant clones to those clones collected from Papua New Guinea was 75.4%, Solomon Is. 75.0%, New Britain 66.7%, Irian Jaya 60.9%, Hong Kong 50.0%, Timor 45.5%, New Hebrides 40.9%, Philippines 30.4%, Society Is. 28.6%, Fiji 16.7%, New Caledoneia 14.3%, and Cook Is. 12.5%. Frequency of resistant clones was highest in Papua New Guinea and decreased with distance from the island. There was no resistant clone in New Zealand, Tonga, West Samoa, Niue Is., Hawaii, Tuamotu Is., Marquesas Is., Easter Is., Porto Rico, Cuba and West Indies. The frequency was 5.7% in a bunch of clones from Peru, Colombia, Ecuador and Mexico, and this region is generally estimated as the center of origin of sweet potato.

There was a long discussion on the sweet potato routes from the coastal region of America to Polynesia and Melanesia. The introduction to these regions in prehistoric time has not been properly examined. It could have been accidentally transported by one of the Peruvian rafts lost in the Central Pacific which reached Polynesia where the sweet potato was established by Indo-Americans and developed later on by Polynesians. It has also been proposed that the sweet potato might have been taken to Polynesia, Guam and Philippines by one of the Spanish expeditions that visited the area from Peru in the sixteenth century. On the one hand, Portuguese voyagers following the track of da Gama might have carried the sweet potato eastwards from the Caribbean, Brazil and Europe to Africa, India, Southeast Asia and Indonesia.

We think the sixteenth-century Spaniards to be responsible for the introduction to Papua New Guinea and neighboring islands. We are trying to estimate the reason why the frequency of resistant clones in Papua New Guinea was 75.4% and that of neighboring islands was also extremely high as compared with that of America, 5.7%. We propose two hypotheses. It has been firstly assumed that highly resistant clones were introduced to those regions accidentally, because the chance of introduction to those regions was limited, the term of the voyage being long in those days.

This assumption is not a plausible explanation for the large difference in the frequencies of both regions. It has been secondly considered that the frequencies of resistant clones were increased by natural selection among sweet potato populations from natural crossing, and that selection pressure was highest in Papua New Guinea and neighboring islands. However, we do not have enough information about the density of root-knot nematodes in the soil of those regions. We have to study this point.

In the islands of Polynesia and Melanesia, except the neighboring islands of Papua New Guinea, the frequency of clones resistant to root-knot nematodes was much lower than that of Papua New Guinea and was the same as that of America. These facts indicate that the introduction routes of sweet potato to Polynesia and Melanesia were different from that to Papua New Guinea and neighboring islands.

We have preserved the clones with resistance to root-knot nematodes at our Breeding Center as shown in Table 2. The clones have high value as a genetic resource for the improvement of sweet potato. If we need much more highly resistant clones, we might be able to collect them in Papua New Guinea and neighboring islands.

References

Leon, J. 1976. Origin, evolution, and early dispersal of root and tuber crops. Proc. Internat. Symp. Soc. Trop. Root Crops 4:20-36.

Takemata, T., and K. Sakai. 1975. Agronomic characters of an introduced sweet potato collection from New Zealand. J. Central Agr. Exp. Sta. 22:203-239.

Yen, D. E. 1976. Sweet Potato in Evolution of Crop Plants, ed. by N. W. Simmonds. pp. 42-45.

Yen, D. E. 1976. The economic aspects of the Pacific sweet potato collection. Proc. Internat. Symp. Trop. Root Crops I:45-56.

Table 1. Distribution of resistant clones to root-knot nematode in sweet potato clones collected by Dr. Yen.

Country	No. of clones examined	HR	R	MS	S	VS	% of resist.
Thailand	7	-	1	6	-	-	14.2
China	6	-	-	1	4	1	0
Hong Kong	2	-	1	1	-	-	50.0
Japan	1	-	-	1	-	-	0
Ryukyu	9	-	1	6	2	-	11.1
Philippines	102	14	17	36	19	-	30.4
Timor	11	1	4	4	1	1	45.5
Irian Jaya	23	8	6	6	2	1	60.9
Papua New Guinea	69	34	18	11	4	2	75.4
New Britain	3	2	-	-	1	-	66.7
Solomon Islands	4	-	3	1	-	-	75.0
New Hebrides	22	4	5	6	5	2	40.9
New Caledonia	7	-	1	5	-	1	14.3
Fiji Island	6	-	1	4	1	-	16.7
Tonga	6	-	-	-	1	5	0
West Samoa	2	-	-	2	-	-	0
Cook Island	8	-	1	5	2	-	12.5
Niue Island	1	-	-	-	1	-	0
New Zealand	12	-	-	2	2	8	0
Hawaii	1	-	-	1	-	-	0
Society Island	14	-	4	9	1	-	28.6
Tuamotu Island	1	-	-	1	-	-	0
Marquesas Island	6	-	-	5	-	1	0
Easter Island	5	-	-	2	1	2	0
Peru	52	-	2	20	11	19	3.8
Colombia	13	1	-	4	4	4	7.6
Ecuador	3	-	-	1	1	1	0
USA	3	-	-	-	1	2	0
Mexico	1	-	1	-	-	-	100.0
Port Rico	1	-	-	1	-	-	0
Cuba	1	-	-	1	-	-	0
West India	2	-	-	1	-	-	0
Unknown	4	3	-	1	-	-	75.0
Total	408	67	66	144	64	67	32.6

Note: HR = highly resistant, R = resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible.

Table 2. Highly resistant clones to root-knot nematode selected from Yen sweet potato collection

No. of collection	Name of clone	Source	Infestation category
98	Qubūwan	Philippines	0.6
121	Yāwa	do.	1.5
128	Qiyambabag	do.	0.7
135	Qontig	do.	0.5
150	Qananay	do.	1.0
151	Pattnki	do.	0.6
168	Manila	do.	0.8
178	Unknown	do.	0.5
233	Werene	Irian Jaya	0.6
238	Halteking	do.	1.1
269	Fatena	Papua New Guinea	1.1
275-2	Serenta	do.	0.6
312	Moro piye	do.	0.8
321	Bana	do.	0.8
323	Maiga	do.	0.6
324	Mamale	do.	0.5
332	Simbu kogawa	do.	1.0
338	Bajj	do.	0.5
341	Acic	do.	0.5
343	Sñamiñ	do.	0.5
375	Unknown	New Hebrides	1.0

IDENTIFICATION OF SPECIES AND RACES OF ROOT-KNOT NEMATODE ISOLATES THROUGH THE USE OF PERINEAL PATTERNS AND IMP HOST DIFFERENTIALS

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It has long been recognized in the Philippines that root-knot nematodes, Meloidogyne spp., are widely distributed throughout the country causing serious damage on most economic crops (David and Roldan, 1926; Begonia and Davide, 1968; Cortado and Davide, 1968; Valdez, 1968). The need to control them effectively has been the object of our research studies for the last 15 years. We have studied the possibility of using chemical and biological control for root-knot nematodes and obtained promising results (Ducusin and Davide, 1972; Reyes and Davide, 1975; Ruelo and Davide, 1978, 1979; Davide, 1979). However, we feel that a thorough knowledge of the root-knot nematode species and race distribution as well as the crops and varieties that they specifically attack is necessary in the development of effective control measures especially through the use of cropping systems and certain cultural practices.

In line with the IMP objectives, we conducted a study to determine the species and races of root-knot nematodes affecting various crops in different parts of the country. Partial results of the study are presented in this report.

Materials and Methods

Several isolates of root-knot nematodes were collected from different crops grown in various provinces of the Philippines. These isolates were separately cultured on potted-tomato plants in the greenhouse for population increase. Later the species identification of each isolate was made based mainly on perineal patterns and host plant reactions. To identify races, the different isolates of the same species were tested on the IMP standard host differentials, Table 3 (Sasser et al., 1978). The crops used were NC 95 tobacco, Deltapine 16 cotton, California Wonder pepper, Charleston Grey watermelon, Florunner peanut, and Rutgers tomato. All the test plants were separately grown in clay pots filled with sterilized soil.

When the plants were fully established, the soil was inoculated with approximately 1,000 newly hatched second-stage larvae of the different isolates through two 2-inch holes made opposite each other near the base of the plant. Five to 10 pot replicates were assigned to each isolate. After inoculation the holes were covered with soil from the same pot. All inoculated plants were randomly placed on a cement bench in a greenhouse with temperature at 22 to 33°C. Thirty to 40 days later the plants were carefully pulled out from the pots, and the root systems were washed with tap water. Each cleaned root system was examined in the laboratory for gall development.

Results and Discussion

A total of 20 isolates (Table 1) were examined, and out of these, 8 were identified as M. incognita, 3 M. javanica, 7 M. arenaria, one M. hapla and one isolate from a pine tree looked like M. megatyla with perineal pattern quite similar to that reported by Baldwin and Sasser (1979) in North Carolina. This isolate was sent to Dr. Sasser last year for further identification study. If the identification is verified by Dr. Sasser, then this would be our first report of the species outside the state of North Carolina.

On the race identification (Table 2) through the IMP standard host differentials, 7 M. incognita isolates showed the existence of races 1, 2 and 4, while 3 isolates of M. arenaria also reacted differently, but none could fit into the known races 1 and 2 as reported in North Carolina. It seems that we have here two different races which may be called races 3 and 4 of M. arenaria. None of the isolates infected peanut and cotton, while two isolates had a ± reaction on tobacco. Likewise, one M. javanica isolate which did not infect peanut and cotton could be race 1, while two isolates with ± reactions on pepper and cotton may indicate a mixture of two races, possibly 1 and 2.

On the other hand, the isolate from pine tree which may be M. megatyla had only a negative reaction on peanut and a ± reaction on cotton. A host range study of this isolate is now being done.

The present findings confirm results of our previous investigations that Philippine root-knot nematodes consist mainly of M. incognita, M. arenaria and M. javanica (Valdez, 1968; Cortado and Davide, 1968), and that M. incognita could be a mixture of different races based on reaction to local hosts (Begonia and Davide, 1968).

Research Proposal

Since identification of root-knot nematode species and races is necessary in the development of control measures such as breeding for resistant crops and varieties, and formulation of cropping systems and cultural practices, we therefore propose to continue this work on species and race identification. In addition, we would like to evaluate the root-knot damage on various crops involved in the present cropping systems practiced by different farmers and to conduct experiments on crop rotation involving rice, corn, vegetable crops and others for the control of root-knot nematodes and other species.

References

Begonia, D. T., and R. G. Davide. 1968. Pathologic reactions of field and fiber crops to three isolates of Meloidogyne incognita. Philippine Phytopathol. 4:52-73.

Baldwin, J. G., and J. N. Sasser. 1979. Meloidogyne megatyla n. sp., a root-knot nematode from loblolly pine. J. Nematol. 11:47-56.

Davide, P. A., and E. F. Roldan. 1926. Important field diseases of tobacco in the experiment station at Los Banos and in the Northern Luzon, Philippine Islands. Philippine Agr. 15:287-301.

Davide, R. G. 1979. Effect of nematicides and Tagetes erecta on the control of Meloidogyne incognita and on yield of tomato. Philippine Phytopathol. 15:141-144.

Ducusin, A. R., and R. G. Davide. 1972. Meloidogyne incognita: Its effects on tomato yield and some methods of control. Philippine Agr. 55:261-281.

Ortado, R. V., and R. G. Davide. 1968. Survey, identification and pathogenicity of nematodes associated with tobacco in Cagayan Valley and Ilocos Region. Philippine Agr. 51:779-801.

Reyes, T. T., and R. G. Davide. 1975. Fungi for biological control of plant parasitic nematodes. Tech. Bull. No. 3, Series 1975. 53 pp.

Ruelo, J. S., and R. G. Davide. 1978. Studies on the control of Meloidogyne incognita: I. Evaluation of four chemicals for nematicidal effectiveness. Philippine Agr. 61:313-329.

Ruelo, J. S., and R. G. Davide. 1979. Studies on the control of Meloidogyne incognita: II. The effectiveness of nematode-trapping fungi alone and in combination with chicken manure and hostathion. Philippine Agr. 62:153-158.

Ruelo, J. S., and R. G. Davide. 1979. Studies on the control of Meloidogyne incognita. III. Integration of biological and chemical control. Philippine Agr. 62:159-165.

Sasser, J. N., J. L. Starr, and A. C. Triantaphyllou. 1978. A progress report of research completed at the research center of the International Meloidogyne Project. IMP Proceedings, 2nd Research Planning Conference on Root-knot Nematodes, Meloidogyne spp., Abidjan, Ivory Coast. p. 79-86.

Valdez, R. B. 1968. Survey, identification and host-parasite relationships of root-knot nematodes occurring in some parts of the Philippines. Philippine Agr. 51:802-824.

Table 1. Species of root-knot nematodes identified from the different isolates collected from various parts of the Philippines

Isolate No.	Meloidogyne species	Host Plant	Locality
1	*M. incognita*	Santan	UPLB
2	*M. incognita*	Cotton	Pangasinan
3	*M. incognita*	Banana	Cebu
4	*M. arenaria*	Banana	Davao
5	*M. arenaria*	Tomato	Bicol
6	*M. incognita*	Sweet Potato	Bicol
7	*M. arenaria*	Banana	Davao
8	*M. arenaria*	Cassava	Bicol
9	*M. hapla*	Papaya	Bicol
10	*M. javanica*	Citrus	Bicol
11	*M. arenaria*	Squash	Bicol
12	*M. arenaria*	Begonia	Baguio
13	*M. arenaria*	Bougainvilla	UPLB
14	*M. megatyla*	Pine tree	Bicol
15	*M. incognita*	Grapes	Cebu
16	*M. javanica*	Potato	Baguio
17	*M. incognita*	Celery	Baguio
18	*M. javanica*	Tomato	Baguio
19	*M. incognita*	Mungbean	UPLB
20	*M. incognita*	Tomato	UPLB

Table 2. Reaction of different *Meloidogyne* species isolates to IMP standard host differentials

Meloidogyne species & race	HOST DIFFERENTIAL						Host Plant	Locality
	Tomato (Rutgers)	Tobacco (NC95)	Pepper (Calif. Wonder)	Peanut (Florunner)	Cotton (Deltapine 16)	Watermelon (Charleston Grey)		
M. incognita 2	+	+	+	–	–	+	Tomato	UPLB
M. incognita 1,2	+	±	+	–	–	+	Banana	Davao
M. incognita 2	+	+	+	–	–	+	Santan	UPLB
M. incognita 4	+	+	+	–	+	+	Cotton	Pangasinan
M. incognita 1	+	–	+	–	–	+	Banana	Cebu
M. incognita 1,2	+	±	+	–	–	+	Sweet Potato	Bicol
M. incognita 2	+	+	+	–	–	+	Celery	Baguio
M. arenaria 3,4?	+	±	+	–	–	+	Bougainvilla	UPLB
M. arenaria 3?	+	+	+	–	–	+	Banana	Davao
M. arenaria 3,4?	+	±	+	–	–	+	Cassava	Bicol
M. megatyla ?	+	+	+	–	±	+	Pine	Bicol
M. javanica 1	+	+	+	–	–	+	Citrus (soil)	Bicol
M. javanica 1,2	±	+	±	–	±	+	Tomato	Baguio
M. javanica 1,2	+	+	±	–	±	+	Potato	Baguio

Table 3. IMP standard host differentials for *Meloidogyne* species and race identification (After Sasser, et al.)

Species & Race	HOST DIFFERENTIAL					
	Tomato (Rutgers)	Tobacco (NC95)	Pepper (Calif. Wonder)	Peanut (Florunner)	Cotton (Deltapine 16)	Watermelon (Charleston Grey)
M. incognita						
Race 1	+	-	+	-	-	+
Race 2	+	+	+	-	-	+
Race 3	+	-	+	-	+	+
Race 4	+	+	+	-	+	+
M. arenaria						
Race 1	+	+	+	+	-	+
Race 2	+	+	-	-	-	+
M. javanica	+	+	-	-	-	+
M. hapla	+	+	+	+	-	-

SCREENING OF CROP VARIETIES FOR RESISTANCE TO *MELOIDOGYNE INCOGNITA*: I. VEGETABLE VARIETIES

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Root-knot nematodes, *Meloidogyne* spp., are very common in soils grown to vegetables in the Philippines. In upland areas of this country, these nematodes are encountered in almost any field where susceptible crops grow, and heavy infestations are usually associated with crop decline. Castillo (1977) reported that root-knot nematodes are the most important nematode pests of vegetables in the country.

Precise information on yield loss to root knot is still scanty. An initial infestation of 100 to 5,000 *M. incognita* larvae per hill has been found to cause 24.1% to 38.7% reduction in tomato yield (Ducusin & Davide, 1971). On the other hand, Castillo *et al*. (1977) reported a 28% yield reduction in mungbean from an initial infestation of 600 *M. acrita* larvae per hill.

Studies on the pathologic reaction of vegetable varieties to *Meloidogyne* spp. in the Philippines are very few. Davide and Deanon (1967) reported that all bitter gourd lines they tested were susceptible to *M. incognita*, but found 8 out of 13 tomato lines to be resistant. This study was conducted to determine the pathologic reaction of some vegetable varieties to the root-knot nematode, *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949, which has been reported to be the most prevalent and widespread among the *Meloidogyne* spp. identified in the Philippines (Madamba *et al*., 1978).

Materials and Methods

The vegetable varieties tested for their pathologic reaction to *M. incognita* were grown in decontaminated soil contained in 4-inch clay pots and kept on top of GI-pipe bench with wire screen in the greenhouse. One week after either planting or transplanting, each was inoculated by dispensing, with the aid of a Buchler pipetter, one ml of inoculum containing

about 500 eggs to a depression in the soil close to the roots. Ten plants of each variety were used. An equal number of uninoculated plants were provided for each variety to serve as controls.

The reactions of the test varieties to M. incognita were evaluated 45 days after inoculation using the root-gall and egg-mass indices. The root-gall index used was 1 = no infection or root galling, 2 = slight infection (1-25% of roots galled), 3 = moderate infection (26-50% of roots galled), 4 = severe infection (51-75% of roots galled), and 5 = very severe infection (76-100% of roots galled). The egg-mass index was 0 = 0, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100 and 5 = greater than 100 egg masses.

Results and Discussion

The eggplant, tomato and pepper varieties tested showed varied reactions to M. incognita as indicated by the root-gall and egg-mass indices (Table 1). Eggplant varieties Numuro Long, Dumaguete Long Purple and Annamalai brinjai showed intermediate reaction while the rest were susceptible. None of the 17 tomato varieties tested were resistant to M. incognita. However, Saturn, Venus, Pope and C 170-0-LB-2-0 showed intermediate reaction. All of the 20 pepper varieties used were found resistant to M. incognita except one, Pimiento Perfection, which showed an intermediate reaction.

The pathologic reaction of Pimiento Perfection and Anaheim Chili was similar to the result obtained by Hare (1951). The reaction of World Beater Thick Wall, Hungarian Yellow Wax, Early Calwonder, Floral Gem and California Wonder was in contrast to the findings of Hare (1956). The variation in their reaction could possibly be due to the level of inoculum and/or to a difference in invasiveness of the nematodes used.

The cucumber, cabbage and radish varieties used in the study also showed varied reactions to M. incognita (Table 2). Two of the cucumber varieties, Ashley and SMR-58, were intermediate in reaction whereas the rest were susceptible. Of the three cabbage varieties, Leo #80 and K-K were resistant, whereas Chogo was susceptible.

The radish variety Ramgo was resistant. Based on the root-gall index, the variety 60-day showed a susceptible reaction, but based on the egg-mass index, it may be considered resistant. The high root-gall index indicates only nematode penetration, not development. A low number of nematodes was observed in the roots. This may be due to the presence of a toxic substance

in the root exudate or to low larval populations which left the roots a few days after penetration, instead of becoming sedentary.

All of the lettuce varieties tested were found to be susceptible to M. incognita.

Summary and Conclusions

Varieties of eggplant, pepper, tomato, lettuce, cucumber, cabbage, and radish were tested for their pathologic reactions to M. incognita. Of the 7 eggplant and 17 tomato varieties tested, none was rated resistant. Those with intermediate reaction rating were Numuro Long, Dumaguete Long Purple and Annamalai brinjai eggplant varieties and Saturn, Venus and Pope tomato varieties. All of the pepper varieties tested except Pimiento Perfection, which showed intermediate reaction, were rated resistant. The cabbage varieties Leo #80 and K-K and radish variety Ramgo were rated resistant to M. incognita. All of the lettuce varieties used were rated susceptible.

Studies in Progress

1. Identification of Meloidogyne collections by the use of differential hosts and perineal pattern of egg-laying females.

2. Screening of tobacco, cotton, mungbean, soybean and sugar cane varieties for resistance to Meloidogyne spp.

3. Cropping sequence for the control of root-knot nematodes on tobacco.

Cropping Sequence Scheme

First	Second	Third	Fourth	Fifth
Tobacco	Fallow	Tobacco	Fallow	Tobacco
Tobacco	Rice	Tobacco	Rice	Tobacco
Tobacco	Corn	Tobacco	Corn	Tobacco
Tobacco	Rice	Tobacco	Corn	Tobacco
Tobacco	Rice	Corn	Tobacco	Tobacco
Tobacco	Mungbean	Cotton	Beans	Tobacco
Tobacco	Tobacco	Rice	Cotton	Tobacco
Tobacco	Tobacco	Rice	Mungbean	Tobacco

References

Castillo, M. B. 1977. Nematodes of field legumes and vegetables in the Philippines. Proc. Symp. Philippine Phytopathol. 1917-1977, 14-15 December 1977, UPLB, College, Laguna, pp. 220-270.

Castillo, M. B., M. S. Alejar, and J. A. Litzinger. 1977. Pathologic reaction and yield loss of mungbean to known population of Rotylenchulus reniformis and Meloidogyne acrita. Philippine Agr. 61:12-24.

Davide, R. G., and J. R. Deanon, Jr. 1967. Reactions of various breeding lines of tomato and ampalaya to Meloidogyne incognita. Philippine Phytopathol. 3:4-5.

Ducusin, A. R., and R. G. Davide. 1971. Meloidogyne incognita: Its effects on tomato yield and some methods of control. Philippine Agr. 55:261-281.

Hare, W. W. 1951. Resistance to nematodes in pepper. Phytopathology 41:6.

Hare, W. W. 1956. Comparative resistance of seven pepper varieties to five root-knot nematodes. Phytopathology 46:669.

Madamba, C. P., T. T. Reyes, and R. B. Valdez. 1978. Research on integrated crop protection systems with emphasis on the root-knot nematodes (Meloidogyne spp.) affecting economic crops. Kasetsart J. 12:49-52.

Table 1. Reaction of eggplant, tomato and pepper varieties to *Meloidogyne incognita*[a]

Variety	Gall index	Egg-mass index	Ave.	Pathologic reaction rating[b]
Eggplant (*Solanum melongena* L.)				
Numuro Long	2.9	3.1	3.0	I
Dumaguete Long Purple	3.1	3.2	3.0	I
Annamalai brinjai	3.3	3.6	3.5	I
Sinampiro	3.6	4.1	3.9	S
CA-Clustered	4.0	4.2	4.1	S
PPC	4.1	4.3	4.2	S
Multiple Dingras	4.5	4.2	4.4	S
Tomato (*Lycopersicon esculentum* L.)				
Saturn	2.9	3.2	3.1	I
Venus	3.7	3.1	3.4	I
Pope	4.3	2.5	3.4	I
1169	4.3	3.3	3.8	S
C170-0-LB-2-0	4.4	2.6	3.5	I
C32D-0-1-2-0	4.4	2.8	3.6	S
Marikit	4.4	3.0	3.7	S
C90-0-0-1-0	4.5	2.7	3.6	S
Imelda	4.5	3.2	3.9	S
C1279-0-1-0	4.5	2.6	3.6	S
Yellow Plum	4.6	3.2	3.9	S
2029	4.7	2.6	3.7	S
C32D-0-1-24-0	4.9	3.8	4.3	S
Improved Harbot	4.9	3.6	4.3	S
VC-11-1	4.9	3.0	4.3	S
Kewalo	4.9	3.7	4.3	S
VC-48-1	5.0	2.8	3.9	S
Pepper (*Capsicum annum* (L.) Sendth)				
Serrano Chili	1.3	0.6	1.0	R
Chili jalapeno	1.3	0.8	1.1	R
Yolo Wonder B	1.4	0.7	1.1	R
Resistant Florida Giant	1.6	1.8	1.7	R
Yellow Sweet Long	1.7	1.8	1.8	R
Miss Belle	1.8	1.1	1.5	R
Calif. Wonder 300 TMR	1.8	1.5	1.7	R
Yolo Wonder L	1.8	1.9	1.9	R
World Beater Thick Wall	1.9	1.6	1.8	R
Keystone Resistant Giant	1.9	2.0	2.0	R
Yolo Wonder Improved	1.9	2.1	2.0	R
Yolo Wonder A	2.0	1.6	1.8	R
Hungarian Yellow Wax	2.0	2.2	2.1	R
Big Belle	2.0	2.3	2.2	R
Anaheim Chili	2.0	2.3	2.2	R
Early Calwonder	2.0	3.0	2.5	R
All Big	2.2	2.6	2.4	R
Floral Gem	2.3	2.3	2.3	R
Pimiento Perfection	2.3	2.9	2.6	I
California Wonder	2.7	1.9	2.3	R

Table 1 (Continued)

[a]Data are means of 10 plant replicates

[b]Average gall and egg mass indices of 1.0 - 2.5, resistant (R); 2.6 - 3.5, intermediate (I); and 3.6 - 5.0, susceptible (S).

Table 2. Reaction of lettuce, cucumber, cabbage and radish varieties to *Meloidogyne incognita*[a]

Variety	Gall index	Egg-mass index	Ave.	Pathologic reaction rating[b]
Lettuce (*Lactuca sativa* L.)				
Calmar	3.7	4.0	3.9	S
Green Mignonette	3.8	3.4	3.6	S
Great Lakes 118	3.8	4.0	3.9	S
Black Seeded Simpson	4.4	3.9	4.2	S
Van Max	4.4	3.9	4.3	S
Empire	4.2	4.4	4.3	S
Mesa 659	4.6	4.3	4.5	S
Prize Head	4.7	4.3	4.5	S
Minetto	4.7	4.3	4.5	S
Grand Rapids TBR	5.0	4.9	5.0	S
Cucumber (*Cucumis sativus* L.)				
Ashley	2.8	2.8	2.8	I
SMR-58	3.3	3.1	3.2	I
Marketer	3.8	4.1	4.0	S
Explorer Formula Mix	4.2	3.7	4.0	S
La Salle Formula Mix	4.3	4.7	4.5	S
Cabbage (*Brassica oleracea capitata* L.)				
Leo #80	2.0	0.4	1.2	R
K-K	2.0	0.7	1.4	R
Chogo	3.6	3.1	3.4	I
Radish (*Brassica oleracea italica* L.)				
Ramgo	2.4	0.4	1.4	R
60-day	4.5	2.9	3.7	S

[a]Data are means of 10 plant replicates.

[b]Average gall and egg-mass indices of 1 - 2.5, resistant (R); 2.6 - 3.5, intermediate (I); and 3.6 - 5.0, susceptible (S).

SCREENING TOMATO, EGGPLANT AND WINGED BEAN FOR RESISTANCE TO *MELOIDOGYNE INCOGNITA* AND *M. JAVANICA*

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Introduction

There are over 210 plant species belonging to more than 50 families, which includes major food and fiber crops, that are reportedly attacked by root-knot nematodes in the Philippines. They are believed to cause tremendous losses annually; however, the exact amount for each crop has not been fully quantified.

The status of root-knot nematode research until 1975 in the Philippines was reported by Valdez (1976) in the First Asian Regional Planning Conference of the International *Meloidogyne* Project (IMP) held at the University of the Philippines at Los Banos (UPLB) in February, 1976. In that review paper, the work on the search for resistant germ plasm in some vegetable, field, and other crops was included. In view of the importance of vegetables in the national food program, the work on breeding for resistance to root-knot nematodes, particularly *M. incognita* and *M. javanica*, was continued. The former was found to be the most predominant and widely distributed species with 64-88% occurrence throughout the country followed by the latter with 29% occurrence (Valdez, 1968; Madamba, 1981). The present paper, which gives the results obtained in screening foreign and local cultivars/lines of tomato, eggplant and winged bean, was aimed at finding sources of resistance to *M. incognita* and *M. javanica*.

Race Identification of M. incognita

Eight single egg mass cultures of *M. incognita*, that were earlier identified by means of perineal patterns, were used in this study. Those cultures represented populations obtained from tomatoes, white potatoes and jute in eight different localities in five provinces of Luzon Island. The North Carolina Differential Host Test (Taylor & Sasser, 1978), with the six

recommended host plant cultivars, was used to determine the races and also to check the possible occurrence of other species. The results given in Table 1 show that all the isolates were M. incognita race 1.

Varietal Screening

Various cultivars and breeding lines of tomato, eggplant and winged bean were screened for resistance to M. incognita and M. javanica. The inoculum used in all the tests were eggs of both species that were first produced on susceptible tomato plants for 55 days. The egg inoculum of each species was processed separately following the method described by Taylor and Sasser (1978).

The test plants were transplanted singly into baked soil in No. 4 clay pots with a soil volume of 1 liter. After about 10 days, when the root systems were fully established, each plant was inoculated close to the roots using a "macro set," with 5,000 eggs of each test nematode. There were 20 replications per test cultivar per nematode species. The inoculated plants were placed on greenhouse benches and given complete fertilizer (14-14-14) when necessary.

Fifty days after inoculation, each plant was carefully uprooted. The root system was washed gently in a bucket of water and rated for the degree of galling and egg mass production using Taylor's (1970) work sheet method of getting the average infection index and Taylor and Sasser's (1978) 0-5 rating scale which was adapted for both galling and egg-mass production. The average infection for each cultivar/line was obtained by multiplying the class number by the number of plants in each class, adding all the products, and dividing the sum of the products by the total number of plants. Infection classes of 0-1.9 were rated as resistant (R), 2.0-2.9 as moderately resistant (MR); 3.0-3.9 as moderately susceptible (MS); and 4.0-5.0 as susceptible (S). The results are shown in Tables 2-5.

Among 50 tomato accessions screened, only Kewalo and Hawaii proved resistant to both M. incognita and M. javanica (Table 2). Anahu, Patriot and Atkinson were also resistant against M. incognita, but were only moderately resistant to M. javanica. A similar decreasing resistance was obtained with Healani, indicating that M. javanica is more virulent than M. incognita.

In a test on tomato F_1 progenies and some root-knot resistant and bacterial-wilt resistant parental lines for resistance to race 1 of M.

incognita and biovar III of Pseudomonas solanacearum, similar results as those in Table 2 were obtained in spite of using an inoculum of 1,500 eggs per plant. The results of this study, conducted by Cervantes (1981) and given in Table 3, showed that all 21 F_1 progenies were rated as resistant, based on egg mass production, when Kewalo, Patriot, Atkinson and/or Hawaii were used either as female or male parent. However, based on gall ratings of these progenies, seven were resistant and 11 moderately resistant; but only R 3034 -3-48-N-N X R 3034-3-4-N-58 UG gave an infection index of 0 for both galling and egg mass production. Against bacterial wilt, nine crosses showed resistant reactions with 83-100% survival and three showed moderately resistant reactions with 67% survival. Similarly, Kewalo and the lines developed at UPLB gave 100% survival to bacterial wilt.

On eggplant, none of 16 selections was rated as resistant to either test nematode. However, Dingras Long Purple, a local cultivar, showed moderate resistance to both nematode species along with La Granja Long Purple and Florida Market (Table 4).

Of 55 winged bean accessions screened against M. incognita, none was rated as resistant or moderately resistant while eight showed moderate susceptibility. However, UPS-62 and UPS-99 were rated as resistant and moderately resistant, respectively, against M. javanica in 43 accessions (Table 5). Los Banos Medium, a local cultivar, showed moderate susceptibility to both nematode species.

Research Plans

The search for resistant germ plasm against root-knot nematodes and the development of resistant cultivars against species and races of these pests will be a continuing program at the Institute of Plant Breeding, U.P. at Los Banos. Presently, the thrust is on the conventional vegetable crops such as tomato, eggplant, etc., where the interrelationships between Meloidogyne spp. and Pseudomonas solanacearum on the resistant cultivars being developed are also studied.

Work has also been initiated on indigenous vegetable crops, such as Basella rubra, jute, squash, etc., particularly on the identification of species and races of Meloidogyne affecting them, and on screening for resistance.

The other commodity crop groups where the need for resistant varieties is becoming realized are the field legume and fiber crops. Hopefully, work on these will soon be started.

References

Cervantes, J. J. 1981. Combining bacterial wilt (*Pseudomonas solanacearum*) and root-knot nematode (*Meloidogyne incognita*) resistance in tomato. M.S. Thesis, U.P. at Los Banos. 91 pp.

Madamba, C. P. 1981. Distribution and identification of *Meloidogyne* spp. in the Philippines and five Asian countries. Philippine Agr. 64:21-39.

Taylor, A. L. 1970. Introduction to research on plant nematology. FAO, Rome. 133 pp.

Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (*Meloidogyne* species). A cooperative publication of the Department of Plant Pathology, North Carolina State University, and the United States Agency for International Development. North Carolina State Graphics, Raleigh, N.C. 111 pp.

Valdez, R. B. 1968. Survey, identification and host-parasite relationships of root-knot nematodes occurring in some parts of the Philippines. Philippine Agr. 51:802-824.

Valdez, R. B. 1976. The status of root-knot nematode research in the Philippines. *In* Proc. First Asian Regional Planning Conference on Root-knot Nematodes, Feb. 16-20, 1976. College, Laguna, Philippines.

Table 1. Race identification of single egg mass isolates of *M. incognita* using the North Carolina differential hosts

Isolate No./Host	Place collected	Differential host reaction[1/]					
		Tobacco	Cotton	Pepper	Peanut	Watermelon	Tomato
B_1-Potato	Buguias, Benguet	-	-	+	-	+	+
C_2-Potato	Buguias, Benguet	-	-	+	-	+	+
E_1-Tomato	MSAC, Benguet	-	-	+	-	+	+
M_1-Tomato	Calaca, Batangas	-	-	+	-	+	+
J_2-Jute	San Carlos, Pang.	-	-	+	-	+	+
L_4-Jute	UPLB, Laguna	-	-	+	-	+	+
I_2-Potato	Bayambang, Pang.	-	-	+	-	+	+
O_1-Potato	Sariaya, Quezon	-	-	+	-	+	+

[1/] All isolates belong to Race 1.

Table 2. Resistance/susceptibility of tomato cultivars/accessions to *M. incognita* and *M. javanica*

Meloidogyne spp.	Resist.	Mod. Resist.	Mod. Suscep.	Suscep.
M. incognita Race 1	Kewalo Anahu Hawaii Patriot Atkinson	Healani		44 accessions
M. javanica	Kewalo Hawaii	Anahu Patriot Atkinson	Healani Manalucie	43 accessions

Table 3. Resistance/susceptibility of tomato F_1 progenies and parental lines/cultivars to Race 1 of *M. incognita* and biovar III of *Pseudomonas solanacearum*

Lines/cultivars	RKN Reaction			BW Reaction	
	G	EM	Rating	% Survival	Rating
R3034-3-48-N-N	3.7	0.7	R	83	R
R3034-3-4-N-58 UG	1.3	1.2	R	100	R
R3030-3-12-1-N-50	2.3	1.3	R	100	R
Kewalo	1.0	0.2	R	50	MS
Patriot	1.2	0.2	R	0	S
Atkinson	1.2	1.0	R	0	S
Hawaii	2.0	1.7	R	0	S
Marikit	3.0	2.0	MR	67	MR
Rutgers	4.5	4.0	S	33	MS
R3034-3-48-N-N X R3034-3-4-N 58 UG	0.0	0.0	R	100	R
R3034-3-48-N-N X Atkinson	2.0	0.0	R	83	R
R3034-3-48-N-N X Patriot	2.7	0.5	R	33	MS
R3034-3-4-N-58 UG X R3034-3-48-N-N	3.5	0.0	R	100	R
R3034-3-4-N-58 UG X Kewalo	2.5	0.3	R	100	R
R3034-3-4-N-58 UG X Patriot	1.5	0.2	R	83	R
R3034-3-4-N-58 UG X Hawaii	2.5	0.8	R	67	MR
R3034-3-4-N-58 UG X Rutgers	2.5	1.0	R	0	S
R3030-3-12-1-N-50 X VC 11-1	4.2	1.5	R	100	R
R3030-3-12-1-N-50 X Atkinson	2.3	0.5	R	67	MR
R3030-3-12-1-N-50 X Hawaii	1.5	0.5	R	0	S
Kewalo X R3034-3-48-N-N	2.8	1.2	R	100	R
Kewalo X Atkinson	0.8	0.5	R	0	S
Kewalo X Marikit	0.2	0.3	R	83	R
Kewalo X Rutgers	2.7	0.7	R	0	S
Patriot X R3034-3-48-N-N	3.2	0.7	R	83	R
Patriot X VC 11-1	1.0	1.2	R	50	MS
Patriot X R3034-3-4-N-58 UG	2.0	0.3	R	17	S
Hawaii X VC 11-1	2.0	0.5	R	67	MR
Hawaii X R3030-3-12-1-N-50	1.0	0.3	R	17	S
Hawaii X Atkinson	2.5	0.7	R	0	S

Table 4. Resistance/susceptibility of eggplant cultivars/accessions to *M. incognita* and *M. javanica*.

Meloidogyne spp.	Cultivar Reaction			
	Resist.	Mod. Resist.	Mod. Suscep.	Suscep.
M. incognita Race 1	0	Dingras Long Purple La Granja Long Purple	Nueva Ecija Green Ilocos Round Green Annamali Brinjal PI181807 PI269653 PI276104	7 accessions
M. javanica	0	Dingras Long Purple Florida Market	Multiple Dingras Nueva Ecija Green Ilocos Round Green La Granja Long Purple Annamali Brinjal Brinjal S-16	8 accessions

Table 5. Resistance/susceptibility of winged bean cultivars/accessions to *M. incognita* and *M. javanica*

Meloidogyne spp.	Cultivar Reaction			
	Resist.	Mod. Resist.	Mod. Suscep.	Suscep.
M. incognita Race 1	0	0	Puerto Princesa 11-8 Pangasinan Long Los Banos Medium PRCTC No. 2 PRCTC No. 11 PRCTC No. 22 PRCTC No. 31 PI 17266	47 accessions
M. javanica	UPS-62	UPS-99	Los Banos Medium TPT-2 TPT-14 WB 12-4 F-011	36 accessions

ROOT-KNOT NEMATODES, MELOIDOGYNE SPP., IN THAILAND

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Like in other tropical countries, root-knot nematodes, Meloidogyne spp., are considered serious pests to many kinds of vegetables, field crops and ornamental plants in Thailand. Surveys conducted by both local and foreign nematologists since 1962 revealed that among all the genera of plant-parasitic nematodes found in soil samples and plant specimens, root-knot nematodes are widely spread in different soil types and localities throughout the country (Fig. 1). Their frequencies of occurrence and population density are in general much less in clay soils than in sandy or loamy soils. Even though more than 80 plant species are recorded to be infected by these pests, crop losses and economic losses due to the nematodes are scarcely studied.

Field experiments on tomato plants conducted by the author during the last 5 years indicated that disease severity was dependent on nematode species, initial inoculum, plant species and environmental factors; however, the most important factor was plant age. Plant growth was enormously reduced if the plants were infected during the seedling stage--before they were 4 weeks old or before transplanting. Besides tomato, this phenomenon also applies to other vegetable crops like lettuce, cucumber, cabbage and coriander as well. In pot experiments on Rutgers tomato, the author found that yield and plant height were greatly reduced--51% and 18%, respectively, when inoculated with M. incognita.

Taxonomic studies on root-knot nematode species in the country revealed that altogether there are 6 species. M. incognita is the dominant species found on various economically important crops. M. javanica and M. arenaria are less prevalent while M. graminicola, M. exigua and M. naasi were recorded from rather specific areas, i.e., from Rice Experiment Station in Ubol Ratchatani province in the Northeast, a rice paddy field in Ayudhya province in the Central Plain and a sorghum plantation at the National Corn and Sorghum Research Center about 160 kilometers from Bangkok, respectively.

The role and importance of root-knot nematodes, Meloidogyne spp., in Thai agriculture are now widely recognized by students in agriculture, research workers, agricultural extension officers and plant breeders in various

governmental agencies. The Department of Plant Pathology in the College of Agriculture of each regional university, i.e., North, Northeast and South, has now recruited, at least, 2 persons with an advanced degree in Nematology to participate in a teaching and research program. By March, 1982, it is expected that 6 more graduates with advanced degrees in Nematology will be from Kasetsart University.

Pre-IMP Research on Root-Knot Nematodes

From extensive surveys conducted by the author of plant-parasitic nematodes of economically important crops in Northeast Thailand from 1970-1972, it is obvious that the most commonly found plant nematodes and the ones which cause greatest losses to crop plants, particularly tomato, other vegetables and some field crops are the root-knot nematodes, *Meloidogyne* spp. Summaries of research concerning root-knot nemaotdes are given below.

Life cycle of *M. incognita*. In screen-house, *M. incognita* completed the life cycle within 30 days at 30 degrees Celsius. Penetration occurred and the infected roots started swelling 18 and 48 hours after inoculation, respectively.

Population dynamics under Northeast conditions. Under the environmental conditions of Northeast Thailand, the annual population fluctuation was largely dependent on soil moisture. Soil temperature had less influence. Population buildup started one month after rainfall started and decreased to almost zero in April. The population peaked in September.

Yield and height of root-knot nematode-infected tomato. In pots, with Rutgers tomatoes, it was found that the plants inoculated with *M. incognita* were 51% and 18% decreased in yield and height compared to the non-inoculated plants.

Screening of tomato cultivar resistant to *M. incognita*. (Suebsak Sontirat, Waewchak Kongpolprom and Suriyan Boonnakka). This project was conducted in cooperation with the Subcommittee on Vegetable Research and Development Cooperation of the National Research Council in 1979. For this experiment, 41 tomato cultivars and 4 replications were used. There were 8 plants in each replication. Gall rating indices used were: 0 = no galls at all. There might be some necrotic lesions. 1 = few small galls, not more than 25% of the root system. 2 = galls small and large scattering on roots, not more than 50% of the whole root system. 3 = large galls, almost the whole root system, or at least 75%. 4 = large galls, 75-100% of the roots. Plant growth was retarded since the host was infected at seedling stage. Some died before harvesting.

At harvest, every plant was dug up so the root system could be checked. The infection index was calculated by the formula (Table 3):

$$\text{Infection index} = \frac{\text{Sum of individual ratings}}{\text{Number of plants assessed}} \times \frac{100}{\text{Max. disease category}}$$

Accordingly, all of the 41 tomato cultivars could be categorized as follows:

1. Resistant cultivars - Kewalo, Healani and Daruma,
2. Moderately resistant - Floradel-8, Ohkan and Floradel-15,
3. Susceptible - Sida, Manalucie, L-15, Saturn, L-15-1-10, L-15-1-20, AHTM-2A, Tropicgro, F-1296, SVRDC-3, SVRDC-4, Floradel-2, Floradel-14, Floradel-16, White Skeen, Fireball, Vagabond, Ace Improve, Maglobe, SSD#26, VC 9-1, T-367, KL-2, KL-250, Tropic, Manapal, Green Shoulder, Yuanlin, Bact. TSS#122, Tomato 601, Heat & Bact. TSS 6574 (F1), Japan, Kalohi and Florida.

Confirmation of the experiment is being conducted in the university screen-house.

An observation on Kewalo hybrids. (Suebsak Sontirat and Taworn Kowityakorn). This experiment was a preliminary study on the effects of root-knot disease and tomato hybrids--Kewalo and other commercial varieties. Due to high inoculum levels, the experiment could not be statistically analyzed, but a rough conclusion could be made that, regardless of the 10 varieties used to cross with Kewalo, either as male parent or female parent lines, Kewalo hybrids were still as resistant to root-knot nematodes as the original Kewalo.

IMP-Collaborating Projects

Effects of chemicals on tomato yields. (Suebsak Sontirat, Waewchak Kongpolprom and Suriyan Boonnakka). Three sets of experiments were conducted--one as off-season and the other two as in-season for tomato growing. Treatments were as follows: (a) Tomato cultivars - Kewalo, Healani, Sida and L-15, and (b) Chemicals (at manufacturer's recommended rates) - Vydate, Furadan and Furadan, Furadan and Posse, and Control. There were 3 replications for each experiment in the set. Tomato seedlings were 28 days old at transplanting. Nematode counts were made from soil samples collected at planting, 45 days after planting, and on harvesting day. Gall ratings were made by checking the whole root system after digging up from the heavily infested field.

Results (Tables 1,2,3) were as follows:

1. Yields of the 4 tomato cultivars were not significantly different. Sida, a local cultivar which is considered as the susceptible check, gave the highest yield in the first experiment.

2. Among the nematicidal treatments to control the nematodes, treatment C (Furadan and Posse) gave the highest yield. Treatment A (Control) was statistically different from the other 3 chemically treated plots in the first experiment.

3. L-15, a high-yielding cultivar, gave the highest average in the third experiment also.

4. Conclusively, there is no difference, in terms of yield, when nematicides are used to control root-knot nematodes no matter whether the crop plants are resistant or not.

Breeding tomatoes resistant to M. incognita. (Tavat Lavapaurya and Suebsak Sontirat). This project was started about 6 months ago. A pure line of Kewalo tomato is grown in controlled room at Kampangsan campus, Kasetsart University and is almost ready for emasculation.

After crossing with cultivars like L-15, SVRDC-3, SVRDC-4, Sida and others, the new hybrids will be tested for performance both in the lab and in the field before release to farmers.

Future Research Project on Root-Knot Nematodes

To minimize crop damage due to root-knot nematode in Thailand, easy-to-apply and economically practical methods should be used. Resistant varieties are one of the best ways for Thai farmers. Crop rotation is another choice applicable for control of the pest. Research plans in the future will emphasize the following methods.

Utilization of crop manure and crop residue. This is an interesting method to decrease nematode population. Improvement of soil texture, structure and fertility are the main purpose, but as a biological control, root-knot density will be lowered below the threshold level. This project will begin next year.

Screening and breeding resistant cultivars. In other parts of the country, especially in the northern region where tomato can be used as an industrial crop, this method will be important.

Chemical control on upland rice and sugarcane.

Differential host tests.

References

Chunram, C. 1972. A list of plant parasitic nematodes in Thailand. Plant Protection Service Tech. Bull. No. 1. Ministry of Agriculture, Bangkok. 44 pp.

Sontirat, S., G. Sittisuk, and S. Rachta. 1978. Plant parasitic nematodes in Northeast Thailand. Res. Bull. No. 3. Northeast Regional Agricultural Center, Khonkaen. 51 pp.

Sontirat, S., W. Kongpolprom, and T. Kowityakorn. 1980. Screening of tomato cultivars resistant to root-knot nematodes, Meloidogyne incognita. Paper presented at the 6th National Tomato Improvement Workshop. September 20-23, 1980. Udornthani province (in Thai).

Sontirat, S. 1981. Plant parasitic nematodes of tomatoes. Thai Plant Pathology Newsletter 1(1):7-12. (In Thai.)

Table 1. Effects of chemicals on yield of tomato varieties: analysis of variance

SOV	df	SS	MS	F
Block	2	4.46	2.23	2.165^{ns}
Chemical	3	48.92	16.30	15.82**
Error (a)	6	6.23	1.03	
Variety	3	10.21	3.40	1.354^{ns}
Chemical x Var.	9	13.18	1.46	0.581^{ns}
Error (b)	24	60.27	2.51	
Total	47			

Table 2. Effects of chemicals on yield of tomato varieties: Yields (kg.) of tomatoes under nematicide treatments[a/]

Cultivar		Nematicide				Total	Average
		Control	Vydate	Furadan +Posse	Furadan +Furadan		
Healani	A	0.78	2.48	3.15	2.94	9.35	2.32 ns
	B	33.20	23.60	32.00	23.30	112.10	28.03 ns
	C	33.90	27.40	37.60	30.80	129.70	32.43b**
Sida	A	2.63	4.41	4.32	2.86	10.22	3.56
	B	24.60	29.60	24.00	25.20	103.40	25.85
	C	40.80	33.40	22.10	31.90	128.20	32.00b
Kewalo	A	0.79	3.75	4.09	3.29	11.92	2.98
	B	26.50	31.40	43.80	26.40	128.10	32.03
	C	36.40	38.40	37.80	25.20	137.80	34.45b
L-15	A	0.51	2.17	3.84	3.93	10.45	2.61
	B	30.50	31.30	44.30	28.20	134.30	33.58
	C	45.40	38.10	51.70	41.30	176.50	44.13a
Total	A	4.71	12.81	15.40	13.02	45.94	
	B	114.80	115.90	144.10	103.10	477.90	
	C	156.50	137.30	149.20	129.20	572.20	
Average	A	1.18a	3.18b	3.85b	3.26b**		
	B	28.70	28.98	36.03	25.78 ns		
	C	39.13	34.33	37.30	32.30 ns		

a/There were three experiments: A = July-October, 1980
B = Nov., 1980 - February, 1981
C = Nov., 1980 - February, 1981

Table 3. Effects of chemicals on yield of tomato varieties: nematode population and infection index

Treatment	Nematode population		Infection index(%)	
	Planting day	Harvesting day	Ex. I	Ex. 2 & 3
A (Control)	1, 26	203, 220	80.56	28.00
B (Vydate)	2, 9	244, 22	35.42	15.38
C (Furadan+Posse)	1, 6	25, 62	33.33	21.61
D (Furadan+Furadan)	3, 20	375, 72	39.16	23.18

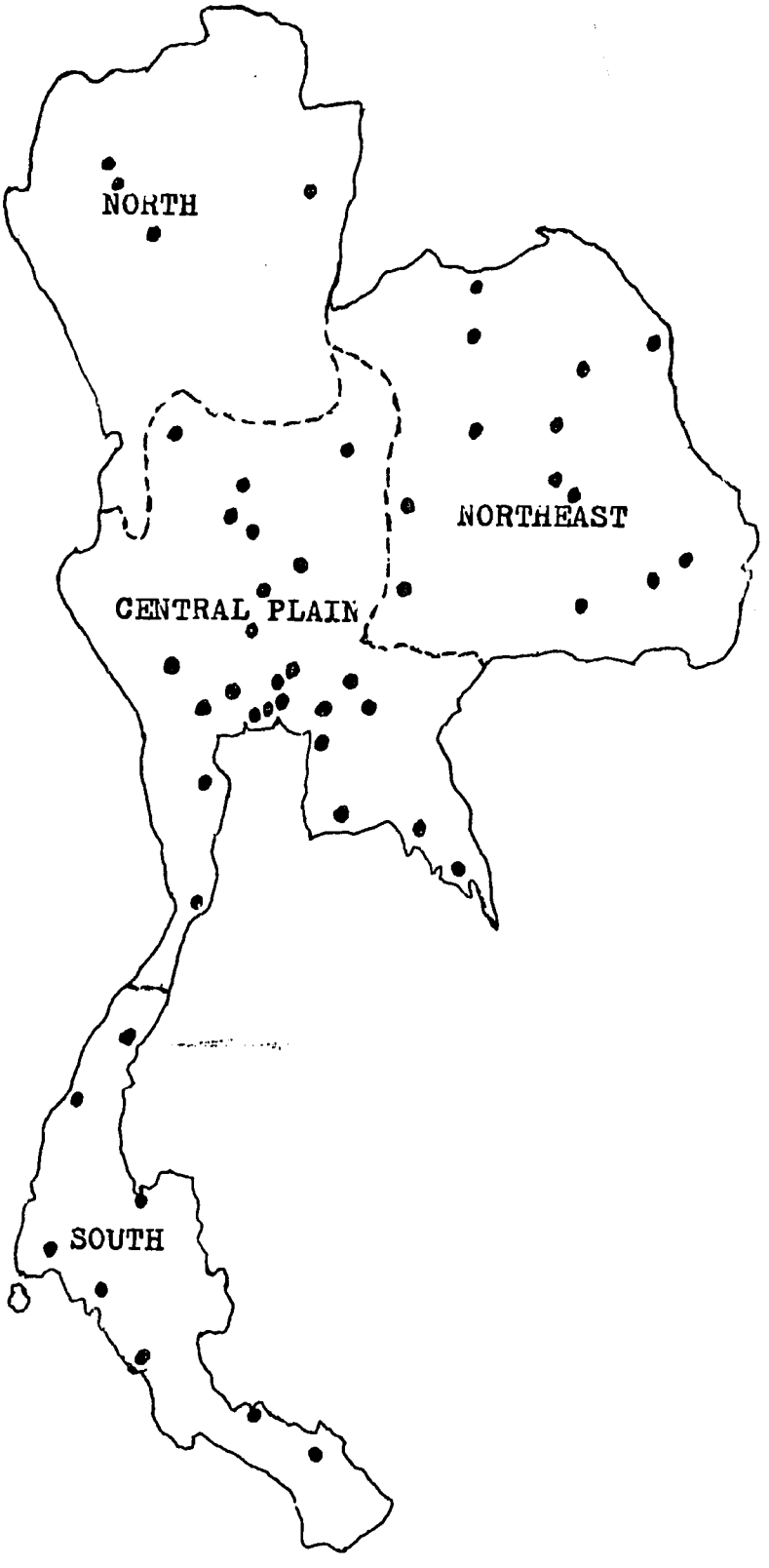

Figure 1. Map of Thailand showing locations where root-knot nematodes of different species have been reported. Circles represent provinces where nematodes were found in soil samples and plant specimens.

PROGRESS REPORT ON THE ROOT-KNOT NEMATODE STUDIES IN THAILAND

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Root-knot nematodes, Meloidogyne spp., are worldwide in distribution. In Thailand they are found associated with very wide ranges of crop hosts such as vegetables, ornamentals, fruit trees, upland crops, plantation crops and weeds. Their economic importance appears in Sontirat's report.

A. SCREENING AND BREEDING CERTAIN UPLAND, PLANTATION, AND VEGETABLE CROPS FOR RESISTANCE TO ROOT-KNOT NEMATODES, MELOIDOGYNE SPP.

Breeding for high-yield, cultivated crop varieties has been going on for many years in the Department of Agriculture and has resulted in a number of new lines and varieties of rice, soybean, corn, vegetables and ornamentals. The original work, however, has not aimed very much at disease resistance. Consequently, many cultivated crops have to be retested for disease resistance due to susceptibility of the crops to various diseases of economic importance including root-knot nematodes. Examples of such plant-disease interactions are rice to Yellow Orange Leaf Virus (YOLV) and root-knot nematode, corn to downy mildew, and kenaf to foot and root rot and root-knot nematode.

Among crop plants which draw our attention to screening and breeding for nematode resistance in recent years are rice, kenaf, tomato, black pepper, soybean, and various vegetables. They are economically important at both local and international levels.

Screening and Breeding Rice for Resistance to Meloidogyne graminicola Golden and Birchfield, 1965

Screening and breeding rice for agronomic purposes have been performed for several years. The necessity for work toward disease resistance, however, was not realized until about 1971 when certain rice varieties were damaged by Yellow Orange Leaf Virus (Disthaporn, 1981). New rice varieties of dwarf types from the Philippines were introduced for crossing with local ones. Crossing lines were tested for resistance to the disease. Finally,

Variety RD1, a crossing line of Luangthong (local) and IR8 (introduced), was proven to be resistant to YOLV. In recent years upland rice varieties were damaged by the root-knot nematode M. graminicola thereby affecting the government's approach to turn farmers to grow more upland rice in rainfed areas. The nematode caused stunting and reduced tillering. Hundreds of rice lines and varieties, both from local areas and abroad, have been screened and crossed for resistance to the nematode. The work has been carried out mainly by plant breeders of the Rice Division, Department of Agriculture (Sukhapanphotharam and Weerapat, 1981). Of all rice lines and varieties tested, the following were recorded as resistant to M. graminicola: Khao Dok Ma Li 105, Rd 6, Rd 7, Rd 8, Rd 15, IR 36, Arya 66 (field rice), RD 1/ IR 28 (SPRIR 75001-68-2-2), RD 7 2/IR 28 (SPRIR 76077-89-1-3), Rd 7/IR 1746-226-1-2-3 (BKNIR 76035-PSI-16-1), Biplab/BKN 6819-33-3-2-2-3 (BKNBR 1155-11-1-1-1-3), Biplab/BKN 6819-33-3-2-2-3 (BKNBR 1155-11-1-2-1-3), Biplab/BKN 6819-33-3-2-2-3 (BKNBR 1155-11-1-3-3-3), RD 7/RD 6//IR 29 (BKNBR 1141-14-7-1-3) and RD 7/RD 6//IR 29 (BKNBR 1141-1-1-1-1-3-1). The work is still underway.

Screening and Breeding Kenaf for Resistance to Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949

Cuban kenaf (Hibiscus cannabinus Linn.) has been introduced from abroad to replace existing local varieties (Hibiscus sabdariffa Linn.) since the former has a shorter growing period. An advantage of growing kenaf is that when it has been harvested, farmers can grow other crops while the soil is still wet. It is necessary in multiple-cropping systems when the land is rainfed. Having been introduced to serve the purpose, Cuban kenaf lines and varieties were distributed for suitability tests locally in many experiment stations throughout the country. In 1975, a number of tested lines and varieties, such as Madras Blue, Master fibre, Cubano, Salvador, C-131, 977-044, grew poorly, failed to produce flowers and finally died prematurely due to heavy infestation by M. incognita. The same situations were reported from other experiment stations later. This encourages further screening and breeding for resistance to the root-knot. In 1977, 71 lines and varieties of Cuban kenaf introduced from abroad were tested for resistance to M. incognita in plastic bags in laboratory (Pholsawat et al., 1977). It was reported that 7 lines and varieties produced less than 25% galls (Salvador, Wagahana, C-131, 70-4-139, 006-128, 034-112, 51-056). When tested in a field heavily infested with M. incognita in 1978,

the kenaf lines and varieties all died prematurely, suggesting that they were not resistant to the root-knot under field conditions.

Screening Tomatoes for Resistance to *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949

The work has been carried out since 1976 as part of the national tomato development program in cooperation with the Asian Vegetable Research and Development Center (AVRDC) based in Taiwan, Republic of China. Tomato seeds from that country were distributed to various countries in Asia including Thailand for local field tests. One hundred twenty-two lines and varieties of tomatoes, received from the institute, were tested at Hangchat Experiment Station, Plantation Crops Division in North Thailand, for resis to *M. incognita* (Sunthornkasemsuk and Pholcharoen, 1977). The test showed that four lines and varieties (Monte Carlo, L 274, L 387, TNBR), as well as the breeding lines of Kewalo and L 274, were recorded as resistant to the root-knot species. The work was repeated again with 26 existing and new lines and varieties from AVRDC by the same workers at the same place in 1980-81. The results are given in Table 1. Of all the plants tested, five lines and varieties were categorized as resistant to *M. incognita*: L274, L1477, L383, L4088, and L387. They all produced considerably low yields. L387, however, was severely infected with bacterial wilt and died prematurely due to the disease.

Screening Soybean for Resistance to *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949

One hundred forty-four varieties of soybean received from the Oil Crops Section, Division of Upland Crops, Department of Agriculture were tested in field conditions at Maejo Experiment Station, North Thailand, for resistance to *M. incognita* (Pholcharoen and Sunthornkasemsuk, 1979). Of all soybean lines and varieties studied, twenty-two were recorded as comparatively resistant to the nematode species: CES 16-17, 7312-P2-43-79-5-P6-P7-P8, 7204-P2-P3-2(8)-2-1-4-P8-P9, Kaoshiung E32, 7303-P2-P3-21-2-P6-P7, 9-4 DM 28, ISVEX 10, 7206-P2-P3-2-4-3-4-P8-P9-P10, 7020-1, 7316-P2-6-3-5-P6-P7, PI 230970, No 3 (Cutter 71), 7315-P2-26-36-1-P6-P7, 7316-P2-27-55-4-P6-P7, Calland, 7021-2, ACC 99, 7024-1, Rampage, Goru zairaice, ISVEX 4 (Buson) and 7314-P2-15-47-4-P6-P7. They all produced less than 10% root galls, while the susceptible check SJ 2 had 95%.

Screening Black Pepper (*Piper nigrum* Linn.) for Resistance to *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949

Five varieties of black pepper (*Piper nigrum* Linn.), Palian, Krabee, Malaysia, Chanburi, and Sarawak (known as Taichung in Malaysia or Singapora in Brazil) were tested for resistance to *M. incognita* at Pongrat Experiment Station, Rubber Division, East Thailand in field conditions (Pholcharoen and Pholcharoen, 1980). Black pepper cuttings were planted in MBr-fumigated soil in cement pots of 80 cm diameter. When plants were about one year old, root-knot infested roots were chopped into small pieces and about 200 cc of them were incorporated into the soil around the root system of each plant. One month after inoculation, roots 1 m long collected from each plant were indexed for gall presence. The root-knot nematode index used contains five categories: 0 = no galls, 1 = very light and small galling, 2 = lightly galled, 3 = abundant galling, 4 = very heavily galled. Of all black pepper varieties tested, not a single variety showed resistance to the nematode species. Palian and Sarawak, however, could grow in heavy infestation provided that cultural practices were taken as normal suggesting that the two varieties were tolerant to the root-knot attack.

B. CROP ROTATION AND POPULATION DYNAMICS OF *MELOIDOGYNE INCOGNITA* (KOFOID AND WHITE, 1919) CHITWOOD, 1949

A trial was conducted at Sri-Sa-Ket Experiment Station, Division of Plantation Crops, Northeast Thailand from May 1979 to September 1981 (Iemwimangsa *et al.*, 1981). The main plot was 23 x 23 sq. m consisting of sixteen small plots each of which were 5 x 5 sq. m and arranged in a chest-board scheme. Four different plant crops representing cereals, root crops, beans and vegetables were grown as planned. They were corn (cereal), sweet potato (root crop), groundnut (bean), and cabbage (vegetable). Population of the nematode species was increased to high levels in the experiment plots on Cuban kenaf variety Salvador. Rotation plants were grown for three growing seasons. Soil samples were collected for nematode counts at monthly intervals throughout the course of the experiment. Results of the experiment are given in Table 2. Nematode counts in this experiment varied considerably due to different cropping systems and crops within each system. Besides that, adverse conditions, like uncontrollable flooding from abnormally heavy rains in June 1980, caused retardation of plant growth, especially cabbage. Groundnut,

sweet potato and corn grown monoculturally could suppress the nematode population to very low levels in the second rotation. Groundnut or corn in rotation with sweet potato decreased numbers of M. incognita to low levels in second rotation. Cabbage as a monocrop system, and groundnut/corn and sweet potato/cabbage as multicrop systems, suppressed numbers of M. incognita to low levels in the third rotation. Cabbage in rotation with corn, however, did not decrease numbers of the nematode in the third rotation. The susceptible check crop was grown in June 1981, and cannot be assessed at present.

C. FUTURE PLANS

Work plans for the future include the continuation of screening and breeding rice, crucifers, tomatoes, beans (soybean, mungbean), kenaf, and jute for resistance to root-knot nematodes, Meloidogyne spp. Control of M. incognita will be accomplished by multicropping systems in three locations representing three different soil types in the North and Northeast.

1) Screening and breeding rice for resistance to M. graminicola will be carried out by plant breeders of the Rice Division in collaboration with nematologists from the Nematology Section. Screening will be done both in the laboratory and in the field.

2) Crucifers have been crossed and screened for agronomic purposes for several years. Although some cruciferous plants occasionally suffered from root-knot damage, screening for its resistance has never been realized. At the beginning we will be working on screening all lines and varieties available at the Vegetable Crops Section, Division of Plantation Crops in the laboratory.

3) Tomato screening for resistance to M. incognita will continue as part of the national tomato development program. At the same time it serves as the cooperating plan of the IMP. The work will be done in cooperation with Kasetsart research team, AVRDC, and the Vegetable Crops Section of the Division of Plantation Crops.

4) Screening and breeding Cuban kenaf (Hibiscus cannabinus Linn.) for resistance to M. incognita in the past few years have failed to produce resistance. The work will continue in search of resistant genes from abroad. We will also be testing Thai kenaf (Hibiscus subdariffa Linn.) and jute (Corchorus spp.) in the laboratory and in the field for their resistance to the said nematode.

5) We will be working on screening soybean and mungbean for resistance to M. incognita in the laboratory. The two crop plants, especially mungbean, were occasionally severely damaged by the root-knot species and have been used as intercrops in the cropping system.

6) Crop rotation remains to be studied in different crop systems, soil types, and climatic conditions. We will be conducting experiments by using multicropping systems to control populations of M. incognita in three locations of different soil types and climatic conditions in North and Northeast Thailand.

7) Controlling the population of the root-knot nematodes by chemicals is still necessary in certain crops when other alternative methods are not practicable. Plantation crops such as black pepper, for example, can stand for several years, and crop rotation or some other control methods cannot be applied. Thus chemical control is the only method to be effective. We will still continue to use chemicals to control the root-knot nematodes on those plants.

References

Disthaporn, S. 1981. Rice Diseases Section, Division of Plant Pathology, Dept. of Agric., Bangkok. (Personal communication.)

Iemwimangsa, M., S. Prachasaisoradej, S. Keereewan and C. Chunram. 1981. (Unpublished results of the experiment, Nematology Section, Division of Plant Pathology, Dept. of Agric., Bangkok.)

Pholsawat, W., V. Saengsit, S. Sermsap, C. Petburanin, S. Prachasaisoradej, and S. Keereewan. 1977. Screening Cuban kenaf varieties for resistance to root-knot nematode. (In Thai with English summary.)

Pholcharoen, S., and A. Sunthornkasemsuk. 1979. Varietal reactions of soybean to the root-knot nematode, Meloidogyne incognita. Annual report of the Division of Plant Pathology, Dept. of Agric., Bangkok. (In Thai with English summary.)

Pholcharoen, S., and Sanong Pholcharoen. 1980. Varietal reactions of certain black pepper (Piper nigrum Linn) to the root-knot nematode, Meloidogyne incognita. Annual report of the Division of Plant Pathology, Dept. of Agric., Bangkok. (In press)

Sukhapanphotharam, S., and P. Weerapat. 1981. Breeding for Disease and Insect Resistance Branch, Division of Rice, Dept. of Agric., Bangkok. (Personal communication.)

Sunthornkasemsuk, A., and S. Pholcharoen. 1977. Varietal reactions of certain tomatoes from the Asian Vegetable Research and Development

Center (AVRDC) to the root-knot nematode, Meloidogyne incognita. Annual report of the Division of Plant Pathology, Dept. of Agric., Bangkok. (In Thai with English summary.)

Table 1. Tomato Cultivars Tested for Resistance to *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949

Line/Variety	Percentage roots galled Rep 1	Rep 2	Mean
L1	41.67	39.28	40.48
L8	33.33	41.66	37.50
L285	57.50	95.00	76.25
L755	35.00	33.33	34.17
L1477	9.37	3.57	6.47
L1629	25.00	50.00	37.50
L1737	25.00	25.00	25.00
L272	3.57	25.00	14.29
L274	2.50	4.16	3.33
L383	12.50	dead	12.50
L3893	14.28	5.55	9.92
L4088	15.00	dead	15.00
L27	43.33	40.62	41.98
L94	31.25	dead	31.25
L302	61.11	dead	61.11
L337	50.00	25.00	37.50
L3682	62.50	33.33	47.92
L3705	87.50	66.66	77.08
L3745	65.00	25.00	45.00
L3786	50.00	12.50	31.25
L4066	55.00	33.33	44.17
L4410	50.00	25.00	37.50
L4540	65.62	33.33	49.48
L4670	30.55	34.37	32.46
CL9-0-0-1	25.00	31.25	28.13
L387	dead due to Bacterial Wilt		

Table 2. Crop Rotation and Population Dynamics of *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949

Crop grown	Initial population (PI) expressed as 100 (Dec 79-Mar 80)	Soil population expressed as % of PI		
		Rot 1 (Apr-Aug 80)	Rot 2 (Sept-Dec 80)	Rot 3 (Jan-May 81)
G	100	4.71	0.00	0.00
SP	100	128.30	1.83	1.09
C	100	14.43	188.52	2.95
Co	100	10.00	0.36	0.00
G/SP	100	46.00	2.30	2.07
G/C	100	9.09	100.47	5.69
G/Co	100	48.56	78.99	0.31
SP/C	100	102.36	97.05	6.79
Co/SP	100	36.16	16.64	5.92
C/Co	100	576.97	142.42	43.64

G = Groundnut (Var. Tainan 9)

SP = Sweet potato (Var. PB 104-1)

C = Cabbage (Var. Copenhagen Market)

Co = Corn (native Var. Khaen-on)

ROOT-KNOT NEMATODES IN TAIWAN

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Review of Past Work

Root-knot nematodes have been reported to be associated with 108 crop species in Taiwan representing 91 genera in 41 families (Table 1). Among them, 72 species are known hosts for *Meloidogyne*. This information is the result of an island-wide survey of plant parasitic nematodes in Taiwan conducted in 1970-71. Root-knot nematodes were found in 2,976 samples out of a total of 10,577 samples collected in the survey and were rated as the most widely disseminated plant-parasitic nematodes among the 27 genera found in Taiwan (7). The crops attacked included 35 kinds of vegetables, 25 kinds of fruits, 12 kinds of flowers, 9 kinds of staple food, 8 kinds of trees and shrubs, and 19 other miscellaneous crops. Even though there has been no official assessment of crop losses, the importance of root-knot nematodes in Taiwan is apparent by their wide distribution and the number of crops involved.

The species and races that have been reported in Taiwan include *M. incognita* race 1, 2, and 3; *M. javanica*; *M. hapla*; *M. arenaria*; and *M. acrita* (1, 9, 10). The precise relationship between crops and species or races of root-knot nematodes was not determined in the island-wide survey. Of the above five species, *M. incognita*, however, is considered to be the most common. The most recent case of a severe crop loss due to *M. incognita* was in the carrot production area of southern Taiwan last year. A control program is currently being devised by the Tainan District Agricultural Improvement Station (DAIS). Damage to peanuts caused by *M. arenaria* has just become a serious threat to the Yun-lin and Chia-yi areas in the last three years. This problem has attracted the attention of nematologists in Taiwan (1). Peanuts are important to farmers as a non-host rotation crop. If *M. arenaria* spreads widely, it will become a major threat to the cropping systems currently practiced by Taiwan farmers. In studies of *M. arenaria*, the Tainan DAIS workers have tested

thirty dry-land crops commonly grown in Taiwan for their reactions to this nematode (Table 2) (2). Sixteen of these rate moderately to highly susceptible to M. arenaria, indicating the potential threat of this nematode to Taiwan agriculture. Four nematicides have been evaluated for the control of M. arenaria in peanuts (Table 3) (2). All were effective in reducing disease incidence, and Nemacur 10% G was effective even when applied at the low rate of 15 kg/ha.

Sugarcane is one of Taiwan's major cash crops. Research on nematode problems of sugarcane at the Taiwan Sugar Research Institute (TSRI) has been one of the longest ongoing projects in Taiwan. M. incognita race 2 was found to be prevalent in sugarcane fields in a survey of 26,595 hectares (3, 6). M. javanica was also found in sugarcane fields but was rare. Fumigating the sandy sugarcane land suitable for furrow irrigation when five root-knot larvae are collected from a 100g soil sample has proven to be a commercially feasible control method (3). Nematicide screening is one of the major activities of the nematology research section at TSRI. Counter 10% G has been chosen by TSRI to control nematodes in their sugarcane fields (Table 4) (4). Interplanting with resistant crops for root-knot nematode control is also being investigated. Planting peanut or sunhemp 2 months before sugarcane resulted in respective increases of 43.8% to 44.4% and 128.6% to 147.6% in the height and dry weight of 4-month old sugarcane plants (5).

Another species that has recently attracted attention in Taiwan is M. hapla. Eighty-three species of vegetables, grasses, and ornamentals were tested at the Asian Vegetable Research and Development Center (AVRDC) for their reaction to M. hapla. Twenty-four plant species were determined to be new hosts for M. hapla (8).

Resistance screening has been one of the major research activities in nematology at AVRDC. A root-knot nematode nursery has been established for this purpose. A total of 313 accessions and 215 breeding lines of tomato, 288 accessions and 89 breeding lines of mungbean, and 78 accessions and 157 breeding lines of soybean have been screened for resistance to M. incognita under field conditions. The results for the past five years are summarized in Table 5.

Current Research at AVRDC

1. Collection of all local species and races of Meloidogyne in Taiwan and the establishment of stock cultures for screening purposes.
   -Previous screenings were made for resistance to M. incognita only. It is necessary to test the resistance against as many species and races as possible to select resistant varieties for different countries or regions. The nematode collection so far includes M. incognita race 2, M. hapla and M. arenaria.
2. Interaction between mycorrhizae and root-knot nematodes.
   -A preliminary test indicated there was a possibility of controlling root-knot nematodes with VA mycorrhizae. Tests are currently underway to evaluate Glomus fasciculatus as a control for M. incognita in tomatoes and mungbeans.

Future Research Plan

1. To improve screening methods.
2. To evaluate all promising cultivars of tomato, mungbean and soybean against the complete collection of Taiwan root-knot nematode species and races.
3. To continue research on the interaction between mycorrhizae and root-knot nematodes.
4. To investigate the distribution of Meloidogyne species and races in Taiwan.

Literature Cited

1. Cheng, Y. H., and C. C. Tu. 1980. Identification of Meloidogyne arenaria on peanut in Taiwan. (In Chinese with English summary.) J. Agr. Res. China 29(1):47-53.
2. Cheng, Y. H., and W. C. Lo. 1980. Host range studies and appropriate timing of nematicide application for control of peanut root-knot nematode, Meloidogyne arenaria. (In Chinese.) Plant Prot. Bull. (Taiwan) 22(4):431. (Abstr.)
3. Hu, C. H., and T. K. Tsai. 1975. The nematode investigation in sugarcane fields of Taiwan (III). (In Chinese with English summary.) Report of Taiwan Sugar Research Institute No. 70:13-25.

4. Hu, C. H., and T. K. Tsai. 1978. Control of parasitic nematodes with Counter, Furadan, and Temik and its effect on sugarcane yield. (In Chinese with English summary.) Report of Taiwan Sugar Research Institute No. 81:25-34.

5. Hu, C. H., and T. K. Tsai. 1979. Evaluation of sugarcane varieties and some interplanting crops for resistance to sugarcane root-knot nematodes, Meloidogyne spp. (in English). Plant Prot. Bull. (Taiwan) 21(4):452. (Abstr.)

6. Hu, C. H., and T. K. Tsai. 1980. Population dynamics and the control of root-knot nematodes on sugarcane. (In Chinese.) Plant Prot. Bull. (Taiwan) 22(4):430 (Abstr.)

7. Huang, C. S., Y. P. Tsai, C. C. Tu, Y. Y. Lin, and S. P. Huang. 1972. Plant parasitic nematodes in Taiwan. Institute of Botany, Academia Sinica Monograph Series No. 1. 61 pp.

8. Ruelo, Sister J. S. 1980. Host range studies of Meloidogyne hapla in Taiwan. Plant Dis. (in press).

9. Wang, K. C. 1978. Research on root-knot nematodes at the National Taiwan University. The Kasetsart Journal 12(1):36-42.

10. Yang, C. R., K. C. Wang, and Y. S. Huang. 1977. Investigation of the species and races of root-knot nematodes in Taiwan. (In Chinese.) Plant Prot. Bull. (Taiwan) 19(4):311. (Abstr.)

Table 1. Plant families with which root-knot nematodes are associated in Taiwan

Families	No. of genera	No. of species	Families	No. of genera	No. of species
Amaranthaceae	2	2	Malvaceae	3	4
Amaryllidaceae	1	3	Moraceae	1	1
Anacardiaceae	1	1	Musaceae	1	1
Araceae	1	1	Myrtaceae	2	2
Bromeliaceae	1	1	Oleaceae	1	1
Caricaceae	1	1	Orchidaceae	1	1
Chenopodiaceae	1	1	Oxalidaceae	1	1
Compositae	7	8	Palmaceae	2	2
Convolvulaceae	2	2	Pinaceae	1	1
Corylaceae	1	1	Podocarpaceae	1	1
Cruciferae	2	6	Punicaceae	1	1
Cucurbitaceae	7	8	Rhamnaceae	1	1
Ebenaceae	1	1	Rosaceae	4	5
Euphorbiaceae	3	3	Rubiaceae	1	1
Gramineae	10	12	Rutaceae	3	7
Iridaceae	1	1	Salicaceae	1	1
Leguminosae	10	10	Sapindaceae	2	2
Lilaceae	2	2	Solanaceae	3	4
Linaceae	1	1	Theaceae	1	1
			Umbelliferae	2	2
			Vitaceae	1	1
			Zingiberaceae	2	2

Table 2. The reactions of different host plants to *Meloidogyne arenaria*

	Plant	Root gall index a/	Resistant rating b/	Egg mass	Host status c/
1.	*Amaranthus inamoenus* Willd (Edible amaranth)	4	VS	+	H
2.	*Apium graveolens* L. (Celery)	4	VS	+	H
3.	*Arachis hypogaea* L. (Peanut)	4	VS	+	H
4.	*Brassica chinensis* L. (Chinese cabbage)	1	MR	+	H
5.	*B. campestris* L. (Field mustard)	0	R	-	NH
6.	*B. oleracea* L. (Cabbage)	1	MR	+	H
7.	*B. juncea* Cosson (Mustard)	1	MR	+	H
8.	*Capsicum frutescens* L. (Sweet pepper)	0	R	-	NH
9.	*Citrullus vulgaris* Schrad. (Watermelon)	2	S	+	H
10.	*Coriandrum sativum* L. (Coriander)	1	MR	+	H
11.	*Cucumis sativus* L. (Cucumber)	3	VS	+	H
12.	*C. melo* L. (Melon)	4	VS	+	H
13.	*Cucurbita moschata* Duch. (Squash)	2	S	+	H
14.	*Cucurbita pepo* L. (Pumpkin)	0	R	-	NH
15.	*Daucus carota* L. (Carrot)	4	VS	+	H
16.	*Foeniculum vulgare* Gaertn. (Fennel)	1	MR	+	H
17.	*Glycine max* Merr. (Soybean)	4	VS	+	H
18.	*Ipomoea batatas* var. edulis Mak. (Sweet potato)	1	MR	+	H
19.	*Lactuca sativa* L. (Lettuce)	2	S	+	H
20.	*Lycopersicon esculentum* Mill. (Tomato)	2	S	+	H
21.	*Luffa cylindrica* Roem (Vegetable sponge)	2	S	+	H
22.	*Nicotiana tabacum* L. (Tobacco)	2	S	+	H
23.	*Phaseolus vulgaris* L. (Kidney bean)	0	R	-	NH
24.	*Phaseolus mungo* L. (Mungbean)	4	VS	+	H
25.	*Raphanus sativus* L. (Radish)	1	MR	+	H
26.	*Saccharum officinarum* L. (Sugarcane)	0	R	-	NH
27.	*Sorghum vulgare* Pres. (Sorghum)	0	R	-	NH
28.	*Solanum melongena* L. (Eggplant)	2	S	+	H
29.	*Spinacia oleracea* L. (Spinach)	2	S	+	H
30.	*Zea mays* L. (Corn)	0	R	-	NH

a/ Gall index: 0 = no visible galls, 1 = very few, small galls, 2 = scattered small galls to moderate galls, 3 = many galls or few moderate galls, 4 = many moderate galls.

b/ R = resistant, MR = moderately resistant, S = susceptible, VS = very susceptible

c/ H = host plant, NH = non-host plant.

Table 3. Field evaluation of nematicides for the control of peanut root-knot nematode.

Nematicide	Dosage (kg/ha)	Disease index*
Marshal 1% D.	200	5.6 a
Marshal 1% D.	400	3.1 a
Furadan 3% G.	60	12.5 a
Furadan 3% G.	100	7.5 a
Nemacur 10% G.	15	8.1 a
Nemacur 10% G.	25	5.6 a
Vydate 24% L.	1/750 dilution	6.9 a
Vydate 24% L.	1/500 dilution	4.4 a
Control		42.5 b

* Each value is the mean of 4 replications.
Column means followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

Table 4. Effects of nematicides on sugarcane yield, field experiments, 1974-77

Treatments		1974-75 Crop season				1975-76 Crop season				1976-77 Crop season			
		Autumn planting		Spring planting		Autumn planting		Spring planting		Autumn planting		Spring planting	
		Cane yield t/ha	Index	Cane yield t/ha	Index	Cane yield t/ha	Index	Cane yield t/ha	Index	Cane yield t/ha	Index	Cane yield t/ha	Index
Terracur P 5%G	100 kg/ha	156.9	115.5	77.1**	124.3	114.0	109.6	73.9**	218.2	175.9	109.5	100.0*	121.4
Terracur P 5%G	200 kg/ha	157.8	116.2	79.2**	127.6	—	—	—	—	—	—	—	—
Thimet 10%G	30 kg/ha	—	—	—	—	120.5	115.9	66.9**	197.5	170.5	106.1	99.8*	121.1
Temik 10%G	30 kg/ha	153.8	113.2	73.4*	118.3	111.8	107.5	80.9**	238.8	—	—	—	—
Nemacur 10%G	200 kg/ha	161.6	118.9	84.0**	135.3	—	—	—	—	182.4	113.5	103.2**	125.3
Furadan 3%G***	60 kg/ha	164.7	121.2	77.3**	124.6	102.8	98.8	76.9	227.0	180.5	113.3	102.3**	124.2
Counter 10%G	20 kg/ha	—	—	—	—	115.9	111.4	78.4**	231.5	171.3	106.6	101.2**	122.8
Counter 10%G	30 kg/ha	—	—	—	—	122.9	118.2	81.6**	240.9	180.0	112.0	108.9**	132.2
Fumazone 70E	15 l/ha	152.9	112.6	71.7	115.5	107.3	103.1	58.6**	173.0	—	—	—	—
C K		135.9	100	62.1	100	104.0	100	33.9	100	160.7	100	82.4	100
L. S. D.		Not significant		*5% = 8.6 t **1% = 11.7 t		Not significant		**1% = 14.3 t		Not significant		*5% = 13.1 t **1% = 17.8 t	

*** Applied at the rate of 75 kg/ha in 1976-77.

Table 5. Screening of soybean, mungbean and tomato for resistance to *M. incognita* at AVRDC

Crops	No. of times tested	No. of highly resistant accessions and breeding lines *
Soybean	4	5
	3	10
	2	82
Mungbean	2	29
	1	12
Tomato	4-6	7
	3	8
	2	25

* 0-2 galls or egg masses per root system.

STUDIES ON ROOT-KNOT NEMATODES IN PAKISTAN

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Root-knot nematodes have been known as pests of great economic importance throughout the world, and Pakistan, being situated between 24° to 37° north and 60° to 70° east, is no exception. As compared to other parasitic nematodes in Pakistan, the root-knot nematode problem is more serious and complex. Reasons are many and varied. This country lies in a tropical region where the climate is suitable for the activity and reproduction of nematodes throughout the year. Sandy and warm soil, such as found in most parts of this country, favorable to nematode infestation, especially in irrigated areas which are used for crop production almost continuously. Staple food crops including fruits and vegetables grown in the same field year after year are often so heavily attacked by the root-knot nematodes that their production becomes hardly economical.

During the last few years, extensive surveys on plant-parasitic nematodes were carried out in the country. As a result, besides other plant-parasitic nematodes as in other tropical countries, four species, viz. M. incognita, M. javanica, M. arenaria and M. hapla, were found associated with many cereal, fruit and vegetable plants (Table 1), and producing galls on the roots and damaging the crops. Apart from this, a specimen collected from Petonia (Petonia alba) seems to be an undescribed species. Detailed investigation which includes differential host tests has been planned.

Pakistan consists of four provinces, namely Sind, Punjab, Frontier and Baluchistan, which have different ecological zones ranging from coastal areas to a high altitude of 4500 meters (Fig. 1).

The province of Sind is situated in the southern zone of the country where the climate is warm and humid. It also possesses large, arid areas. In this province, banana, sugar cane, cotton, papaya, tomato, orange, okra and many other crops are extensively cultivated. M. incognita, M. javanica and M. arenaria generally attack these crops. M. hapla is rarely found and then associated only with tomato. M. javanica has been found attacking okra plants very severely in this region (Fig. 2).

The province of Punjab which is situated in the north of Sind consists of plains and hilly areas. M. incognita, M. hapla and M. arenaria have been found parasitizing many cereal, fruit and vegetable crops. In general, M. hapla occurs in the hilly areas whereas M. incognita and M. arenaria attack the crops in the plains.

In the province of N.W.F.P. (Frontier), which is located at a high altitude in the extreme north of the country, M. hapla commonly occurs followed by M. incognita. These two species are associated with most of the root-knot-infested plants of this region. Generally, M. hapla is found attacking chillies, potato, tomato and beans in this region, but sometimes it occurs with M. incognita in low frequencies.

In the province of Baluchistan, M. hapla and M. arenaria were found attacking tomato and potato plants (Table 2).

Table 1. Main Crops of Pakistan

		Severity of Root Knot Infestation
Cereals and Other Crops		
1. Wheat	(*Triticum vulgare* L.)	-
2. Rice	(*Oryza sativa* L.)	-
3. Maize	(*Zea mays* L.)	+ +
4. Cotton	(*Gossypium hirsutum* L.)	+
5. Sugar cane	(*Saccharum officinarum* L.)	+
6. Groundnut	(*Arachis hypogaea* L.)	+ +
7. Tobacco	(*Nicotiana tabacum* L.)	+ +
Fruits		
1. Banana	(*Musa sapientum* L.)	+ +
2. Citrus	(Orange *Citrus auranium*, Lemon *Citrus limonia*, *Citrus medica*)	+
3. Mango	(*Mangifera indica* L.)	-
4. Apple	(*Pyrus malus* L.)	-
5. Grape	(*Vitis vinifera* L.)	-
6. Plum	(*Prunus domestica*)	-
7. Papaya	(*Carica papaya* L.)	+ + +
Vegetables		
1. Tomato	(*Lycopersicon esculentum* Mill)	+ + +
2. Potato	(*Solanum tuberosum* L.)	+ + +
3. Okra	(*Abelmoschus esculentus* L.)	+ + +
4. Onion	(*Allium cepa* L.)	+ +
5. Cauliflower	(*Brassica oleracea* L.)	+
6. Sweet potato	(*Ipomoea batatas* L.)	-
7. Brinjal	(*Solanum melongena* L.)	+ + +
8. Chillies	(*Capsicum frutescens*)	+ +
9. Sponge gourd	(*Luffa cylindrica*)	+ + +

+ + + = High infestation

+ + = Medium infestation

+ = Low infestation

Table 2. Occurrence of Root-Knot Nematodes in Pakistan

Common name	Botanical name	Nematodes	Localities
Banana	*Musa sapientum*	*Meloidogyne incognita* *M. javanica* *M.* sp.	S
Bean	*Glycine soja*	*M. hapla* *M. incognita*	S & F
Bean	*Dolichos lablab*	*M. javanica* *M. incognita*	P & S
Betel	*Piper betel*	*M. javanica* *M. incognita*	S
Black nightshade	*Solanum nigrum*	*M. incognita*	S
Brinjal (Eggplant)	*Solanum melongena*	*M. javanica* *M. incognita*	F, P & S
Cabbage	*Brassica oleracea* L.V. *Capitata*	*M. incognita*	S
Cauliflower	*Brassica oleracea* L.V. *Botrytis*	*M. incognita*	F, S & P
Chenopodium	*Chenopodium album*	*M. incognita* *M. javanica*	S
Chillies	*Capsicum frutescens*	*M. incognita* *M. hapla*	F, S & P
Cotton	*Gossypium hirsutum*	*M. incognita*	S
Ginger	*Zingiber officinale*	*M. incognita* *M. javanica*	
Maize	*Zea mays*	*M. incognita* *M. javanica*	F & P
Okra	*Hibiscus esculentus*	*M. javanica* *M. incognita*	S & P
Papaya	*Carica papaya*	*M. javanica* *M. incognita*	S
Potato	*Solanum tuberosum*	*M. hapla* *M. javanica*	F, B & S
Pyrethrum	*Chrysanthemum* sp.	*M. incognita* *M. hapla*	S, P & F
Sponge gourd	*Luffa cylindrica*	*M. incognita* *M. javanica*	S & P
Sugarbeet	*Beta vulgaris*	*M. incognita* *M. javanica*	F & P
Sugar cane	*Saccharum officinarum*	*M. arenaria* *M. incognita*	F & S

Table 2 (Continued)

Common name	Botanical name	Nematodes	Localities
Tobacco	*Nicotiana tabacum*	*M. incognita* *M. javanica*	F
Tomato	*Lycopersicon esculentum*	*M. incognita* *M. arenaria* *M. hapla*	S, P, F & B

S = Sind, P = Punjab, F = N.W.F.P., B = Baluchistan

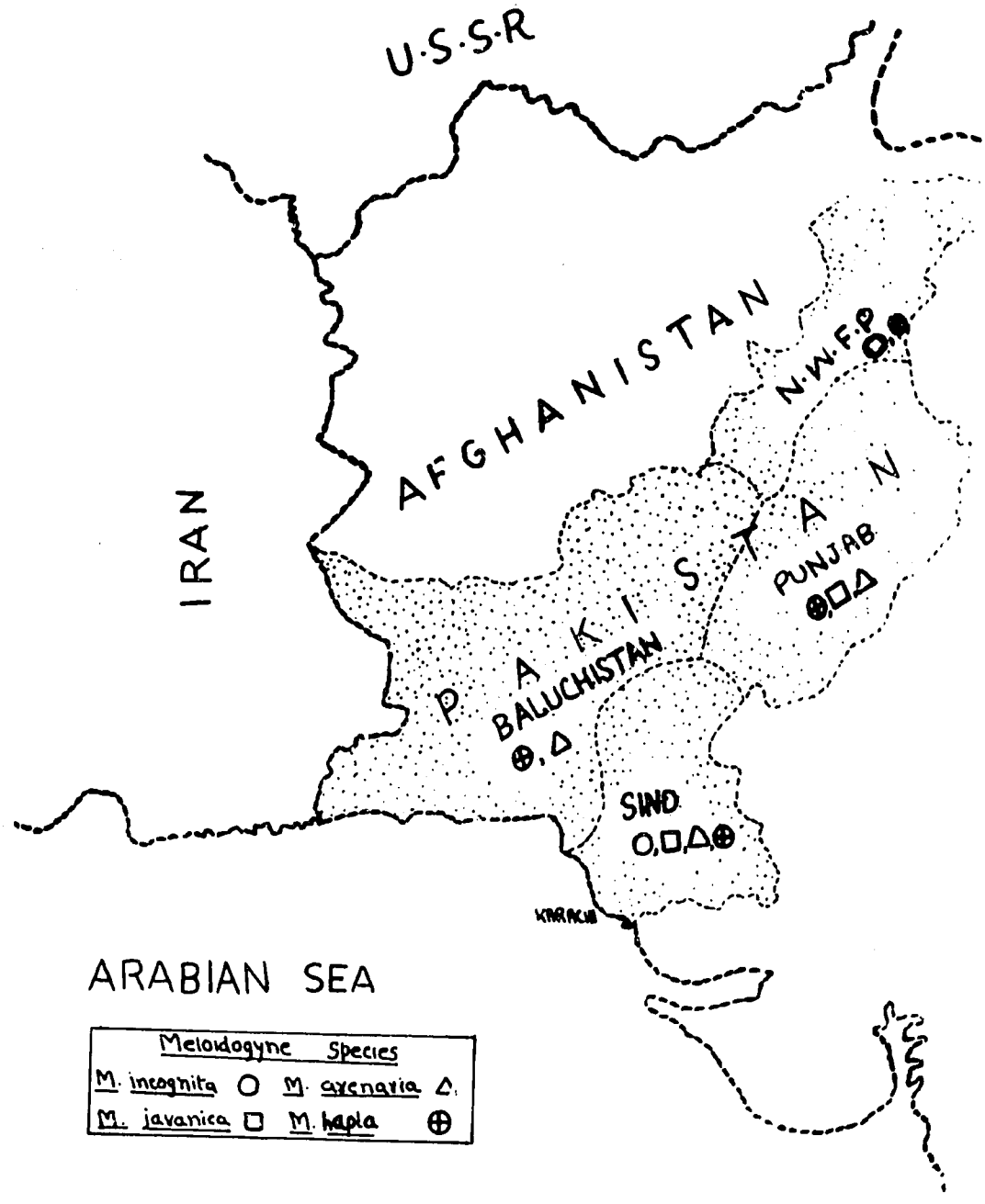

FIG.1.
DISTRIBUTION OF MELOIDOGYNE SPP IN PAKISTAN

Fig.2. Okra roots infested with *M. javanica*.

ROOT-KNOT NEMATODES ASSOCIATED WITH BANANA IN PAKISTAN

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Introduction

In Pakistan, cultivation of banana started only some 34 years ago. Climate of the province of Sind being favorable, banana spread in this area and within two decades it occupied about 30,000 acres of land, mostly in the non-frost districts. The yield of banana was reasonably good in the beginning, but in the last decade, the growers have been complaining of poor harvest despite fairly good irrigation and fertilization measures. This decline notwithstanding, banana continued to draw the attention of growers and spread further to occupy about 50,000 acres as of 1978 (Rizvi, 1978).

In the last several years, however, the continued decline in harvest forced growers to start substituting other crops for banana. Since this decline in yield could not be attributed to any of the visible pathogens or other more familiar causes, nematodes were looked upon as the possible agents, and therefore, a survey of banana plantations was undertaken in 1977-78. Since collection of the empirical experiences of common farmers was also in view, one of the questions invariably asked of them was if they had seen galls or swellings on the roots of plants in their fields. As such, though not aimed, the survey became one bearing emphasis on root-knot nematodes.

Based on an extensive survey of 30 Taluqas (agricultural units), belonging to all the seven banana-growing districts of lower Sind, the present report is a part of a comprehensive report submitted to the Pakistan Council of Scientific and Industrial Research (PCSIR), Ministry of Science and Technology, Government of Pakistan (Saeed *et al.*, 1978). In this survey, 774 samples of soil and roots were collected from over 100

Cooperation of Director, and Plant Protection Officer, Ministry of Agriculture, Government of Sind is acknowledged.

localities, and about 150 farmers were interviewed to fill up the questionnaire constructed especially for this purpose. These 774 samples represented the odd 50,000 acres land presently occupied by banana in Sind.

Materials and Methods

Usual methods of a nematological survey were followed. Species were identified on the basis of perineal patterns. However, no attempt was made to index the infestation level, as we believe that it is difficult to obtain reliable estimates of this kind with a plant like banana (though easier in comparison to trees).

The presence of galls on the roots of a plant was taken as an indication of the presence of root-knot nematodes. However, in several cases (when galls were not visible), number of nematodes was also taken into consideration; this was when at least 10 of them were recovered in a 100-ml soil sample, and there was no dispute over their generic identification. So it is possible that in some cases root-knot nematodes might have escaped our observation; the other possibility was, however, remote.

Results and Discussion

Occurrence. *Helicotylencus* spp. (*multicinctus*, *indicus*, *dihystera*) constituted the most prominent phytonemic fauna. This was followed by *Meloidogyne* spp. Of the 774 samples which were analyzed in this survey, root-knot nematodes were recovered in 355 (46%) samples (galls on 308, over 10 larvae in 47 cases). Another 35 samples were suspected to contain root-knot nematodes as each of them yielded less than 10 larvae. It may be mentioned that *Helicotylenchus* spp. were found in more than 50% of the samples, whereas the notorious parasite of banana--*Radopholos similis*--was found in only 20% of the samples.

As shown in Table 1, the highest occurrence of root-knot nematodes was found in district Hyderabad (51.1%). This was followed by Nawabshah (50.7%), Thatta (49.5%), Sanghar (44.2%), Tharparkar (40.1%), Badin (36.9%) and Karachi (33.3%). Galls were of small to moderate size, the biggest being about 1.2 cm in diameter.

Distribution of root-knot nematodes in relation with Indus. The river Indus enters the province of Sind to form the boundary between the districts of Sukker and Jacobabad (Fig. 1). Down to the south it forms natural boundaries for other districts: Larkana-Khairpur, Nawabshah-Dadu, Hyderabad-Thatta. It is only in Thatta that the river passes through the middle of the district and forms her delta before joining the Arabian sea.

Except in Thatta, banana is cultivated only in the eastern plain of the Indus up to 90 miles (Taluqa Diplo: District Tharparkar). However, in Thatta, the major share comes from the western side, from up to 30 miles in this district (Taluqa Mirpursakro) and farther up to 50 miles in Karachi district. As shown in Fig. 1, the Indus passes through only three of the seven banana districts (Nawabshah, Hyderabad, Thatta). It was interesting to note that these three districts gave the highest occurrence rate (%) of root-knot nematodes (Table 1). Further, in these three districts, the highest root-knot nematode-yielding localities were found to lie within a distance of about 20 miles from the Indus, this being both east and west in Thatta and only east in the remaining two districts (Fig. 2). This area lies between 24° to 27° N and zigzags over 68° E.

The correlation between the distribution of Meloidogyne spp. and the course of the Indus could not be explained. The sandy texture of the soil and plentiful supply of water (due to the network of irrigation canals) could probably be the attributable factors. As mentioned earlier, this survey was only for banana, and therefore, it would be worthwhile to study if this correlation stands with other crops and other districts as well.

Species of Meloidogyne. Only two species could be identified. Meloidogyne incognita was the most dominant one, and out of 308 root samples that bore galls, this species was found in 172 samples (Table 2). M. javanica was found in 62 samples, whereas these two species occurred simultaneously in only 14 samples. There were as many as 60 samples in which nematodes could not be identified to specific level and have been identified only as Meloidogyne sp. (g). These are in addition to 47 samples which were included as RKN samples on the basis of recovery of more than 10 larvae per 100 ml soil and classified as Meloidogyne sp. (l).

Information presented here shall be found useful as long as root-knot nematodes are considered as a group and the approach is practical and pragmatic. It would be worthwhile to mention that at present banana is fetching about 50,000,000 dollars annually. It has been estimated that the production of banana can be increased by 50% (= 25,000,000 dollars) if proper measures of nematode control are taken. This twenty-five million dollar annual loss to banana in Pakistan is attributable to all the species, and separate statistics for different species do not exist. Though, in the case of banana, root-knot nematodes are not considered as virulent

as Radopholos similis or Helicotylenchus spp., yet in view of their widespread occurrence, certainly they are responsible for a sizable proportion of this loss that is worth consideration. Taylor & Sasser (1978) envisage a loss of 5% being caused by root-knot nematodes as an average on a world basis.

Certainly, as they fear, developing countries like Pakistan are on the upper side of this average. In other experiments (not included here) root-knot nematodes were found responsible for up to 30% of loss in yield. This work is in progress and shall be presented elsewhere.

References

Rizvi, S. I. A. 1978. Recorded personal discussions.

Saeed, M., H. A. Khan, V. A. Saeed, and F. Qamar. 1978. Nematode Problem of Banana in Sind. Report submitted to the Pakistan Council of Scientific and Industrial Research. 41 pp.

Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (Meloidogyne species). A cooperative publication of the Department of Plant Pathology, N. C. State University and the USAID. 111 pp.

Table 1. Break-up Analysis of Samples Collected in Sind

District	Number of Taluqas surveyed	Number of villages surveyed	Number of samples collected	Number of samples yielding RKN		4 vs 5 in terms of Percentage
				Galls	Over 10 larvae	
1	2	3	4	5		6
Thatta	7	27	216	82	25	49.5
Hyderabad	4	21	168	79	7	51.1
Tharparkar	6	19	152	55	6	40.1
Badin	3	12	84	27	4	36.9
Sanghar	4	10	70	29	2	44.2
Nawabshah	5	9	63	29	3	50.7
Karachi	1	3	21	7	0	33.3
Total	30	101	774	308	47	45.8

Table 2. Species of *Meloidogyne* and Their Occurrence in Banana Fields

District	Total number of samples	*M. incognita*	*M. javanica*	*M. incognita* + *M. javanica*	*Meloidogyne* sp.
Thatta	82	51	12	8	11
Hyderabad	79	42	17	1	19
Badin	27	15	4	0	8
Sanghar	29	14	8	2	5
Nawabshah	29	17	5	1	6
Karachi	7	4	1	0	2
Total	308	172	62	14	60

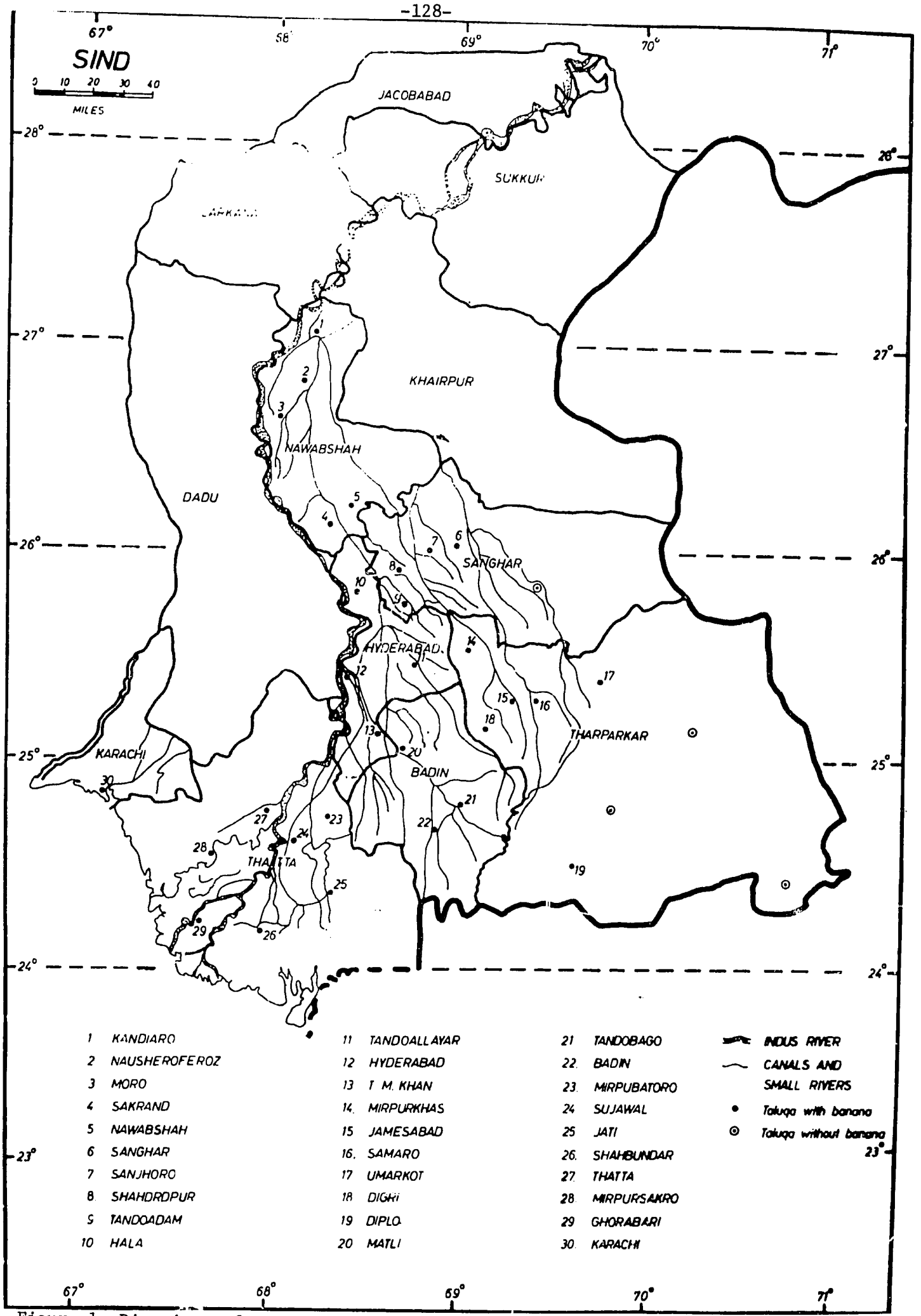

Figure 1. Districts of province of Sind and areas sampled.

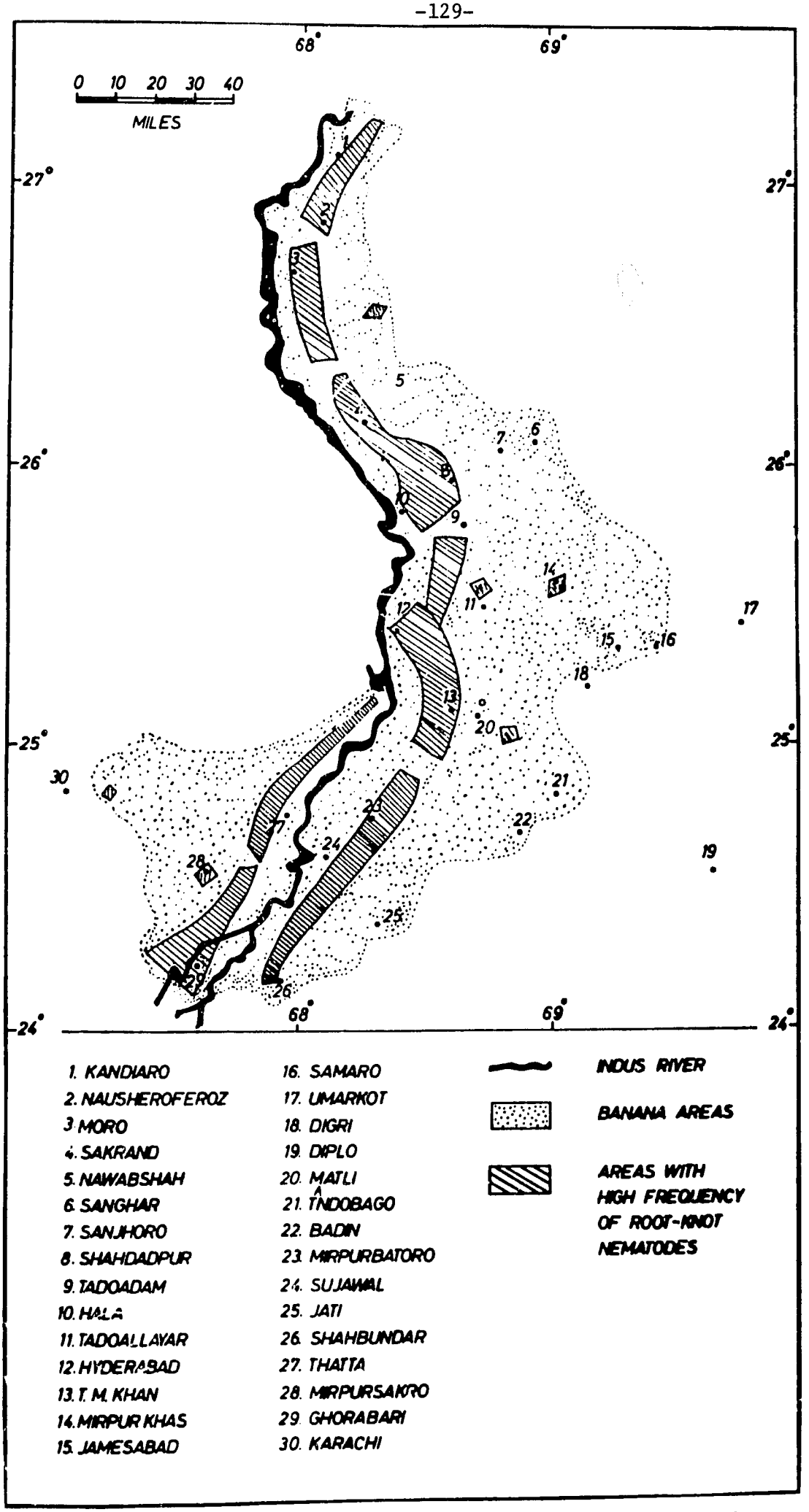

Figure 2. Showing relationship of root-knot nematodes with Indus.

STUDIES ON THE CHEMICAL CONTROL OF ROOT-KNOT NEMATODES

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In Pakistan banana, papaya and okra are extensively cultivated in the southern region. These crops are heavily attacked by root-knot nematodes like M. incognita, M. javanica and M. arenaria. Among these three root-knot nematodes, M. incognita has been found in high frequency (60%) followed by M. javanica (30%) and M. arenaria (10%).

In view of the wide occurrence of M. incognita in this region in the present experiment, this species was selected for use in chemical control studies. Roots of okra, banana and papaya were inoculated with Meloidogyne incognita larvae and were treated with furadan (3G) and aldicarb (10G) to determine the efficacy of these nematicides under local conditions. Production of root galls and biochemical changes in soil and roots were compared with: 1) normal root-biochemical components; 2) treated plants before treatment and then again 30, 60 and 90 days after treatment; and 3) the control. Biochemical experiment data on okra plant yield has also been collected.

Materials and Methods

Treatments made with different plants were as follows:

1. Okra. Five replicates of four-week-old plants were planted in 18"-diameter pots filled with sterilized soil.

a. Sterilized soil was treated with aldicarb (10G) at 0.5 gms a.i./plant and furadan (3G) at 0.2 gms a.i./plant. Five untreated pots were kept as controls.

b. Pots containing sterile soil were inoculated with 500 larvae of Meloidogyne incognita and treated with aldicarb (10G) at 0.5 gms a.i./plant and furadan (3G) at 0.2 gms a.i./plant at the time of transplantation of okra. Pots inoculated with Meloidogyne larvae and receiving no nematicide treatment were kept as controls.

c. In this experiment, in addition to the treatment of experiment b, 0.2 gms nitrogen (as ammonium sulfate) were added to the soil of each pot at

the time of transplantation. Control plants were supplied with ammonium sulfate and inoculated with Meloidogyne incognita larvae.

2. Banana. One-year-old banana plants infested with M. incognita were treated with aldicarb (10G) at 5.0 gms a.i./mat and furadan (3G) at 2.0 gms a.i./mat in ten replicates. Plants without treatment served as controls.

3. Papaya. One-year-old infested papaya plants were treated with aldicarb (10G) at 5 gms a.i./plant and furadan (3G) at 2.0 gms a.i./plant in ten replicates. Plants without any nematicidal treatment served as controls.

Results and Discussion

Effect of Chemical Treatment on the Gall Formation in Okra

According to Table 1, in plants treated with aldicarb and furadan alone, gall formation was not observed for up to 60 days. After 90 days some gall formation took place in aldicarb-treated plants, while with furadan treatments gall formation was not significant. In control plants after 90 days gall formation was significant.

No change in root biochemical constituents was observed for up to 60 days. Within 90 days the biochemical composition became altered in treated plants to some extent, but this change was not significant. In control plants the following changes were significant: cellulase activity was observed in control plants after 90 days, and acid and alkaline phosphatase were more active when compared with normal (healthy) root components.

Effect of Chemical Treatment on Gall Formation and Biochemical Constituents in Inoculated Plants of Okra

In order to determine the effect of nematicides on gall formation in inoculated okra plants, the plants were inoculated with larvae of M. incognita and then treated with aldicarb and furadan. As indicated in Table 1, observation on gall formation was made in okra plants (inoculated with M. incognita and treated with nematicides).

Thirty days after application of both nematicides, no gall formation was observed on inoculated plants. After 30 days, galls started developing in aldicarb-treated plants. At 60 days in furadan-treated plants, the rate of gall formation was very high as compared to that in aldicarb-treated plants. At 90 days, a slow increase in amount of gall formation was observed in the aldicarb treatment. In control plants a high rate of gall formation was observed throughout the experimental period as shown in Fig. 1.

The results showed that the effect of aldicarb treatment was more persistent in controlling multiplication of M. incognita as compared with the furadan treatment in the gall formation on inoculated okra plants.

Biochemical analysis of roots showed that in aldicarb-treated plants there was no change in root constituents analyzed up to 30 days when compared with the values of normal root constituents, but after 30 days the changes were considerably more in furadan-treated plants up to 90 days. Cellulase and acid and alkaline phosphatase activities were increased up to a high level, and all the other components checked also changed significantly due to a metabolic disorder in the root system.

Effect of Nematicides and Ammonium Sulfate on Gall Formation and Biochemical Constituents in Inoculated Okra Plants

As indicated in Table 1, in this experiment no gall formation was observed for 30 days following the application of aldicarb, while some galls were formed in furadan-treated plants. At 60 days, rate of gall formation increased in both the treatments. At 90 days in aldicarb, the number of galls was constant, while it increased frequently in furadan. A regular increase in gall formation was observed in the control as shown graphically in Fig. 2.

This experiment was conducted to explore the effect of nitrogen on the development of root-knot in plants in the presence of nematicides. It was noticed that nitrogen was utilized in the development of galls rather than in the control of the rate of galling. The nematicidal effect lasted up to 30 days, but within 90 days in aldicarb and furadan-treated plots, significant biochemical changes were induced in the presence of the nitrogenous substance. These changes were considerably greater in those plants which were not treated with nematicides but which were treated with nitrogenous substance.

The general trend of the nematicidal effect was to lower the enzymatic activities of acid phosphatase and alkaline phosphatases and cellulases. As observed from control plants (without nematicides), the activities of these enzymes increased with time. In treated plants, as nematicidal effect lowered with time, the amount of gall formation increased. Also noticeable were the changes involved in total lipid content, triglyceride and phospholipid content, dry matter organic matter, protein content, nitrogen and total carbohydrates.

Effect of Chemical Treatment on Yield of Okra Fruit Per Plant

As mentioned in Table 2, the yield of okra plants was also determined under these three experiments. The yield was highest in aldicarb-treated plants grown in sterilized soil without *M. incognita* larvae, as compared to that of inoculated plants treated with nematicides. In the furadan-treated plants, the yield was highest in plants treated with furadan alone. With inoculated, chemically-treated plants, yield lowered and was lowest in inoculated plants to which ammonium sulfate had been added.

Yields of control plants were lower than those of treated plants. The minimum yield was obtained from those control plants which were inoculated and incorporated with ammonium sulfate. In Fig. 3 okra fruit yield in kg/plant is illustrated.

Effect of Chemical Treatment on Gall Formation in Banana

Gall formation was checked at the time of application of nematicides and again 30, 60 and 90 days after application of nematicides. Results are summarized in Table 3 and shown graphically in Fig. 4. Formation of galls of *Meloidogyne incognita* was completely controlled by furadan and was reduced by aldicarb at 30 days. No gall formation was observed from furadan-treated plants. At 60 and 90 days the number of galls increased in both the treatments, but at a much higher rate in aldicarb-treated plants. In control plants, gall formation increased constantly during the experimental period. Furadan gives better results than aldicarb in controlling gall formation on banana.

The biochemical composition of selected infested roots was different in these plants as compared to healthy or normal plants. After treatment within 30 days in aldicarb-treated plants, the biochemical composition changed rapidly and returned to normal level as compared to furadan-treated plants. As the nematicidal effect lowered after 90 days, biochemical constituents again altered, but this change was considerably less than in control plants. Whereas gall formation increased with time, the root exudates changed more significantly. Acid and alkaline phosphatase activities decreased with the increase in gall formation. All the treated plants showed less activity of these enzymes after 90 days, but in untreated plants the decrease in activity of these enzymes was considerably more significant. Cellulase activity was undetectable after 30 days of treatment, but increased with increase in gall formation.

Effect of Chemical Treatment on Gall Formation and Biochemical Constituents of Root in Papaya

Gall formation was observed from papaya experimental plots before nematicidal treatment, and a biochemical analysis of roots was also carried out. Table 3 summarizes the results.

In aldicarb- and furadan-treated plants at 30 days, gall formation was reduced, but after 60 and 90 days, number of galls increased in furadan-treated plants, while in aldicarb-treated plants gall formation was completely reduced. In the control, the amount of gall formation increased throughout this period. In papaya, aldicarb was more effective. Fig. 5 illustrates the number of galls against experimental time period.

The biochemical changes were observed in infested roots, but within 90 days after treatment, enzymatic activities of cellulase, acid phosphatases and alkaline phosphatases came to normal level in aldicarb-treated plants. In furadan-treated plants, however, activities of these enzymes again increased after 30 days. The enzymes were more active in control plants and activities of these enzymes increased more significantly throughout the experimental period.

Table 1. Effect of Chemical Treatment on Gall Formation in Okra Plants

Treatments	30 days	60 days	90 days	30 days	60 days	90 days	30 days	60 days	90 days
	ALDICARB (No. of galls)			FURADAN (No. of galls)			CONTROL (No. of galls)		
Sterilized soil	-	-	5	-	1	3	-	2	6
Soil inoculation	-	14	26	-	24	50	16	40	60
Soil inoculation and $(NH4)_2SO_4$ incorporation.	-	24	28	8	28	52	16	48	64

In 100 gms of root

Table 2. Effect of Chemical Treatment on Yield of Okra Fruit/Plant

S. No.	Treatment	Yield (kg)
1.	Aldicarb	1.27
2.	Aldicarb + Root knot	1.16
3.	Aldicarb + Root knot + ammonium sulfate	1.02
4.	Furadan	1.13
5.	Furadan + Root knot	1.08
6.	Furadan + Root knot + ammonium sulfate	0.81
7.	Control	0.20
8.	Control + Root knot	0.31
9.	Control + Root knot + ammonium sulfate	0.15

Table 3. Effect of Chemical Treatment on Gall Formation in Banana and Papaya

Crop	Before treat-ment	30 days after treat-ment	60 days after treat-ment	90 days after treat-ment	Before treat-ment	30 days after treat-ment	60 days after treat-ment	90 days after treat-ment	Before treat-ment	30 days after treat-ment	60 days after treat-ment	90 days after treat-ment
	ALDICARB (No. of galls)				FURADAN (No. of galls)				CONTROL (No. of galls)			
Banana	56	19	24	40	35	-	10	14	40	45	50	60
Papaya	36	12	-	-	67	12	17	23	30	46	48	65

In 100 gms of root.

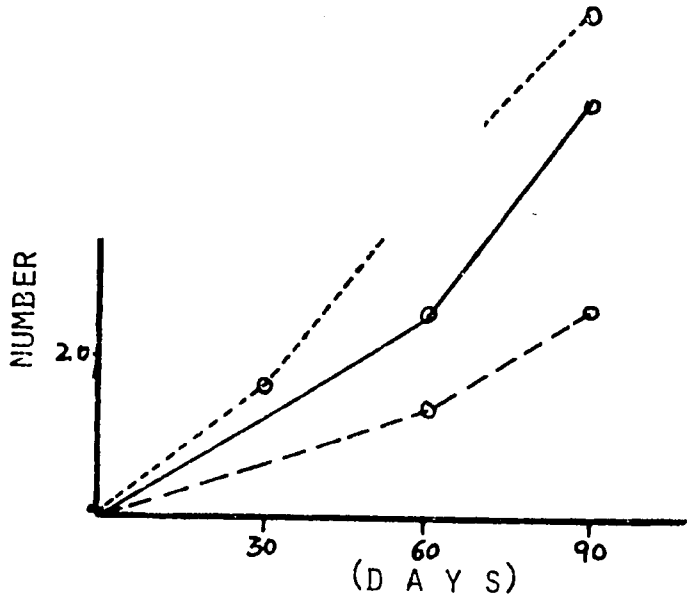


Fig. 1. Effect of chemical treatment on gall formation in inoculated okra.

Aldicarb

Furadan

Control

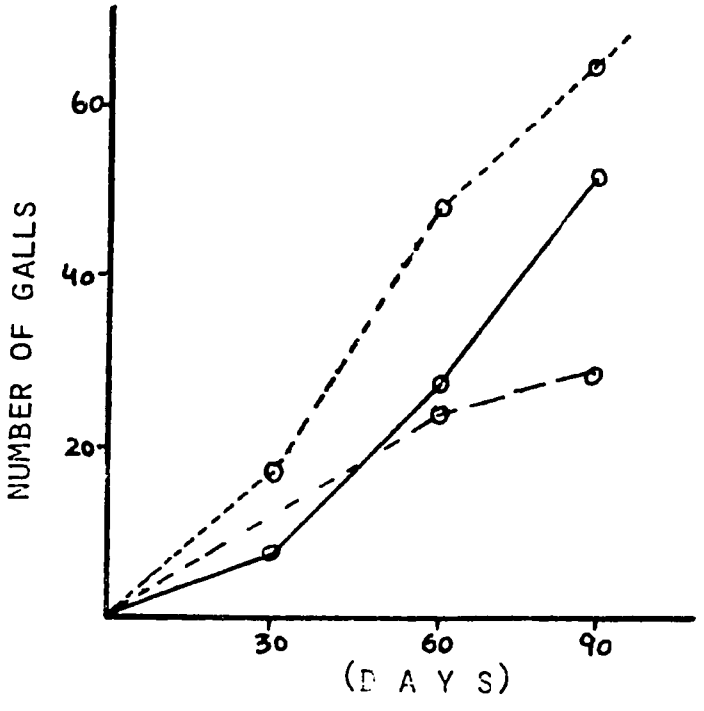


Fig. 2. Effect of chemical treatment and ammonium sulfate on gall formation in inoculated okra.

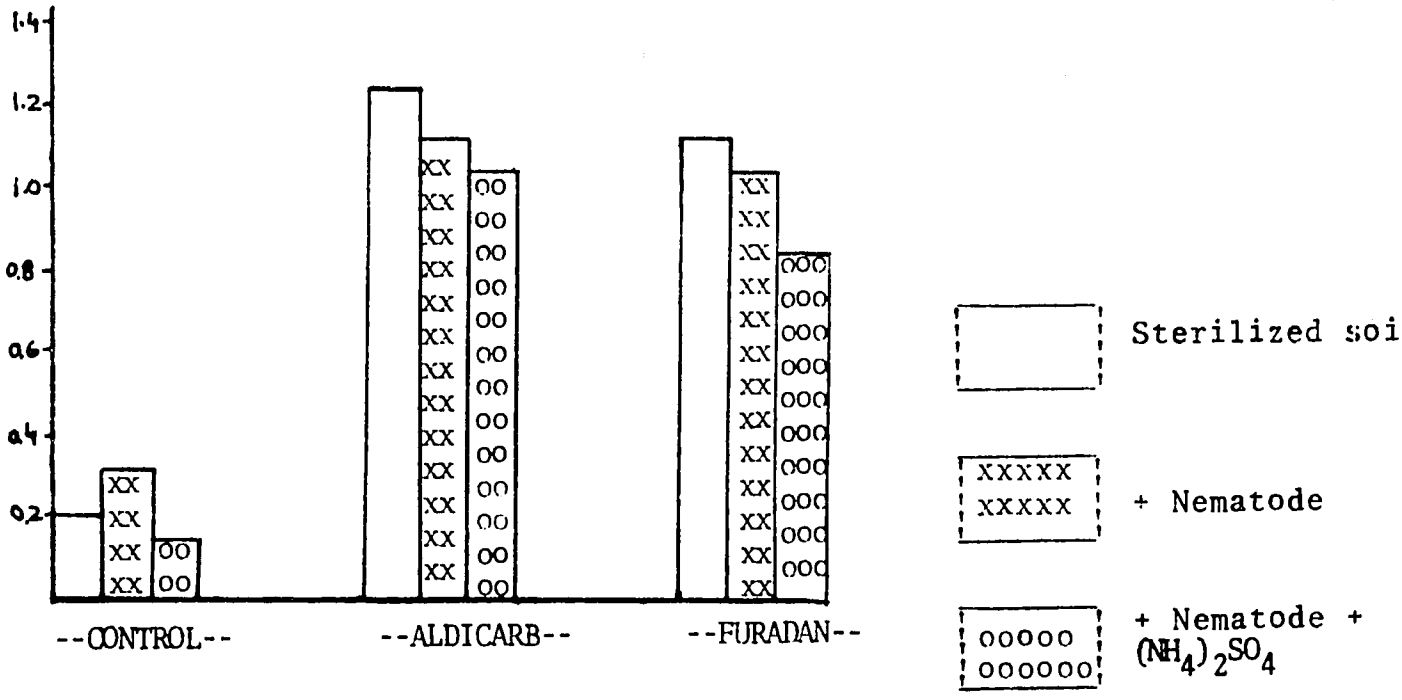


Fig. 3. Effect of chemical treatment on yield of okra fruit/plant.

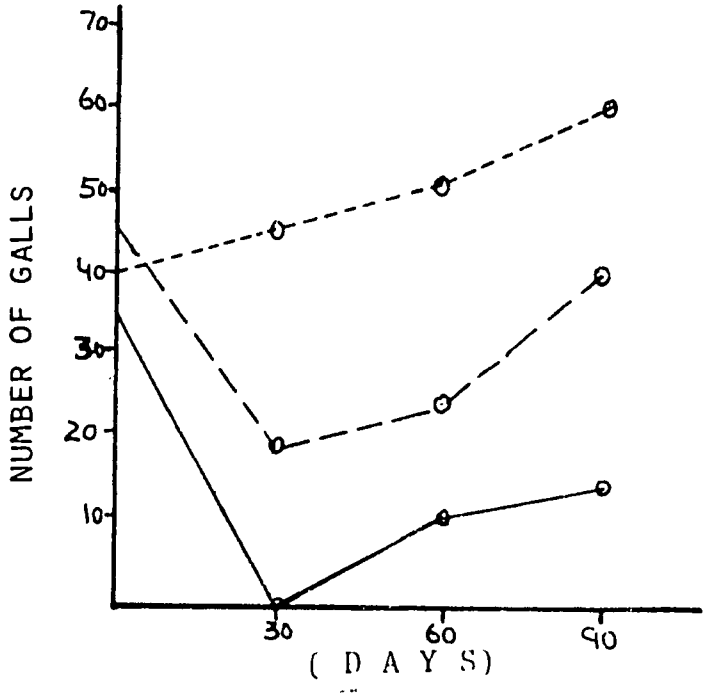


Fig. 4. Effect of chemical treatment on the gall formation in banana.

Aldicarb

Furadan

Control

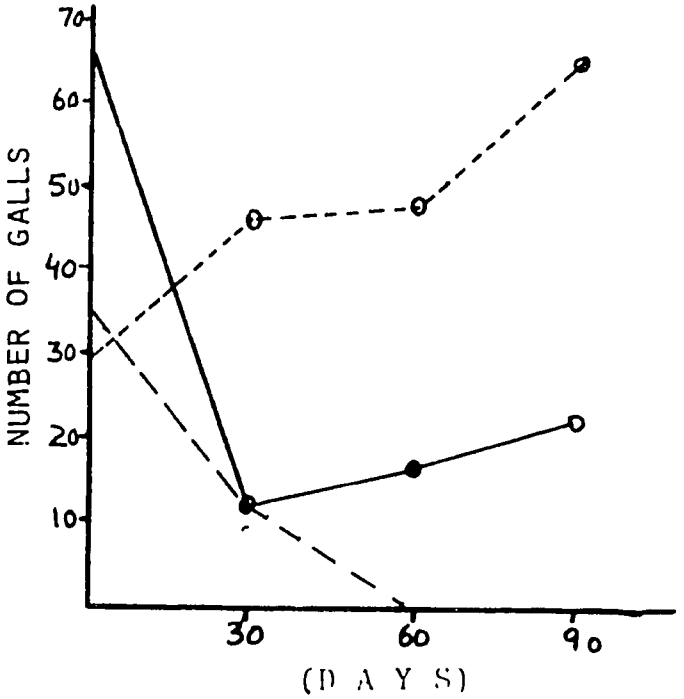
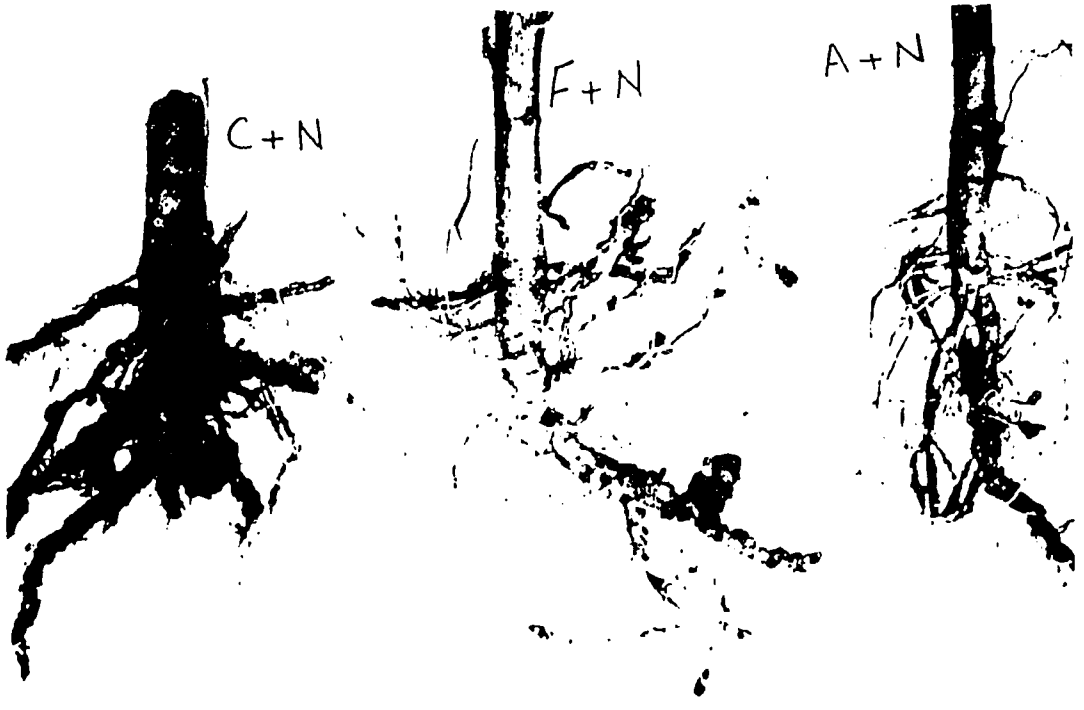


Fig. 5. Effect of chemical treatment on the gall formation in papaya.

Okra roots showing the effect of A) aldicarb F) furadan C) without nematicides after 90 days of treatment.



Okra roots showing the effect of nematicides in inoculated plants after 90 days. A + N) inoculated plant and treated with aldicarb, F + N) inoculated and treated with furadan, C + N) untreated (control) inoculated plants.

ROOT-KNOT NEMATODE PROBLEM ON VARIOUS CROP PLANTS IN BANGLADESH

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Background

Bangladesh, a delta of 55,000 sq. miles mainly of alluvial soil in the Bengal basin, stretches latitudinally between 20.35 N and 26.75 N and longitudinally between 88.03 E and 92.75 E. The temperature varies from 80°-95° F in the summer (April-September) and 55°-80° F in the winter with total rainfall of 85 inches per annum occurring mostly during the summer. The average humidity is 80 percent in the summer and 65 percent in the winter.

Importance of Root-Knot Nematodes in Bangladesh Agriculture

The climate of Bangladesh is most favorable for plant-parasitic nematodes. Most important of all is the *Meloidogyne* spp. The problem of root-knot nematode is widespread and increases in magnitude with the increasing cropping intensity. A large number of crop cultivars, excepting a few, are susceptible to root-knot nematodes, fruits and vegetables being the worst victim. Most of the popular vegetables are grown in the winter and almost all of them are susceptible to the root-knot nematode to varying degrees.

The crop loss due to root-knot nematodes has been estimated to vary from 10-15% resulting in substantial loss of yield. Soil and plant samples collected from a good number of kitchen gardens and commercial fields showed in many cases the presence of very high populations of root-knot nematodes. The crops in such cases were found either to be a complete failure or growing very poorly. *Fusarium* spp., *Sclerotium* and *Rhizoctonia* spp. frequently are found to be associated with root-knot disease on tomato, tobacco, brinjal, okra and Indian spinach. In such cases the damage is extremely high with little or no harvest. Root-knot nematodes thus act as one of the main obstacles for horizontal and vertical increase in the production of vegetables in Bangladesh.

Meloidogyne javanica is the predominant species which causes significant damage to vegetables in Bangladesh. In a survey of root-knot nematodes, 45% of all the fields sampled were infested with this nematode. Of the

thirty-six different crops that were sampled, half of them were found to be very susceptible to M. javanica, and these were brinjal, tomato, common bean, ladies finger, all the cucurbits, tobacco, jute, sugar-beet, Indian spinach, lettuce, paw-paw, and banana. Some were found to be susceptible but tolerant to M. javanica, and these were groundnut, cowpea, soybean, kesheri, gram, lentil, green manure crop, sunflower, carrot, and all the brassicas. Only ten crops were found not to support populations of M. javanica, and these were rice, onion, chilli, sweet potato, Irish potato, amaranthus, radish, wheat, sorghum and maize.

Meloidogyne incognita is a serious problem of jute, chilli, eggplant, tomato, sweet corn, and banana. In kitchen gardens, chilli production suffers most.

Meloidogyne graminicola is a common pest of rice in the shallow water situations of Bangladesh. It is often seen to cause yellowing and stunting of the rice plant and may have been responsible for a considerable loss in some of the deep water fields. It is an unusual root-knot nematode in that it does not cause obvious root-galling. It is found to be present in substantial numbers in fields already flooded to a depth of 1.5 to 2.5 meters. M. graminicola is likely to be causing extensive damage to the boro and aus crops. This pest is found during the dry season in onion roots, and it is associated with severe stunting of both roots and the foliage.

Meloidogyne arenaria was reported to occur on tomato, banana and sugarcane, but no further work has been done on this pest.

Preliminary Research Work Done

Seed-bed sterilization. Root-knot nematodes very often spread in the kitchen gardens and field plots through infested seedlings. Plants infested at seedling stage are affected most and yield very poorly. So a study was conducted to determine the most effective method of seed-bed sterilization with a view to raising healthy seedlings. Soil of a root-knot-nematode-infested brinjal seed bed with a population of 500 larvae per liter of soil was sterilized by burning straw, paddy husk and sawdust. Paddy husk was the most effective followed by sawdust and straw. (Table 1.)

Host status of some important crops. Seventeen different crops were studied on soil which was artificially infested with a mixture of root-knot nematodes to determine their host status on the basis of presence of root-knots, the larvae, and the mature females in roots. Nine crops were graded as excellent hosts, five as poor hosts, and three as non-hosts:

a) Groundnut, cotton and sesame were non hosts; b) Amaranthus, maize, soybean, chilli and aus paddy were poor hosts; and c) Brinjal, tomato, Indian spinach, string bean, jute, tobacco, sweet pepper, bean and lady's finger were excellent hosts.

Study of the influence of Tagetes spp. on the control of root-knot nematode. An experiment was conducted to determine the efficacy of Tagetes spp. (marigold) as an interplant in reducing the root-knot nematodes on brinjal. Number of root-knots and mature females in the susceptible brinjal was significantly fewer when the brinjal was grown with marigold than when it was grown alone. The plant height, however, did not show any significant difference between the treatments (Table 2).

Screening

Twenty-nine cultivars of tomato, 15 of brinjal and 9 of okra have been tested in a heavily-infested, nematode-disease nursery, and none was found to be resistant. However, different levels of disease severity have been observed.

Research Work Underway

1) Determination of the host status of important crops to Meloidogyne spp.

2) Screening of various nematicides for the control of root-knot nematode on vegetables and rice.

3) Studies to determine the effective and economic crop rotation sequences for nematode control.

4) Screening and evaluation of vegetable crops and rice against root-knot disease.

Future Research Plans

1) Survey of native sources of resistant germ plasm of crops, particularly vegetables, food legumes and oil seeds.

2) Systematic screening of introduced germ plasm of various crops against nematodes.

3) Development of resistant varieties through selection and hybridization.

4) Varietal screening of all groups of rice to find a source of resistance to M. graminicola.

5) Development of integrated control measures against root-knot nematodes.

References

Choudhury, B. C., and M. O. Hoque. 1979. Influence of marigold on the control of root-knot nematode disease. Bangladesh J. of Agr. (in press).

Choudhury, B. C., and M. O. Hoque. 1979. Host status of some crops to Meloidogyne spp. Bangladesh Horticulture (in press).

Choudhury, B. C. 1980. Effect of different inoculum levels of Meloidogyne incognita on two tomato varieties. Bangladesh J. Agr. Res. 5(2):13-16.

Choudhury, B. C., and M. O. Hoque. 1980. On the control of root-knot nematodes. Bangladesh J. of Agr. Res. (in press).

Hoque, M. O., B. C. Choudhury, and M. J. Talukdar. 1970. Survey of plant parasitic nematodes in East Pakistan. Proc. 21st-22nd Pak. Sci. Conf. Rajshahi.

Page Sam, L. J., and J. Bridge. 1978. Plant nematodes on deep water rice in Bangladesh. 48 pp.

Page Sam, L. J. 1979. An assessment of the importance and control of plant parasitic nematodes of vegetable crops in Bangladesh. 36 pp.

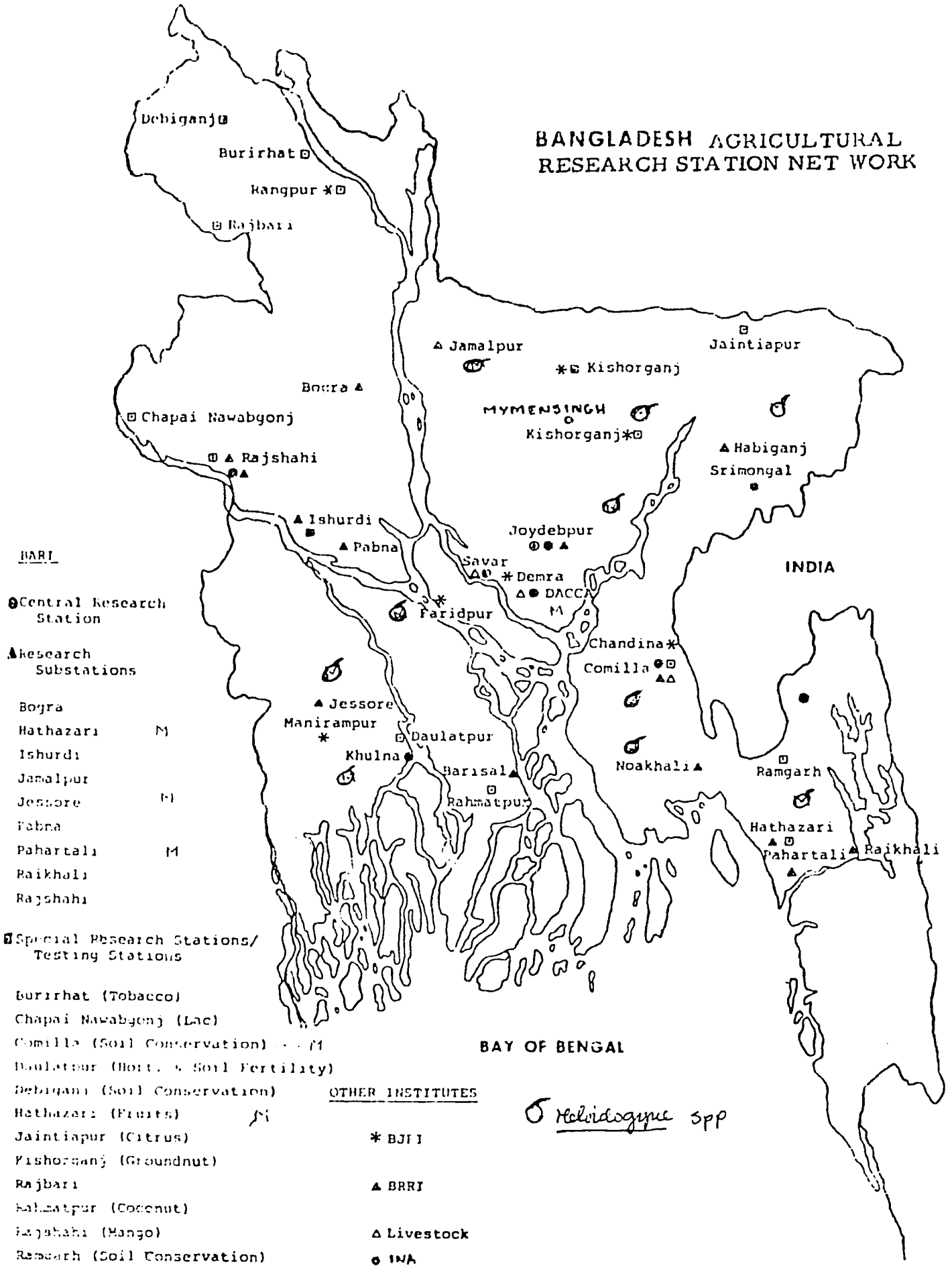
Timm, R. W., and M. Ameen. 1960. Nematodes associated with commercial crops in East Pakistan. Agriculture Pakistan XI(3):355-363.

Table 1. Effect of soil burning on root-knot nematode

Treatment	Average no. of knots/plant	No. of larvae/litre soil
Straw	10.1	540
Paddy husk	6.5	330
Sawdust	7.5	450
Untreated	20.2	1050

Table 2. Influence of intercropping of Tagetes with brinjal on the nematode infestation

Treatments	Average no. of knots/plant	Average no. of females per gm of root	Average height of plant in cm
With marigold	20.10	19.75	14.98
Without marigold	37.00	38.75	14.48



Agricultural research station network in Bangladesh.

ROOT-KNOT NEMATODES IN NEPAL

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Nepal can be divided roughly into three ecological zones of agricultural importance: 1) Terai, 100-300 m asl in the Gangetic Plain, 2) Midhills, 300-1800 m asl in the southern foothills of Himalayas, and 3) High hills, 1800-4500 m asl. The first nematode survey was conducted in 1968 in the Terai and Midhills locations (Amatya and Shrestha. 1969. Nepal J. Agr. 4: 17-27). Economically important yield reductions by root-knot nematodes are encountered in the Terai and the lower Midhills mainly on tomato and brinjal (eggplant) grown for fresh consumption. The major disease of tomatoes and potatoes, however, is late blight caused by Phytophthora infestans.

Occasionally Meloidogyne incognita is found on potatoes grown for seed. Infected lots are disposed of as are potatoes: i.e., control is by elimination. Since the problem is a minor one, work is restricted to identification of causes of infection and to prevention of spread. No research is done on control. General agronomic improvements and introduction and dissemination of late-blight resistant varieties have priority. Surveys should not be conducted just to uncover potential problems. There is still enough work to do for the limited manpower and facilities on the very obvious causes of yield loss.

In vegetable crops like tomatoes and brinjals, agronomic measures for good sanitation and crop rotations, e.g. with paddy, will bring some degree of control of root-knot. In addition, screening of root-knot and late-blight resistant tomato varieties is an important factor for control (see later paper by Drs. K. P. Sharma and L. N. Bhardwaj). Spread of improved agronomic practices and release and multiplication of resistant varieties for an integrated control approach are tasks for the Extension Service and reliable private seed growers. Chemical control is impractical because supplies of foreign materials are not assured and because of the present low level of technical understanding among many farmers.

RESEARCH ON ROOT-KNOT NEMATODES IN INDONESIA

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Introduction

Nothing had been reported on root-knot nematode in Indonesia until 1950 when Van der Vecht observed galls on the root system of sugar cane and made the first record of Meloidogyne species, formerly known under the name Heterodera marioni. In 1959, Thrower reported that the most common plant-parasitic nematode genera in Indonesia were Meloidogyne, Rotylenchulus, Pratylenchus, Tylenchus and Radopholus. Another ten years or more elapsed until some research was undertaken by Lembang Research Institute for Food Crops, formerly known under the name Horticultural Research Institute. The research on root-knot nematodes presented here was conducted in cooperation with the Netherlands Agriculture Technical Assistance 111.

Survey

From 1973 to 1976, two soil-and-root samples were collected from each of the following districts: North and West Sumatra, Java, and Bali. Samples were obtained from tomato, potato, tobacco and other solanaceous plants and broadleaf weeds, such as Galinsoga parviflora, Polygonum nepalense and Alternanthera ficoidea.

Egg masses, or root pieces with egg masses, were used to inoculate healthy tomato (cv. "Money maker") seedlings so as to build up the nematode population in a glasshouse. Perineal patterns were prepared from several females in each sample. This procedure usually enabled identification to the species level.

The results indicate that root-knot nematodes are common and very damaging to susceptible crops throughout the country (Widjaja, 1976). They are found in backyards of houses in cities and villages, in virtually virgin forests and, most frequently and particularly serious, in the cultivated crops, such as potato, tomato, tobacco, pepper, bean, carrot and eggplant. Broadleaf weeds are good host plants of root-knot nematodes (Widjaja, 1978). The number of host plants recorded in Indonesia now exceeds 125 species of cultivated and uncultivated plants (Widjaja, 1976).

M. incognita has been found most frequently, followed by M. javanica and M. arenaria. The results are shown in Table 1.

Other important plant-parasitic nematodes frequently found include Rotylenchulus, Helicotylenchus, Pratylenchus, Paratylenchus, Tylenchus, Hoplolaimus, Rotylenchus, Trichodorus and Xiphinema as well as saprophagous nematodes, such as Dorylaimus and Rhabditis. The roles of these nematodes need further investigation.

Contamination of Root-Knot Nematodes in Organic Manure

Eleven kinds of stable manure and compost from several origins used in and around Lembang, Bandung, were tested in the presence of Meloidogyne spp. using tomato (cv. "Money maker") as indicator plants. The results showed that stable manure from cow, horse and goat (Margahayu and Lembang), manure from the slaughter-house (Bandung), and local compost (from Margahayu) are infected by nematodes. The main source of infection is not the faecal material, but the added ingredients (soil and plant refuse, particularly gall-bearing roots of host plants), mixed with the manure prior to application to the land. These preliminary studies indicate that the contamination of stable manure with root-knot nematodes is extremely variable (Widjaja, 1974).

Effect of Different Initial Population Densities on Yield

Potato plants (variety Desiree) were grown individually in 35-cm-diameter clay pots. Second-stage larvae of a mixture of M. javanica, M. incognita, and M. arenaria, as commonly found in the experimental area, were added to the pots at various densities before planting. One to 100,000 larvae per kg soil were added. At nematode densities of more than 500 larvae per kg soil, the weight of harvested potato tubers decreased as nematode populations increased. At nematode populations of 500, 1,000, 5,000, 10,000, 50,000 and 100,000 larvae per kg soil, marketable potato yields were lowered by 12, 31, 35, 37 and 46% respectively.

At the higher nematode densities, yields of potato were reduced by 53 grams to 198.34 grams per plant, while the time from planting to harvest was reduced by more than 35 days. The results of this experiment indicate that at pre-planting population densities of more than 500 larvae per kg soil, control measures should be taken (Widjaja, 1978) (Table 3).

In another experiment, tomato seedlings (cv. Money maker) were planted individually in clay pots and inoculated just before planting with different population densities of suspension of root-knot nematodes containing second-stage larvae of M. javanica, M. incognita and M. arenaria in mixture, as commonly found in the area of the experiment. The population densities were from 1 to 100,000 nematodes per kg soil.

At low inoculum densities (less than 100 larvae per kg soil), a slight stimulation of root growth could be observed. At higher densities (more than 500 larvae per kg soil), the effect of nematodes on the root system was inhibitory. Flowering, fruiting and fruit maturation occurred earlier, and the yield was decreased. At nematode densities of 500, 1,000, 5,000, 10,000, 50,000 and 100,000 larvae per kg soil, tomato yields were lowered by 14, 39, 46, 54, and 54%, respectively.

Management Practices

On the traditionally irrigated rice fields ("sawah"), farmers always wish to grow as many crops of vegetables as possible, since these are profitable. Comparison of soil samples from vegetable plantings that had been preceeded by "sawah" for at least five months with those from plantings that had been preceeded by other vegetables or weed growth indicated that rotation with flooded rice fields had a suppressing effect on population of root-knot and other nematodes (Table 4) (Sudarwohadi et al., 1975; Widjaja, 1976; Widjaja et al., 1976).

In the main vegetable crop areas in Indonesia, farmers have used crop rotation to control root-knot nematodes and other soil-borne diseases, but without planning. The effectiveness of crop rotation depends on the initial crop and history of the field because these factors certainly affect populations of Meloidogyne spp. in the soil and are correlated with yield. Experiments are in progress to study the influence of cropping sequence on root-knot nematode population development. Widjaja and Windrich (1974) showed that marigold (Tagetes patulanana), Glycine javanica, Crotalaria usaramoensis, maize and sweet potato are useful plants for reducing nematode density in the soil. Fallow without weeds for three months showed a combination of relatively high yields with low incidence of nematodes (Table 5).

Chemical Control

During the last five years, experiments have been made in potato and tomato which included a fumigant and nonfumigant nematicides. Studies on the effectiveness of eleven contact and systemic nematicides to control root-knot nematodes on tomato were carried out at the experimental garden Segunung (Pacet, West Java) at the altitude of 1,100 meters above sea level. The results showed that application with Triazophos (40% EC) (4 l/ha) and aldicarb (10% G) (40 kg/ha) gave significantly higher yields, followed by metham sodium (376 gr/l) (300 l/ha) and 1,3-D (50%) (250 l/ha). DBCP (75% EC) (20 l/ha), oxamyl (25% EC) (60 l/ha), carbofuran (3% G) (25 kg/ha) and fensulfothion (10% G) (25 kg/ha) showed also some promise against root-knot nematodes (Widjaja, 1976) (Table 6).

In another experiment, fensulfothion (10% G) at the rate 50 kg/ha gave the best control and highest potato as well as tomato yield (Table 7) (Widjaja, 1978). On the other hand, carbofuran (3% G) at the rate 50 kg/ha was the best treatment in controlling root-knot nematodes on potato and tomato and also produced a higher yield than the control plots (Widjaja, 1979) (Tables 7 and 8).

In a randomized block field experiment, plots heavily infested with Meloidogyne spp. were treated with fumigant nematicide fourteen days before planting. Metham sodium at the rate of 600 l/ha gave the best nematode control and the highest increase in potato tuber yield, followed by 1,3-D at 250 l/ha, and DBCP at 20 l/ha. Fumigants injected into the soil by means of a soil injector controlled nematodes better than drenching with jar applicator along the rows (Widjaja and Rustaman, 1979) (Table 9).

Results from other field experiments indicated that fumigation with metham sodium at rates of 300, 350 and 400 l/ha gave a significant increase in yield of potato as well as tomato in comparison with lower dosage rates or the untreated check, but did not differ significantly from each other (Widjaja, 1979) (Tables 7 and 8).

References

Sudarwohadi, S., A. Suhardi, W. Widjaja, and K. G. Eveleens. 1975. Laporan survai hama, penyakit dan nematoda di Propinsi Sumatera Barat dan Sumatera Utara, Dalam bulan September 1975. Lembaga Penelitian Hortikultura, KP Segunung, Pacet. 46 hal.

Widjaja Wisnuwardana, A. 1976a. Report on studies of parasitic nematodes with special reference to root-knot nematodes (Meloidogyne spp.) on vegetables. Kongress Nasional PFI ke IV, Gambung, Bandung, 21-22 Des. 1976. 32 p.

_____. 1976b. Pengujian 11 macam nematisida untuk menekan serangan nematoda puru akar (root-knot nematodes) Meloidogyne spp. pada tanaman tomat (Solanum lycopersicum). Bull. Penel. Hort. IV, 2:35-45.

_____. 1978a. Tumbuhan pengganggu hortikultura dataran tinggi sebagai tanaman inang dari nematoda bengkak akar (Meloidogyne spp.). Bull. Penel. Hort. VI, 1:37-47.

_____. 1978b. Pemberantasan nematoda bengkak akar (Meloidogyne spp.) pada tanaman kentang dengan Terracur P 10G. Bull. Penel. Hort. VI, 2:9-16.

_____. 1978c. Hubungan antara jumlah populasi awal dari nematoda bengkak akar (root-knot nematodes) Meloidogyne spp. dan kerugian hasil kentang. Bull. Penel. Hort. VI, 2.

_____. 1979. Percobaan pemberantasan Meloidogyne (root-knot nematodes, nematoda bengkak akar) pada tanaman kentang dengan Furadan 3G (carbofuran). Bull. Penel. Hort. VII, 4:7-16.

_____, B. Masdiar, S. Sudarwohadi, and H. Vermeulen. 1976. Laporan hasil survai hama, penyakit dan nematoda parasit pada tanaman sayuran dataran tinggi Propinsi Jawa Tengah, Jawa Timur dan Bali. 20 Juli - 2 Agustus 1975. Lembaga Penelitian Hortikultura, KP Segunung, Pacet. 47 hal.

Widjaja Wisnuwardana dan Rustaman. 1979. Penggunaan Nemagon, D-D dan Vapam untuk memberantas nematoda bengkak akar pada tanaman kentang. Bull. Penel. Hort. VII, 1.

_____ and Windrich. 1974. Studies on nematological problems in horticulture. Agricultural Cooperation Project Indonesia-The Netherlands. Research Reports Section II. Technical Contribution, Bogor. 393-402.

TABLE 1. Distribution of *Meloidogyne* species in Sumatra, Java and Bali.

A. Samples from Solanaceous crops (potato, tomato, chilli)

Province	No. of samples	Meloidogyne species					
		incognita		javanica		arenaria	
		++	+	++	+	++	+
North Sumatra	19	14	5	13	6	14	5
West Sumatra	9	7	2	7	2	2	6
West Java	17	13	4	11	6	15	2
Central Java	11	10	1	8	3	6	5
East Java	6	4	2	5	1	6	0
Bali	4	2	2	2	2	0	2
Total	66	50	16	46	20	43	20

B. Samples from non-Solanaceous crops (cabbage, cauliflower, carrot, celery, sweet potato)

Province	No. of samples	Meloidogyne species					
		incognita		javanica		arenaria	
		++	+	++	+	++	+
North Sumatra	8	3	5	1	4	1	6
West Sumatra	4	0	4	0	4	0	3
West Java	6	2	3	0	5	4	2
Central Java	12	2	10	0	9	0	9
East Java	5	3	2	2	3	3	2
Bali	3	3	0	0	2	1	1
Total	38	13	24	3	27	9	23

++ indicates species prevalent in sample
\+ indicates species present in sample

TABLE 2. The number of root-galls on tomato roots planted in stable manure of various origins and compost from Lembang (Bandung), two month after planting time.

Medium	Location	Mean number of galls[1)]
Cow	Margahayu	262
	Lembang	62
Horse	Margahayu	432
	Lembang	217
Goat	Margahayu	223
	Lembang	307
Pig	Lembang	0
	Bandung	0
Fowl	Lembang	0
Slaughter house	Lembang	155
(mixed manure)	(originaly from Bandung)	
Compost	Margahayu	609
Steril soil (check)	Margahayu	0

TABLE 3. Preplant nematode density (Pi) and yield of potato and tomato[1)]

Pi[2)]	Potato		Tomato	
	Yield (gram)[3)]	percentage	Yield (gram)[3)]	percentage
0	434.2	100	709.8	100
1	442.2	100.2	737.3	103.8
10	423.3	95.2	713.3	100.4
50	431.8	97.3	731.3	102.9
100	438.[illegible]	100.1	729.3	102.8
500	381.2	87.6	611.0	86.1
1,000	313.8	60.9	431.7	6[illegible] 9
5,000	300.2	64.7	387.7	54.2
10,000	274.2	65.1	329.2	46.3
50,000	272.0	62.5	325.7	45.9
100,000	235.8	54.3	329.2	46.3
HSD 5%	24.76		74.42	
1%	29.06		87.35	

1) Means of six replicates
2) Number of second stage larvae per kilogram soil
3) Values followed by the same lower case letters are not significantly different according to Duncan's Multiple Range Test at the 5% level.

TABLE 4. The density of parasitic nematodes per 100 cc of soil samples "sawah" and vegetables as a preceding crops.

Localities	Density of parasitic nematodes					
	Meloidogyne larvae		*Tylenchids*		*Dorylaimids*	
	1	2	1	2	1	2
North Sumatra (20 samples)	104	749	43	170	28	108
West Sumatra (22 samples)	86	967	84	487	76	294
Center & East Java (28 samples)	156	841	105	333	126	199

1. Field which had been preceded by "sawah" (irrigated rice)
2. Field which had been preceded by other vegetables/weed growth.

TABLE 5. Potato and tomato yields and *Meloidogyne* infestations on tuber and root after preceding crops at the termination of the experiment.

Preceding crops	Potato		Tomato	
	Yield (kg/ plot)	Infected tuber (%)	Yield (kg/ plot)	Number of galls (5 plant samples
Apium fistulosum	36	60	53	185
Tagetes patula nana	12	13	21	65
Potato	15	47	35	1290
Glycine javanica	13	24	24	890
Crotalaria usaramoensis	13	28	27	485
Tomato	7	34	27	1190
Maize	13	24	33	600
Sweet potato	16	25	29	265
Cabbage	14	36	36	770
Phaseolus vulgaris	13	48	29	1045
Fallow without weeds	11	7	52	775
Fallow with weeds	11	58	26	775

Table 6. Tomato yield (kg) and root-gall indices from eleven nematicides screening trial on tomato planted in heavely infected field by Meloidogyne spp. [1)]

Dosage of formulated product	Yield [2)]	Galls index [3)]
1,3-D (50%)(250 l/ha)	17.166 ef	1.10 gh
DBCP (75%)EC (20 l/ha)	16.500 de	1.07 gh
DBCP (10%)G (150 kg/ha)	14.060 ab	3.57 j
Fensulfothion (10%)G (25 kg/ha)	15.226 c	2.13 i
Carbofuran (3%)G (25 kg/ha)	15.166 c	2.02 i
Aldicarb (10%)G(40 kg/ha)	17.673 f	0.80 g
Metham sodium (376 gr/l)(300 l/ha)	17.343 ef	0.88 g
Triazophos (40%)EC(4 l/ha)	17.830 f	0.45 g
Triazophos (5%)G(32 kg/ha)	14.826 bc	3.10 j
Oxamyl (25%)EC(60 l/ha)	16.180 d	1.65 hi
Oxamyl (10%)G (150 kg/ha)	13.503 a	3.65 g
untreated (control)	12.246 a	4.15 g
HSD 5%	0.912	0.751
1%	1.097	0.905

1). Means of three replicates

2). Values followed by the same lower-case letters are not significaltly different according to Duncan's Multipe Range Test at the 5% level.

3) Root-knot indices based on 1 - 5 scale : 1 = no galls visible, 2 = very light galling, 3 = light galling, 4 = moderate galling, 5 = heavy galling.

Table 7. Healthy and infected tubers of potato harvested from soil treated with nematicide [1)]

Dosage of formulated product		Average yields	
		Healthy tubers (kg)[2)]	infected tubers (kg)[2)]
Fensulfothion (10% granule)	60 kg/ha	6.205 e	0.21 j
Fensulfothion (10% granule)	50 kg/ha	6.120 e	0.32 j
Fensulfothion (10% granule)	40 kg/ha	5.100 d	0.96 i
Fensulfothion (10% granule)	30 kg/ha	3.870 c	1.71 h
Fensulfothion (10% granule)	20 kg/ha	2.500 b	3.29 g
Untreated (control)		1.590 a	5.20 f
HSD 5%		0.691	0.48
1%		0.872	0.60
Carbofuran (3% granule)	80 kg/ha	6.418 n	2.315 s
Carbofuran (3% granule)	70 kg/ha	6.373 n	2.380 s
Carbofuran (3% granule)	60 kg/ha	6.128 n	2.985 s
Carbofuran (3% granule)	50 kg/ha	5.688 m	4.105 r
Carbofuran (3% granule)	40 kg/ha	3.463 l	5.232 q
Carbofuran (3% granule)	30 kg/ha	1.978 k	6.218 op
Carbofuran (3% granule)	20 kg/ha	1.900 k	6.113 op
Untreated (control)		1.823 k	6.435 o
HSD 5%		0.866	1.094
1%		1.057	1.336
Metham sodium (376 gr/l)	400 l/ha	6.99 w	0.74 z
Metham sodium (376 gr/l)	350 l/ha	6.84 w	0.85 z
Metham sodium (376 gr/l)	300 l/ha	6.65 w	1.17 y
Metham sodium (376 gr/l)	250 l/ha	4.88 v	1.36 y
Metham sodium (376 gr/l)	200 l/ha	3.97 u	3.24 x
Untreated (control)		1.46 t	3.24 x
HSD 5%		0.672	0.48
1%		0.891	0.64

1). Means of four replicates
2). Values followed by the same lower case letters are not significantly different according to Duncan's Multiple Range Test at the 5% .evel.

TABLE 8. Tomato yields and root-gall indices of tomates planted in treated soil with nematicides[1].

Dosage of formulated product		Average yields (kg)[2]	Average gall indices[3]
Fensulfothion (10% granule)	60 kg/ha	13.76 b	2.40 d
Fensulfothion (10% granule)	50 kg/ha	13.84 b	3.10 d
Fensulfothion (10% granule)	40 kg/ha	12.10 ab	3.95 c
Fensulfothion (10% granule)	30 kg/ha	11.03 a	4.00 c
Fensulfothion (10% granule)	20 kg/ha	10.99 a	3.95 c
Untreated (control)		9.93 a	4.10 c
HSD	5%	2.30	0.78
	1%%	2.90	0.99
Methan sodium (376 gr/l)	400 l/ha	15.02 g	1.10 j
Methan sodium (376 gr/l)	350 l/ha	14.90 g	1.20 j
Methan sodium (376 gr/l)	300 l/ha	14.10 g	1.85 ij
Methan sodium (376 gr/l)	250 l/ha	12.08 f	1.95 ij
Methan sodium (376 gr/l)	200 l/ha	11.72 f	2.20 i
Untreated (control)		9.12 e	3.50 h
HSD	5%	1.66	0.92
	1%	2.09	1.16

1). Means of four replicates
2). Values followed by the same lower case letters are not significantly different according to Duncan's Multiple Range Test at the 5% level.
3). Root-knot indices based on 1-5 scale :
1 = no galls visible; 2 = very light galling; 3 = light galling; 4 = moderate galling; 5 = heavy galling.

Table 9. Healthy and infected tubers of potato harvested from soil treated with three fumigant nematicides [1)]

Dosage of formulated product	Healthy tubers (kg) [2)]	Infected tubers (kg) [2)]
DBCP 75% EC, spot treatment, 20 l/ha	6.038 cd	8.193 ef
DBCP 755 EC, row treatment, 20 l/ha	5.055 bc	8.673 ef
DBCP 10 G, row treatment, 150 kg/ha	4.490 b	9.333 f
1,3-D (50%), spot treatment, 250 l/ha	6.095 d	8.403 ef
1,3-D (50%), row treatment, 250 l/ha	4.915 b	8.525 ef
Metham sodium (376 gr/l) spot treatment 600 l/ha	6.678 d	7.618 e
Metham sodium (376 gr/l) row treatment 600 l/ha	6.235 d	8.130 e
Untreated (control)	3.298 a	11.373 g
HSD 5%	1.012	1.186
1%	1.235	1.448

1) Means of four replicates

2) Values followed by the same lower case letters are not significantly different according to Duncan's Multiple Range Test at the 5% level.

COUNTRY REPORT ON ROOT-KNOT NEMATODE IN BURMA

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Burma, as an agricultural country, has much land devoted to field crops such as rice, cotton, jute, tobacco, sugarcane, wheat, peanut, sesamum, maize, sorghum and legumes, as well as to horticultural crops such as banana, papaya, pineapple, citrus, tomato, potato, onion, sweet potato, lettuce, cabbage, cauliflower, carrot and cucurbits.

Root-knot nematodes were first discovered in Burma during 1964. At that time they were only noticed on tomato. Later, in 1970, they were found to occur in tobacco nurseries as well. These root-knot nematodes were identified to be Meloidogyne javanica. Further survey and diagnosis work on root-knot nematodes and other plant-parasitic nematodes in Burma was not conducted until 1978. Since that time, twenty-eight genera of plant-parasitic nematodes, including root-knot nematodes Meloidogyne sp., have been discovered. Among the root-knot collections, 654 of the samples were found to contain Meloidogyne javanica (Table 1); the rest were M. incognita (Table 2) and M. graminicola (Table 3).

Common in the tropics, root-knot nematodes are observed to damage some of the field and horticultural crops, among which solanaceous crops and rice are mainly affected in Burma. The real economic damage is unquestionably observed on tomato plantations, tobacco nurseries, and upland rice fields.

In Burma, there are only two qualified nematologists (2 Ph.D's). Work has increased with the discovery of root-knot nematodes in some important field and horticultural crops, such as rice (Fig. 1), potato, tomato, tobacco, sunflower, jute, cowpea, cucurbits, crucifers (Fig. 2), etc.

The rice root-knot nematode, Meloidogyne graminicola, was first discovered on the rice varieties Manawhari, Kulu, and Kn-96 during November and December of 1980 at ARI and Thawuti in Lewe township (Fig. 1A). Sampling, collecting, identification, and infectivity tests were systematically carried out (Table 4). Infectivity on the rice varieties C_4-63, IR-36, Manawthukha, Shamalay, and Yakyawtun was proven to be significant (Fig. 1B). The proposed

research program of screening tests, varietal susceptibility tests, host-range tests, and control experiments will be carried out for *M. graminicola*, *M. javanica* and *M. incognita*, especially on rice and solanaceous crops in the following year.

Table 1. Naturally Infected Hosts of *M. javanica* Collected in Burma

Common Name	Scientific name	Family	Root-knot Index	Locality
Cabbage	*Brassica oleracea capitata*	Cruciferae	5	Yezin
Cauliflower	*Brassica oleracea botrytis*	Cruciferae	5 5	Yezin Maymyo
Knol-Kohl (Kohlrabi)	*Brassica oleracea caulorapa*	Cruciferae	5	Yezin
Chrysanthemum	*Chrysanthemum maximum*	Compositae	5 5	Maymyo Yezin
Sunflower	*Helianthus annus*	Compositae	5	Yezin
Sweet potato	*Ipomoea batatas*	Convolvulaceae	1	Pyinmana
Cucumber (Kasit)	*Cucumis trigona*	Cucurbitaceae	4	Yezin
White gourd (Chinese waxgourd)	*Benincasa cerifera*	Cucurbitaceae	4	Yezin
Red gourd (Winter squash)	*Cucurbita maxima*	Cucurbitaceae	5	Yezin
Indian leek	*Allium tuberosum*	Liliaceae	5	Taungyi
Rozelle	*Hibiscus sabdariffa*	Malvaceae	5 5	Yezin Pokepa
Bombay hemp (Kenaf)	*Hibiscus cannabinus*	Malvaceae	3	Yezin
Cowpea (Southern pea)	*Vigna unguiculata*	Papilionaceae	5	Yezin
Sword bean (Common jackbean)	*Canavalia ensiformis*	Papilionaceae	5 5	Yezin Lewe
Bird's eye pepper	*Capsicum minimum*	Solanaceae	3	Yezin
Green gram	*Vigna radiata*	Papilionaceae	3	Yezin
Eggplant	*Lycopersicum melongena*	Solanaceae	5	Yezin

Table 1. Continued

Common Name	Scientific name	Family	Root-knot Index	Locality
Indian night-shade	Solanum indicum	Solanaceae	5	Yezin
Tomato	Lycopersicum esculentum	Solanaceae	5 5	Yezin Maymyo
Tobacco	Nicotiana tabacum	Solanaceae	5 3	Kyautsei Tatkone
Jute	Corchorus olitorius	Tilliaceae	3	Yezin
Katsine	Triumfetla spp.	Tilliaceae	3	Yezin
Sesamum	Sesamum indicum	Pedaliaceae	5	Kungyankore
Bottle gourd	Lagenaria siceraria	Cucurbitaceae	5	Yezin
Celery	Carum petroselinum	Umbelliferae	5 5 5 5	Mandalay Pegu Maymyo Yezin
Winged bean (Indies goabean)	Psophocarpus tetragonolobus	Papilionaceae	5 5 5 5	Yezin Tadaroo Doqueen Kyautsei
Prickly amaranth	Amaranthas spinosus	Amaranthaceae	5	Yezin
Mon-hnyin-myet	Fimbristylis complanata F. dichotoma	Cyperaceae	2	Yezin
Flatsedge	Cyperus strigosus	Cyperaceae	4	Yezin
Padawnyo (India bluestem)	Andropogon carricosus Dichanthium cariosum	Gramineae	3 3	Yezin Yezin
Byaingchi	Erigeron asteroides	Compositae	3	Yezin
Indian Acalypha	Acalypha indica	Euphorbiaceae	5	Yezin
Amongachin	Oxalis corniculata	Oxalidaceae	5 5	Maymyo Taungyi
Me-yeing (Indigo)	Indigofera pulchella	Papilionaceae	5	Yezin
Lettuce	Lactuca sativa	Compositae	4	Yezin

Table 2. Naturally Infected Hosts of *Meloidogyne incognita*

Common name	Scientific name	Family	Root-knot Index	Locality
Papaya	*Carica papaya*	Caricaceae	5 5	Yezin Naungshwe
Edible Chrysanthemum	*Chrysanthemum* spp.	Compositae	5	Hehoe
Spinach	*Spinacia oleracea*	Cruciferae	5	Hehoe
Cauliflower	*Brassica oleracea botrytis*	Cruciferae	4	Maymyo
Knol-Kohl (Kohlrabi)	*Brassica oleracea caulorapa*	Cruciferae	2	Taungyi
Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	5	Taungyi
Sponge gourd	*Luffa aegyptiaca*	Cucurbitaceae	5	Yezin
Ridge gourd	*Luffa acutangula*	Cucurbitaceae	4	Yezin
Chayote	*Sechium edule*	Cucurbitaceae	3	Taungyi
Banana	*Musa arakanensis*	Musaceae	3	Yezin
Potato	*Solanum tuberosum*	Solanaceae	5	Taungyi
Indian bean	*Lablab purporeus*	Papilionaceae	5	Yezin
Tobacco	*Solanum tabacum*	Solanaceae	5	Tatkone
Coriander	*Coriandrum sativum*	Umbelliferae	3	Maymyo
Wild mustard	*Cleome viscosa*	Capparidaceae	3	Yezin
Taw Bizat	*Eupatarium odoratum*	Compositae	4	Yezin
Tawpe (Common vetch)	*Vicia sativa*	Papilionaceae	3	Yezin
Bitter gourd (Balsam pear)	*Momordica charantia*	Cucurbitaceae	3	Yezin
Okra	*Hibiscus esculentus*	Malvaceae	5	Yezin
Tomato	*Lycopersicum esculentum*	Solanaceae	5	Yezin
Wild celery	*Apium graveolens*	Umbelliferae	5	Kyautsei
Bishop's weed (Ajowan-caraway)	*Carum copticum*	Umbelliferae	5	Doguen

Table 3. Naturally Infected Hosts of *M. graminicola* Collected in Burma

Common name	Scientific name	Family	Root-knot Index	Locality
Rice IR-36	*Oryza sativa*	Gramineae	5	Yezin
Manawhari	*Oryza sativa*	Gramineae	4	Lewe
Kulu	*Oryza sativa*	Gramineae	5	Yezin
Kn-96	*Oryza sativa*	Gramineae	5	Yezin
Glutinous rice (Shan Ma Lay)	*Oryza sativa*	Gramineae	5	Yezin
Sorghum	*Sorghum bicolor*	Gramineae	4	Yezin
Soybean	*Glycine max*	Papilionaceae	5	Yezin
Weed-Mon-hnyin-Myet	*Fimbristylis complanata* *F. dichotoma*	Cyperaceae	5	Yezin
The prickly Amaranth	*Amaranthas spinosus*	Amaranthaceae	5	Yezin
Tet-Kovet grass	*Ischaemum rugosum*	Gramineae	5	Yezin

Figure 1B.

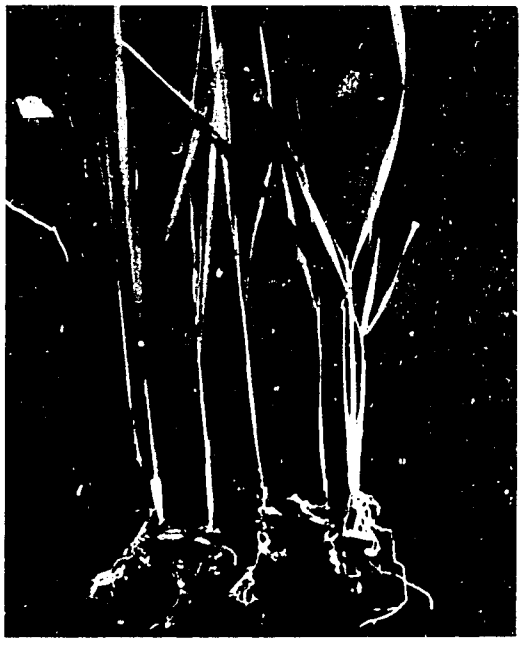

Figure 1A.

Figure 1. Plants infected with Meloidogyne graminicola. A) Rice variety Kn-96, B) Rice variety IR-36, infected (left) and healthy (right).

Figure 2A

Figure 2B

Figure 2. Plants infected with Meloidogyne javanica. A) Knol-Kohl (Kohlrabi), B) Cauliflower.

RELATIVE IMPORTANCE AND FREQUENCY OF OCCURRENCE OF THE VARIOUS SPECIES, PATHOGENIC VARIATION AND HOST RACES

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Approximately 1,300 live populations of *Meloidogyne* species, forwarded to project headquarters from approximately 100 cooperators representing more than 60 developing nations, are being studied. To date, 855 have been identified and frequency of species encountered is as follows: *M. incognita*, 52%; *M. javanica*, 31%; *M. hapla*, 8%; *M. arenaria*, 8%; *M. exigua*, 1%; and others, *M. graminicola*, *M. megatyla*, *M. microtyla*, *M. naasi*, *M. graminis* and *M. oryzae*, 1%. Within the *M. incognita* complex are four host races. Race 1 comprises 72% of 443 populations studied; Race 2, 13%; Race 3, 13%; and Race 4, 2%. Within the species *M. arenaria*, there are two host races. Race 1 (16% of 68 populations) infects and reproduces on peanut, while Race 2 (84%) does not attack peanut. Research on root-knot nematodes in agricultural soils must hereafter take into consideration the existence of host races. Otherwise, it will be incomplete and of limited value. Previous reports on resistance to *M. incognita* and *M. arenaria* must be reviewed and the races involved identified.

Identifications are initially based on host response and perineal patterns of adult females. Oftentimes, additional morphological, cytological or biochemical studies are necessary. Although some variation has been found within populations of the same species, uniformity of characters, including pathogenicity, far outweighs the variability. For the widely distributed and agriculturally important species *M. incognita*, *M. javanica*, *M. hapla* and *M. arenaria*, there is a strong correlation between the standard characters used for identification and the behavior of the individual nematode species. These studies suggest that once the identity of the nematode is known, its pathogenicity can be predicted except for variations among races. If future studies continue to confirm these correlations, it may be practical to develop resistant cultivars and conduct host range studies at a single location and expect the results to be applicable throughout the world. Studies involving a few populations of each of the major

species could be conducted under standard conditions and at minimum cost. These studies should make breeding cultivars for resistance to root-knot more attractive, since breeding lines can be tested against a small number of populations. Once a resistant cultivar has been developed, it can be marketed with assurance that results in the field will be satisfactory. Furthermore, a much larger, indeed a worldwide market, is open to producers of seed of resistant cultivars.

PROGRESS IN DELINEATING RELIABLE MORPHOLOGICAL CHARACTERS FOR SPECIES IDENTIFICATION

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A major objective of the International Meloidogyne Project (IMP) has been to discover new and more reliable morphological characters that are useful for species identification. Accurate identification of the four most common root-knot nematode species--Meloidogyne incognita, M. javanica, M. arenaria, and M. hapla--has been emphasized. Females, males, and second-stage juveniles of each of the most common species have been critically examined. The scanning electron microscope (SEM) has been utilized because the specimens are extremely small. The SEM also gives a three-dimensional image with high resolution and large depth of focus of the external surface morphology. The value of the SEM is that it greatly clarifies morphological details that are sometimes subsequently visible by light microscopy (LM). Because the SEM is not readily available to many investigators, only characters that can also be seen by LM are of practical value.

The external morphology of second-stage juveniles of the four most common Meloidogyne species were examined by SEM. Observations were made on head structures, lateral field, excretory pore, anal opening, and tail. Body morphology was of little taxonomic value. Head morphology--including expression of sensilla; shape of labial disc, medial lips, and lateral lips; and markings on the head region--was distinctly different among the species. Unfortunately, differences in the head morphology of second-stage juveniles were too small to be seen clearly by LM.

In the past, the morphology of the female has provided the most important characters in routine species identifications. Perineal patterns and head morphology of the four common species were examined by SEM. In addition, a technique was developed for the removal of the stylet from a female for SEM observation. New characters of perineal patterns among the species were not revealed by SEM. Differences in head morphology, however,

were found. Head shape differed among the species in the expression of sensilla; shape of the labial disc, medial lips, and lateral lips; and markings on the head region. Unfortunately, the heads of females are difficult to prepare, orientate, and see clearly by LM. The most useful new character of females is stylet morphology. As elucidated by SEM, distinct differences exist among the species. Differences occur in the shape of the cone, shaft, and knobs and distance of the dorsal esophageal gland orifice to the base of the stylet. The morphological characters of the stylets of females first detected by SEM were seen subsequently by LM and are thus helpful in species identification. Difficulty in specimen preparation, however, reduces the usefulness of this character. In order for these differences to be seen clearly, the stylet must be in exact lateral position and level.

Examination of males of the four most common species revealed the most useful and reliable characters for species identification. Observations were made on head structures, lateral field, excretory pore, and tail. As in the females, the stylets were excised from the males and examined by SEM. The only differences that occurred in the external morphology was in the shape of the head. The expression of the labial sensilla; the shape of the labial disc, medial lips, and lateral lips; the markings on the head region; and the width of the head region in relation to the first body annule were different among the species. Likewise, differences occurred among the species in the shape of the stylet cone, shaft and knobs and in the distance of the dorsal esophageal gland orifice to the base of the stylet. Unlike in the second-stage juvenile and female, the morphological characters revealed by the SEM were readily visible by LM. Head shape and stylet morphology of males are thus recommended as useful and reliable characters in the identification of the four most common species of root-knot nematodes.

The head shape and stylet morphology of males are not, of course, the only characters that should be examined in the identification of root-knot species. As many different characters (morphology, host response, cytology, biochemistry, ecology) as possible should be used congruently in the final identification of a species. A correct identification is extremely important in the design of effective control programs. A more complete characterization of the four common species has been prepared recently and should allow more accurate identifications (Eisenback _et al._, 1981).

References

Eisenback, J. D., H. Hirschmann, J. N. Sasser, and A. C. Triantaphyllou. 1981. A guide to the four most common species of root-knot nematodes (*Meloidogyne* species) with a pictorial key. A cooperative publication of the Departments of Plant Pathology and Genetics, North Carolina State University and The United States Agency for International Development. Raleigh, NC. 48 pages.

CYTOGENETIC AND BIOCHEMICAL STUDIES AS AN AID TO IDENTIFICATION

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About 150 populations belonging to the most common species of Meloidogyne were studied with regard to mode of reproduction, process of maturation of oocytes, and chromosome number. The total number of populations studied since the beginning of the IMP has now exceeded 500. Cytogenetic characters are very helpful and reliable in the identification of many species. The following is a summary of the cytogenetic characteristics of the four major species of Meloidogyne.

M. incognita. Populations of M. incognita reproduce exclusively by mitotic parthenogenesis. There are two chromosomal forms within this species. One form has 2n=32 to 36 chromosomes and is considered to be diploid; the other form has 2n=40 to 46 chromosomes and probably represents a triploid. The triploid form is by far the more common and widely distributed around the world. All populations of M. incognita have a unique cytological feature that separates them from populations of all other species of Meloidogyne. The oocytes of M. incognita are at prophase as they pass through the spermatotheca and remain in this stage until they have migrated to the posterior part of the uterus, when they suddenly advance to metaphase. During all this prolonged period of prophase, the chromosomes are bunched close to each other and cannot be seen individually or counted. Contrary to this situation, oocytes of all other Meloidogyne species advance to metaphase as soon as they pass through the spermatotheca into the uterus. Furthermore, the chromosomes are spread in a large area; they are discrete, and can be counted fairly easily.

M. arenaria. All populations of M. arenaria reproduce by mitotic parthenogenesis. Two chromosomal races are recognized in this species. Race A is the most common and includes triploid populations with 2n=50 to 56 chromosomes. Race B is the diploid race with 2n=34 to 37. The chromosomes of M. arenaria are similar in morphology and behavior to those of M. javanica. The two species differ only in chromosome number. Therefore, determination

of the approximate chromosome number is essential for differentiating between these two species.

M. hapla. This species is made up of populations belonging to two distinct cytogenetic races (A and B). Race A is the more common and includes populations that reproduce by facultative, meiotic parthenogenesis. Most of them have a haploid chromosome number of n=16 or 17; some have n=14 or 15. Race B populations reproduce exclusively by mitotic parthenogenesis. Some of them are diploid with 2n=30 to 31, but most are triploid with 2n=43 to 48 chromosomes.

Populations of race A are readily identified cytogenetically by the presence of 14 to 17 bivalent chromosomes (tetrads) at metaphase of the first maturation division of oocytes. None of the other three major species form bivalents. Distinguishing race B of M. hapla from other species, however, is not possible without the help of additional taxonomic characters. Race B populations have univalent chromosomes (dyads) similar in morphology and behavior to those of M. arenaria and M. javanica. Also there is an overlap in chromosome number between M. hapla (race B) and M. javanica.

M. javanica. Populations of M. javanica reproduce by mitotic parthenogenesis. The chromosome number varies from 2n=43 to 48. All populations belong to the same chromosomal form, which may represent a triploid. At metaphase of the single maturation division, the chromosomes of M. javanica are univalents (dyads) spread in a large metaphase plate, and can be counted easier than those of any other species. Usually, two to four oocytes located in the uterus close to the spermatotheca are at metaphase and can be studied. All other oocytes in the uterus have advanced to anaphase and telophase and are of limited value for cytological study.

ECOLOGY OF MELOIDOGYNE SPECIES OF AGRICULTURAL SOILS

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Cooperators of the International Meloidogyne Project have sent about 650 samples of populations of root-knot nematodes collected from agricultural soils in 69 countries of the world. A soil sample was sent with most of these samples. The cooperators estimated the severity of the infection (Gall Index) on a scale of 1 to 5 for no infection to 70% or more galled roots. Because the samples were selected for having visible infection by Meloidogyne species, they are representative of fields with nematode problems.

The population samples were increased and subjected to the North Carolina Differential Host Test then identified by morphological study using perineal patterns and other female characters, male head characters, chromosome counts and electrophoresis. The soil samples were analyzed for physical and chemical characteristics. Climatic data was obtained for all locations.

All of the data was analyzed by computer with the help of the Soils Department. Results of the analysis are the subject of the remainder of this report.

Latitude

About 70% of the samples are from the northern hemisphere, and about 90% of all samples are from latitudes 33°N to 33°S. The northern limit is about 50° in Europe, and the southern limit is about 33° in South America.

Temperature

Samples with M. incognita and M. javanica were received from countries having yearly average temperatures as high as 29.3°C, and samples containing M. hapla from localities having a yearly average of 5.3°C. M. incognita samples were received from localities having average yearly temperatures as low as 12°C, but were most numerous from regions having averages between

21° and 27°C. M. javanica has the same range, but samples were most numerous between about 18° and 25°C. The few samples of M. arenaria indicate a temperature distribution about the same as M. javanica.

Average temperature for the coldest month of the year (January in the northern and July in the southern hemisphere) is also interesting. No samples of M. incognita, M. javanica or M. arenaria have been received from localities where the average cold month temperature is less than 0°C. M. hapla has been received from a locality with a cold month temperature of -13°C.

Average temperatures for the warmest month of the year range from 10°C to 25°C for M. hapla, to 15° to 36° for M. incognita and M. javanica. The largest percentage of samples of M. incognita and M. javanica came from regions where the warm month temperature was 24° to 27°C. M. hapla has a peak at about 22°C, and no samples have been received from above about 25°C.

Precipitation

Samples have been received from regions with total annual precipitation ranging from nearly zero to 5,000 mm; the majority are from regions with about 1,000 mm to 1,500 mm.

Only 3% of the M. hapla samples came from regions with less than 500 mm annual precipitation, compared to 13% of the M. arenaria samples, 22% of the M. incognita samples, and 40% of the M. javanica samples. This is an indication that M. javanica is best adapted of the four species to survive in dry climates.

Many regions of the world have distinct wet and dry seasons which can be classified by the number of "dry months" with precipitation less than 10 mm. About 87% of the M. hapla samples, about 68% of the M. arenaria samples, and 46% of the M. incognita samples came from regions with precipitation well distributed throughout the year, that is, with no dry months.

Only 31% of the M. javanica samples came from such regions; about 25% were from regions with 4 or 5 dry months, compared to 8% of the M. incognita samples.

The data on precipitation indicate: 1) M. javanica is best adapted to survive in climates with distinct wet and dry seasons; 2) M. incognita is less well adapted to such conditions; 3) the data on M. arenaria and M. hapla is much less dependable because there is less of it, but both species seem to be best adapted to wet climates with well-distributed rainfall.

Soil Texture

Soil samples have been received with percentages of sand ranging from less than 10 to more than 90. About two-thirds of the soil samples contained more than 50% of sand, but one in three also came from soils with less than 50%, and about 10% of the samples were from soils with less than 10% of sand. The relation between sandy soil and root-knot nematodes is apparently not as definite as has been widely believed.

There is a more definite relationship between sample numbers and both silt and clay content of soil samples. Only about 6% came from soils having more than 50% of either.

Sand percentage apparently has only a small and insignificant effect on Gall Index. The same is true of clay. Gall Index does decrease significantly with increasing silt percentage.

Soil pH

A graph of percentages of samples and soil pH indicates an increase of percentages of samples of both *M. incognita* and *M. javanica* with increasing pH, both showing a peak at pH 7.0 to 8.0. There is also a positive correlation coefficient of 0.187 between number of samples and pH, probability 0.0005 for 346 observations. This is apparently not a direct effect of pH, but a consequence of increased occurrence of *M. javanica* in climates with distinct wet and dry seasons. The correlation coefficient of Dry Months with pH is 0.501, probability 0.0001, 439 observations.

Significant correlations: Gall Index with each of the following:

	Correlation Coefficient	Probability	Number of Observations
Crop loss	0.700	0.001	367
pH in water	0.187	0.005	346
Buffer acidity	0.139	0.0097	346

Average Crop Loss Estimates for Some Hosts:

	Crop loss	Number of observations
Beets	3.20	10
Pepper	2.77	12
Okra	3.60	20
Tomato	3.56	80

Average Crop Loss Estimates for Some Hosts (continued):

	Crop Loss	Number of observations
Tobacco	3.00	22
Bean	3.50	14
Eggplant	3.06	36

Crop loss code 3.0 corresponds to 10% to 20% loss, and 4.0 is 20% to 50%

Practical Applications of Ecology Program Results

At this time it seems probable that it will be possible to predict which species of root-knot nematode occur in any region by study of its climatic records. *M. incognita* will be found in regions where precipitation is more or less evenly distributed over the year, and the annual average temperature is in excess of 12°C. *M. javanica* will be found where the average annual temperature is 15°C or more and is often mixed with *M. incognita* where rainfall is in excess of 500 mm per year and distributed over 10 of the 12 months. Where there are 4 or more dry months per year, *M. javanica* may be the predominant species.

The status of *M. arenaria* is not yet clear, but there are indications that it will be found mixed with *M. incognita* and *M. javanica* in regions where there is well-distributed rainfall. *M. hapla* is the most common cool climate species and will be found in regions where the average temperature for the coldest month of the year is less than 0°C; the other species will not be found in these regions. *M. hapla* will also thrive where the average annual temperature is about 15°C, but will be less common where it is higher. There is still some uncertainty as to the upper limit for *M. hapla*. It occurs sporadically in Florida where the average warm month temperature reaches about 27°C, but most infections can be traced back to strawberry plants brought in from northern states.

Consideration of these facts will simplify future surveys for root-knot nematodes and provide a basis for estimating needs for resistance in crop cultivars to be used.

BREEDING CROPS FOR ROOT-KNOT NEMATODE RESISTANCE

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It was just over 68 years ago that the feasibility of breeding for root-knot nematode resistance to root-knot nematodes was genetically controlled after crossing the resistant 'Iron' cowpea with susceptible cowpea cultivars. Much progress has since been made in the development of root-knot nematode resistant cultivars through plant breeding and selection. The recent review by Sasser and Kirby (1979) lists over 450 cultivars in 13 botanical families with resistance to one or more species of Meloidogyne.

Resistant cultivars offer a practical and inexpensive means of controlling root-knot nematodes. However, before specific recommendations can be made to growers, they will have to be evaluated for horticultural and agronomic traits and resistance to the species and/or race of Meloidogyne associated with crop damage.

ESTABLISHING A PLANT BREEDING PROGRAM

Today, a fully trained breeder must have a knowledge of horticulture, entomology, pathology, and nematology. Lacking some of this training he must obtain assistance from a specialist. In establishing a breeding program for root-knot nematode resistance, the plant breeder, naturally, should seek assistance of a nematologist or a plant pathologist with training in nematology. Major progress in the development of root-knot nematode resistant cultivars has been made when the program involves the cooperative inputs of both a plant breeder and nematologist/pathologist.

In a cooperative breeding project the nematologist assists the breeder in several ways:

1. Judgment must be used as to the most prevalent root-knot nematode species and race causing damage.

Limited resources should not be used in developing resistance to a root-knot nematode species that is of minor importance.

2. Pure cultures of the nematode species must be established and increased so a constant and uniform inoculum will be available when plants are ready for testing.

Natural populations often consist of a mixture of species which make them undesirable for screening valuable genetic material. Pure cultures are started from a small number of specimens that have been accurately identified. Individual egg masses are removed from the root tissue, and each is placed in a small amount of water in a watch glass; a perineal pattern is prepared of the corresponding female dissected from the root.

After accurate microscopic identification of several specimens, the egg masses are added to a 10-cm pot of sterile soil in which a susceptible tomato seedling is planted. After 30 to 50 days, the root system is examined for galling and nematode reproduction. The root-knot nematode species, once again, is confirmed microscopically, and the infected roots are subdivided among other susceptible noninfected tomato plants in order to increase the culture. The population is also subjected to the IMP Differential Host Test to further verify the species and define the race of the nematode.

The culture is subsequently maintained in the greenhouse on host plants to provide a continuous source of inoculum for screening plant material. Pure populations of the nematode species are cultures on susceptible host species. In our laboratory *M. incognita* is increased on 'Homestead' or 'Rutgers' tomato; *M. javanica* on NC-95 tobacco since it is resistant to *M. incognita*; *M. hapla* on 'Patriot' tomato since this cultivar is resistant to *M. incognita*, *M. javanica* and *M. arenaria*; and *M. arenaria* on *Solanum sisymbriifolium* which is resistant to *M. incognita* and *M. javanica*.

3. Inoculum must be prepared.

Eggs are extracted from infected roots using the sodium hypochlorite maceration technique described by Hussey and Barker (1973). This technique is a major contribution to nematology and warrants repeating. Infected roots are shaken vigorously in 200 ml of 20% commercial bleaching solution (approximately 1% NaOCl) in a 1-liter container for 4 min. The NaOCl solution is passed through a combination of 200/500-mesh sieves. The eggs collected on the 500-mesh sieve are rinsed with tap water to remove the residual NaOCL.

The roots are rinsed two more times with water to remove additional eggs. Over a million eggs could be collected from one heavily infected

tomato plant with this method. The eggs are transferred to a vessel. The concentration of eggs per ml is then calculated and the volume of water is adjusted to dispense about 1,000 or 2,000 eggs per ml. The advantage of this technique is that the eggs are surface sterilized, thereby eliminating the introduction of possible fungal or bacterial pathogens. The inoculum is easily standardized for distribution around the root systems or for direct mixing into the soil.

Any pipetting apparatus that can be calibrated to deliver a known quantity of inoculum can be used. For large scale screening we have found the Pistolpet™, manufactured for dispensing preset volumes of liquid, useful for dispensing the egg inoculum into the soil accurately and rapidly without causing fatigue to the hand.

4. Screening techniques must be devised that utilize the optimum amount of nematode inoculum to permit differentiation among plant genotypes.

Even the most resistant plant can be damaged if overwhelmed by large numbers of nematodes. It is therefore important to control the inoculum level so that population pressures from extremely high dosages do not mask potentially useful genetic material. The screening technique should be simple and results should be repeatable. The method should leave virtually no room for escapes. Screening should be done under conditions where soil preparation, inoculation, temperature, light, and moisture are controllable.

In our laboratory all screening of plant material for resistance to *Meloidogyne* spp. is done in the greenhouse. Field screening offers the advantage of simultaneous selection of horticultural traits and resistance to the root-knot nematode species. However, escapes are more likely to occur since levels of inoculum and environmental conditions are difficult to control.

Greenhouse tests are usually conducted in 4.3 x 0.9 x 0.15 m benches containing a steam-sterilized mixture of 2 parts sand and 1 part of a soilless planting mixture consisting of vermiculite and peat moss (Jiffy Mix). Planting holes 2 cm deep are made at 4 to 5 cm intervals in rows 10 cm apart. The holes are inoculated with approximately 2,000 eggs before the seeds or seedlings are planted. Soil temperatures are maintained between 22 and 26 C and plants are evaluated about 30 to 50 days after planting. Each test should include a known susceptible cultivar to ensure that the inoculum is viable and infective.

Polystyrene planter flats (speedling trays) offer an alternative method for screening large plant populations if space is a limiting factor (Fassuliotis, 1978). The trays consist of 128 3.8-cm square, inverted, pyramid-shaped root cells. They are filled with a mixture of builders sand and soilless planting medium (2:1 v/v) supplemented with a complete fertilizer. Each cell is inoculated with 2,000 eggs and then planted with either a seed or seedling. The trays are open at the bottom and set on aluminum T-rails, allowing the roots that grow through the hole to be air pruned. An excellent root system grows within the cell. After 30 to 50 days, the plant is lifted from the cell, washed of adhering growing medium, and evaluated.

Some plants such as the tomato and sweet potato can be uprooted, evaluated for their root-knot response and replanted for use as parents in cross pollination; others cannot. For example, a difficulty encountered in breeding snap beans for resistance to root-knot nematodes has been the propagation of plants following their evaluation for resistance (Fassuliotis _et al._, 1979). The plants cannot be uprooted and survive transplanting. Remnant seed of resistant lines must then be used. This is time consuming, and unless the seed is homozygous for resistance, there is no assurance that the plants from remnant seed will be resistant. To avoid using remnant seed, it was necessary to wait until the bean pods were partially mature before evaluating the plants for resistance, but by this time, the plant was too old for crossing or backcrossing. In addition, root senescence and root-rotting organisms often caused cortical sloughing, making an accurate root-knot evaluation difficult.

Wyatt and Fassuliotis (1979) developed a technique for evaluating snap bean plants and propagating resistant individuals for crossing and selfing. Seeds were germinated and grown in paper towels until radicles were 6 to 8 cm long. Seedlings were then placed in 10-cm clay pots with the root tips protruding 1 cm through the drain hole. The pot was filled with sterile soil. Holes 1 cm deep in the soil of a greenhouse bench were inoculated with 6,500 _M. incognita_ eggs and the clay pots were placed over the holes. Roots that grew through the drain hole became infected and were cut off for evaluation without permanently damaging the plant. Unlike tomato roots, bean roots can be difficult to evaluate with accuracy since many infected lines do not produce galls and egg masses are difficult to differentiate from soil particles adhering to the roots. Phloxine B stains the egg masses bright red and differentiates them from the non-infested portions of the roots.

5. A rating scheme should be utilized that quickly differentiates between resistant and susceptible plants during the initial phases of the project.

A simple classification system such as resistant (R), susceptible (S) and intermediate (I) based on galling response and reproduction is usually sufficient. On a 0-5 scale these would correspond numerically as: R = 0-1, I = 2-3 and S = 4-5.

6. Sources of resistance must be identified.

The search is carried out in logical sequence. First, established cultivars and working collections of the breeder should be tested for resistance. After failure to find resistance in this material, a search should be made through genetic resource collections or gene banks for primitive cultivars from the gene centers. Finally, failing to find any resistance in primitive cultivars, the nematologist should evaluate wild species and related species.

It is preferable to find a resistance source that is compatible with the horticultural crop species and one that does not have too many undesirable traits. Plant breeding is a long tedious process, taking 10 to 15 years before a cultivar could be used by a farmer, so there is no need to extend this time unnecessarily by use of a wild type if better material exists.

Transfer of resistance from wild species may require special genetic manipulations such as embryo culture or cell culture. These methods often become specialized research problems all their own. An excellent example of the transfer of resistance from one plant species to another is the incorporation of root-knot nematode resistance from *Lycopersicon peruvaianum* to the tomato, *L. esculentum*, through embryo culture. After the initial hybrid was produced, the first commercial tomato was released 11 years later.

7. The nematologist should review the nematological literature to keep abreast of any new developments in resistance and share this knowledge with the plant breeder.

RESISTANCE REACTIONS

Resistance to root-knot nematodes usually operates after the larvae has invaded the host roots. Resistance is indicated by the degree to which the plant can support the parasite through its life cycle. A proper host-parasite interaction is necessary for feeding, development and reproduction of the nematode. This interaction is manifested through cellular changes (in the form of giant cells or syncitia) in the differentiating xylem after penetration

of the host roots by the nematode. Usually 5 or 6 giant cells surround the head of the feeding nematode. These large, thick-walled and multinucleate cells extend parallel to the long axis of the root.

Generally, larvae enter the roots of resistant plants as readily as susceptible plants. After penetration, resistance may be expressed by (i) failure of larvae to develop into adults; (ii) prolongation of the developmental cycle; (iii) larval death within root tissues; (iv) alteration of sex ratio toward maleness; or (v) larval egress soon after penetration.

The hypersensitive reaction is the most usual type of response in resistant plants. Hypersensitivity implies the death of the host cells and the pathogen and occurs within a few hours after penetration. Hypersensitivity is indicated by a general browning discoloration of the affected tissues. The root discoloration is attributed to an accumulation of phenolic compounds in the tissues around the infection sites (Fassuliotis, 1979).

SOME FOOD CROPS IN BREEDING PROGRAMS

The food crops that have received much attention in breeding for root-knot nematode resistance are tomato, cowpea, sweet potato, beans, muskmelon and eggplant.

Tomato (*Lycopersicon esculentum* Mill.)

The source of resistance came from *L. peruvianum* which was partially incompatible with *L. esculentum*. A hybrid was produced with embryo culture in 1944, and the cultivar Anahu was released in 1955 from the Hawaiian Experiment Station as the first commercial-type tomato with resistance to root-knot nematode. Recent releases from other stations include Nematex, Atkinson and Patriot.

The inheritance of resistance was investigated by a number of workers (Harrison, 1960). A single dominant gene for resistance was identified and designated Mi. The same gene confers resistance to *M. incognita*, *M. javanica* and *M. arenaria*, but not to *M. hapla*. The nature of resistance is through the hypersensitive reaction which occurs rapidly after the larva penetrates the root preventing giant cell formation from which the nematode received its nourishment for growth.

Sweet Potato (*Ipomoea batatas* (L.) Lam.)

Sweet potato is a major crop nourishing mankind and one subject to heavy damage by root-knot nematodes. Injury caused to the sweet potato results in

malformed roots, stunted plants, scabbing and cracking. The nematodes develop in colonies in the swollen root and appear as small discolored areas about one-sixteenth inch, or smaller, in diameter. They usually occur about 1.2 cm beneath the epidermis but sometimes are deeply embedded in the fleshy tissue.

Many sources of resistance have been reported to root-knot nematodes. Jersey types were consistently more resistant than 'Porto Rico.' 'Tinian' (PI 153655) has also been an important source of resistance from which a number of resistant sweet potato cultivars have been derived.

To increase the genetic variability in sweet potato by broadening the gene base, Jones (1965) initiated a sweet potato breeding procedure using open-pollinated seedlings from polycross nurseries of parental types developed through mass selection. Recent releases of sweet potato germ plasm from the U. S. Vegetable Laboratory are highly resistant to M. javanica, M. hapla and to at least two races of M. incognita (Jones et al., 1980). Resistance to M. incognita and M. javanica is inherited independently. Although some lines are highly resistant to root-knot nematodes, they are also susceptible to root necrosis (Jones and Dukes, 1980). Therefore, reproduction, galling and necrosis must be considered when sweet potato lines are evaluated.

Bean (Phaseolus vulgaris L.)

Root knot of the common bean is a major problem in all areas with warm or subtropical climates. Two highly resistant selections were discovered in Alabama and later named 'Alabama No. 1' and 'Alabama No. 2.'

Resistance has been found only to M. incognita. Hartmann (1968) released a new pole bean cultivar 'Manoa Wonder' derived from the progeny of a cross between 'Alabama No. 1' and 'Hawaiian Wonder.' Wyatt et al. (1980) recently released the first resistant bush type snap bean, B 4175, which has greater resistance to M. incognita than any other resistant bean. Resistance was derived from a wild Mexican bean, PI 165426.

Root response in beans to infection by M. incognita varies greatly. Some lines gall profusely while others show no galling response but support high reproduction. As many larvae penetrate resistant as susceptible cultivars. Within three days after infection, a hypersensitive reaction occurs in resistant root tips. Larval migration within the roots causes necrosis of meristem and cortical parenchuma. In contrast to large giant cells that are produced in susceptible roots, resistant roots develop only small giant cells around the head of the nematode. Many of the giant cells also become necrotic and deprive the nematode of nourishment for further development.

Resistance is apparently confined to the roots and not transferable to stem tissues. Fassuliotis and Deakin (1973) found that stems of resistant beans become severely galled and contain mature ovipositing females when seeds are planted too deep into infested soil. Resistance to M. incognita has been found to be due to the interaction of two independent recessive genes (Blazey et al., 1964).

Cowpea (Vigna unguiculata (L.) Walp.)

The cowpea (southern pea) is also a major food crop in many developing countries. Cowpeas are frequently planted in sandy soils and much of this acreage is heavily infested with root-knot nematodes. M. incognita is the most common species pathogenic on cowpeas, but cowpeas are also infected by M. javanica, M. arenaria and M. hapla. Breeding programs to increase resistance to root knot have been highly successful.

There is apparently no paucity of resistance to root-knot nematodes in cowpeas and transferring resistance into cultivars is not difficult since a singly dominant gene determines resistance. Recent work by Fery and Dukes (1980) found that a single dominant gene conferred resistance to M. incognita, M. javanica and M. hapla in Colossus, Mississippi Silver, Iron and PI 353383. The gene for resistance was designated Rk.

Muskmelon (Cucumis melo L.)

Despite considerable progress being made in developing root-knot nematode resistance in other vegetable crops, none has been made in the muskmelon because compatible resistant germ plasm has not been found after extensive search. Efforts are being made to hybridize the wild species, C. metuliferus, and the muskmelon with embryo culture (Fassuliotis, 1979).

Eggplant (Solanum melongena L.)

All cultivars of eggplant are susceptible to M. incognita and M. javanica. Research is underway to transfer resistance from the wild species S. sisymbriifolum to the eggplant with somatic hybridization techniques (Fassuliotis et al., 1981).

MODIFICATION OF RESISTANCE REACTION

Resistance can be modified by the plant's genotype and by environmental factors. Probably the most important environmental factor in the expression of resistance is soil temperature. Detailed studies by Dropkin (1969)

show that resistant tomatoes become susceptible when grown at soil temperatures above 28 C. Similar temperature effects have been observed on bean (Fassuliotis et al., 1970) and sweet potato (Jatala and Russell, 1972). It is stated that the root-knot nematode resistant gene in tomatoes is ineffective in Florida because of high soil temperatures.

EFFICACY OF RESISTANCE

Root-knot resistance in vegetable crops can have the same effect on nematode populations as the application of nematicides to the soil. Resistant lines can reduce root-knot nematode populations equal to or greater than nematicide treatment to produce yields equivalent to a susceptible cultivar planted in nematicide-treated soil (Wyatt et al., 1980). Therefore, the use of root-knot nematode resistant cultivars could reduce the cost of crop production and minimize losses in areas where the nematodes are economic pests. Resistance is one of the primary tools with which to combat the root-knot nematodes. It is up to the plant breeders and nematologists to utilize the existing resistant germ plasm and to search for new germ plasm with which to develop new resistant cultivars which are adapted to local environmental conditions and which will be acceptable to both grower and consumer.

References

Blazey, D. A., P. G. Smith, A. G. Gentile, and S. T. Miyagawa. 1964. Nematode resistance in the common bean. J. Heredity 55:20-22.

Dropkin, V. H. 1969. The necrotic reaction of tomatoes and other hosts resistant to Meloidogyne: Reversal by temperature. Phytopathology 59:1632-1637.

Fassuliotis, G. 1978. A system for screening large plant populations for root-knot nematode resistance. Nematropica 8:10 (Abstr.).

Fassuliotis, G. 1979. Plant breeding for root-knot nematode resistance, pp. 425-453. In Root-knot nematodes (Meloidogyne species), systematics, biology and control, F. Lamberti and C. E. Taylor (ed.). Acad. Press, London.

Fassuliotis, G. and J. R. Deakin. 1973. Stem galls on root-knot nematode resistant snap beans. J. Amer. Soc. Hort. Sci. 98:425-427.

Fassuliotis, G., J. R. Deakin, and J. C. Hoffman. 1979. Root-knot nematode resistance in snap beans: breeding and nature of resistance. J. Amer. Soc. Hort. Sci. 95:640-645.

Fery, R. L. and P. D. Dukes. 1980. Inheritance of root-knot resistance in the cowpea (Vigna unguiculata (L.) Walp). J. Amer. Soc. Hort. Sci., 105:671-674.

Harrison, A. L. 1960. Breeding of disease resistant tomatoes with special emphasis on resistance to nematodes, pp. 57-58. In Proc. Plant Science Seminar, Campbell Soup Co., Camden, New Jersey.

Hartmann, R. W. 1968. Manoa Wonder, a new root-knot nematode resistant pole bean. Hawaii Agric. Exp. Sta., Univ. of Hawaii, Circ. 67. 12 pp.

Hussey, R. S. and K. R. Barker. 1973. A comparison of methods of collecting inocula of Meloidogyne spp. including a new technique. Plant Dis. Rep. 57:1025-1028.

Jatala, P. and C. C. Russell. 1972. Nature of sweet potato resistance to Meloidogyne incognita and the effect of temperature on parasitism. J. Nematology 4:1-7.

Jones, A. 1965. A proposed breeding procedure for sweet potato. Crop Science 5:191-192.

Jones, A. and P. D. Dukes. 1980. Heritabilities of sweet potato resistance to root knot caused by Meloidogyne incognita and M. javanica. J. Amer. Soc. Hort. 105:154-156.

Jones, A., P. D. Dukes, J. M. Schalk, M. A. Mullen, M. G. Hamilton, D. R. Paterson, and T. E. Boswell. 1980. W-71, W-115, W-119, W-125, W-149, and W-154 Sweet potato germplasm with multiple insect and disease resistances. Hortscience 15:835-836.

Orton, W. A. 1913. The development of disease resistant varieties of plants. Compt. Rend. and Rapp. IV Conf. Intern. Genetigue, Paris 1911:247-265.

Sasser, J. N. and M. F. Kirby. 1979. Crop cultivars resistant to root-knot nematodes, Meloidogyne species. International Meloidogyne Project Pub. Dep. Plant Pathology, N.C. State Univ., and U.S. Agency for International Development. Raleigh, N.C. 24 pp.

Smith, P. G. 1944. Embryo culture of a tomato species hybrid. Proc. Amer. Soc. Hort. Sci. 44:413-416.

Wyatt, J. E. and G. Fassuliotis. 1979. Methods for screening snap beans for resistance to root-knot nematodes. Hortscience 14:27-28.

Wyatt, J. E., G. Fassuliotis, A. W. Johnson, J. C. Hoffman, and J. R. Deakin. 1980. B 4175 root-knot nematode resistant snap bean breeding line. Hortscience 15:530.

FUTURE DEVELOPMENT OF TROPICAL TOMATO RESISTANCE TO ROOT-KNOT NEMATODES (*MELOIDOGYNE INCOGNITA*) IN THAILAND

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Seven varieties of tropical tomato were already improved and extensively adapted to the Thai environmental conditions. They are: L22 (VC 11-3-1-8), L246 (KL2), SVRDC 3, SVRDC 4, Fire Ball, MCP 186 (Sida) and P-1. These varieties give very good fruit set even in high temperatures and heavy precipitation. L22 is only one variety resistant to bacterial wilt, *Pseudomonas solanacearum* E. F. Smith, but all of the others are not resistant or tolerant to root-knot nematodes (*Meloidogyne incognita*).

Sontirat *et al*. (1980) found that three tomato varieties, Kewalo, Healani and Daruma, were resistant to *Meloidogyne incognita* in northeast Thailand. He also found that some hybrid tomatoes in which Kewalo was used as parent breeding material still gave good resistance to root-knot nematode, *Meloidogyne incognita*. Kewalo is a large-fruited tomato whose yield can be increased in the cool season of Thailand. The tomato varieties mentioned, except Fire Ball, are small-fruited and plum-shaped. All of these will be used as male parents by crossing with Kewalo. F1 up to F6 progenies will be selected by pedigree method. The selected hybrids should be large fruited, heat tolerant, resistant to root-knot nematodes, and well adapted to tropical region of Thailand.

References

Boonaka, S. *et al*. 1980. Progress report and tomato cultivation problems in the eastern Thailand. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Kriangyakul, W. *et al*. 1980. Studies on 15 varieties of tomato resistance to diseases and waterlog at Hantra, Ayuthaya prov. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Lamyong, P., and M. Wiwatwongwana. 1980. Study on reaction of some tomato varieties to bacterial wilt disease. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Lavapaurya, T. 1980. Breeding and improving tomato varieties in off-season. Progress report presented to Vegetable Crops Conference at Udon Thani Prov., Thailand.

Sirikuanchai, S., and S. Boonwanno. 1980. A study on eighteen varieties of tomato in late rainy season. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Sontirat, S. et al. 1980. Preliminary study on selection of tomatoes resistance to Meloidogyne incognita. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Soopamethi, S., and M. Chuawiroj. 1980. Progress report on tomato cultivation in central low land. The report presented to the fifth Tomato's Workshop Conference at Prachuab Kirikan Prov., Thailand.

Wongwat, S., and W. Buachareon. 1980. Yield trial on tomato in rainy season. Report presented to Vegetable Crops Conference at Udorn Thani prov., Thailand.

Table 1. Performances of tropical tomatoes in Thailand during 1979-1980

Code No.	Pedigree	Bacterial wilt infection (%)[1/]	Root-knot nematode infection index[2/]	Days to flowering (days)	Days to harvest (days)	Yield per plant (g)	Plant height (cm)	Source of data
L22	VC11-3-1-8	8.7	3	41	92	955	87	1,2,3,4,6
L246	KL2	84.4	-	41	93	1,005	58.6	1,3,4,6,7
SVRDC3	-	69.0	3-4	46	80	526	89.2	1,2,5,6,7
SVRDC4	-	87.2	3-4	-	-	500	110.4	1,2,7
-	Fire Ball	-	3-4	-	-	1,248	-	2,8
MCP186	Sida	96.7	3-4	51	87	450	92	1,2,3,4
	P-1	-	-	-	-	1,581	-	8
MCP90	Healani	78.7	0	-	-	-	-	1,2
L274	Kewalo	92.6	0	36	78	50	-	1,2,3,5,6

[1/] *Pseudomonas solanacearum* E. F. Smith was inoculated plant materials through cutting seed leaves of 14-day tomato seedlings.

[2/] Root-knot infection index was standardized at five grades as follows:

grade 0 all roots are normal
grade 1 root knot are 1-25% } of whole root system
grade 2 root knot are 26-50% }
grade 3 root knot are 51-75% } or the plants die before harvest
grade 4 root knot are 76-100% }

STATUS OF RESEARCH ON BREEDING CROPS FOR RESISTANCE TO ROOT-KNOT NEMATODES IN NEPAL

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Nepal, with a wide range of climatic conditions (tropical to alpine) and soils, grows tomato, potato, tobacco, cotton, jute, cauliflower, cabbage, chilli, okra, eggplant, bean and cucurbits in considerable scale besides rice, corn and wheat--the three main crops of the country. The distribution of crops, potential to root-knot nematode infection at different regions of the kingdom, is shown in the map.

The importance of root-knot nematodes Meloidogyne spp. in the production of different crops of Nepal depends upon presence or absence of other diseases of major importance, crop grown, soil type and soil reaction of the region, and combinations of crop rotation practiced. Reductions in the yield of different crops, and the total annual losses in the country due to Meloidogyne spp. have not been estimated. However, Amatya and Shrestha (1969) have reported the occurrence of Meloidogyne in a few crops.

Root-knot nematodes have been observed in Rampur area where the Institute of Agriculture and Animal Science is located. The crops affected are tomato, eggplant, bean, okra, cabbage, cauliflower, papaya, chilli, jute, potato, spinach, carrot, and cucurbits. The incidence of this disease and the crops infested at different locations of the country have not been surveyed. The species of Meloidogyne involved in the infestation of different crops at different regions of the country are also not identified.

At present root-knot nematode is not a major yield-limiting pest of potato in major potato-growing areas of the country (Hogger 1981); however, no reports have been made in tobacco, cotton and jute. It is one of the major yield-limiting factors of tomato, chilli, eggplant, okra, and papaya in Rampur area though its importance on tomato is dominated by a major problem of late blight (Phytophthora infestans). Therefore, the development of character resistance to late blight is of primary importance in screening tomato germ plasm against Meloidogyne spp. for Rampur area.

Germ plasm introduction, evaluation and its direct utilization are principal methods of crop improvement in Nepal. A group of varieties of tomato were introduced and evaluated against Meloidogyne spp. in 1980-81 at Rampur.

SCREENING TOMATO GENOTYPES AGAINST MELOIDOGYNE SPP.

Materials and Methods

Thirty-two-day-old seedlings of forty-three genotypes of tomato introduced from Taiwan, USA and India with some local collections were planted on the first week of November 1980, at Institute of Agriculture and Animal Science, Rampur. Tomato and eggplant were grown in that plot in the preceeding two years. The experiment was set up in a RBD with three replications. The experimental unit consisted of 2m x 2m plot with inter- and intra-row spacing of 60 cm. Fertilizers were applied at the rate of 100:60:40 kg NPK/hectare.

One-hundred fifty days after transplanting, roots of five plants from each experimental unit were pulled out, washed and scored for the degree of galling according to Daulton and Nusbaum (1961) with modification. The root-knot nematode index contained six categories: 0 = immune, no galls; 1 = resistant, traces of galling (1-5% of the root galled); 2 = moderately resistant, light galling (6-25% of the root galled); 3 = moderately susceptible, moderate galling (26-50% of the root galled); 4 = susceptible, heavy galling (51-75% of the root galled); and 5 = highly susceptible, very heavy galling (76-100% of the root galled). A one-gram root sample was also randomly taken from each unit and studied for the presence of adult females and egg masses in the galled tissues.

Results and Discussion

All the tomato genotypes tested under natural infestation showed susceptibility to Meloidogyne spp. at varying degrees, except Ponderosa, CL 1094F5-57 and CL1094F5-58 (Table 1). None of the genotypes were immune with respect to galling and production of females. The lowest root-knot indices were 1.4, 1.9 and 2.0 in Ponderosa, CL1094F5-58, and CL1094F5-57, respectively. All other commercial varieties, including Rampur local, had root-knot indices of 3 and above. However, adult females and egg masses were present in all genotypes.

Our observation on the susceptible nature of Pusa Ruby, Marglobe, New Yorker, Sioux, Best of All and Pusa Early Dwarf are in agreement with the report of Khan et al. (1971) and Ogunfowora (1966). Moderately resistant response of Ponderosa also agrees with the finding of Khan et al. (1975)

who also reported low infestation of Meloidogyne incognita in Ponderosa. It is concluded that the genotypes Ponderosa, CL1094F5-57 and CL1094F5-58 can be grown in root-knot nematode problem areas where late blight is not a problem.

Future Outlook

Work concerning the survey of areas, identification of the species of Meloidogyne, the reaction of locally important crops, and introduction of crop varieties resistant to root-knot nematode infection is hoped to be continued through the help of IMP.

References

Amatya, P., and M. Shrestha. 1969. Preliminary survey of plant-parasitic nematodes in Nepal. Nepalese J. of Agr. 4:17-28.

Daulton, R. A., and C. J. Nusbaum. 1961. The effect of soil temperature on the survival of the root-knot nematodes Meloidogyne javanica, and M. hapla. Nematologica 6:280-294.

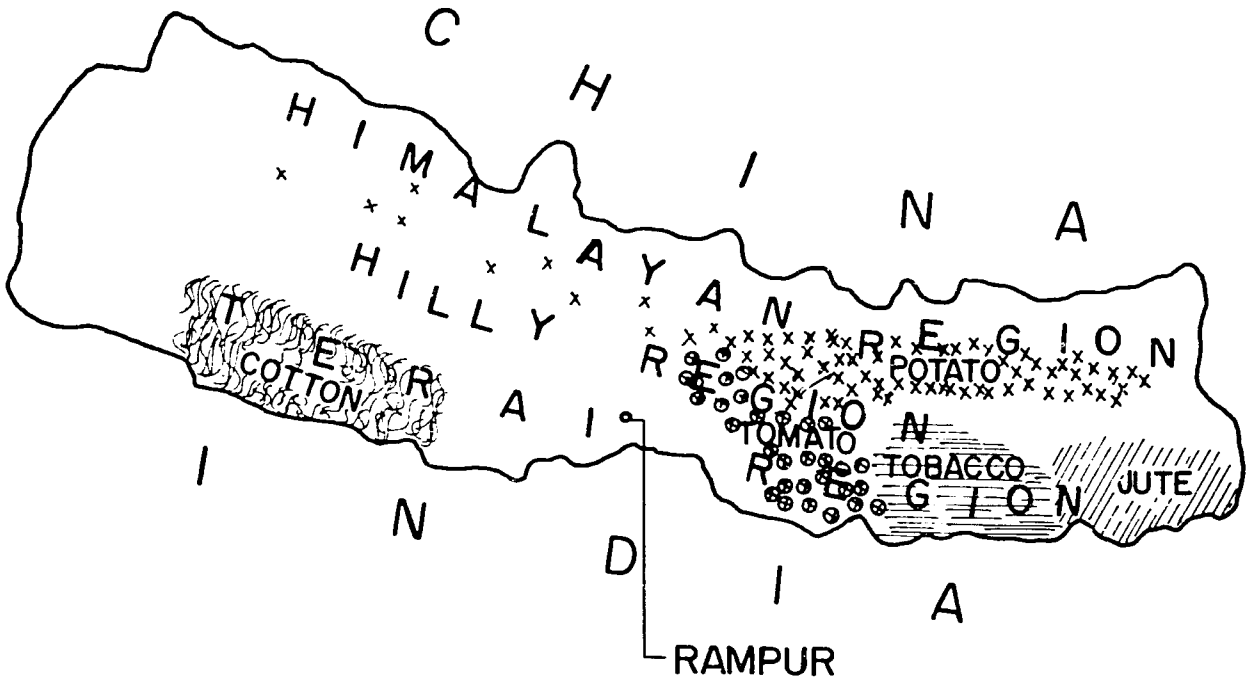
Hogger, C. H. 1981. Personal communication.

Khan, A. M., S. K. Saxena, and Z. A. Siddigi. 1971. Indian Phytopathology 24:197-199.

Ogunfowora, A. O. 1976. Research on Meloidogyne at the Institute of Agricultural Research and Training, University of Ife, Moor Plantation, Ibadan, pp. 9-14 In Proceedings of the research planning conference on root-knot nematode, Meloidogyne spp., Ibadan. 83 pp.

Table 1. Reactions of forty-three genotypes of tomato to root-knot nematodes *Meloidogyne* spp.

Category	Reaction	No. of entries	Genotypes
0	Immune	-	-
1	Resistant	-	-
2	Moderately resistant	3	Ponderosa, CL1094F5-57, CL1094F5-58
3	Moderately susceptible	31	Pusa Ruby, Marglobe, New Yorker, Manapal, S-120, Money marker, Ped, Homestead 24, Roma, Early Red, Pusa Early Dwarf, Kalyanpur, Vc 134 Imp, Nanprakash, Best of All, Oxheart, Salimar, Sioux, Pansa, Catala, Solangola, Peto 96, PB-CH, Rampur local, CL143-0-10-3, CL123-2-4, CL1561-6-0-22-4, CL1591-5-0-1-6, CL1591-5-0-1-7, (1), 387
4	Susceptible	8	Italian Red Pear, Peto 81, HS101, Walter, Westoner, Monpresco, vc 22 A, CL9-0-01
5	Highly susceptible	1	Castlex 1604



NOTE :—

Other crops potential to root-knot nematodes infection are grown in small scale and are scattered throughout the country.

Map of Nepal showing the distribution of some economically important crops potential to root-knot nematodes infection.

BREEDING FOR RESISTANCE TO ROOT-KNOT NEMATODE OF SWEET POTATOES IN JAPAN

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Introduction

Sweet potatoes were introduced through two routes into Japan. One route was from China to Hirato, Kyushu, by the English in 1615, and the other was from Okinawa to Kagoshima, Kyushu, by King of Ryukyu in 1698. Sweet potatoes were adopted by Japanese farmers and widely cultivated in the southern region of Japan. For famine relief, crop sweet potatoes were extended into the northern region of Japan up to 39°N. In the 30th year after introduction, sweet potatoes were transmitted from Kyushu to Edo, Tokyo of today. The approximately 70 thousand hectares cultivated in 1979 produced 1.4 million tons of sweet potatoes.

The symptoms of infection by root-knot nematode were first found in the sandy soil of the sweet-potato-growing area at Chiba Prefecture in 1935. It was confirmed that this injury was caused by Meloidogyne incognita var. acrita Chitwood in 1938. Subsquently, injury by root-knot nematodes was reported at many places in Japan: Miyazaki in 1939, Ibaraki and Kagoshima in 1940, Shizuoka in 1941, and Gifu and Ehime in 1942. Ministry of Agriculture and Forestry built the Unakami Station for control of root-knot nematodes in sweet potato at the heavily infested field, Chiba, in 1941. Much research on the nature of the nematode, its control, and tests for host-plant resistance was carried out at this Station until 1966. Many reports were published by Kondo et al. (1972), etc. In spite of research on root-knot nematodes, about 20 thousand kiloliters of nematicide are used in the cultivation of sweet potato and other upland field crops in Japan. This indicates that to be economically produced sweet potato cultivars need to possess higher resistance to root-knot nematodes.

This paper deals with 1) outline of breeding for resistance to root-knot nematode in Japan, and 2) classification of sweet potato cultivars according to the degree of resistance to root-knot nematodes.

BREEDING FOR RESISTANCE TO ROOT-KNOT NEMATODE

Breeding System and Breeding Targets

Sweet potato was introduced by officials from China to Okinawa in 1605. After the introduction, the selection for more suitable sweet potato clones was carried out by farmers from sprout mutation and seedling populations of natural crossing until the 1910's. Hybridization breeding was started by Okinawa Agricultural Experiment Station in 1914. Hybrid seeds and tubers were sent to Saitama, Iwate, Chiba, Ishikawa, Kochi, Nagasaki, Mie, Tottori, Kagoshima, Miyazaki, Ehime and Ibaraki Agricultural Experiment Stations, and suitable clones were selected in these Stations.

A sweet potato breeding system was established systematically by Ministry of Agriculture and Forestry, Japan, at Okinawa, Kagoshima, Chiba and Iwate Agricultural Experiment Stations in 1937. Hybridization in Okinawa was closed in 1945 because the island was occupied by the U.S. Army, and the crossing center was transferred to Ibusuki, Kyushu. From 1951, sweet potato breeding was conducted by three Breeding Centers in Kumamoto, Fukuyama and Chiba, and breeding in Chiba was transferred to Yotsukaido in 1963. Breeding in Fukuyama was ceased in 1975.

Now, the target of our Breeding Center in northeastern Japan is the improvement of sweet potato cultivars for food with high tuber productivity, high quality and high resistance to black rot and root-knot nematode. The target of Kumamoto Breeding Center in southwestern Japan is improvement of those for industrial material with high tuber productivity, high starch content and high resistance to black rot and root-knot and root lesion nematodes.

Screening Tests for Sweet Potato Cultivars Resistant to Root-knot Nematode

Screening tests were carried out at Unakami Station, Chiba, for control of root-knot nematode from 1941 until 1966. Many local and bred cultivars were examined at this Station, and the results were reported by Kondo *et al.* (1972). A screening field of 1,000 m^2 was established at our Breeding Center. Screening tests have been conducted at the Station since 1957. A high population of root-knot nematodes was maintained by planting a susceptible sweet potato cultivar, Kanto 14, in alternate years, and garden balsam was grown promptly before the test in the spring.

Hybrid seeds used in breeding program were sown in the heavily infested nursery bed in a vinyl house, and F_1 seedling plantlets with many root-knot galls nematode were abandoned. The remaining plantlets were

transplanted in a non-infested field, and practical characters and productivity of tuberous roots were evaluated. Excellent plants were selected. The selected clones were tested in the screening field in the following years.

Seven hundred to 1,000 second-year clones used in line selection, 50 to 100 third-year clones used in line selection, 30 to 50 clones used in a preliminary performance trial, and 10 to 15 clones used in a performance trial were planted in the screening field every year. Early in July five vines of every clone were transplanted at 15 x 30 cm intervals in replicated plots. Early in September the roots of all plants were examined by visual inspection for the presence of root-knot galls, and each plant was classified according to the degree of infection. The infection grade was similar to that used by Smith: Class 0, all roots without visible galls; Class 1, 1 to 25%; Class 2, 26 to 50%; Class 3, 51 to 75%; and Class 4, 76 to 100% of roots with galls.

Classification of Sweet Potato Cultivars Used as Genetic Resources According to the Degree of Resistance to Root-knot Nematodes

Many clones of local cultivars, early-bred cultivars and introduced cultivars from foreign countries were collected and used as genetic resources for breeding programs. The cultivars were examined in the screening fields at Unakami, Chiba, Yotsukaido, Kumamoto and Kagoshima. The results of screening tests were reported by Shibuya (1952), Kikukawa and Sakai (1969), Kondo et al. (1972) and Marumine and Sakamoto (1979). From the papers and our unpublished data, local, early bred and foreign cultivars were classified according to the degree of resistance to root-knot nematode as shown in Table 1.

The highly resistant cultivars are Taihaku, Yoshida, Sanyo, Konpira, Rokkaku and Hayato-imo, and resistant cultivars are Chiba-aka, Ibaraki 1, Okinawa 104 and Kokei 3. The highly resistant cultivars Taihaku and Yoshida play an important part in the sweet potato breeding program for root-knot nematode as mentioned later. Highly resistant cultivars are scarce among foreign cultivars. The ratio of highly resistant and resistant cultivars to all local and early bred cultivars is 35.7 percent.

The Degree of Resistance to Root-knot Nematode of Registered Sweet Potato Cultivars in Japan

From the sweet potato breeding system, 35 cultivars were bred and were registered by Ministry of Agriculture and Foresty during 44 years from

1937 to 1981 as shown in Table 2. The degree of resistance of 32 of these cultivars was examined by Shibuya (1952), Kondo et al. (1972), Marumine and Sakamoto (1979), Kikukawa and Sakai (1969), and us, except three cultivars, Gokoku-masari, Beni-yutaka, and Setoyoshi. Six cultivars, Norin 2, Norin 3, Norin 5, Norin 9, Norin 10 and Beni-wase, were highly resistant, and six others, Norin 7, Oki-masari, Beni-sengan, Satsuma-aka, Minami-yutaka and Tsuru-sengan were resistant. Most of the highly resistant cultivars were bred in the 1940's; Beni-wase is the only highly resistant cultivar developed in the last 30 years.

A genealogical figure of the cultivars is shown in Fig. 1. All highly resistant and resistant cultivars are derived from the crosses between Yoshida and Okinawa 100 or Yoshida and Okinawa 104. All susceptible cultivars originated from the susceptible cultivars Choshu, Genki and Shichifuku. Foreign cultivars, Nancy Hall and L-4-5 (Perican processor), also play a role of susceptible source. The ratio of highly resistant and resistant cultivars to all registered cultivars is 37.5 percent. The ratio is almost the same as that of the local and early-bred cultivars.

The Degree of Resistance to Root-knot Nematode of Sweet Potato Strains Bred by our Breeding Center

Our Breeding Center was founded at Chiba Agricultural Experiment Station, Chiba, in 1937, and was moved from Chiba to Yotsukaido in 1963. During 44 years we bred 90 sweet potato strains at our Center and distributed them to Agricultural Experiment Stations of related prefectures for performance trials and adaptability tests. Fifteen strains were registered by Ministry of Agriculture and Forestry for high productivity, excellent practical characters, and high adaptability.

The degree of resistance of these strains to root-knot nematode was examined by Kondo et al. (1972) and us. The degree of resistance is shown in Table 3. Twelve strains were found to be highly resistant and twelve strains were resistant; thirty strains were moderately susceptible; ten strains were susceptible; and 21 strains were very susceptible. One-half of highly resistant and resistant strains were bred in the first decade of the breeding program, and the rest were bred in the last 30 years.

A genealogical figure of the highly resistant strains is shown in Fig. 2. All highly resistant strains, except Kanto 18, are originated from the highly resistant local cultivars Yoshida and Taihaku. Norin 2 bred by

Kagoshima Agricultural Experiment Station also plays a role of resistant source. Ratio of highly resistant and resistant strains to all bred strains is 27.2 percent. The ratio is less than that of the local cultivars and registered cultivars.

Discussion

Forty years have passed since the sweet potato breeding program for root-knot nematode resistance was started in Japan. Thirty-five cultivars were bred by three Breeding Centers and were registered, and 90 strains were bred by our Breeding Center. Most of these cultivars and strains were examined in the screening tests for resistance to root-knot nematode. The number of the cultivars and strains classified according to the degree of resistance to root-knot nematode in the decennial period of the sweet potato breeding program is in Table 4.

In the first decade of the sweet potato breeding program, many highly resistant cultivars and strains were bred. There were few resistant local cultivars as genetic sources, and most local cultivars, such as Shichifuku, Genki and Genji, etc., were all susceptible to root-knot nematode in the early period of the breeding program. The symptoms caused by root-knot nematode in these susceptible cultivars in infested sandy soil fields impressed the sweet potato breeders, so they concentrated their efforts to develop root-knot resistant sweet potatoes.

The breeders (Kikukawa and Sakai, 1969) noticed that there was a large variation in gall indices among individual F_1 hybrid seedlings in sowing beds and recognized parent-offspring correlation between gall indices of mid-parents and mean gall indices of F_1 hybrid seedlings in many combinations. They assumed that the root-knot nematode resistance was controlled by the effects of additive genes. They also recognized that there was negative genotypic correlation between tuber yield and gall index, and no correlation between dry matter content and gall index. We observed that there was negative correlation between appearance frequency of uninfected F_1 hybrid seedlings and gall index of mid-parents. When we use highly resistant cultivars as parents, we can get highly resistant F_1 seedlings. A positive correlation exists between the gall index of the F_1 hybrid seedlings in the sowing bed and that of the clones in field. These correlations indicate that the selection of uninfected F_1 hybrid seedlings in the sowing bed can be used in breeding for root-knot nematode resistance.

During the last 30 years of the sweet potato breeding program, we bred only one highly resistant cultivar and six strains. The reasons were: 1) sweet-potato-cultivating area was decreased; 2) there was no sweet potato cultivation in heavily infested fields; 3) highly resistant cultivars had already been bred and were extended in cultivation; and 4) effective nematicides were developed. Even though highly resistant strains were selected successfully in the breeding program, they have not always had high tuber yield and high starch content, and failed to possess combined resistance to root-lesion nematode, black rot and stem rot. With the progress of the breeding program, inbreeding coefficients of cultivars and strains were increased and heterosis of F_1 hybrids between these cultivars and strains were decreased by consanguineous mating. In order to get heterosis effects, foreign cultivars (L-4-5, Nancy Hall and Siam, etc.) were used as parents of combination; however, these cultivars were not root-knot nematode resistant. Koganesengan, bred by Kumamoto Breeding Center, possessed a high tuber yield of 30 to 40 tons per hectare, and a high starch content of 24 to 26 percent, but this cultivar was not root-knot nematode resistant.

We have to make our effort to the improvement of sweet potato for highly combined resistance to root-knot nematode, root-lesion nematode, black rot and stem rot, high tuber yield and high starch content. It is very difficult to improve all these characters at the same time because sweet potato is an out-crossing plant. Root-knot nematode resistance is increased easily by accumulation of the resistant genes. However, tuber yield is not increased by inbreeding depression. We must develop a new breeding method by which heterozygosity is maintained and resistant genes are accumulated. We think that the breeding method is a maternal clone selection used jointly with random matings and exact performance trials.

References

Elliot, G. H. 1918. Nematode injury to sweet potatoes. Phytopathology 8:169.

Kikukawa, S., and K. Sakai. 1969. Studies on the breeding method for resistance to the root-knot nematode (*Meloidogyne incognita*) and the root-lesion nematode (*Pratylenchus coffeae*) in sweet potato. Bull. Kyushu Agr. Exp. Sta. 14:365-397 (in Japanese with English summary).

Kondo, T., I. Hayashi, S. Anazawa, T. Yamazaki, W. Yamamoto, and T. Saigusa. 1972. Varietal difference of sweet potato in susceptibility to the root-knot nematode, Meloidogyne incognita (Kofoid & White 1919) Chitwood 1949. Jap. J. Nematol. 1:14-17 (in Japanese with English summary).

Marumine, S., and S. Sakamoto. 1979. Selection for resistant cultivars to root-lesion nematode. Kyushu Agr. Res. 41:48 (in Japanese).

Mizokami, T. 1948. Anatomical researches on the resistance of sweet potato to root-knot nematode injury. Proc. Meeting Res. Workers in Kyushu 1:19-20 (in Japanese).

Poole, R. F., and R. Schmidt. 1927. The nematode disease of sweet potatoes. Phytopathology 17:549-554.

Sakai, K. 1964. Studies on the enlargement of variations and the improvement of selection methods in sweet potato breeding. Bull. Kyushu Agr. Exp. Sta. 9:247-397 (in Japanese with English summary).

Shibuya, M. 1952. Studies on the varietal resistance of sweet potato to the root-knot nematode injury. Mem. Fac. Agr., Kagoshima Univ. 1:1-22.

Smith, A. L., and A. L. Taylor. 1947. Field methods of testing for root-knot infestation. Phytopathology 37:85-93.

Weimer, J. L., and L. L. Harter. 1925. Varietal resistance of sweet potatoes to nematodes, Heterodera radicicola (Greaf.) Muller, in California. Phytopathology 15:423-426.

Table 1. Classification of local, early bred and foreign sweet potato cultivars used as genetic resources in breeding programs according to the degree of resistance to root-knot nematode.

	Local and early bred cultivars	Foreign cultivars
Highly resistant	Taihaku + ●, Yoshida + Sanyo +, Kompira +, Rokkaku o, Hayato-imo o ●	
Resistant	Chiba-aka +, Ibaraki 1 + ●, Okinawa 104 +, Kokei 3 +	Port Rico +, Wenholy 1 +
Moderately susceptible	Okinawa 100 + o ●, Gifu 1 + o Beniaka o, Motokajya o	Southern Queen o
Susceptible	Shichifuku + o ●, Gokoku-imo + ●, Genki o	Nancy Hall o, Sant Amaro o
Very susceptible	Tachi-kagoshima +, Oiran-saki 1 +, Oiran ●, Kagoshima +, Tokyo-kintoki o, Kokei 14 o, Kenroku o, Tsurunashi-genji o ●, Gokoku-imo o, Genji ●, Kintoki (Itsukaichi) o, Choshu o	Tennian o, Philippines o, L-4-5 o

+: Kondo *et al*. (1972), ●: Shibuya (1952), o: our unpublished data.

Table 2. The degree of resistance to root-knot nematode of registered sweet potato cultivars

No. Regis.	Name	Abridg. form	Breed. Center	Regis. year	Use	Degree of resistance to RKN
1	Norin 1	N-1	*	1942	F,I	VS + o ●
2	Norin 2	N-2	***	1942	F,I	HR + o ● -
3	Norin 3	N-3	***	1944	F,I	HR + o ● -
4	Norin 4	N-4	*	1944	I,F	MS + o ●
5	Norin 5	N-5	*	1945	F	HR + o ●, S -
6	Norin 6	N-6	*	1945	Fr,I	VS + o ●, S -
7	Norin 7	N-7	***	1946	I,F	R + o ●
8	Norin 8	N-8	*	1947	I,Fr	S + o ●
9	Norin 9	N-9	***	1948	Fr	HR + o ● -
10	Norin 10	N-10	*	1950	F	HR + o -
11	Kuro-shirazu	Kurosi	*	1952	I,F	VS + o
12	Chihaya	Chihay	*	1952	I	VS + o
13	Shiro-sengan	Shiros	*	1952	Fr	MS +, M-S o
14	Okimasari	Okimas	*	1952	I,F	R +, M-R o
15	Aji-yoshi	Ajiyos	***	1952	F	MS + o -
16	Fuku-wase	Kukuwa	***	1952	F	MS + o -
17	Kaka-murasaki	Nakamu	***	1952	F	MS + o -
18	Yake-shirazu	Yakesi	**	1953	F	S +, M-VS o, VS -
19	Beni-sengan	Benise	***	1955	Fr	R o
20	Seto-aka	Setoak	**	1955	F,I	VS + o -
21	Kuri-masari	Kurima	*	1960	F	S +, VS o
22	Tama-yutaka	Tamayu	*	1960	I,Fr	MSo -
23	Beni-wase	Beniwa	***	1961	F	HR o
24	Gokoku-masari	Gokokm	**	1961	I,Fr	
25	Satsuma-aka	Satsum	***	1962	I	R o, HR -
26	Ariake-imo	Ariake	***	1962	I	MS o -
27	Kona-sengan	Konase	*	1962	I	MS o -
28	Tsukumo-aka	Tsukum	**	1962	F	MS o
29	Beni-yutaka	Beniyu	**	1966	Fr	
30	Seto-yoshi	Setoyo	**	1966	I	
31	Kogane-sengan	Kogane	***	1966	I	S o -
32	Nae-shirazu	Naeshi	**	1974	I,Fr	S o
33	Beni-komachi	Beniko	*	1975	F	VS o
34	Minami-yutaka	Minami	***	1975	I	R o, HR -
35	Tsuru-sengan	Tsurus	*	1981	Fr	R o

Breeding Center: * Yotsukaido, Chiba; ** Fukuyama; *** Kagoshima, Kumamoto

Use: F, food; I, industrial material; Fr, forage

Reporter: + Kondo *et al.* (1972); ● Shibuya (1952); - Marumine & Sakamoto (1979); o our unpublished data.

Degree of resistance: HR, highly resistant; R, resistant; MS, moderately susceptible; S, susceptible; VS, very susceptible

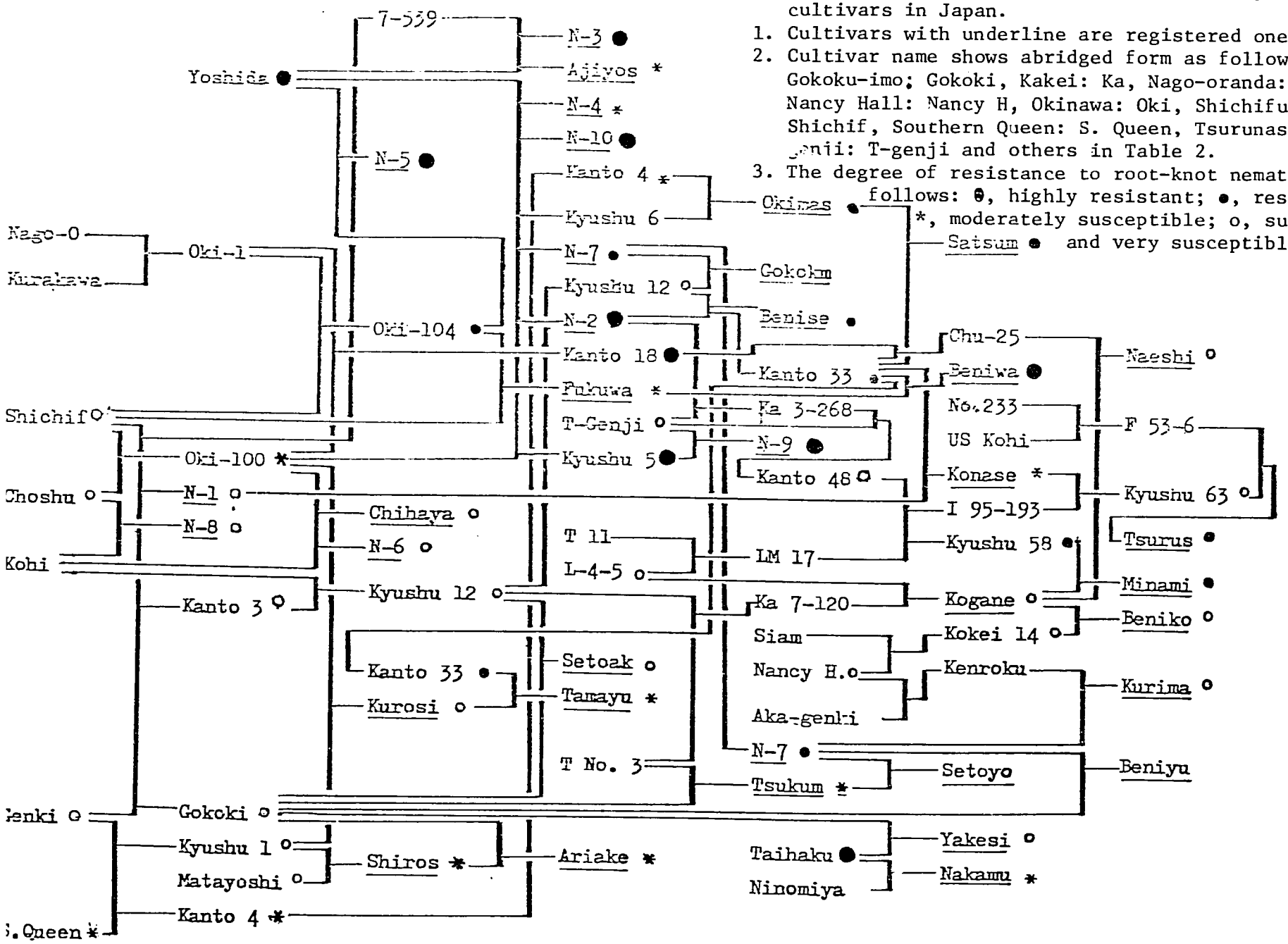

Fig. 1. Genealogical figure of registered sweet potato cultivars in Japan.

1. Cultivars with underline are registered one.
2. Cultivar name shows abridged form as follows: Gokoku-imo; Gokoki, Kakei: Ka, Nago-oranda: Nago-o, Nancy Hall: Nancy H, Okinawa: Oki, Shichifuku: Shichif, Southern Queen: S. Queen, Tsurunashi-genii: T-genji and others in Table 2.
3. The degree of resistance to root-knot nematode as follows: ●, highly resistant; ●, resistant; *, moderately susceptible; o, susceptible and very susceptible.

Table 3. The degree of resistance of sweet potato strains to root-knot nematode

Name	Year	Degree of resist.	Use	Name	Year	Degree of resist.	Use	Name	Year	Degree of resist.	Use
Kanto 1	1940	VSo	I	Kanto 31	1949	HR+	I	Kanto 61	1960	VSo	I
Kanto 2*	1940	VS+o	F.I	Kanto 32	1950	HR+	F.I	Kanto 62	1960	So	I
Kanto 3	1941	S+Mo	I	Kanto 33	1950	R+	F	Kanto 63	1961	HRo	I
=Kanto 4	1941	MSo	F.I	Kanto 34	1951	HR+	I	Kanto 64	1961	MSo	I
Kanto 5	1941	MSo	I	Kanto 35	1951	S+	I.F	Kanto 65	1961	So	I
Kanto 6*	1942	HR+o	F	Kanto 36	1952	MS+	I.F	Kanto 66	1962	MSo	I.F
Kanto 7*	1942	MS+o	I.F	Kanto 37	1952	R+	F	Kanto 67	1962	HRo	I
=Kanto 8	1942		I.F	Kanto 38	1952	MS+	I.F	Kanto 68	1962	MSo	I
=Kanto 9	1942		I	Kanto 39*	1954	S+VSo	F	Kanto 69	1963	VSo	I
=Kanto 10	1942	Ro	I	Kanto 40	1954	HR+	I.Fr	Kanto 70	1963	VSo	I
Kanto 11	1943	S+	F.I	Kanto 41	1955	MSo	I	Kanto 71	1965	VSo	I.F
=Kanto 12	1943	HR+o	F	Kanto 42	1955	MSo	I	Kanto 72	1965	MSo	I
Kanto 13*	1943	S+o	I.Fr	Kanto 43	1955	MSo	I	Kanto 73	1966	VSo	I
Kanto 14	1944	VS+	F.I	Kanto 44	1956	VSo	I	Kanto 74	1966	MSo	I
Kanto 15*	1944	HR+o	F	Kanto 45	1956	Ro	I	Kanto 75	1966	MSo	I
=Kanto 16	1944	MS+	I	Kanto 46	1956	VSo	I	Kanto 76	1967	MSo	I
Kanto 17*	1944	VS+o	Fr.I	Kanto 47	1956	MSoo	I	Kanto 77	1967	So	I
Kanto 18	1945	HR+o	I	Kanto 48	1957	VSo	I	Kanto 78	1968	So	I
Kanto 19*	1945	VS+o	I.F	=Kanto 49	1957	MSo	I	Kanto 79	1969	MSo	I
Kanto 20	1946	S+	I.F	Kanto 50	1957	MSo	I	Kanto 80	1970	VSo	F
Kanto 21*	1946	VS+o	I	Kanto 51	1958	VSo	I	Kanto 81	1970	So	I
Kanto 22*	1946	M+M-So	Fr	Kanto 52	1958	MSo	I	Kanto 82*	1972	VSo	F
Kanto 23	1947	R+	F	Kanto 53	1958	MSo	I	Kanto 83	1972	VSo	F
=Kanto 24	1947	R+M-Ro	I.F	Kanto 54*	1958	MSo	I	Kanto 84	1972	HRo	I
Kanto 25	1947	MS+	I	Kanto 55*	1959	MSo	I	Kanto 85	1977	MSo	F
=Kanto 26	1948	VS+	F	Kanto 56	1959	Ro	I	Kanto 86	1977	MSo	F
=Kanto 27	1948	VS+	F	Kanto 57	1959	MSo	I	Kanto 87*	1977	Ro	Fr
=Kanto 28	1948	R+	F	Kanto 58	1959	MSo	I	Kanto 88	1980	HRo	F
Kanto 29	1949	MS+	F	=Kanto 59	1959	Ro	I	Kanto 89	1980	MSo	I
Kanto 30	1949	R+	I	Kanto 60	1960	Ro	I	Kanto 90	1980	MSo	I

Name: Strains with equal mark (=) are not preserved and others are preserved at our Breeding Center. Strains with asterisk (*) were registered by MAF in following name: Kanto 2, Norin 1; Kanto 6, Norin 10; Kanto 7, Norin 4; Kanto 13, Norin 8; Kanto 15, Norin 5; Kanto 17, Norin 6; Kanto 19, Kuroshirazu; Kanto 21, Chihaya; Kanto 22, Shiro-sengan; Kanto 24, Okimasari; Kanto 39, Kurimasari;

Table 3 (continued)

Kanto 54, Tamayutaka; Kanto 55, Konasengan; Kanto 82, Beni-komachi; Kanto 87, Tsuru-sengan.

Degree of resistance: HR, highly resistant; R, resistant; MS, moderately susceptible; S, susceptible; VS, very susceptible.

Use: I, industrial material; F, food; Fr, forage.

Reporter: +, Kondo et al. (1972); o, our unpublished data.

Table 4. Number of bred cultivars and strains classified according to the degree of resistance to root-knot nematode in decennial period of sweet potato breeding program in Japan.

Period	HR	R	MS	S	VS	Total	%*
Registered Cultivars							
1937-1950	5	1	1	1	2	10	60.0
1951-1960	0	2	5	0	5	12	16.7
1961-1970	1	1	3	1	0	6	33.3
1971-1980	0	2	0	1	1	4	50.0
Total	6	6	9	3	8	32	37.5
Bred strains in our Breeding Center							
1937-1950	6	6	7	4	8	29	41.4
1951-1960	2	5	14	2	6	29	24.1
1961-1970	2	0	8	4	5	19	10.5
1971-1980	2	1	4	0	2	11	27.3
Total	12	12	33	10	21	88	27.3

Note: HR, highly resistant; R, resistant; MS, moderately susceptible; S, susceptible; VS, very susceptible. *: Ratio of highly resistant and resistant strains to the total strains.

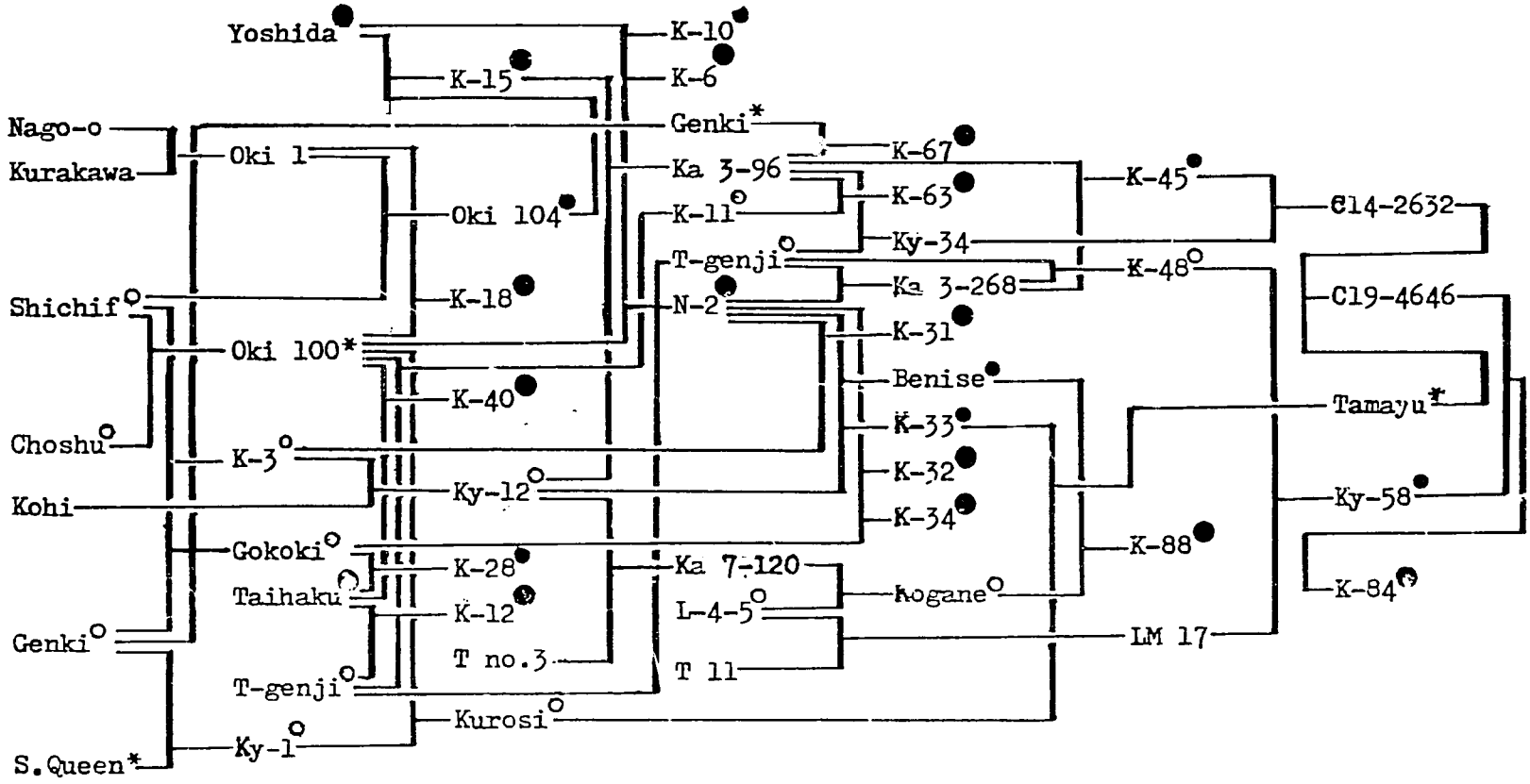

Fig. 2. Genealogical figure of sweet potato strains bred at our Breeding Center.

1. Strains with K were bred at our Breeding Center. K is abridged form of Kanto.
2. Strain and cultivar names are abridged as follows : Norin: N; Kyushu: Ky; Chikei: C; and others same in Fig. 1.
3. The degree of resistance to root-knot nematode as follows :
   ◉ : highly resistat; ●: resistant; * :moderately susceptible; o: susceptible and very susceptible.

CROPPING SYSTEMS FOR THE CONTROL OF ROOT-KNOT NEMATODES

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Root-knot nematode is a major problem in crop production, particularly under tropical weather conditions. Its severity increases as more susceptible crops are planted on the same land (Johnson and Campbell, 1977). Undoubtedly, successive monocultures of such crops would favor the buildup of the nematode population in the soil (Mai and Lownsberry, 1952; Good et al., 1954; Oostenbrink et al., 1956). Chemical control of nematodes by the use of nematicides has long been developed and practiced. However, the rising cost of its application in recent years has prompted nematologists to search for alternatives. Consequently, research emphasis has swayed to the development of resistant crops and varieties and improved cultural practices through the use of various types of cropping systems such as crop rotation, multiple cropping, intercropping and trap cropping to control root-knot nematodes and other species. It has been shown earlier that inclusion of resistant crops or varieties in a cropping system would suppress the soil nematode population to a less damaging level (Good et al., 1954; Murphy et al., 1974).

This paper presents a review of studies on the influence of cropping systems on the control of root-knot nematodes. Admittedly, the literature along this subject is still limited but there is already sufficient evidence to show that cropping system is a potential measure for root-knot nematode control.

In the United States, Brodie and associates (1969, 1970, 1974, 1975) conducted a series of studies on the population dynamics of plant-parasitic nematodes in cultivated soils as influenced by different cropping systems. In one of their papers, they showed that in a land previously cropped to native pasture, one year of fallow or crotalaria, 3 years of marigold, or 4 years of bahiagrass or bermuda grass reduced the M. incognita population below detectable levels (Fig. 1-A). Similarly, in land previously cropped to okra, M. incognita population was reduced to below detectable levels after 2 years of fallow, crotalaria or marigold (Fig. 1-B). After 5 years,

bahiagrass and crotalaria reduced M. incognita to an undetectable level (Fig. 1-C). Consequently, the growth of tomato plants based on height was significantly greater following crotalaria, bermuda grass, or fallow than following okra. On the other hand, they noted that during 5 years of cropping systems, the population densities of other important parasitic nematodes increased on certain crops. Trichodorus christiei increased on all cropping systems except in fallow and on crotalaria. Population density of Pratylenchus brachyurus increased significantly on crotalaria. However, these nematodes did not show any effect on growth and yield of tomato plants. (Murphy et al., 1974).

Attempts to control root-knot nematodes on tomato in Georgia, U.S.A., through cropping systems and by a nematicide treatment were conducted by Johnson and Campbell (1977). A remarkable control of root-knot nematodes on tomato transplants was initially observed in cropping sequences of milo-tomato-crotalaria-tomato, millet-tomato-millet-tomato, soybean-tomato-millet-tomato, pea-tomato-crotalaria-tomato (P-T-C-T), pea-tomato-pea-tomato (P-T-P-T), and fallow-tomato-fallow-tomato, but later the number of nematodes continued to increase. The application of nematicide fensulfothion prior to seeding tomatoes adequately protected seedlings against root-knot nematode infection in pea-tomato-millet-tomato, P-T-C-T, and P-T-P-T cropping sequences to meet Georgia's certification standards which specify that transplants must be free of root-knot nematodes. They considered milo as less effective; soybean, crotalaria and millet as intermediate; and pigeon pea and fallow as most effective in suppressing root-knot nematodes.

On tobacco, Muro (1975) reported that such crops as peanut, corn, wheat and sorghum when planted prior to tobacco significantly reduced the incidence of M. incognita in the soil. We also had a similar observation in the Philippines where tobacco is planted after rice (Cortado and Davide, 1968).

On soybean, Kinlock (1980) found that a rotation of soybean susceptible and resistant cultivars with corn outyielded the monoculture soybean 25 to 46% at the 5th year and 65 to 100% at the 8th year of rotation. Likewise, a significant yield increase on barley was shown by Allen et al. (1970) when M. naasi was controlled by planting potato for two consecutive growing seasons before planting barley.

In Nigeria, Ogunfowora (1978) demonstrated that growing resistant crops such as corn, peanut, rice, and stylozanthes prior to growing tomato appreciably increased yield of tomato as a consequence of root-knot nematode control (Table 1).

In the Philippines, Castillo and associates at the International Rice Research Institute (IRRI) made some survey and experiments on the influence of various cropping systems on the population density of plant-parasitic nematodes. Results of their survey (1977) in the province of Batangas on various cropping systems showed that leguminous and solanaceous vegetable crops generally favored build-up of root-knot nematodes while rice, corn, asparagus, and radish suppressed the nematode population (Table 2). They observed that 2½ years cropping with rice and corn seems necessary before planting a susceptible crop. In an experiment conducted at the IRRI farm (1976) they demonstrated that M. incognita could be controlled effectively by three successive croppings of either corn, marigold (Tagetes erecta) prior to tomato, or tomato with marigold and crotalaria as intercrops. Likewise, preplant soil application of organic matter, such as chicken manure and rice straw compost, and fallow for three growing seasons significantly suppressed M. incognita (Fig. 2). Adequate control was provided by corn, marigold and crotalaria as intercrop or rotation with tomato (Figs. 3-6).

In a separate experiment using marigold (T. erecta) as an intercrop with tomato, Davide (1979) observed that although there was a considerable reduction in the gall index of M. incognita on the tomato plants, yield was still lower than that of the control. This may be attributed to marigold plants' competitive effects for soil nutrients, sunlight and other ecological factors as they also grew luxuriantly partially shading the tomato plants. We have evidence, however, from our previous experiment that marigold could provide excellent control of root-knot nematodes when planted 1-2 months ahead of tomato plants as a rotation crop (Ducusin and Davide, 1972). Our findings corraborate the report of Suatmadji (1969) that under Netherlands conditions marigold as a rotation crop or intercrop with vegetables could effectively control root-knot nematodes and other species. However, in the Philippines, marigold has practically no economic value, and it would be rather difficult to convince our farmers to include it in a cropping system.

An Analysis of Cropping Systems for Root-Knot Nematode Control

The potential of utilizing resistant crops and varieties along with susceptible but desirable crops in a cropping system for root-knot nematode control is evident in the literature. It is possible to manipulate cropping sequence, crop composition in crop rotation, multiple cropping and intercropping systems to suppress nematode population in the soil. However, determining and developing an appropriate cropping system for root-knot nematode control may be difficult because there are a number of limiting factors that have to be considered. Foremost among these factors are the variability of root-knot nematode species and race, availability of resistant crops and varieties, adaptability of the crops to local climate and weather conditions, susceptibility of the crops to other nematodes, insects, and diseases, and the economic value of the crops.

Variability of root-knot nematodes. More than 30 species of root-knot nematodes are known to attack different crops and varieties. Our IMP host differential studies revealed that there are now four races of *M. incognita*, two in *M. arenaria* and maybe more than one race of either *M. hapla* or *M. javanica*, and perhaps races of other species which are still undetermined. If the species and races of root-knot nematodes are not properly identified before selection of crops in a cropping sequence, the sequence may increase the nematode population instead of suppressing it. Johnson and Campbell (1980) observed that root-knot nematodes increased in the soybean-tomato-soybean-tomato sequence in spite of the fact that the "Bragg" soybean used was resistant to *M. incognita*. It was found later that the field had also *M. javanica*, *M. hapla* and *M. arenaria*, and "Bragg" soybean is susceptible particularly to *M. javanica*. This illustrates the disadvantage of using a monospecific resistant variety. They also observed that pigeon pea-tomato-pea-tomato sequence resulted in a heavy galling of peas by *M. javanica* even though this sequence deters the same nematode species in North Carolina. This result suggests the presence of two different races of *M. javanica*. In our host differential studies, we also found that NC-95 tobacco and Deltapine 16 cotton, which are regarded resistant to *M. incognita* in the United States, could readily become infected by some Philippine isolates of *M. incognita*. Results of these studies clearly indicate the need to define species and races of root-knot nematodes before designing a cropping system to control them.

Availability of resistant crops and varieties. In most cases, because of the wide variability of root-knot nematodes, it is difficult to line up crops or varieties that have a broad spectrum of resistance to a number of root-knot nematode species and races. Proper identification of crops and their varieties is therefore necessary before a cropping system is developed. Their reactions to root-knot nematode infection should be known. In the Philippines, rice and corn have demonstrated resistance to all known species and races of root-knot nematodes. Their use in a cropping system is adaptable and has been encouraged in this country.

Build-up of other important nematodes. This factor really makes more difficult the development of appropriate cropping systems designed for root-knot nematode control. A number of studies have already shown that the use of root-knot nematode resistant crops such as corn, cotton, peanut, and millet in a cropping system could result in the rapid build-up of *Pratylenchus brachyurus*, *Trichodorus christiei* and *Belonolaimus longicaudatus* and others (Good *et al.*, 1954; Brodie *et al.*, 1970). Thus far only marigold has been shown to have resistance to root-knot nematodes and many other parasitic genera (Suatmadji, 1969; Brodie *et al.*, 1970). An ideal cropping system, therefore, must include crops that could also suppress the population of other important parasitic nematodes.

Susceptibility of crops to other pests and diseases. Nematologists who want to develop cropping systems for nematode control should not overlook the fact that aside from nematodes there are a number of pests and diseases that are even more destructive than nematodes on most crops. A cropping sequence of resistant varieties of potato-tomato-tobacco may suppress root-knot nematodes but can expose all the crops to bacterial wilt, a common disease which could wipe out all the crops under severe disease outbreak. Crops or varieties with multiple resistance to pests and diseases may be more desirable than those with resistance only to a specific pest or disease.

Economic value of crops in the cropping system. This is another vital factor to consider inasmuch as no matter how effective the cropping sequence for nematode control may be, if the crops involved have no economic advantage to growers, the control measure will be worthless. In the Philippines, it may be difficult to adapt a cropping system with marigold and crotalaria as these crops have no economic value. Farmers would rather plant rice, corn and vegetable crops.

Adaptability of crops to local climate. It is impossible to adapt or transfer a cropping system technology developed from temperate countries to tropical countries if the crops involved are not climatically adapted to local conditions. A cropping system where wheat, oat, and barley are involved is not feasible under Philippine or tropical conditions as these crops, for climatic reasons, cannot be grown normally. Therefore, the use of indigenous crops that are customarily grown nationwide will be more desirable than imported ones in developing a cropping system for root-knot nematode control.

A Practical Approach to Development of Cropping Systems Against Root-knot Nematodes

In the development of a sound and practical cropping system for the control of root-knot nematodes, particularly in developing countries in the tropics, it may be worthwhile to consider the existing typical cropping system of farmers and make studies to modify or reorient these systems toward the control of nematodes. For instance, our tobacco farmers in Northern Luzon have a cropping system that can effectively keep the root-knot nematode population to a less destructive level, that is, by planting rice during the rainy season and either tobacco, cotton, garlic, watermelon, onion or vegetables during the dry season. Likewise, in the provinces of Batangas and Cavite, some farmers practice multiple cropping with upland rice, corn, vegetables and fruit crops such as pineapple, banana, and papaya; others plant such crops as coffee, cacao, banana, papaya and pineapple under coconut groves. These cropping systems may be a good starting point for a study on how they would affect root-knot nematodes and other species. The findings of the study would undoubtedly be useful in the development of a more practical and economical cropping system since the growers are already familiar with the crop production technology. This approach is worth trying with IMP support.

References

Allen, M. W., W. H. Hart, and R. Baghott. 1970. Crop rotation control of barley root-knot nematode at Tulelake. California Agric. 24(7):4-5.

Brodie, B. B., J. M. Good, and C. A. Jaworski. 1969. Population dynamics of plant nematodes in cultivated soils: Effect of summer cover crops in old agricultural land. J. Nematol. 2:147-151.

Brodie, B. B., J. M. Good, and W. H. Marchant. 1970. Population dynamics of plant nematodes in cultivated soil: Effect of sod-based rotations in Tifton sandy loam. J. Nematol. 2:135-138.

Brodie, B. B., and W. S. Murphy. 1975. Population dynamics of plant nematodes as affected by combinations of fallows and cropping sequence. J. Nematol. 7:91-92.

Castillo, M. B., M. S. Alejar, and R. R. Harwood. 1976. Nematode in cropping patterns. II. Control of Meloidogyne incognita through cropping patterns and cultural practices. Philippine Agr. 59:295-312.

Castillo, M. B., M. S. Alejar, and J. A. Litsinger. 1977. Nematodes in cropping patterns. III. Composition and populations of plant parasitic nematodes in selected cropping patterns in Batangas. Philippine Agr. 60:285-292.

Cortado, R. V., and R. G. Davide. 1968. Survey, identification and pathogenicity test of nematodes associated with tobacco in the Cagayan Valley and Ilocos Region. Philippine Agr. 51:779-801.

Davide, R. G. 1979. Effect of nematicides and Tagetes erecta on the control of Meloidogyne incognita and on yield of tomato. Philippine Phytopathol. 15:141-144.

Ducusin, A. R., and R. G. Davide. 1972. Meloidogyne incognita: Its effects on tomato yield and some methods of control. Philippine Agr. 55:261-281.

Good, J. M., Jr., W. K. Robertson, and L. G. Thompson, Jr. 1954. Effect of crop rotation on the populations of meadow nematode, Pratylenchus leiocephalus, in Norfolk loamy fine sand. Plant Dis. Rep. 38:178-180.

Johnson, A. W., and G. M. Campbell. 1977. Effects of cropping systems and nematicide on root-knot nematodes and quality and yield of tomato transplants. J. Amer. Hort. Sci. 102:819-821.

Johnson, A. W., and G. M. Campbell. 1980. Managing nematode population densities on tomato transplants using crop rotation and a nematicide. J. Nematol. 12:6-19.

Kinlock, R. A. 1980. Yield increases of soybean, grown in rotational sequences with maize in soil infested with Meloidogyne incognita. Abstr. 15th Internacional Nematology Symposium, Bari, Italy. 48 pp.

Mai, W. F., and B. F. Lownsberry. 1952. Crop rotation in relation to the golden nematode population of the soil. Phytopathology 42:345-347.

Murphy, W. S., B. B. Brodie, and J. M. Good. 1974. Population dynamics of plant nematodes in cultivated soils: Effects of cropping systems and nematicides. J. Nematol. 6:103-107.

Muro, A. D. 1975. Root-knot nematode (Meloidogyne incognita) control by two- and three-year crop rotations. An. Inst. Sper. Tobacco 2:89-91.

Ogunfowora, A. O. 1978. Further studies on control of root-knot nematodes, Meloidogyne spp. Proceedings, Second Research Planning Conference on Root-knot Nematodes, Meloidogyne spp. in Abidjan, Ivory Coast. pp. 31-46.

Ostenbrink, M., J. J. Jacob, and K. Kuiper. 1956. An interpretation of some crop rotation experiences based on nematode surveys and population studies. Nematologica 1:202-214.

Suatmadji, R. W. 1969. Studies on the effect of Tagetes species on plant parasitic nematodes. H. Veeman and N. V. Zonen, Wageningen. 132 pp.

Table 1. Cropping sequence and resulting tomato yields (After Ogunfowora, 1978.)

Test No.	1975 Late Season	1976 Early Season	1976 Late Season	1977 Early Season Yield (Ife No. 1 tomato cultivar) tons/ha.			
				ILORA	% Increase	IKENNE	% Increase
1	Maize	G'nut/rice[a]	Maize	10.98	59.6	6.20	19.7
2	Tomato	G'nut/rice	Maize	5.69	0	7.13	39.6
3	Tomato	Maize	Maize	8.13	18.2	6.94	34.0
4	Maize	G'nut/rice	Bush fallow	6.09	0	4.47	0
5	Maize	G'nut/rice	Tomato	9.20	33.7	6.18	19.0
6	Maize	Tomato	Stylo	7.53	9.4	5.09	0
7	Stylo	Stylo	Stylo	9.97	44.9	4.01	0
8	Bush fallow	Bush fallow	Bush fallow	8.71	26.6	5.20	0.4
9	Cowpea	Bush fallow	Bush fallow	7.78	13.1	4.88	0
10	Tomato	Tomato	Tomato	6.88	-	5.18	-

[a]Groundnut at Ilora, rice at Ikenne.

Table 2. Distribution and population density of root-knot nematodes and other plant parasitic nematode genera in various cropping systems employed by farmers in the province of Batangas, Philippines. (Part of Table 1, M. B. Castillo, *et al.*, 1977).

Cropping Pattern (3-yr period)	Number of nematodes of each genus collected[a]			
	Meloidogyne	Rotylenchulus	Helicotylenchus	Tylenchorhynchus
Successive monoculture				
Tomato	194	485	1	1
Asparagus	0	33	2	0
Successive rotation of cereals and vegetables				
Rice-tomato	142	17	1	1
Rice-eggplant	312	19	1	2
Rice-corn-tomato	276	106	20	1
Corn-tomato-radish	1	45	3	3
Rice-garlic-corn-tomato	24	546	54	4
Mixed rotation				
Rice-(corn, pechay, mustard, tomato)-rice-corn-rice-soybean)	0	4	1	1
Corn-corn-eggplant-rice-corn rice-tomato-bush sitao	8	222	183	370
Rice-garlic-eggplant-corn-eggplant-hyacinth bean	1,218	767	27	1

[a] Averages of counts from ten 250 cc soil and 1-g root samples.

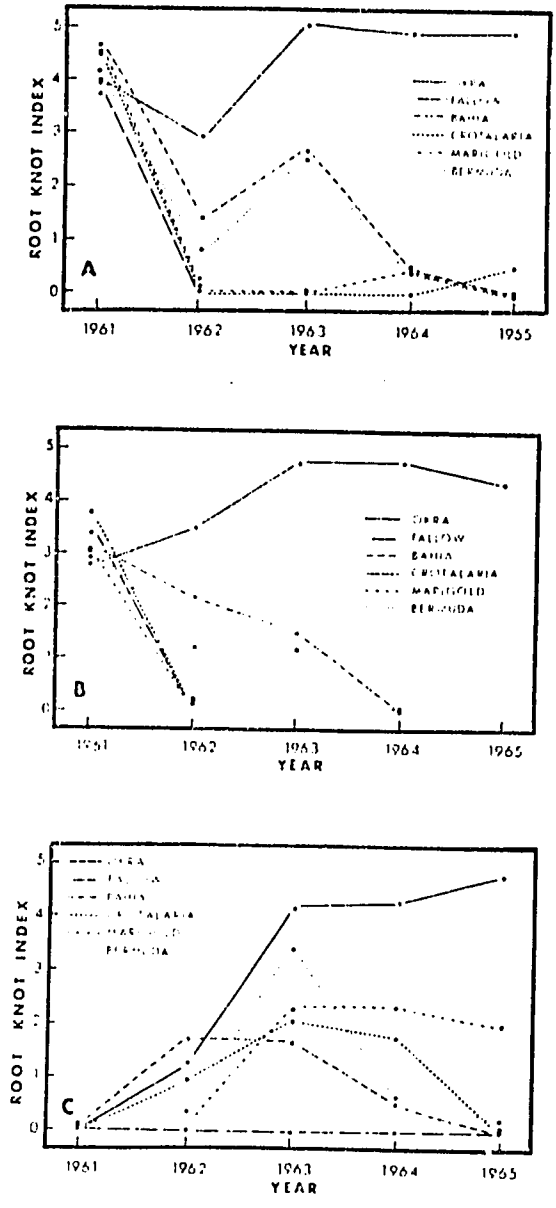


FIG. 1. Effects of selected crops and fallow on the population density of *Meloidogyne incognita*. A, Land previously in native pasture. B, Land previously cropped to okra. C, Land previously cropped to crotolaria. (Population line discontinued after the population reached zero for A, B and not used until above zero for C). (After Murphy, et al. 1974).

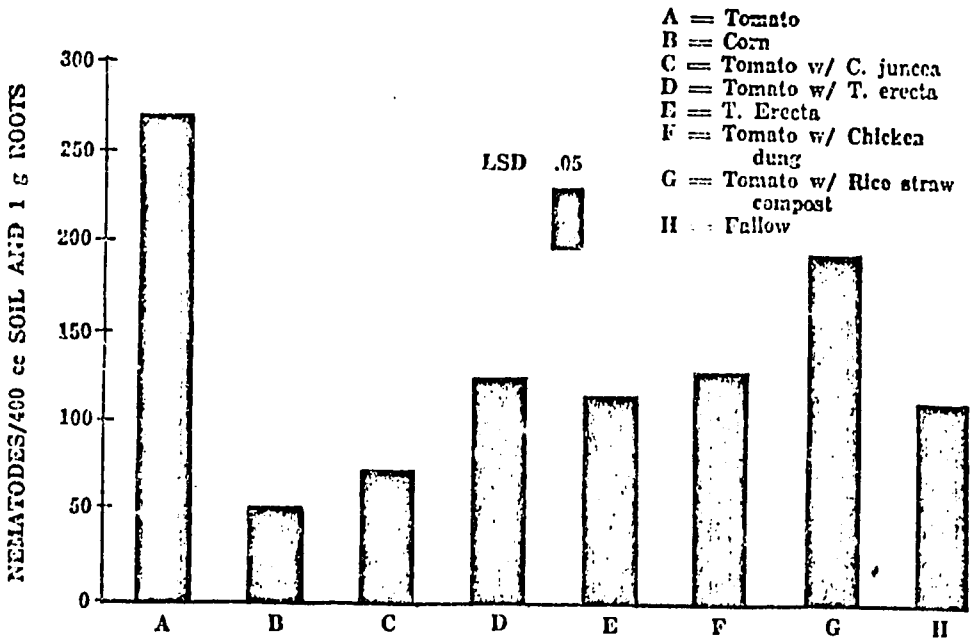


Fig. 2. Average numbers of *Meloidogyne incognita* in soil and roots of tomato after successive monoculture and successive use of certain cultural practices for three growing seasons. (After Castillo, et al. 1976).

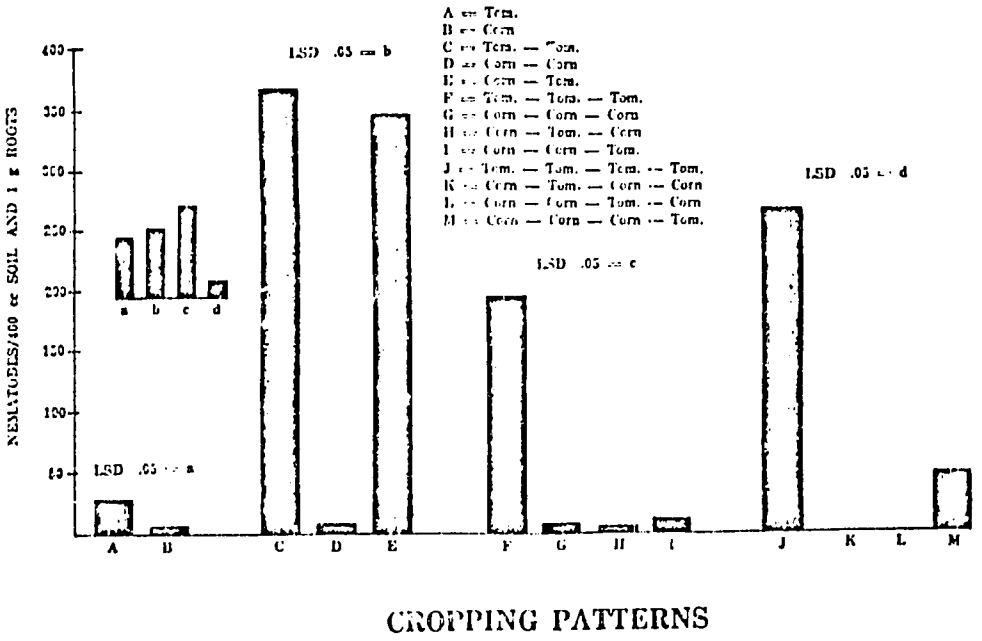
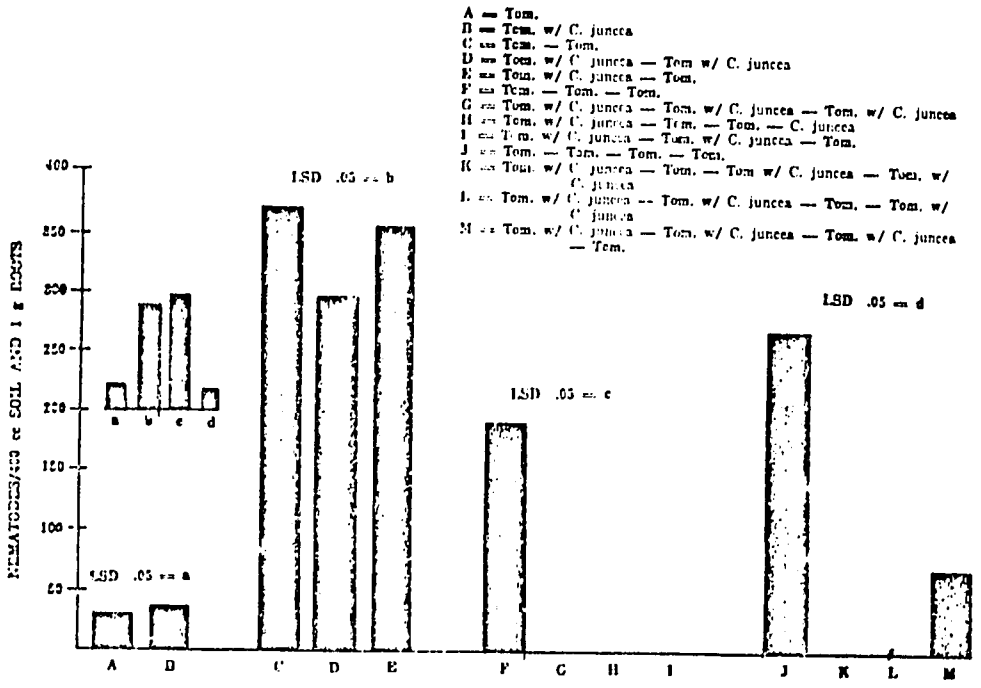
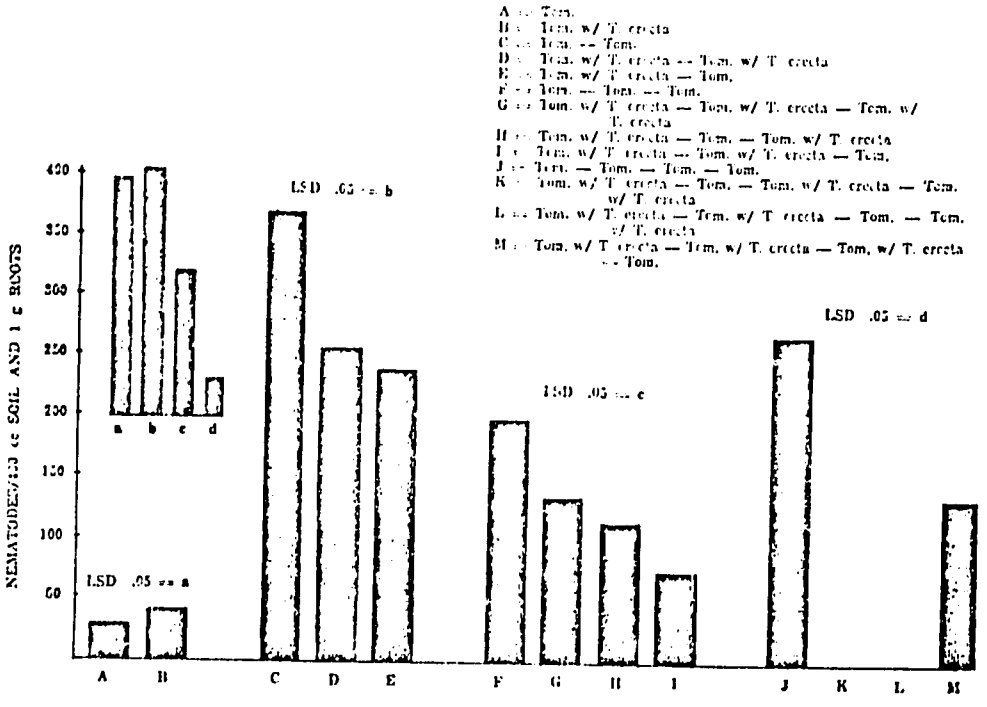


Fig. 3. Average numbers of *Meloidogyne incognita* in soil and roots after monoculture and rotation of tomato and corn for four growing seasons (first growing season: A and B; second growing season: C, D and E; third growing season: F, G, H and I; fourth growing season: J, K, L and M). (After Castillo, et al. 1976).



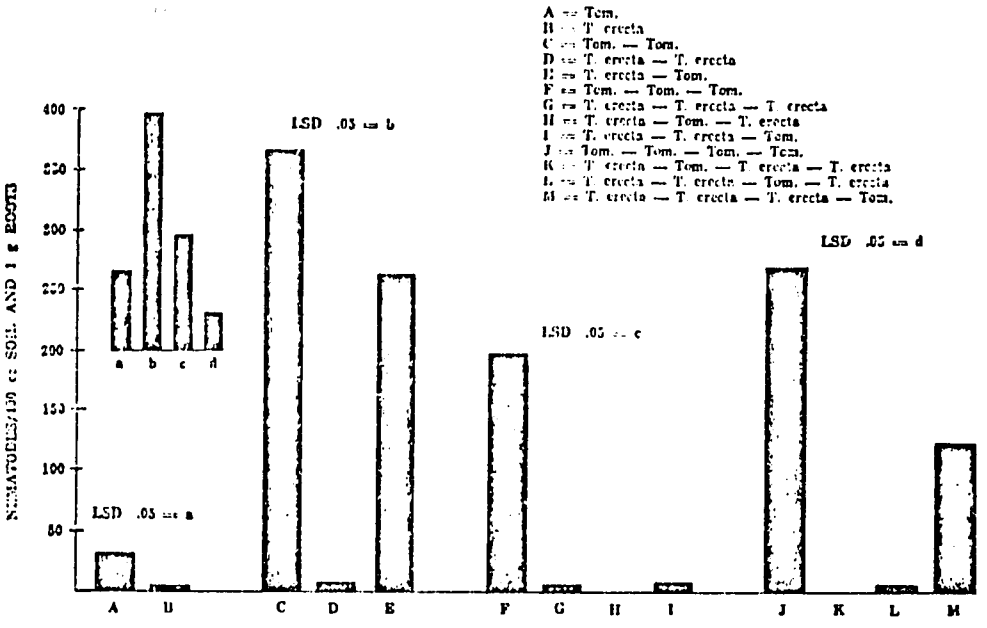
CROPPING PATTERNS

Fig. 4. Average numbers of *Meloidogyne incognita* in soil and roots of tomato with and without sequential intercropping of *Crotalaria juncea* for four growing seasons (first growing season: A and B; second growing season: C, D and E; third growing season: F, G, H and I; fourth growing season: J, K, L and M). (After Castillo, et al. 1976).



CROPPING PATTERNS

Fig. 5. Average numbers of *Meloidogyne incognita* in soil and roots of tomato with and without sequential intercropping of *Tagetes erecta* for four growing seasons (first growing season: A and B; second growing season: C, D and E; third growing season: F, G, H and I; fourth growing season: J, K, L and M). (After Castillo, et al. 1976).



CROPPING PATTERNS

Fig. 6. Average numbers of *Meloidogyne incognita* in soil and roots after monoculture and rotation of tomato and *Tagetes erecta* for four growing seasons (first growing season: A and B; second growing season: C, D and E; third growing season: F, G, H and I; fourth growing season: J, K, L and M). (After Castillo, et al. 1976).

BIOLOGICAL CONTROL OF *MELOIDOGYNE* SPECIES: METHODOLOGY FOR PREPARATION AND ESTABLISHMENT OF *PAECILOMYCES LILACINUS* FOR FIELD INOCULATION

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Laboratory, greenhouse and field experiments conducted in Peru confirmed that the fungus *Paecilomyces lilacinus* Thom. Samson effectively controls the root-knot nematode *Meloidogyne* species. The fungus penetrates the nematode eggs and destroys the embryo. It also attacks and grows inside developing females resulting in their death. So far, the fungus has been most effective for controlling *M. incognita*. However, trials are underway to determine if it also would aid in controlling other nematodes. *P. lilacinus* is not pathogenic to plants and can be readily cultured under laboratory conditions.

Isolation Establishment of the Fungal Culture

To isolate the fungus from the sand culture and multiply for field inoculation, the following procedures are used:

1. Shake the vial containing the sand culture well and aseptically place a capful (1 gm) in a test tube containing 9 ml sterilized-distilled water.

2. Mix well and take 1 ml of this solution to add to another tube containing 9 ml sterilized-distilled water.

3. Repeat step #2.

4. Place 2 or 3 drops of the solution from the third dilution tube on a plate containing potato dextrose agar medium. Spread the liquid with a sterilized loop on the medium and store the plates at room temperature.

5. Step #4 can be repeated using dilution tube number 2 or further dilutions can be made to obtain individual colonies.

6. Fungal colonies will appear in two days, and within 7-10 days the surface of medium will be covered by the fungal hyphae. Sporulation takes place within 48 hours.

P. lilacinus grows very flat with no aerial mycelium and the colonies are light violet or lilac in color. The fungus can be maintained on PDA by periodic transfer without losing its effectivity to control *Meloidogyne* species.

Preparation for Field Inoculation

Good results have been obtained by growing the fungus on sterilized wheat grains. However, similar results may be obtained using rice, oat, barley, etc. You may need to make modifications in the procedure if you use a medium other than wheat grains.

Procedure:

1. Soak wheat seeds in water for 12 hours. After this period, dry the seeds with paper towel or cloth, place them in an Erlenmyer flask and sterilize in an autoclave for 50 minutes.

2. Place several milliliters sterilized water in the plates containing 10- to 14-day-old fungal colonies. Gently mix well with a sterilized needle or loop to make a spore suspension. (Care should be taken not to break the agar medium.)

3. Collect the spore suspension from several plates in a sterilized bottle and inoculate the sterilized wheat grains with several milliliters of this suspension. Allow the fungus to grow on wheat grains in room temperature. Shake the flask every day to promote uniform growth of the fungus.

4. Fungus will grow on wheat grains and can be observed within a few days.

5. After 14 days from inoculation, there should be sufficient fungal growth for field application.

Field Inoculation and Experiment

1. Prepare a uniformly *Meloidogyne*-infested field for planting.

2. If possible, use potatoes as the experimental crop. If not, use a crop that *Meloidogyne* species infect and that produces readily visible egg masses. It is advisable to avoid a crop that exhibits big galls with not many visible egg masses.

3. Conduct a randomized block design experiment using at least 5 replications per treatment. Each treatment should consist of at least 5 rows.

4. Treatments should consist of non-treated, fungus-treated and, if possible, nematicide-treated plots with a 1-meter space between plots.

5. If sufficient field space is not available for the experiment described above, use the above 3 treatments with at least 10 rows of 20 meters per row in each treatment.

6. Apply approximately 1.5 kg of fungus-infected wheat grains per 40-square-meter plot at planting. Spread the inoculum evenly 10 to 15 cm deep in the soil and cover well before planting. If potatoes or other tuber crops are used, the inoculum may be applied together with the seeds.

7. If possible, in nematicide-treated plots, recommended rates of granular preparations, such as Temik, Furadan or Nemacur, should be used at planting.

8. Care should be taken so that the run-off water from the irrigation does not enter from one plot to another. Avoid re-using the tools used in the fungus-treated plots in other plots. First, use the tools in other plots, then in the fungus-treated plot.

9. Upon harvest, examine and rate the roots for nematode infection using a galling index of 1 to 5 (1 = no root galling and/or nematode reproduction to 5 = very severe root galling index and/or a very high nematode reproduction).

10. If a randomized block design experiment with 5 or more replications is used, evaluate each plant root of the 3 center rows per plot. In case of the 10 rows of 20-meter-per-row treatment, use the center 8 rows and randomly evaluate at least 20 plants per row.

11. If the crop is potatoes, evaluate tuber infection using the following index of 1 (no tuber infection per plant) to 5 (100% tuber infection per plant).

12. Random root samples should be taken to the laboratory for staining.

13. Stain a 10 gm composit root sample per row with acid fuchsin in lactophenol and clear in lactophenol for 24 hours prior to examination.

14. Extract 20 to 50 egg masses per sample. Crush 5 egg masses on a microscope slide using a coverglass. Examine under a compound scope for fungal infection. Data should be recorded on the number of fungus-infected egg masses and the percentage of infected eggs per egg mass.

15. Yield should also be recorded. If the experimental crop is potato or other root of tuber crops, yield of infected and non-infected tubers or

roots per plot should be recorded. To accurately calculate yield per hectar, it is advisable to record the yield of a definite number of plants per plot.

16. If possible, the subsequent crop should be examined as described above using the same treatment plots without further fungal or nematicide application.

Comments

There might exist a crop effect on population establishment and effectiveness of the fungus. As far as it is known, sweet potatoes should not be used as the first experimental crop.

REPORTS FROM WORK GROUPS

BREEDING FOR RESISTANCE REPORT

The following food crops were identified as possessing germ plasm resistant to one or more species of root-knot nematodes: tomato, banana, soybean, sunflower, rice, sweet potato, white potato, cowpea, green beans, and mung bean. The important food crops lacking resistance are okra, papaya, brinjal, winged bean and all cucurbits.

In order to hasten efforts in identifying resistant germ plasm and breeding for resistance, a collaborative effort was proposed based on the procedure established by SAPPRAD.

The following countries were designated to be responsible for collecting resistant germ plasm of the following crops:

Philippines - (Dr. Rasco) potato, cucurbits

Thailand - (Mr. Lavapaurya) tomato

Japan - (Dr. Shiga) sweet potato, soybean

Bangladesh - (Dr. Choudhury) brinjal

Nepal - (Mr. Sharma) okra

Burma - ( ) rice, papaya, sunflower, winged bean

Pakistan - (Dr. Saeed) banana, green beans

Indonesia - ( ) carrot

Taiwan - (Miss Tsai) mung bean, chinese cabbage

Each lead country will assemble the designated germ plasm reported to have resistance, increase the seed if necessary, and distribute same to cooperating Region VI countries. These crops will be evaluated for resistance using established standardized procedures as outlined by IMP. Reports of results will be sent to the lead country for assembly and reporting.

The Philippines, Thailand, Japan and Taiwan will not require any funding to carry out this proposal. The remaining countries will require financial assistance for handling the material for distribution.

CROPPING SYSTEMS RESEARCH SUBCOMMITTEE REPORT FOR REGION VI

Recognizing the varied cropping systems practiced by the participating countries, the chairman requested each delegate to name the four most important food crops being grown in his/her country. From here it was learned that crops common to countries were rice, maize, field legumes (peanut, soybean and mungbean), sweet and white potatoes and vegetables.

With these crops, five cropping patterns were evolved and are being recommended, but the crops and cropping sequences will be determined by each country participant to suit local conditions.

These cropping patterns are the following:

Cropping	No Nematicide		With Nematicide	With Biocontrol	With Nema + Biocontrol
	1	2	3	4	5
1	S	S	S + Nema	S + B.C.	S. + B.C.
2	R	R	R	R	R
3	S	R	S + Nema	S + B.C.	S + Nema
4	R	S	R	R	R

Note: S = Susceptible or host crop

R = Resistant or nonhost crop

B.C. = Biological control using *Paecilomyces lilacinus*

Nema = Nematicide (any one available)

The general procedures of conducting the study follow:

1. A bioassay for root-knot nematode may be made after each crop.
2. A separate plot of susceptible crop may be planted to serve as check.
3. The data to be gathered are:
   a. Initial nematode population
   b. Final nematode population
   c. Galling index
   d. Eggmass index
   e. Yield (for potato the weight of infected and healthy tubers should be taken separately).

The adoption of the cropping patterns evolved may not be readily accepted by the growers or farmers, hence the need to first conduct the experiment in Experiment Stations or on farms of willing farmer-cooperators which can serve as demonstration plots.

Plot size is dependent on the availability of space, however, a minimum space of 5 rows of 5-10 meters/row should be considered per plot. If possible, each plot should be replicated at least 5 times. If the space indicated above is not available, a 20-row plot of at least 10-20 meters per row should be used per treatment. If a 5 row plot is used, data should be taken from the 3 center rows. If a 20-row plot is used, take data from the 18 center rows and consider each row as a replicate.

TECHNOLOGY TRANSFER SUBCOMMITTEE REPORT

A subcommittee of workshop delegates was organized to discuss various ideas and approaches to effective technology transfer of root-knot nematode information at regional and individual country levels. In this context, technology transfer means providing information generated by the IMP to in-country scientists, technicians, and farmers in a meaningful manner that will lead to improved root-knot nematode control.

Cooperative Effort

The subcommittee believes that for technology transfer to be accomplished in a meaningful manner, the existing IMP structure, as well as in-country infrastructure, must work together at various levels in a cooperative effort.

IMP Role - Leadership Training/Publications/Training Materials

The IMP headquarters staff should concentrate their efforts on furnishing leadership training for selected plant nematologists from participating countries as well as developing publications and model training material suitable for adaptation to individual country needs. Dr. Sasser outlined in general terms one aspect of leadership training which will provide the opportunity for leading plant nematologists from cooperating countries to come to NCSU for 4-6 weeks of advanced instruction and discussion in various aspects of root-knot nematode research and control. Instruction will be provided by leading scientists from around the world as well as the IMP headquarters staff. The committee believes this is an important aspect of technology transfer and should be pursued.

In addition, training should be conducted on a regional basis for technicians, junior scientists and plant protection officers. IMP could take a lead role in the organization of such training, working closely with International Agriculture Research Centers and the AID funded consortium for International Crop Protection.

The IMP headquarters staff also could play an important role in the development of publications as it has in the past, as well as the development of model training brochures and manuals. The model training material should

address the needs of extension workers and farmers and be of a general nature suitable for adaptation and translation by individual countries. The training material may be in the form of brochures, manuals, slides, video tapes, etc.

Individual Country Cooperator Role - Education and Training of Administrators/ Extension Workers/Farmers

The subcommittee believes that for an effective root-knot nematode control program to be adopted and implemented, an education and training program must be established for administrators, extension workers and farmers. Leadership for such a training program should come from IMP country cooperators.

Education of administrators in Ministries of Agriculture and Universities is, in fact, an effort to convince top-level managers of the magnitude of the root-knot nematode problem and the need to support a comprehensive control effort. Brochures and other visual aids, as well as demonstration plots, would be helpful in this effort. Also, farmers voicing their concerns over the root-knot nematode problem, particularly through the news media, can be extremely effective in getting the attention of almost all administrators.

Training of extension workers should be the primary responsibility of the IMP country cooperator and his staff. Training should include general information on nematode identification, biology and control measures such as the use of resistant varieties, cropping systems, nematicides and biologicals. Obviously the data must be developed and thoroughly tested on an individual country level before inclusion in a training effort. Funding for a nation-wide training effort should come from in-country institutions or possibly from international donors. If international donor assistance is sought, individual countries should prepare comprehensive project proposals for review by prospective donors.

Technology transfer to the farmer level should be the responsibility of the extension specialist working closely with the IMP in-country cooperator. Training of farmers should include general information on identification of root-knot nematode symptoms at the field level, demonstration plots and an explanation of appropriate control measures. Here again, all control measures should be adequately tested at the individual country level before recommendations are made to farmers. There also should be a feedback mechanism established to handle individual farmer inquiries and recommend appropriate control measures.

CONFERENCE DELEGATES

Indonesia (L to R): D. M. Tantera, A. W. W. Hadisoeganda

Philippines (L to R): T. T. Reyes, E. T. Rasco, R. G. Davide, R. B. Valdez.

Thailand (L to R): T. Lavapaurya, S. Sontirat, C. Chunram.

CONFERENCE DELEGATES

Japan (L to R): H. Inagaki, T. Shiga.

Bangladesh: B. C. Choudhury.

Pakistan (L to R): M. Saeed, M. Maqbool Ahmad.

Nepal (L to R): K. P. Sharma, L. N. Bhardwaj, C. H. Hogger.

Taiwan: Bie Yun Tsai.

CONFERENCE DELEGATES

Malaysia: A. R. Razak.

Sri Lanka: P. Sivapalan.

Burma (L to R): M. T. Aung, Yi Yi Myint.

Korea: Y. E. Choi

Work group on Breeding for Resistance.

Work group on Technology Transfer.

Presentation of Country Reports.