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Proceedings of the Third Research & Planning Conference on Root-knot Nematodes *Meloidogyne* spp.

September 13-17, 1982

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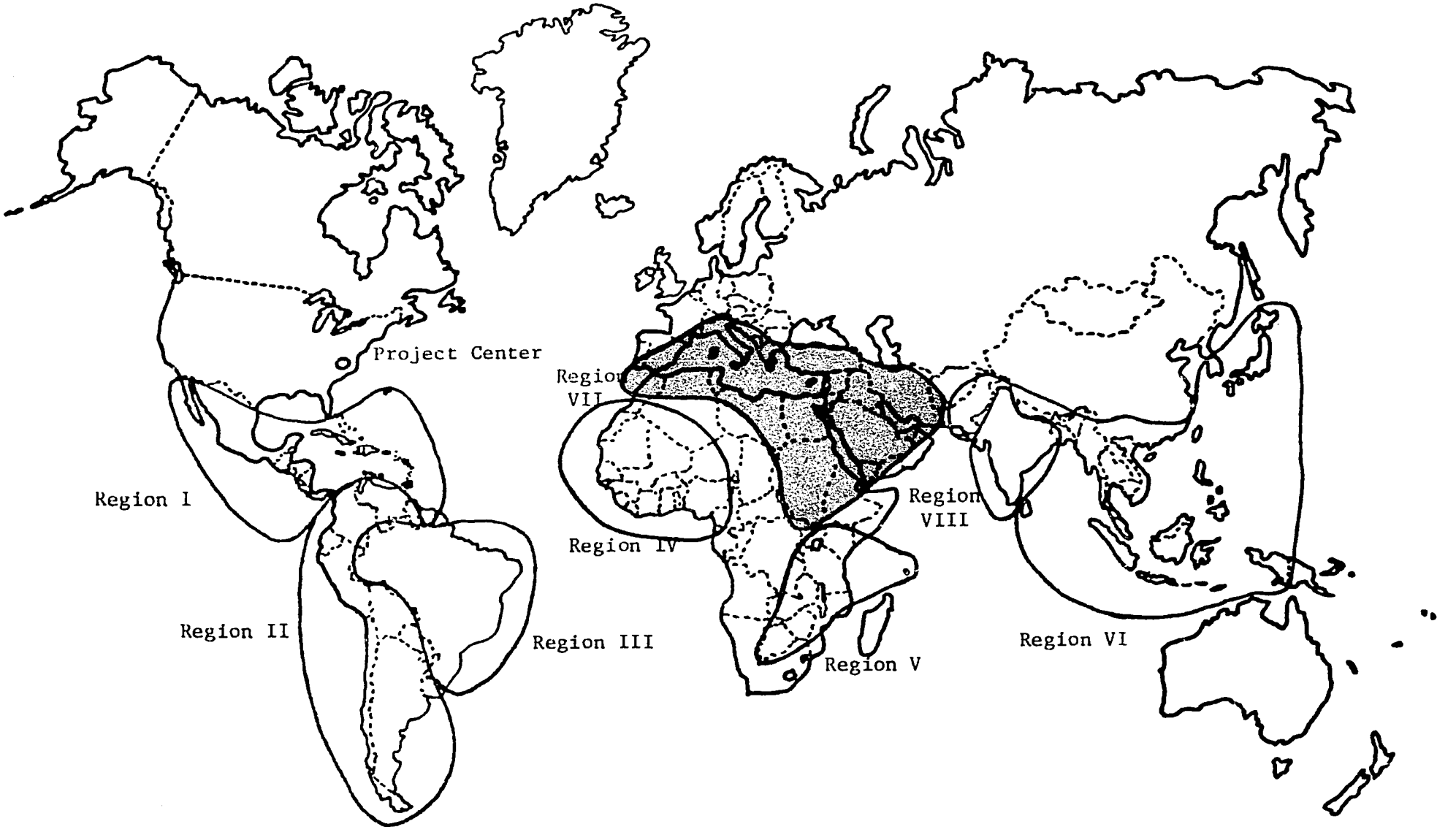
Coimbra, Portugal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PREFACE

The Third Regional Conference on Root-knot Nematode Research for Region VII, held September 13-17, 1982, in Coimbra, Portugal, was organized jointly by the Department of Zoology of the University of Coimbra and the International Meloidogyne Project (IMP). The IMP, headquartered at North Carolina State University, Raleigh, North Carolina, U.S.A., comprises a worldwide network of over 100 scientists grouped into eight geographical regions. Region VII encompasses the Mediterranean countries and includes representatives from Algeria, Cyprus, Italy, Jordan, Egypt, Morocco, Portugal, Spain, Turkey, Sudan, and Tunisia. Participating scientists from these countries are affiliated with nematology research units at universities, agricultural experiment stations, and research institutes.

As with earlier conferences, the aim of this gathering is the exchange of new research findings on root-knot nematodes. IMP's efforts now focus primarily on screening and breeding for resistance, cropping systems research, and technology transfer. Continued research in these areas promises to promote increased crop yields in developing countries through more efficient and economical control of root-knot nematodes.

Gratitude and appreciation are extended to all conference participants for their dedicated efforts to increase knowledge concerning root-knot nematodes. Special thanks are extended to members of the organizing committee and their assistants:

Organizing Committee

J. N. Sasser

Maria Susana Newton de Almeida Santos

Isabel Maria de Oliveira Abrantes

Maria Teresa da Silva Craveiro

Assisted by

Maria Madalena Parreira Branco

Maria Natália Ferreira

João Claúdio Martins das Neves

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Maria Joana de Almeida Vieira dos Santos

The University of Coimbra, Portugal, and especially the Department of Zoology, receive grateful acknowledgement for providing facilities for the conference. Likewise, the support provided by the International Meloidogyne Project; the Instituto Nacional de Investigação Científica, Lisbon, Portugal; and Banco Nacional Ultramarino, Agência de Coimbra, Portugal, are especially appreciated. Finally we wish to thank Mrs. Catherine Carter, Research Assistant, for editing and arranging the proceedings and Miss Mildred Oldham, Secretary, for typing the master copy.

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WELCOMING REMARKS

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On behalf of the University I would like to welcome all of you to Coimbra and to express our sincere appreciation for the choice of Coimbra as the place for this conference of the International *Meloidogyne* Project.

We feel particularly happy to have Professor and Mrs. Sasser and Dr. and Mrs. Triantaphyllou with us. The Project, initiated by Professor Sasser and his colleagues of North Carolina State University, is an international effort to advance knowledge about an important group of plant-parasitic nematodes towards increasing yield of food crops. This conference represents the advanced phase of the cooperative effort of eighteen nations.

On behalf of the Organizing Committee, I would like to express our gratitude to the Vice-Dean and to the Presidents of Conselho Directivo and Conselho Científico of the Faculty and Conselho Directivo of Museu e Laboratório Zoológico who honored us with their presences and have contributed to make this conference possible. Warm thanks are extended to all who helped in various ways.

The nematology research group of Centro de Sistemática e Ecologia da Universidade de Coimbra is indebted to the International *Meloidogyne* Project for the support and encouragement which made it possible to bring together not only nematologists from fourteen countries but also all Portuguese researchers interested in the various fields of nematology.

In 1882, that is to say, one hundred years ago, root-knot nematodes became the first plant-parasitic species to be observed in vineyards in Portugal and the first to be recorded by Moraes. However, it was only about twenty years ago that nematology research began in our country. Professor Branquinho de Oliveira,

Dr. Bravo Lima and Eng. Macara are those who contributed to the foundation of the subject.

Since then the extent and pace with which nematology has developed in relation to other countries, to our actual needs and to other sciences may not be encouraging. Development of any science is influenced by available resources that can be channeled into any one science.

Plant nematologists are few and scattered. Most of them are associated with nematology research units at specialized laboratories and institutes of agricultural research. One research group is associated with Museu e Laboratório Zoológico of our University. As zoologists, nematologists, we study the biology of nematodes. We do hope to aid plant pathologists and nematologists in their research efforts to understand the nematode and in the development of control strategies.

In spite of many difficulties, however, some progress has been made in our country. We hope that this conference will develop increasing interest in nematology.

I will finish my opening and welcoming remarks quoting Professor Sasser: "Our appreciation, understanding and encouragement are timeless virtues. Our most important role, however, will be our example of hard work, dedication and desire to see our science grow."

OVERVIEW OF THE INTERNATIONAL MELOIDOGYNE PROJECT -- RATIONALE, GOALS, IMPLEMENTATION, AND PROGRESS TO DATE

J. N. Sasser and C. C. Carter*

One of the greatest challenges facing today's world is the feeding of an ever-increasing population. Low agricultural productivity in developing nations and inadequate means of food distribution contribute greatly to this problem. Factors responsible for minimal productivity include low-yielding varieties, poor soil fertility, and inadequate pest management practices, to name a few. Clearly, if world hunger is to be alleviated, such obstacles must be tackled systematically.

One of the most important pests limiting agricultural productivity is the root-knot nematode Meloidogyne species. Almost all of the plants that account for the majority of the world's food supply are susceptible to infection. In areas where root-knot nematodes are not controlled, average crop yield losses are likely to be in the neighborhood of 25%, with damage in individual fields ranging as high as 60%.

Because root-knot nematodes occur throughout most of the world (Fig. 1), infect all major crop plants, and cause substantial reduction in crop yield and quality, scientists at North Carolina State University decided to initiate a worldwide investigation of the problem. In July of 1975, a grant from the United States Agency for International Development made this endeavor possible and led to the formation of the International Meloidogyne Project headquartered at North Carolina State University (NCSU) in Raleigh.

The rationale for Project formation was based on four major premises: 1) the recognition of root-knot nematodes as major world pathogens of food and fiber crops, 2) the necessity of an international approach to the problem, 3) the availability of a network of trained research personnel, and 4) the relevance of this area of research to North Carolina agriculture. The departments of plant pathology, genetics, statistics, and soil science at NCSU, as well as the N.C.

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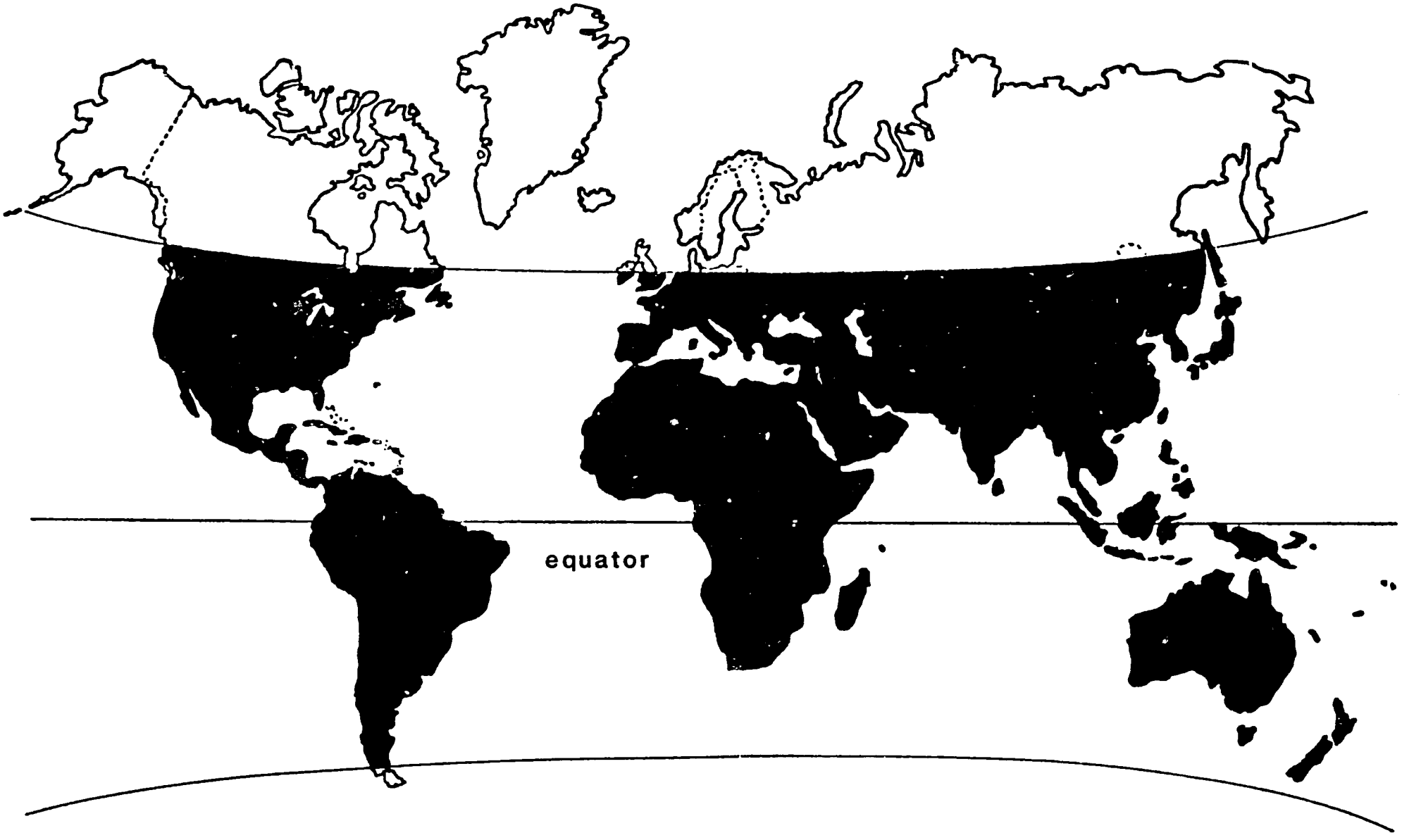
*Principal Investigator, IMP, and Research Assistant, North Carolina State University, respectively.

Figure 1. Approximate distribution of root-knot nematodes.



Agronomic Division cooperate in Project research. Scientists and support staff from these departments work with scientists overseas through regional conferences, personal visits to their home countries and other contacts. These cooperative efforts are mutually advantageous, and the success of the Project is dependent upon the combined efforts of all involved. From this broad academic and geographic base, the Project approaches the problem of world hunger through the study of root-knot nematodes, Meloidogyne species.

Root-knot nematodes are microscopic roundworms which live in the soil and in plant roots. Juveniles and males are slender and threadlike; females are more globular. These nematodes are barely visible to the unaided eye, and the adult female is smaller than the head of a pin. Due to their tiny size and protective habitat, root-knot nematodes remained undiscovered until the mid-19th century, even though the galls they cause are quite visible. In some developing countries, root-knot nematode infection is so common and widespread that galled roots are considered "normal." In such cases, it is not uncommon for poor stands or yields to be attributed to vague agricultural ailments such as "worn out land" or "soil exhaustion."

Because root-knot nematodes limit agricultural production to some degree in all countries, the International Meloidogyne Project has enlisted the assistance of more than 100 nematologists associated with universities and research institutes around the world and has grouped them into 8 geographical regions. Regional conferences are conducted periodically in each of these regions for the purpose of planning research objectives and approaches.

The main goal of the Project is to assist developing nations in increasing yields of economic food crops. This objective is accomplished by promoting knowledge about the world's most important group of plant-parasitic nematodes and by protecting crops from the damaging effects of these nematodes. To accomplish these goals, seven major areas of research have been emphasized: the North Carolina differential host test, Meloidogyne morphology, reproductive characters and cytogenetics, biochemistry, ecology, management, and technology transfer.

Root-Knot Nematode Germplasm Collection

Project research in these areas would be impossible were it not for the nematode germplasm collection established and maintained at North Carolina State University. This collection is the result of extensive sampling by Project cooperators. Root-knot nematode egg masses are collected from infected plants all over the world and sent in saline solution to the Project Center. There, they are used to inoculate seedlings of 'Rutgers' tomato, a highly susceptible host of root-knot nematodes. The nematode population increases rapidly on this host and can be maintained indefinitely by periodic inoculation of new 'Rutgers' seedlings with root-knot nematode eggs.

North Carolina Differential Host Test (2)

Each population of nematodes received is subjected to the North Carolina differential host test. This test involves the inoculation of six standard host plants: cotton cv. 'Deltapine,' tobacco cv. 'NC 95,' pepper cv. 'California Wonder,' watermelon cv. 'Charleston Grey,' peanut cv. 'Florunner,' and tomato cv. 'Rutgers.' On the basis of host susceptibility (indicated by +) or resistance (indicated by -), pure populations of the four major species--*M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*--can be easily distinguished (Table 1). Susceptibility and resistance are based on the average egg mass and root gall indices of three replications of the host test.

The four major species account for more than 95% of the root-knot nematodes received from agricultural soils. Therefore, most pure sample populations encountered by the Project can be reliably identified by means of the North Carolina differential host test. Work completed so far has led to the recognition of multiple host races for *M. incognita* and *M. arenaria*.

Morphology (1)

Identification techniques, other than the North Carolina differential host test, are necessary to detect and verify mixed populations and/or rare species. For this reason, much taxonomic research on *Meloidogyne* species is focused on distinctive morphological characters. Such characters include: the perineal pattern--which is an external, fingerprint-like series of markings in the anal region of the adult female; male head shape; and stylet morphology.

Table 1. North Carolina Differential Host Test Reaction Chart

Meloidogyne Species & Race	Differential Host Plants: Cotton Deltapine 16	Tobacco NC 95	Pepper California Wonder	Watermelon Charleston Grey	Peanut Florunner	Tomato Rutgers
M. incognita						
race 1	$\boxed{-}$ *	$\boxed{-}$	+	+	-	+
race 2	$\boxed{-}$	$\boxed{+}$	+	+	-	+
race 3	$\boxed{+}$	$\boxed{-}$	+	+	-	+
race 4	$\boxed{+}$	$\boxed{+}$	+	+	-	+
M. javanica	-	+	$\boxed{-}$	+	-	+
M. arenaria						
race 1	-	+	+	+	$\boxed{+}$	+
race 2	-	+	-	+	$\boxed{-}$	+
M. hapla	-	+	+	$\boxed{-}$	$\boxed{+}$	+

*Box indicates key differential host plants.

Under a scanning electron microscope, minute morphological details can be thoroughly examined. However, scanning electron microscopes are expensive, and most nematologists do not have access to one. Therefore, in practical terms, only those features also visible under a light microscope will prove useful in the routine process of nematode identification.

Reproductive and Cytological Characters

Reproductive and cytogenetic characters are also being studied for use in root-knot nematode identification. Mode of reproduction and chromosome number show much promise as identifying characters (4). Some species reproduce only by cross-fertilization; other species reproduce by parthenogenesis, that is without fertilization (mitotic parthenogenesis). Still other species can reproduce with or without fertilization (facultative, meiotic parthenogenesis).

Races of some of the more common Meloidogyne species have been identified on the basis of chromosome number and mode of reproduction (Table 2). These races are called cytogenetic races and are designated by letters such as "A" or "B," instead of by numbers, in order to distinguish them from host races.

Biochemistry

Biochemical differences among species, that is, in protein and enzyme content, are also being investigated. Major bands of esterase activity have been found to be noticeably different among the four major species (1). Other distinct isozyme patterns are being studied and show much promise for use as identifying characters.

Ecology

In addition to taxonomic research, the project also conducts ecological studies. Once nematode populations are identified at the Project Center in Raleigh, the soil samples and ecological data which accompany each sample are analyzed. This information is then used to characterize the geographical distribution of Meloidogyne species by host range, temperature, precipitation, soil characteristics, and other ecological characters.

Preliminary findings (3) indicate that M. incognita, M. javanica, and M. arenaria inhabit areas with average annual temperatures between 15 and 33° C. M. hapla, on the other hand, occurs more frequently in

Table 2. Chromosome Numbers and Modes of Reproduction of the Four Major *Meloidogyne* Species

Meloidogyne Species & Cytological Race	Range of Chromosome Numbers	Mode of Reproduction
M. incognita		
race A	40-46	mitotic parthenogenesis
race B	32-36	mitotic parthenogenesis
M. javanica	42-48	mitotic parthenogenesis
M. arenaria		
race A	54 (50-56)	mitotic parthenogenesis
race B	34-37	mitotic parthenogenesis
M. hapla		
race A	14-17	facultative meiotic parthenogenesis
race B	30-32, 43, 45, 48	mitotic parthenogenesis

areas with average annual temperatures of less than 15° C. In areas of low rainfall, M. incognita and M. javanica appear to be prevalent species. In general, root-knot nematodes most frequently occur in soils with less than 10% clay, less than 30% silt, and at least 60% sand. Basically, however, root-knot nematodes can occur anywhere host plants grow.

Management

The current emphasis in IMP research is management of root-knot nematodes. Earlier studies concerning general biology and identification of Meloidogyne species have proven to be valuable prerequisites for research into management practices. Research efforts are concentrating on five aspects of root-knot nematode management: host resistance, cropping systems, chemical control, biological control, and integrated crop protection systems.

Host resistance. Much of the screening and evaluation of cultivars for resistance is being done in cooperation with International Agriculture Research Centers (IARC's). Some of these centers and the crops on which cooperative work is being done appear in Table 3. Individual cooperators are also involved in screening for resistance. Some crops being studied include: cowpea in Nigeria; tomato in Nepal; and tomato, eggplant, bean, pepper, lettuce, cucumber, cabbage and radish in the Philippines.

Cropping systems. Cropping systems research helps pinpoint crops or other plants which prevent increases in Meloidogyne populations. These plants can then be incorporated into cropping sequences or crop rotation schemes. Cropping sequences for each region are analyzed to determine those which most effectively control root-knot nematodes and thereby increase yields.

Chemical control. Investigations into chemical control include tests for nematicide efficacy, and determination of application rates. In developing countries, however, nematicides often cannot be incorporated into control programs. The chemicals may be too expensive or application equipment may not be available. Even so, nematicide tests can serve a very useful purpose by demonstrating to farmers the benefits to be derived from effective nematode control.

Table 3. Cooperating Research Centers & the Major Crops Being Tested for Root-knot Nematode Resistance

Research Center	Crops
Centro Internacional de la Papa (CIP)	potato
Asian Vegetable Research & Development Center (AVRDC)	Chinese cabbage, tomato
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	pigeon pea, chickpea
International Institute of Tropical Agriculture (IITA)	cowpea
Centro Internacional de Agricultura Tropical (CIAT)	bean
Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT)	maize, wheat

Biological control. Research into biological control of root-knot nematodes is being conducted in Peru and at the Project Center at North Carolina State University. The fungus *Paecilomyces lilacinus* occurs naturally in many soils. However, a particularly pathogenic isolate from soils in the Andes mountains has been found to control *Meloidogyne* populations. The fungus penetrates the nematode eggs, thus destroying the embryo and preventing hatch. Under experimental conditions, introduced fungal inoculum has persisted in the soil in spite of fungicide and nematicide applications. Additional tests on its performance are being conducted under a wide range of conditions.

Integrated crop protection systems. The eventual goal of root-knot nematode management studies is increased crop production, particularly food crop production, and development of integrated crop protection systems is a step in this direction. These systems will utilize the best combinations of resistant cultivars, crop rotation, nematicides, biological control agents, and sanitary and cultural practices. In this way, a broader spectrum of pests can be managed simultaneously.

Technology Transfer

Through the process of technology transfer, current research has already begun to focus on development of management strategies for root-knot nematodes. Basic information on *Meloidogyne* biology, ecology, and methodology is being made available to Project cooperators in developing countries, so they can develop management strategies suited to their particular agricultural situations. The publication of books, conference proceedings, journal articles, slide sets, and posters are all part of this effort. Research personnel are kept up to date by means of conferences and field and laboratory training sessions. As a result of the Project's investigations, nematode research capabilities in developing countries are continually advancing.

Summary

In summary, the International *Meloidogyne* Project has accomplished several of its objectives. These include: 1) the promotion of awareness concerning the importance of root-knot nematodes in developing nations;

2) survey of the distribution, frequency and relative importance of Meloidogyne species and races infesting agricultural soils; 3) the discovery and description of new species; 4) the discovery of new and more reliable characters for identification; 5) clarification of phyletic relationships on the basis of cytogenetic and biochemical characteristics; 6) the elucidation of ecological factors affecting survival, distribution, and pathogenicity, and 7) the enhancement of research capabilities in developing nations through conferences, publications, and field and laboratory training sessions.

These accomplishments, along with increased communication and cooperation among nematologists throughout the world, are bringing the ultimate goal of increased food production in developing countries closer and closer to reality.

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STATUS OF NEMATOLOGICAL PROBLEMS IN ALGERIA

A. A. Salem*

Algeria comprises two geographical regions, Northern Algeria and Sahara, which are different in characteristics. Northern Algeria includes the Mediterranian coast which is composed of plains alternating with mountains. The coastal plains specialize in production of early vegetables. The hillsides are usually covered with orchards, while the plateaus are sufficiently well watered for the cultivation of cereals. The Sahara region, a desert in which there are scattered oases, is ten times larger than Northern Algeria. Agriculture is confined to a few selected regions with underground water resources.

The entire population lives in the northern part of the country which is richer than the Sahara region. The rainfall exceeds 23 inches and, in certain places, 40 inches. The greatest amount falls in the northern part and diminishes in the south (Sahara region). Although more than 55% of the population lives off the land, Algeria's income due to agriculture and forestry constitutes about 10-15% of gross domestic products.

Little is known about the presence and distribution of plant-parasitic nematodes in Algeria since the last comprehensive report of the nematological problems in the country (4). Some survey investigations were carried out in some Algerian localities. They dealt with biological aspects of some nematodes such as Tylenchulus semipentrans (5), a number of species of Longidoridae (1), Pratylenchus pentrans (2) and P. pentrans, Xiphinema elongatum, Longidorus congoensis, Ditylenchus dipsaci, Heterodera avanae, H. gottingiana (3).

The root-knot nematode, Meloidogyne spp., is the greatest nematological problem of Algerian agriculture (3). All vegetable

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crops outdoors or in glasshouses were severely damaged by one or more species, and in cases of heavy attacks, the whole yield was threatened. Lamberti et al. observed heavy infestations of M. incognita and M. javanica present on tomato, cucumber and pepper in northern and all oases of the southern regions of Algeria (3).

Salem joined the staff members of Oran University in March, 1982, and began to equip a plant nematology laboratory in the Institute of Biology. Since then several soil and root samples have been collected from various places from the valley of Oran. A group of plant-parasitic nematodes were found associated with citrus, vines, olives and vegetables. Genera found include Criconemoides, Ditylenchus, Helicotylenchus, Heterodera, Meloidogyne, Pratylenchus, Tylenchorhynchus, Tylenchus and Tylenchulus. The root-knot nematode, Meloidogyne spp., was found on vines, tomato, squash, cucumber, and other vegetable crops. In the near future, we hope to make species identification of such nematode pests.

Our present and future programs include:

1. Survey studies of plant-parasitic nematodes on northern regions as well as the southern regions (Sahara);

2. Collection of nematode populations especially root-knot nematodes;

3. Identification of root-knot nematode species using keys and perineal patterns;

4. Host-parasite relations between the prevailing root-knot nematode species and the local cultivars of vegetable crops.

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ROOT-KNOT NEMATODES IN CYPRUS AND THEIR IDENTIFICATION

Ioannis Philis*

Root-knot nematodes (Meloidogyne spp.) are well established in Cyprus, being favored by the warm climate of the mediterranean region. Crop losses caused by Meloidogyne as well as the species present were partly reported previously (2).

The present study gives a detailed account of the root-knot nematodes on the island, their main hosts and the practical use of certain morphological and other criteria in species (and race) identification.

Materials and Methods

The following criteria were used in nematode identification: a) Sasser's Host Differential Test, b) larval length, c) position of excretory pore, and d) appearance of perineal pattern. Preparation of inoculum and plant reaction (egg and gall formation) on Sasser's host differentials were based on the general guidelines of the International Meloidogyne Project (IMP). Larval length and position of the excretory pore were determined from temporary mounts while observations of the perineal pattern were made from permanent slides.

Thirty-nine root and soil samples were collected from 22 locations in Cyprus (Table 1) which is in the subtropical region with latitude 35°N, longitude 32°E and an annual rainfall of about 450 mm in coastal areas. The samples were taken from 12 different crops, most of them during summer, while the rest were collected from glasshouses during winter-early spring. All populations were kept in the glasshouse with care being taken to avoid cross contamination among them.

Results and Discussion

All populations, except 025, reproduce on tobacco, watermelon and tomato, while no reproduction occurred on cotton or peanut (Table 2). Populations 001, 011, 025, 026, 028, 034 and 038 caused

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Table 1. Habitat of *Meloidogyne* populations collected for identification

Populations	Location	Habitat			
				Host	
		Glasshouse	Field	Common name	Variety
001	Astromeritis	+		Carnation	William Sim
002	Akaki	+		Marrow	Senator
003	Akaki	+		Tomato	Unknown
004	Dherinia	+		Cucumber	Pepinex 69
005	Ayia Napa		+	Tomato	Marmande
006	Ayia Napa		+	Eggplant	Black beauty
007	Ayia Napa		+	French bean	Local
008	Ayia Napa		+	Eggplant	Black beauty
009	Paralimni		+	Tomato	Marmande
010	Anafotia	+		Sweet melon	Ananas
011	Anafotia	+		Tomato	Marmande
012	Deftera		+	Celery	Unknown
013	Peristerona		+	Okra	Local
014	Astromeritis		+	Eggplant	Long purple
015	Xylophagou		+	Eggplant	Black beauty
016	Alaminos		+	French bean	Harvester
017	Limassol		+	Swiss chard	Local
018	Fassouri	+		Eggplant	Bonica
019	Pareklishia		+	Tomato	Ace VF-55
020	Pareklishia		+	Tomato	Walter
021	Emba		+	Tomato	Local
022	Pera Orinis		+	Peach	Elberta
023	Pera Orinis		+	Peach	Elberta
024	K. Polemidhia	+		Eggplant	Bonica
025	K. Polemidhia	+		Tomato	Dombo
026	Kolossi	+		Tomato	Dombo
027	Kolossi	+		Cucumber	Maram
028	Limassol	+		Tomato	Dombo
029	Chlorakas	+		Tomato	50-27

Table 1 (continued)

		Habitat			
				Host	
Populations	Location	Glasshouse	Field	Common name	Variety
030	Akhelia	+		Eggplant	Bonica
031	Akhelia	+		Eggplant	Bonica
032	Emba		+	French bean	Harvester
033	Emba		+	Tomato	Ace VF-55
034	Emba		+	Celery	Local
035	Emba		+	Tomato	Local
036	Argaka		+	Tobacco	Virginia
037	Argaka		+	Tobacco	Virginia
038	Choulou		+	Tobacco	Virginia
039	Letymbou		+	Tobacco	Virginia

Table 2. Behaviour of *Meloidogyne* field populations on Sasser's Differential Hosts

Populations	Differential hosts[+]						Species		
								M. inc.	
	Tob.	Cot.	Pep.	W'mel.	P'nut.	Tom.	M. jav.	R-1	R-2
001	5[++]/5[+++]	0/0	4/4	5/4	0/0	5/5			+
002	4/5	0/0	0/0	5/4	0/0	5/5	+		
003	5/5	0/0	0/0	4/4	0/0	5/5	+		
004	4/5	0/0	0/0	4/3	0/0	5/4	+		
005	5/5	0/0	0/0	5/4	0/0	5/5	+		
006	4/4	0/0	0/0	3/3	0/0	4/4	+		
007	4/4	0/0	0/0	4/4	0/0	5/5	+		
008	5/5	0/0	0/0	3/2	0/0	5/5	+		
009	2/2	0/0	0/0	4/2	0/0	5/5	+		
010	5/4	0/0	0/0	5/2	2/0	5/5	+		
011	5/5	0/0	3/3	5/5	0/0	5/5			+
012	2/2	0/0	0/0	3/3	0/0	4/4	+		
013	4/4	0/0	0/0	5/5	0/0	5/5	+		
014	4/4	0/0	0/0	4/4	0/0	5/5	+		
015	4/4	0/0	0/0	4/4	0/0	4/4	+		
016	3/3	0/0	0/0	3/3	0/0	4/4	+		
017	3/3	0/0	0/0	3/3	0/0	4/4	+		
018	5/5	0/0	0/2	5/5	0/0	5/5	+		+
019	5/5	0/0	0/3	4/4	0/0	5/5			+
020	5/5	0/0	0/3	5/5	0/0	5/5			+
021	4/5	0/0	0/3	4/4	0/0	5/5			+
022	4/4	0/0	0/2	4/4	0/0	5/5			+
023	4/5	0/0	0/2	4/4	0/0	4/5			+
024	4/4	0/0	0/2	4/4	0/0	5/5			+
025	0/0	0/0	5/5	4/4	0/0	5/5		+	
026	4/5	0/0	1/2	0/5	0/0	5/5	+		+
027	4/4	0/0	0/0	4/4	0/0	5/5	+		
028	5/5	0/0	4/4	0/5	0/0	5/5			+

Table 2 (continued)

Populations	Differential hosts+						Species		
								M. inc.	
	Tob.	Cot.	Pep.	W'mel.	P'nut.	Tom.	M. jav.	R-1	R-2
029	4/4	0/0	0/1	3/3	0/0	4/4	+		+
030	4/4	0/0	0/0	3/3	0/0	4/4	+		
031	5/5	0/0	0/2	4/4	0/0	5/5	+		+
032	4/4	0/0	0/1	4/4	0/0	4/4			+
033	4/4	0/0	0/0	4/4	0/0	5/4	+		
034	5/4	0/0	3/2	5/4	0/0	5/4	+		+
035	4/4	0/0	0/0	3/3	0/0	4/4	+		
036	4/4	0/0	0/3	5/4	0/0	4/5	+		+
037	4/4	0/0	0/0	4/4	0/0	4/4	+		
038	3/4	0/0	4/4	3/3	0/0	4/4			+
039	4/4	0/0	0/1	0/5	0/0	4/4			+

+ Tobacco cv. 'NC 95;' Cotton cv. 'Deltapine;' Pepper cv. 'California Wonder;' Watermelon cv. 'Charleston Grey;' Peanut cv. 'Florunner;' Tomato cv. 'Rutgers.'

++ Root galling (0 = no galling, 5 = severe galling).

+++ Egg production (0 = no eggs, 5 = many eggs produced).

galling and produced eggs on pepper while other populations, of the same species, laid only eggs without causing any visual symptoms of root galling. This can only be explained by the presence of different physiological races. M. arenaria was not found in the samples examined although it is listed in previous records (1). Our conclusion that this species was not present was based mainly on two factors. First of all, the juveniles of this species are the longest in the genus, usually measuring over 450 μ with an absolute minimum of 400 μ. Secondly, none of the many perineal patterns examined resembled those of typical M. arenaria, even those of populations 011 and 015 which had juveniles with lengths measuring 400 and 420 μ, respectively.

The position of the excretory pore was very helpful in distinguishing between M. javanica and M. incognita. It ranged from 2.4 to 3.0 times the stylet length, measured from the head tip for the former, and from 1.4 to 1.9 for the second species. Mixed populations were also observed with positions of the excretory pore measuring 2.3 to 2.5 times the stylet length, this being the result of the average value of the two species in the population (Fig. 1). Total length of juveniles cannot be used as a criterion for distinguishing between M. javanica and M. incognita (Fig. 1), and the appearance of the perineal pattern has great limitations.

Research Program Underway

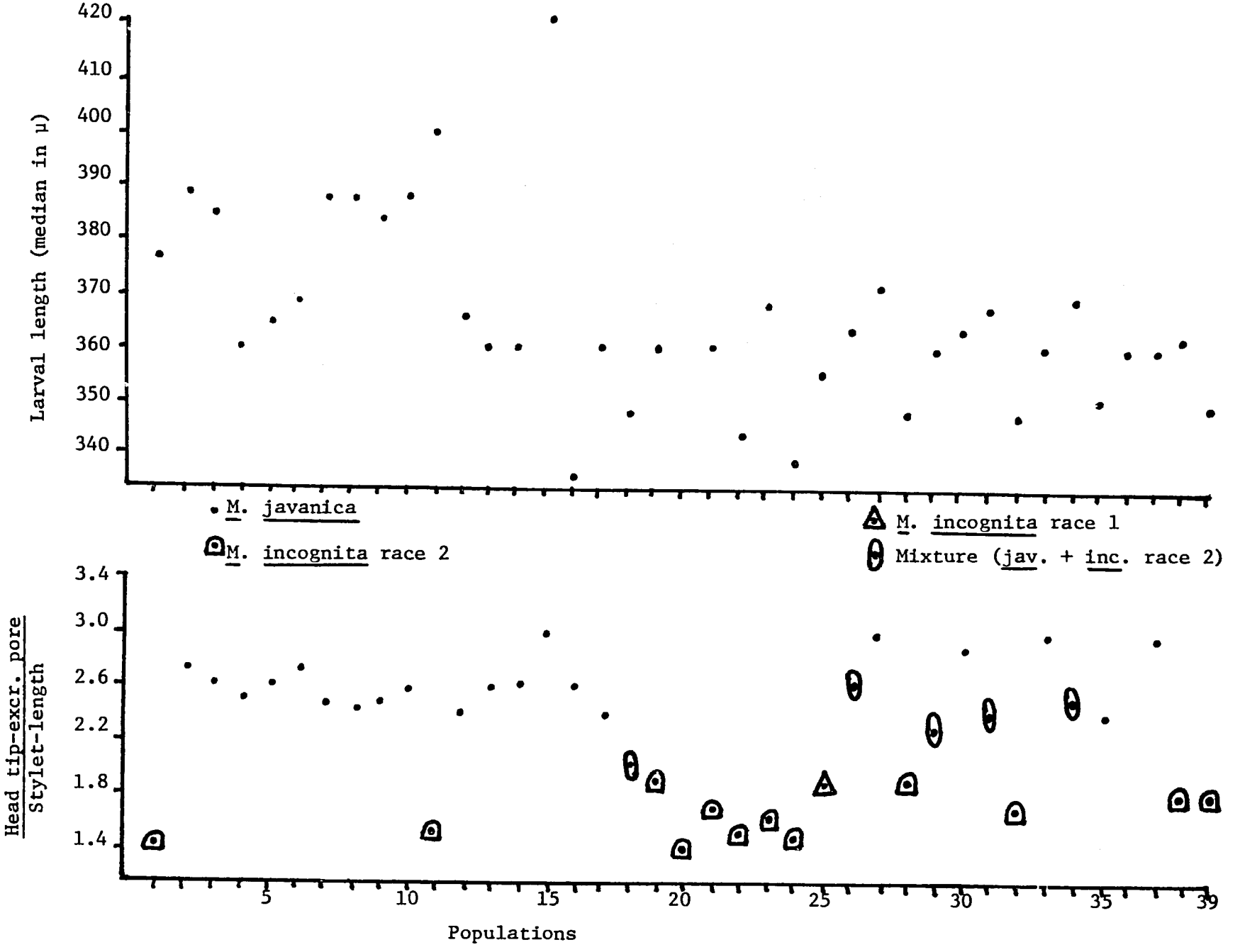
1. Screening tomato varieties resistant to root-knot nematodes.

   Trials were initiated for testing nematode resistance of high yielding tomato varieties, for greenhouse use. Observations are being carried out in pots (controlled conditions) and in greenhouses.

2. Testing resistance of peach and almond rootstocks to root-knot nematodes.

   Several rootstocks, mostly from the U.S.A., will soon be tested under controlled and field conditions for their ability to resist nematode attack.

Fig. 1. Larval length and position of the excretory pore of Meloidogyne spp.



Future Research Plans

Our future research work concerning the International *Meloidogyne* Project will mainly aim at:

1. Reduction of root-knot nematode populations in the soil using solar heat (greenhouses) and granular nematicides (open fields).
2. Adaption of a rotational system to compensate crop losses due to nematode attack.

Acknowledgements

The assistance of Mr. A. Petrides and Mrs. A. Papasolomontos in field and laboratory work is greatfully acknowledged. Great appreciation is also due to Professor J. N. Sasser, North Carolina State University, U.S.A., for planning and organizing the project and USAID for financial support.

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DAY DEGREES DEVELOPMENT AND NUMBER OF GENERATIONS OF MELOIDOGYNE JAVANICA (TREUB.) ON TOMATO IN CYPRUS

Ioannis Philis*

In Cyprus, root-knot nematodes (Meloidogyne spp.) attack many plants causing serious yield losses. Tomato, one of the main vegetable crops, is devastated by this group of parasitic nematodes. Inland, the crop is grown in the open from April to October and in greenhouses from November to May. Near the coast where the climate is milder, tomatoes need cover from January through March only.

Results of an extensive survey carried out on the island revealed that there are two species of root-knot nematodes: Meloidogyne javanica and M. incognita Race 1 and 2, the former species and M. incognita Race 2 being predominant (3).

Vrain et al. reported that the basal temperature for development of M. incognita, a species similar to M. javanica, was 10° C (5). It is also known that the time required by the nematode to complete one generation is defined as that from invading the host root to the next invasion.

No previous work has been done on the life history of Meloidogyne spp. The present study deals with the development and reproduction of M. javanica on tomato under local conditions.

Materials and Methods

The life cycle of the nematode was studied during 1980-81 at four nematode-infested sites, two (S_1, S_2) outdoors and two (S_3, S_4) in a greenhouse. At the first two sites, the cv. 'Pearson' was planted while at the other two sites (S_3, S_4) the cv. 'Dombo' was used (Table 1). Nematode-free seedlings, approximately 15 cm high, were used. Roots at S_1 and S_2 were sampled twice a week throughout the nematode life cycle; at S_3 and S_4, where soil temperatures during nematode

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Table 1. Sites and development times

Site No.	Location	Habitat	Date planted	Cultivar	Development time in days from beginning of invasion	
					First egglaying	Second invasion
S_1	Deftera	Inland, open field	22/4/80	Pearson	37	45
S_2	Deftera	Inland, open field	9/6/80	Pearson	27	41
S_3	Anafotia	Coastal, greenhouse	1/10/80	Dombo	75	95
S_4	Kolossi	Coastal, greenhouse	20/12/80	Dombo	57	78

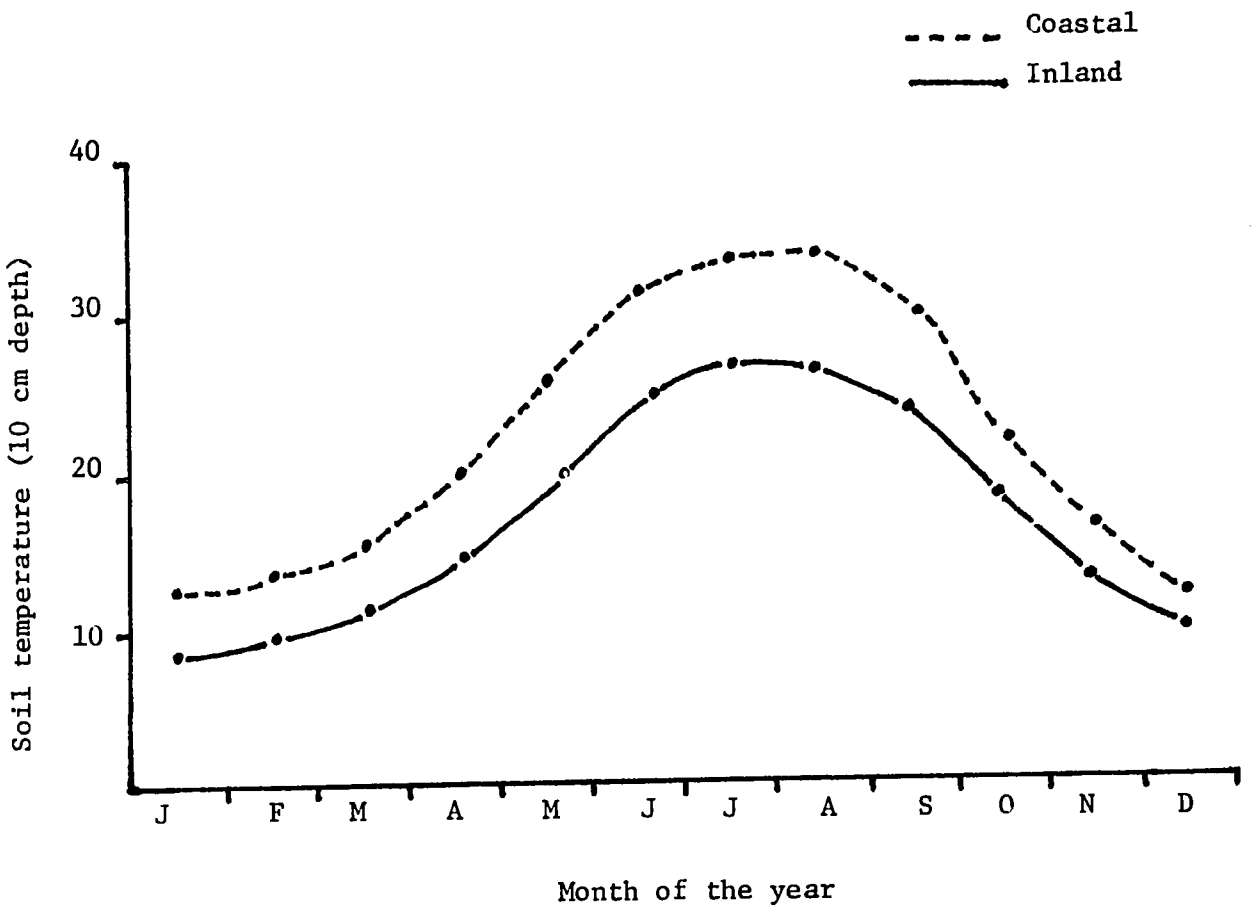
development were lower, only once a week. Sampling commenced one week after planting and continued until the beginning of the second generation. Nematode development within roots during the first 4 or 5 weeks after planting was determined by removing 2 to 3 entire seedlings; thereafter, a sample of roots from an equal number of plants was examined. A one-gram sample of feeder roots was stained in 0.05% acid fuchsin (2) and nematode development determined according to Christie's groups of developmental stages, slightly modified (1). Root sampling continued until the next root invasion. Soil temperatures at S_1 and S_2 12.5 cm deep were recorded continuously and at S_4 daily records were taken at 07.00 and 15.00 hrs. No records were obtained from S_3. Accumulated day degrees, above an assumed basal development temperature of 10° C, were determined by accumulating the average daily soil temperature when the minimum temperature was continually above 10° C. When the minimum was below 10° C, day degrees were derived from record temperatures above 10° C. Only in February and December, 1980, was this necessary. In January 1980, the heat accumulated above 10° C was negligible.

Results and Discussion

In Cyprus, rapid nematode development occurs from April to October and almost ceases from December to February (Fig. 1). Near the coast mean soil temperatures during the year, and especially during winter, are higher than inland temperatures indicating that nematode development is possible throughout the year, although very slow during winter. Near the coast winters are mild and a tomato crop planted early in the year escapes mass nematode invasion during the early stages of growth. In heated greenhouses, where air temperature is kept above 12° C, nematodes develop throughout the growing season.

At Deftera (S_1, S_2), a typical inland area, the monthly soil temperature 12.5 cm deep ranged from 9.5° to 28.4° C in January and July, respectively. Assuming that the development threshold

Fig. 1. Mean monthly soil temperature at coastal and inland areas (uncultivated soil)



for M. javanica is 10° C, nematode activity occurs mainly from March to November (Fig. 2).

Invasion by juveniles

At all sites, invasion occurred at 17, 7, 16 and 19 days after planting, respectively. The earlier invasion at S_2 was aided by increased nematode hatching as a result of favorable temperatures soon after planting. Soil temperatures at the time of invasion at S_1, 2 and 4 were 23°, 29° and 18° C and the accumulated day degrees, above 10° C, from planting to invasion were 168°, 145° and 161° C, respectively. Invasion by juveniles of the second generation at S_1, 2, 3 and 4 occurred 7, 13, 19 and 20 days after egg laying; soil temperature at the time of invasion for S_1, 2 and 4 was 25.5^{o}, 26.5^{o} and 20.0^{o} C, respectively. This agrees with Tyler's findings that the time from egg laying to hatching at 27° and 16.5^{o} C was 9 and 31 days, respectively (4).

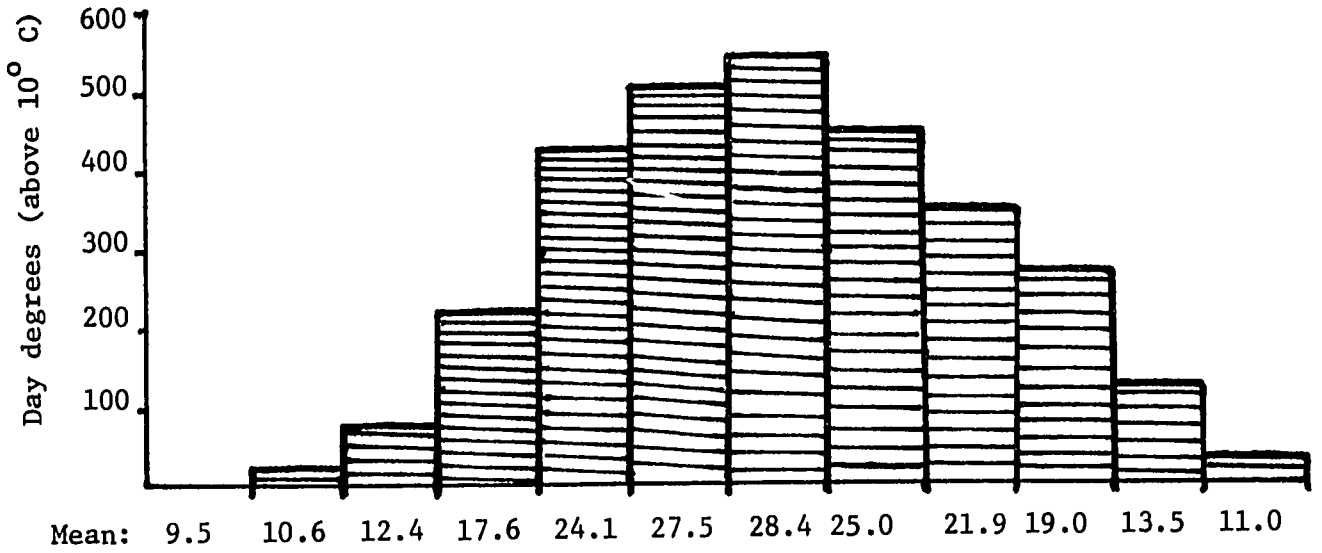
Nematode development

The number of days from the beginning of invasion to first egg-laying ranged from 27 to 57 days, and the second invasion occurred from 41 to 95 days after the initial invasion (Fig. 3). The differences in time required to reach the egg laying and second invasion was due to the different soil temperatures during nematode development, the shortest times (27 and 41 days) being at S_2 where soil temperatures were nearly optimum. S_1 and S_2 were adjacent, but the dates of planting were different (Table 1). Accumulated temperature above 10° C was almost the same for all three sites. At S_1, 2 and 4, the accumulated day degrees from the beginning of invasion to first egg production, i.e. the complete life-cycle of the nematode, were 551, 509, and 516 (Fig. 3).

Number of generations

At S_1, 2 and 4, the accumulated day degrees from the first to the second invasion, i.e. the generation time, was 707, 773 and 771. Assuming a mean of 750 day degrees, the nematode can complete

Fig. 2. Monthly accumulated temperature (above 10° C) at Deftera (1980)



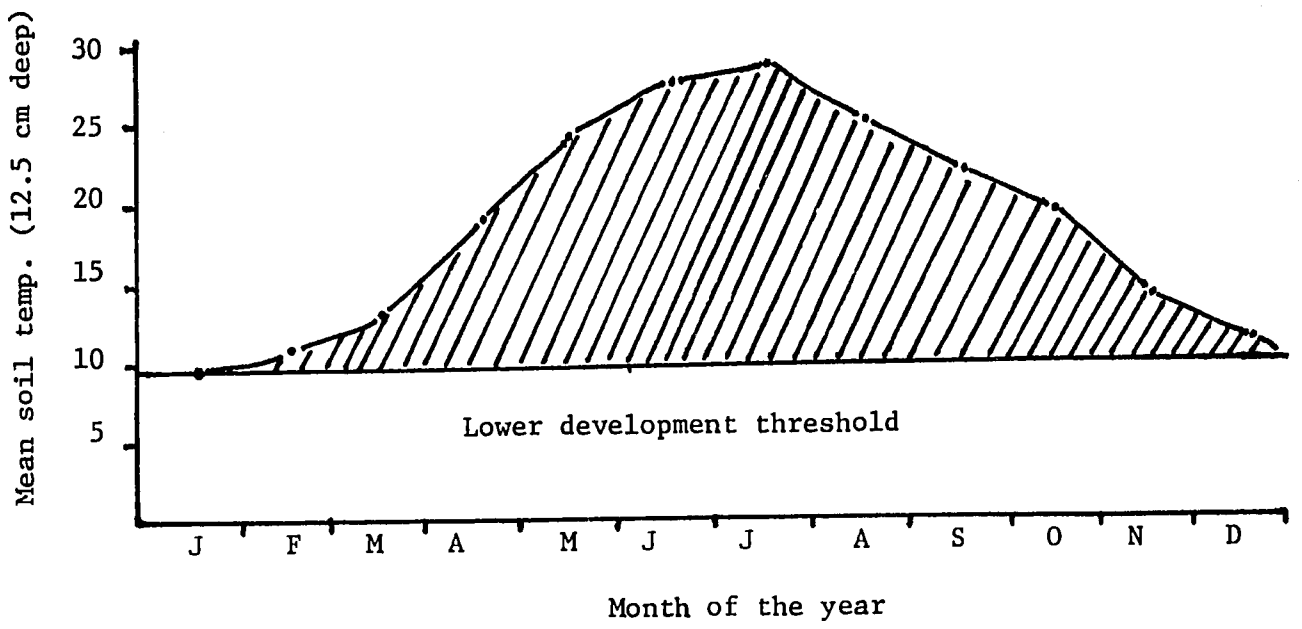
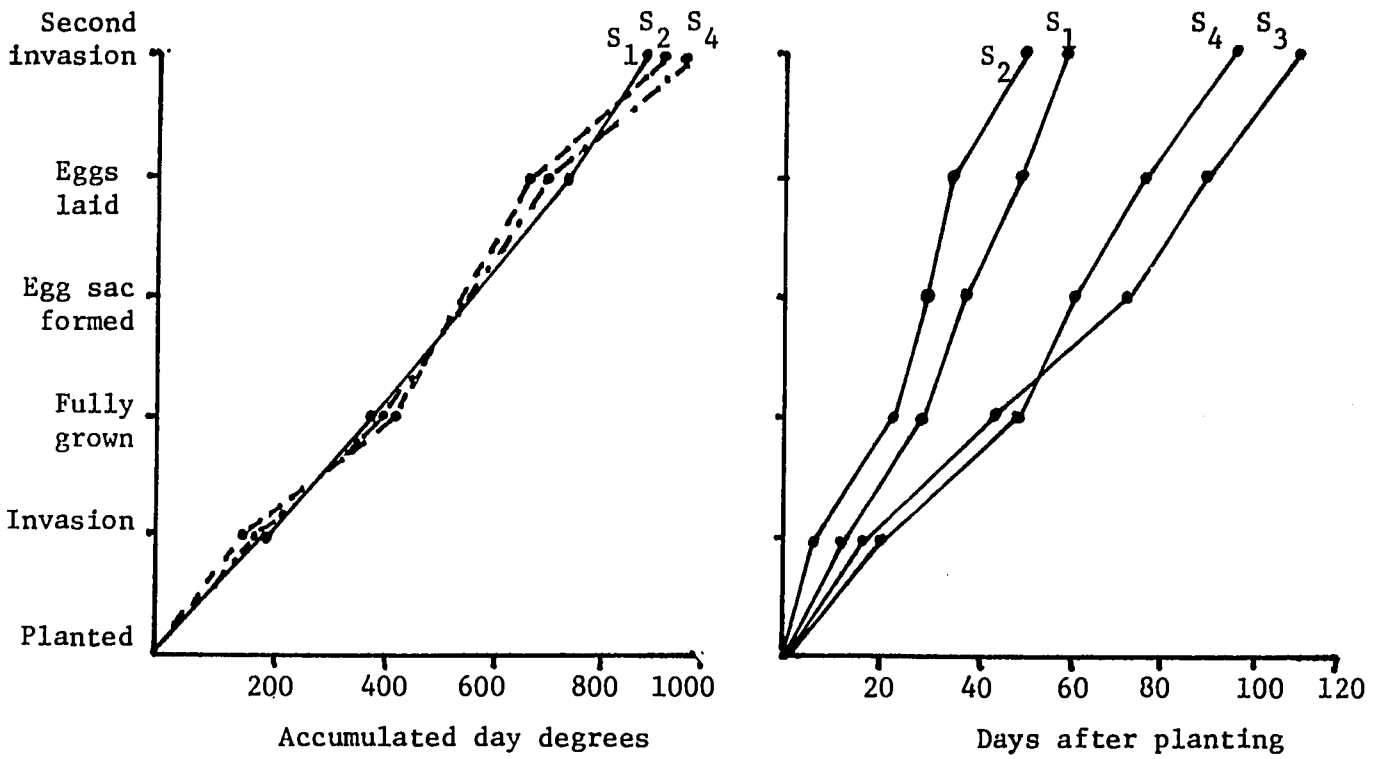


Fig. 3. Relationship between accumulated temperature and time after planting at different developmental stages.



2 to 3 generations per a 5-month growing season at Deftera, depending on the time of planting. When crops are planted in early March, the nematode completes a second and partial third generation, whereas when crops are planted from mid-April to the end of May, the nematode completes three generations and a partial fourth (Fig. 4). However, if tomatoes are left to grow a few more weeks, then the nematode would be able to complete three to four generations depending mainly on the time of planting.

Acknowledgements

The assistance of the International *Meloidogyne* Project (IMP) have made this work possible. Thanks are also due to Mrs. A. Papasolomontos and Mr. A. Petrides for laboratory work.

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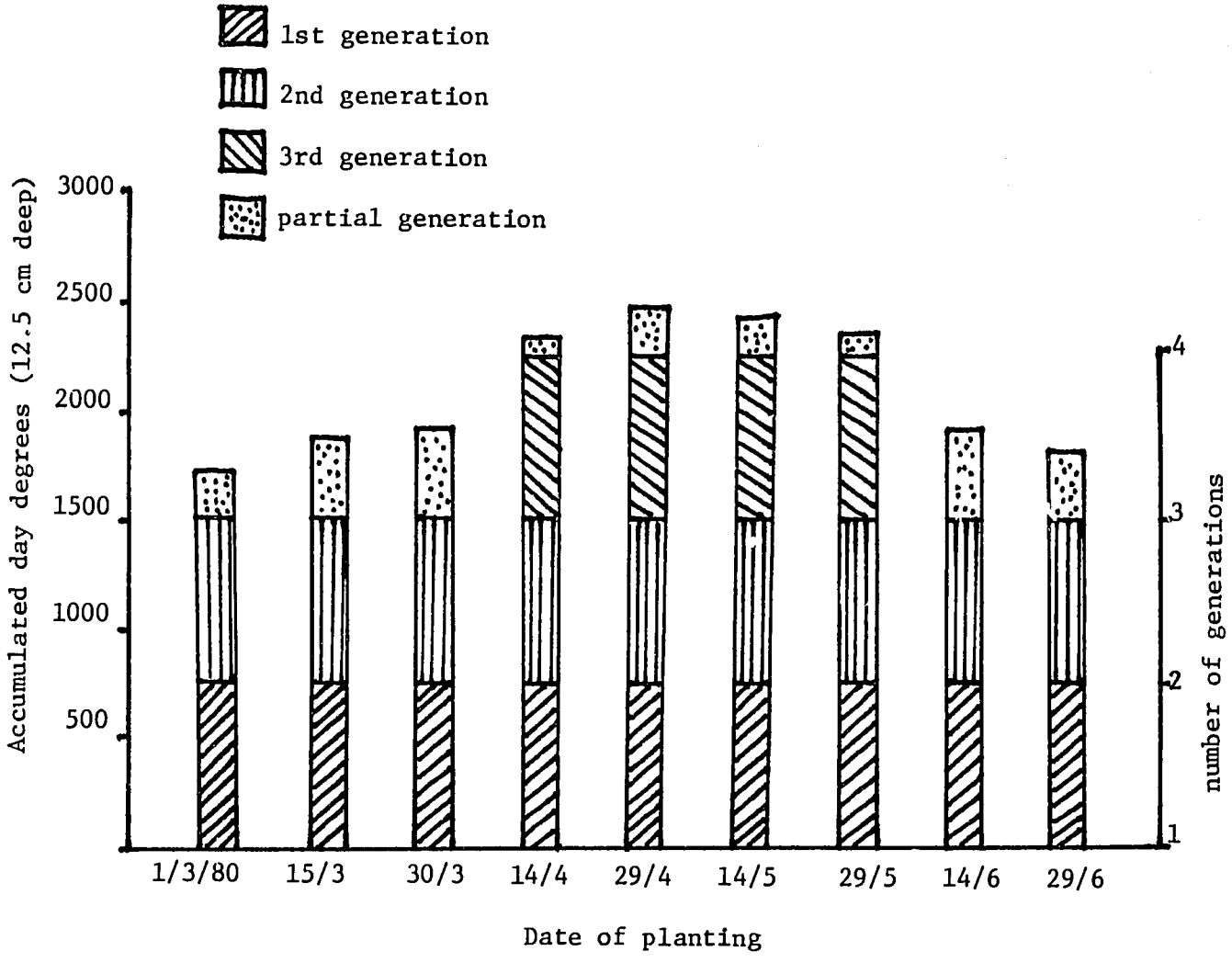
Fig. 4. Effect of planting date on the number of generation of Meloidogyne javanica, on tomato, based on accumulated heat units, above basal development, for a 5-month growing period (Deftera, 1980).



RESEARCH ON ROOT-KNOT NEMATODES IN ITALY

Mauro Di Vito and Nicola Greco*

In Italy, Meloidogyne spp. (root-knot nematodes) cause damage to many crops, especially annual plants (2). For predicting yield losses and suggesting control measures, information is needed on the relationship between nematode population densities and the damage they cause to plants.

Breeding for resistance to Meloidogyne spp. may provide effective and profitable control of these pests. However, populations of root-knot nematodes can differ in their pathogenicity. Therefore, research has been done to provide more information on the relationship existing between population densities of M. incognita (Kofoid and White) Chitwood race 1 and yield of tomato, sugarbeet, and pepper. Also the identification of Meloidogyne spp. races, which occur in Italy, and a plant breeding program have been pursued to introduce resistance to root-knot nematode in cultivars of tomato and pepper.

Relationship Between Population Densities and Yield Losses

Experiments were done in 1980 with tomato 'Chico III' and sugarbeet 'Kawemono,' and in 1981 with pepper 'Yolo Wonder,' using microplots made of concrete pipe (30 x 30 cm in cross section and 50 cm deep) and population densities of 0, 0.125, 0.25, 0.50, 1, 2, ... 256 eggs and juveniles/ml soil. By fitting the data with the equation $y = m + (1 - m)\, z^{P - T}$ proposed by Seinhorst (5), tolerance limits for tomato, sugarbeet and pepper to the nematode were calculated to be 4, 1.1 and 2.2 eggs and juveniles/ml soil, and minimum yields to be 0, 10% and 58%. These differences may be related to the host specificity and cropping practices. Tomato for industry purposes and sugarbeet, as usually done in Italy, were seeded, but pepper was transplanted when seedlings were

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two months old. According to Seinhorst (6), this may have led to a higher minimum yield for pepper with respect to the other crops. Poor quality tomato fruits were obtained from the microplots with large population densities but no differences were found in the average weights of single pepper fruits at all population densities. Tomato and sugarbeet appeared to be more susceptible than pepper to the race 1 of M. incognita. The relationship existing between population densities of M. incognita race 1 and the yields of tomato have also been tested in clay pots in the greenhouse at 24-27° C. A range of population densities up to 512 eggs and juveniles/ml soil were used to compare the varieties 'Roma VF' susceptible with 'Ias-1' resistant to the nematode. Both varieties were affected by the nematode, especially after transplanting the seedlings, but larger weights of aerial parts were obtained with 'Ias-1' than with 'Roma VF,' and large differences were also observed in the tolerance limits to the nematode and in the minimum yields of the tomato cultivar. The tolerance limits were 3.3 and 14.3 eggs and juveniles/ml soil, and minimum yields were 0 and 75% for 'Roma VF' and 'Ias-1' respectively. Later, symptoms of nematode attack were observed on 'Ias-1' but only at population densities larger than 128 eggs and juveniles/ml soil, which are unusual in field conditions. The nematode had maximum reproductive rates of 473 on 'Roma VF' and only 3.5 on 'Ias-1.'

In the microplots the population of the nematode rapidly declined after harvest (4), but remained quite constant from December to March. This finding suggests that soil samples should be collected and processed, immediately after harvest if information on the reproduction of the nematode is required, and prior to planting if information on the population density is required to predict yield losses or to give guidance for the management and control of this pest.

Races of Meloidogyne spp. Found in Italy

Investigations have been carried out during the last five years to identify races of Meloidogyne spp. according to the differential host test (7). Fourteen populations of M. incognita, six of M. javanica

(Treub) Chitwood, three of M. hapla Chitwood, and one of M. arenaria (Neal) Chitwood, from different areas of Italy, have been tested in the greenhouse. Only populations of race 1 and race 2 of M. incognita have been found (Table 1), the latter being the most widespread. Four populations of M. javanica reproduced on tomato, watermelon and tobacco, but two populations from Sicily and Calabria region reproduced on pepper and they may be a new race (2). Among the M. hapla populations, two reproduced on tomato, pepper, peanut and tobacco, while a third, from sugarbeet in Apulia, behaved differently reproducing only on tomato, watermelon and pepper and not on tobacco and peanut. A population of M. arenaria from a peach orchard near Verona was determined to be race 2 since it reproduced on tobacco, watermelon and tomato.

Breeding for Resistance to Root-Knot Nematode

Since 1976, a breeding program has been in progress at our Institute to introduce genetic resistance to M. incognita, M. javanica and M. arenaria in tomato cultivars for peeled tomato and tomato paste and in pepper. F_5 and F_7 lines of tomato have been obtained by selecting progenies of crosses and back-crosses of the cultivars 'Rossol' and 'Piersol,' both resistant to Italian populations of the above nematodes (1), with the susceptible cultivars 'Chico III,' 'Roma VF,' 'High Peel,' 'UC 105J,' 'Sorrento,' and 'Vesuvio.'

F_4 and F_6 lines of pepper have been selected from progenies of crosses and back-crosses of a Meloidogyne spp.-resistant Capsicum frutescens L. plant introduction (2), with the Italian pepper cultivars 'Corno di toro rosso,' 'Corno di toro giallo,' and 'Quadrato di Asti,' all of which are susceptible.

Conclusions

Many crops, other than those reported herein, are damaged by root-knot nematodes, therefore further investigations are in progress to assess the relationship between population densities of M. incognita and the yield of tobacco and cantaloupe. The examination of other crops and more Meloidogyne spp. populations is planned to achieve

Table 1. Races of *Meloidogyne* spp. found in Italy according to the differential host test

Meloidogyne spp. and races	Number of populations	Differential host plant					
		Tobacco 'NC 95'	Cotton 'Deltapine 16'	Pepper 'California Wonder'	Watermelon 'Charleston Grey'	Peanut 'Florunner'	Tomato 'Rutgers'
M. incognita							
Race 1	6	-	-	+	+	-	+
Race 2	8	+	-	+	+	-	+
M. javanica							
Race 1	4	+	-	-	+	-	+
Race 2	2	+	-	+	+	-	+
M. hapla							
Race 1	2	+	-	+	-	+	+
Race ?	1	-	-	+	+	-	+
M. arenaria							
Race 2	1	+	-	-	+	-	+

further information on the races which occur in Italy. The breeding program will continue, and it is anticipated that further cultivars of tomato and pepper, having good marketable characteristics and resistance to root-knot nematodes, will be obtained from the present breeding lines.

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

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IMPORTANCE

Root-knot nematodes have been known to occur in the Jordan Valley since the mid-1950's. Vegetable crops and banana trees grown under irrigation exhibited the characteristic symptoms of the nematode, but because the magnitude of the problem was not apparent, large additional virgin lands were put to irrigated farming (1). With the establishment of the East Ghor Canal irrigation project in the early 1960's and subsequent extensions, additional lands were progressively placed under irrigation. As a result, the nematode rapidly spread. The farmers were unaware of the identity and nature of the disease causal agent. At present, almost all of the irrigated lands, whether in the Jordan Valley or in the elevated highlands, have become infested with root-knot nematodes, and the problem is one of national dimensions. In some field experiments (2), the use of chemical nematicides has increased tomato yield by approximately 200%.

In 1970, Abu-Gharbieh and Hammou (6) processed over 500 soil and root samples from 45 crop species from the various districts of Jordan. About one-fourth of these samples harboured root-knot nematodes. Under rainfed conditions, however, the root-knot nematodes fail to get established (1).

Many samples were tested for species identification. Through morphological examinations and use of Sasser's "Differential Host Test," it was shown that two species of *Meloidogyne* occur in Jordan, namely *M. javanica* and *M. incognita*. The presence of at least one race of *M. incognita*--Race 1--was confirmed (3). In a recent study (4), it was shown that the distribution of *M. javanica* and *M. incognita* on vegetable crops followed a pattern by which the former

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predominates in the southern Jordan Valley while the latter predominates in the irrigated highlands. Both species occur in the intermediate regions. When the distribution of both species was related to air and soil temperatures, it was evident that M. javanica had an optimum temperature 4-5° C higher than that of M. incognita.

RESEARCH PROGRAMS UNDERWAY

Within the framework of testing all possible chemical, cultural and biological means of root-knot nematode control, and for the ultimate objective of integration of useful management practices, the following investigations were carried out in the 1981-1982 season in the Central Jordan Valley.

Field Testing of Tomato Cultivars (Table 1)

In a previous screening test (7), over 100 tomato cultivars were examined under greenhouse conditions for resistance to M. incognita and M. javanica. Fourteen cultivars exhibited a good level of resistance to one or both species. Ten of these cultivars were planted in a field heavily infested with M. javanica in the Jordan Valley. Among the tested cultivars, 'Maramand Trianon VFN' and 'Marette' had been reported to be susceptible to M. javanica but actually exhibited high resistance to M. incognita. The other cultivars ('Mont favet 75-26 Inra,' 'Mistral,' 'Engeria VFN,' 'Piersol Inra VFN,' 'Planter VFN,' 'VFN 8,' 'Calmart' and 'Nemasol') varied from resistant to highly resistant to M. javanica. The standard cultivar, 'Claudia Raf,' which is sensitive to the nematode, was used for comparison.

Preliminary results have indicated that the standard cultivar 'Claudia Raf' was heavily galled and high numbers of second-stage juveniles were found in the soil. 'Maramand Trianon VFN' and 'Marette' were susceptible, but only a moderate rate of reproduction resulted. The other eight cultivars varied from moderately to highly resistant. In terms of productivity, 'Mont favet 75-26 Inra' was by far the highest yielder, followed by 'Trianon.' Those two cultivars also showed some apparently significant tolerance

Table 1. Field testing[1] of certain tomato cultivars in a *Meloidogyne javanica* infested soil

Cultivar	Yield ton/ha.	Av. foliage wt. gm/plant	Av. root wt. gm/plant	Galling index[2]	No. 2nd stage juveniles[3]
Maramand Trianon VFN	36.9 b	200.4 b	29.4 a	2.3 abc	651 b
Marette	25.9 c	155.0 b	34.2 a	3.2 ab	740 b
Mont favet 75-26 Inra	53.7 a	505.5 ab	27.4 a	2.0 bcd	28 b
Mistiral FN	3.9 d	211.4 b	26.3 a	0.7 de	0.0 b
Energia VFN	5.8 d	983.3 a	48.5 a	0.0 e	35 b
Piersol Inra VFN	4.4 d	414.9 ab	32.2 a	1.2 cde	40 b
Planter VFN	8.9 d	279.4 b	30.8 a	2.4 abc	28 b
VFN 8	7.3 d	628.3 ab	63.1 a	0.7 de	0.0 b
Calmart	4.8 d	193.3 b	29.7 a	1.8 bcd	56 b
Nemasol	4.4 d	516.7 ab	33.5 a	0.0 e	23 b
Claudia Raf	23.1 c	356.7 b	67.8 a	3.7 a	3563 a

(1) Data taken at termination time; average of three replicates.

(2) Root-knot nematode galling index: 0 = no galling, 5 = maximum galling.

(3) Number of juveniles per 100 ml soil.

to the tomato yellow leaf curl virus as compared to the other cultivars. All other nematode-resistant tomato cultivars produced poorly.

Vydate for Control of M. javanica on Tomato (Table 2)

Fall tomato plots of the cultivar 'Claudia Raf' were sprayed with Vydate (2000 ppm a.i.) once, twice, three and four times. Treatments were made at two-week intervals, except for the fourth spraying which was made in the spring, 4 months after the third spraying. All tomato plots (10 m long each) were covered for two months with muslin tunnels. Such tunnels were intended to protect plants from reach of the white fly which is the vector of the tomato yellow leaf curl virus.

Mid-season results have shown that the roots of the nontreated control plants were heavily galled, whereas galling decreased with every additional spraying. However, such differences became less apparent at the end of the season when roots of plants in all treatments were found to be heavily galled. Possibly the Vydate concentration was not high enough. No significant differences in yield were observed among treatments. Although tomato plants were heavily infected with the nematode, productivity was satisfactory (around 40 tons/ha). Results of this experiment provide additional evidence that plants growing under more favorable conditions (= less stresses) are more adequately able to overcome the ill-effects of the nematode. Drip irrigation, black plastic mulching, protection from all foliage pests and diseases, and the use of a muslin cover have contributed to good plant growth and high yields. It is believed that the use of muslin cover during the hot summer favorably reduced solar rays.

Influence of Animal Manuring and Clear Plastic Mulching on Eggplant (Table 3)

Vegetable growers in the Jordan Valley usually apply various types of animal manure. Five kg of cow, sheep, poultry or human manure were incorporated in 10 x 1 m soil strips. The soil was brought to seedbed condition and covered with a clear plastic mulch for a month. A plastic-cover-alone treatment and a

Table 2. Vydate for control of *Meloidogyne javanica* on tomato[1]

Treatments[2]	Av. yield ton/ha.	Wt. foliage g/plant	Wt. roots g/plant	Galling index[3] (0-5)
Control	41.6 a	372 a	83 a	4.54 a
One spraying	34.3 a	380 a	48 b	4.38 a
Two sprayings	47.3 a	395 a	59 b	4.10 a
Three sprayings	44.1 a	393 a	53 b	3.98 a
Four sprayings	35.6 a	260 a	44 b	3.65 a

(1) All data were taken at termination time; average of four replications.

(2) All Vydate sprayings were at the rate of 2 g. a.i. oxamyl/L.

(3) Root-knot nematode galling index: 0 = no galling, 5 = maximum galling.

Table 3. Influence of animal manuring and clear plastic mulching on eggplant[1]

Treatments	Av. yield ton/ha.	Wt. foliage g/plant	Wt. of root g/plant	Galling index[2] (0-5)
Manuring with plastic cover:				
Poultry	18.0 a	5150 a	693 a	3.2 a
Cow	10.6 b	5000 a	676 a	3.9 a
Human	7.8 c	3575 b	428 b	3.3 a
Sheep	10.0 b	5375 a	651 a	4.1 a
Control (no manure)	9.3 bc	4300 a	579 a	3.0 a
Control (no plastic cover, no manure)	6.5 c	2775 b	369 b	2.5 a

[1] Data taken at termination time; average of four replicates.

[2] Root-knot nematode galling index: 0 = no galling, 5 = maximum galling.

nonmanured-nonmulched control treatment were also added. Plots were planted to eggplant cultivar 'Black Beauty.'

The results showed a soil temperature increase (at 20 cm depth) of 2 and 1° C above the plastic-mulch-alone control treatment when the poultry and human manures were used, respectively. Conversely, the cow and sheep manures (which were relatively fresh when applied) reduced soil temperature by 2 and 1° C below the plastic-alone control treatment, respectively. The plastic-alone treatment increased soil temperature by an average of 5-6° C over the nonmulched-nonmanured control.

No significant differences were found among treatments in the indices of root galling. However, indications exist that animal manuring increased root galling. Attempts to isolate nematophagous fungi from the soil were not successful. Yield results clearly indicated that poultry manure was superior to all other types.

RESEARCH COMPLETED AS COOPERATOR IN IMP

Testing germplasm for resistance to the various root-knot nematode species and races in Jordan constitutes one of the major objectives of the current research program (5, 7). Resistant cultivar evaluation involves glasshouse and field assessment on vegetable and field crop cultivars grown in Jordan; vegetable and field crops that proved resistant or tolerant to the root-knot nematodes, elsewhere; and new resistant crops that might be suitable for the area.

The present screening studies involved cultivars, lines or entries of the following crop plants or weed species:

I. Cucurbits:

Cucumber, *Cucumis sativus* L.	18
Sweet melon, *Cucumis melo* var. *reticulata*	16
Squash, *Cucurbita pepo* L.	5
Watermelon, *Citrullus lanatus* L.	7

II. Solanaceous crops:

Eggplant, *Solanum melongena* L.	6
Hot pepper, *Capsicum frutescens* L.	4

Sweet pepper, Capsicum grossum L. 6
Tomato, Lycopersicon esculentum Mill. 63
III. Broadbean, Vicia faba var. megalosperma 59
IV. Weeds (various species). 32

Five to ten seeds of the cucurbit or solanaceous crops were planted in 10- to 12-cm diameter pots, filled with methyl bromide-fumigated soil. After nearly two weeks, seedlings were thinned to 1-2 plants per pot. Individual pots were then inoculated with 3000 eggs of either M. javanica or M. incognita. Each cultivar was replicated 5 times for the respective nematode species. Fifty-five to 70 days after inoculation, the roots were rated for galling and eggmass production, as follows: 0 = no galling, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 5 = 100 galls. Eggmass index followed the same rating system.

Broadbean cultivars were subjected to similar screening procedure, except that the germinated seeds were planted in black plastic tubes 10 cm in diameter, and the inoculum level was 7000 eggs per plant.

Screening of the weed plants involved only M. incognita, and the inoculum level was around 3600 eggs per pot.

Results of all these tests are tabulated (Tables 4-13).

FUTURE RESEARCH PLANS

Future research plans will be directed to meet the following general objectives:

1. to construct and evaluate packages of integrated management practices for root-knot nematode control in crop production based on current information.

2. to gain additional new information to update current management systems with more effective and economical practices (crop resistance, cultural practices, nematicides, etc.).

COOPERATORS

Cooperators in this research include Miss Luma Banna (Research Assistant) and Mr. Madhi Abbadi (Laboratory and Field Assistant). Dr. Barakat Abu-Irmaileh, a weed specialist, of the Plant Protection

Dept. participated in the part of screening which involved the common weeds of the Jordan Valley. Mr. M. Asad, a graduate student, also shared in the experiment on the effect of animal manuring.

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Table 4. Screening of cucumber (*Cucumis sativus* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Cultivar	*M. javanica*		*M. incognita*		Source of seeds
	Galling*	Eggmass*	Galling	Eggmass	
Amira	3.4	2.8	5.0	5.0	-
Beit Alpha	2.75	2.75	3.33	2.67	-
Beit Alpha F_1	2.0	1.5	4.5	4.0	-
Beit Alpha F_1	1.6	1.0	4.8	4.8	Vilmorin
Beit Alpha hybrid F_1 ♀	2.5	2.0	2.8	2.8	Pioneer
Beit Alpha F_1 hybrid ♀	1.0	1.0	2.6	2.6	Hurst
Beit Alpha ♀ hybrid F_1 CMR	2.0	2.0	2.4	2.4	Pilote
Beit Alpha ♀ hybrid F_1 CMV	3.0	3.0	2.2	2.0	-
Beit Alpha F_1 hybrid CMV, MMV Leila	5.0	4.8	3.75	3.5	Hurst
Beit Alpha Flora More No. 3	0.8	0.6	5.0	5.0	Hurst
Beit Alpha F_1 Zeus	1.0	1.0	2.0	1.5	Sluis + Groot
Beit Alpha Zeus	2.0	1.5	4.5	4.0	Sluis + Groot
Byblos F_1 hybrid CMV, MMV	1.8	1.6	2.67	2.33	IPB
Dama MMV, CMV	2.2	1.6	2.0	1.6	Peto Seed
Doncens hybrid F_1	1.5	1.0	2.5	2.5	Vita
Mira cross-mix F_1 hybrid CMR, MMR	0.4	0.4	2.5	2.5	Royal Sluis
Tender green M.R. 109 20-137 68	1.4	0.0	5.0	5.0	Ferrymorse
Zena hybrid F_1	2.0	2.0	2.6	2.2	Vilmorin

*Index 0-5.

-Information unavailable.

Table 5. Screening of sweet melon (*Cucumis melo* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Cultivar	*M. javanica*		*M. incognita*		Source of seeds
	Galling*	Eggmass*	Galling	Eggmass	
Amco sweet	4.8	4.4	4.33	4.33	Asgrow
Ananas	5.0	5.0	5.0	5.0	Sluis + Groot
Ananas	4.8	4.8	4.75	4.75	Niagara
Ananas	4.0	3.6	4.8	4.8	Danish
Ananas	3.75	3.0	4.8	4.8	Royal Sluis
Ananas F_1 hybrid	1.67	1.67	1.75	1.75	Hurst
Ananas hybrid F_1	4.0	3.6	4.6	4.6	-
Ananas open pollinated	3.8	3.4	4.5	4.5	Hurst
Cantaloupe Melon-Melon	3.8	3.6	4.5	4.5	-
Early sweet hybrid	3.75	2.5	4.67	4.67	Danish
F_1 hybrid	4.75	4.5	5.0	5.0	-
F_1 Rodin	5.0	5.0	4.4	4.4	Sluis + Groot
Hybrid cantaloupe	5.0	5.0	5.0	5.0	Chinese
Hybrid cantaloupe	4.0	3.67	5.0	5.0	Asgrow
Musk melon	5.0	5.0	5.0	5.0	-
Palestinian Ananas	4.0	3.33	4.6	4.6	Semillas

*Index 0-5.

-Information unavailable.

Table 6. Screening of squash (*Cucurbita pepo* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Cultivar	*M. javanica* Galling*	*M. javanica* Eggmass*	*M. incognita* Galling	*M. incognita* Eggmass	Source of seeds
Alshira'a	0.6	0.4	4.0	3.8	-
Dima F_1	1.6	0.0	4.0	3.4	Vilmorin
Ghada F_1	0.6	0.0	4.2	3.6	Royal Sluis
M Agel F_1	1.8	0.6	4.2	4.0	Vilmorin
Top Kapi	0.0	0.0	3.8	2.8	Peto Seed

Table 7. Screening of watermelon (*Citrullus lanatus* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Ali	1.0	0.75	2.8	2.8	Sluis + Groot
Chilian Black	0.6	0.4	1.8	1.8	IPB
Chilian Black	1.2	1.2	2.4	2.4	Asgrow
Crimson sweet	0.0	0.0	0.0	0.0	Keslone
Melon	4.0	3.4	2.8	2.4	Ferrymorse
Pasteque charleston	2.8	2.0	2.6	2.6	Grey
Watermelon Black	0.5	0.25	2.2	2.2	-

*Index 0-5.

-Information unavailable.

Table 8. Screening of eggplant (*Solanum melongena* L.) cultivars to the root-knot nematodes *Meloidogyne spp*.

Cultivar	*M. javanica*		*M. incognita*		Source of seeds
	Galling*	Eggmass*	Galling	Eggmass	
Black Beauty	0.5	0.0	4.0	3.67	Vita
Black Beauty	3.4	2.8	5.0	5.0	Seed export
Black Beauty	3.2	1.8	4.0	3.8	Niagara
Black Beauty	3.6	2.6	4.8	4.6	Keystone
Black Beauty	3.4	2.6	4.2	4.2	-
Melazama	3.4	2.8	4.33	4.0	Sementi

Table 9. Screening of hot pepper (*Capsicum frutescens* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Anaheim chili (California chili)	0.0	0.0	3.25	2.25	Asgrow
Anaheim M	0.0	0.0	4.0	3.6	Peto Seed
Long chili	0.0	0.0	4.0	3.5	-
Ronge long (ordinaine)	0.0	0.0	3.0	2.8	Semillas

*Index 0-5.

-Information unavailable.

Table 10. Screening of sweet pepper (*Capsicum grossum* L.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Cultivar	*M. javanica*		*M. incognita*		Source of seeds
	Galling*	Eggmass*	Galling	Eggmass	
California Yolo Wonder	0.0	0.0	0.0	0.0	Vilmorin
Florida Giant	0.0	0.0	4.0	3.0	-
Pip	0.0	0.0	1.25	0.75	Asgrow
Yolo Wonder B	0.0	0.0	4.4	4.4	Royal Sluis
Yolo Wonder L.	0.0	0.0	3.0	0.67	Peto Seed
Yolo Wonder Y	0.0	0.0	2.4	2.4	France graines

*Index 0-5.

-Information unavailable.

Table 11. Screening of tomato (*Lycopersicon esculentum* Mill.) cultivars to the root-knot nematodes *Meloidogyne* spp.

Cultivar	*M. javanica*		*M. incognita*		Source of seeds
	Galling*	Eggmass*	Galling	Eggmass	
Acorane Rf TMTD treated	1.8	1.4	4.8	4.8	Vilmorin
Beef master hybrid	1.0	1.0	3.0	3.0	Burpee
Better Boy hybrid VFN	0.2	0.2	0.0	0.0	Burpee
Burpee VF hybrid	3.2	2.6	4.2	4.2	Burpee
Burpee Big Girl hybrid	2.75	2.75	2.0	2.0	Burpee
Caribe	0.75	0.75	4.6	4.6	-
Caribe	2.5	2.5	4.2	4.2	Peto Seed
Claudia Raf	0.8	0.0	5.0	5.0	Clause
CPC 2 FR	2.0	0.0	5.0	4.67	Peto Seed
Early Pack No. 7	3.0	2.8	3.4	3.4	France graines
Early Pack No. 7	0.8	0.60	3.75	3.75	Niagara
Early Pack No. 7	1.5	0.5	4.8	4.6	-
Es 58 IPB	0.75	0.5	5.0	5.0	-
Genone	0.75	0.25	0.25	0.0	Vilmorin
Hestia	2.0	0.33	4.0	3.5	Vilmorin
Hestia	3.2	3.2	3.4	3.4	Sluis + Groot
Homestead Elite	3.0	2.0	3.8	3.6	Burpee
Homestead 61	2.2	2.0	5.0	5.0	Peto Seed
Homestead 61	1.67	1.33	4.6	4.6	Royal Sluis
Homestead No. 61	3.0	2.8	2.33	2.33	Burpee

Table 11. (continued)

Cultivar	*M. javanica* Galling*	*M. javanica* Eggmass*	*M. incognita* Galling	*M. incognita* Eggmass	Source of seeds
Homestead No. 500	2.75	2.5	2.33	2.0	Burpee
Homestead 500	2.8	2.8	3.6	3.6	Peto Seed
J 81	2.2	1.8	2.5	2.5	Ferry Morse
Mand Raf	2.0	1.25	3.6	3.6	Sluis + Groot
Maramande	3.2	3.0	4.5	4.5	Pionnier
Maramande Extra Fusarium resistance	3.4	3.2	3.8	3.8	Danish
Maramande FR	2.6	1.4	4.8	4.8	Hurst
Maramande RF	1.4	0.8	4.2	4.2	Vilmorin
Maramande RF	2.75	2.5	4.8	4.8	Abondonce
Maramande VF	2.0	0.0	4.5	4.0	-
Maramande VR	2.0	1.0	4.4	4.4	Royal Sluis
Maramande VF	1.0	0.4	4.75	4.75	Vilmorin
Marsol	1.6	0.8	1.2	1.2	Graines & Tezier
Marglobe	2.25	2.0	3.4	3.4	Bondan
Midi	1.5	1.0	4.8	4.8	Asgrow
Mini Maramande	0.0	0.0	5.0	5.0	Hurst
Mini Maramande	0.75	0.75	4.8	4.8	Hurst
Nemasan	0.0	0.0	0.75	0.5	France Graines
Nemasol	0.2	0.2	0.6	0.6	Vilmorin
Packmor VF	0.0	0.0	4.5	4.0	-
Packmor VF	2.0	1.5	3.2	3.0	Semences
Piersol	0.0	0.0	0.0	0.0	Pilote

Table 11. (continued)

Cultivar	*M. javanica* Galling*	*M. javanica* Eggmass*	*M. incognita* Galling	*M. incognita* Eggmass	Source of seeds
Piersol Inra	0.0	0.0	3.0	3.0	Graines & Tezier
Piersol Inra VFN	0.2	0.0	0.4	0.4	Graines & Tezier
Piersol VFN	1.0	1.0	1.4	1.0	-
Pearson	3.25	2.25	4.5	4.0	Vilmorin
Pearson ET	3.0	2.75	4.8	4.8	Sluis & Groot
Pearson F_1	2.5	1.75	4.4	3.4	-
Pearson RVF	1.5	1.5	4.0	4.0	Vilmorin
Pomodoro ES-58	2.0	1.67	3.0	3.0	Peto Seed
Tomate Pomodoro Tomato Packmor	0.67	0.33	4.0	4.0	Peto Seed
Robust	1.0	0.0	4.4	4.2	Clause
Saint Pierre	2.0	2.75	3.0	3.0	France Graines
Saint Pierre	1.75	0.6	4.67	4.33	Royal Sluis
Select FR	4.0	3.0	4.5	4.0	Hurst
Silka	2.5	2.5	5.0	5.0	Clause
Special Back	1.5	0.0	4.67	4.67	Asgrow
Special Bonus VF	1.0	0.67	4.8	4.8	-
Springse VF hybrid	0.0	0.0	2.5	2.5	Peto Seed
Super Maramde	2.0	2.0	5.0	5.0	Vilmorin
Tropic	1.0	0.67	3.75	3.75	Peto Seed
VDB Furry (Fusarium resistance)	2.4	2.2	4.8	4.8	VDB Holland
671 BVF	3.5	1.75	3.4	2.4	Peto Seed

*Index 0-5.

-Information unavailable.

Table 12. Response of broadbean cultivars to *Meloidogyne* species

Broadbean Cultivars	*M. javanica*		*M. incognita*	
	Galling	Eggmass	Galling	Eggmass
ILB-Local check	0.8	0.0	0.0	0.0
ILB 5 Jordan	0.6	0.0	1.0	0.0
ILB 9 Jordan	0.0	0.0	0.2	0.0
ILB 16 Syria	0.25	0.0	0.0	0.0
ILB 22 Syria	2.3	0.0	1.8	0.0
ILB 29 Iran	0.75	0.0	1.8	0.0
ILB 30 Iraq	1.8	0.0	1.0	0.0
ILB 31 Iraq	0.8	0.0	1.0	0.0
ILB 33 Iraq	1.4	0.0	0.0	0.0
ILB 37 Iraq	2.0	0.0	0.33	0.0
ILB 121 Eth	1.5	0.0	0.6	0.0
ILB 139 Moroc	1.2	0.0	2.0	0.0
ILB 143 Moroc	1.0	0.0	2.0	0.0
ILB 207 Turkey 75 TA 2633	0.5	0.0	0.7	0.0
ILB 207 Turkey 785 53228	1.7	0.0	0.3	0.0
ILB 269 Spain	2.0	0.0	1.0	0.0
ILB 276 Leban	0.7	0.0	1.3	0.0
ILB 277 Leban	0.75	0.0	1.0	0.0
ILB 281 Leban	1.25	0.0	2.5	0.0
ILB 285 Leban	1.0	0.0	1.0	0.0
ILB 286 Leban	1.2	0.0	0.8	0.0
ILB 287 Leban	0.75	0.0	1.3	0.0
ILB 287 Leban 77 ms 88324	2.5	0.0	0.3	0.0
ILB 295 Urug	1.5	0.0	0.25	0.0
ILB 308 Spain	0.4	0.0	1.5	0.0
ILB 317 U.K	1.4	0.0	1.5	0.0
ILB 317 U.K. 785 48603	0.0	0.0	1.0	0.0
ILB 320 Japan	1.4	0.0	1.0	0.0
ILB 322 Japan	1.6	0.0	1.3	0.0
ILB 328 China	0.0	0.0	0.7	0.0

Table 12. (continued)

Broadbean Cultivars	*M. javanica*		*M. incognita*	
	Galling	Eggmass	Galling	Eggmass
ILB 336 Swed	0.6	0.0	0.0	0.0
ILB 339 Egypt 785 48504	1.6	0.0	0.4	0.0
ILB 356 Egypt 77 ms 88165	1.2	0.0	0.0	0.0
ILB 360 Egypt	2.5	0.0	0.3	0.0
ILB 363 Egypt	1.5	0.25	1.8	0.0
ILB 407 Tunis	2.25	0.0	0.25	0.0
ILB 421 Iran	1.8	0.0	1.4	0.0
ILB 905 Egypt	0.0	0.0	2.7	0.0
ILB 1105 Turkey	1.2	0.0	1.2	0.0
ILB 1260 Spain	0.2	0.0	1.2	0.0
ILB 1270 U.K.	1.2	0.0	0.2	0.0
ILB 1814	0.75	0.0	1.0	0.0
ILB 1816 Leban	2.25	0.0	1.0	0.0
ILB 1817 Leban	0.4	0.0	1.25	0.0
ILB 1817 Leban 785 49893	0.25	0.0	2.0	0.0
ILB 1817 Leban Lebanese large 795 33024 (FL..80-4 x 75 TA4)	2.7	0.0	4.7	0.0
ILB 1819	1.6	0.0	2.0	0.0
ILB 1819 Egypt	1.5	0.0	0.4	0.0
ILB 79L 10826 (F..80-6) x 75 TA26	4.7	0.0	0.75	0.0
ILB 79-10873 (FL..80-7) x 75 TA 35	2.5	0.0	2.7	0.0
ILB 785-330 5 (FL. 80-2) x 75 TA 4	0.6	0.0	1.0	0.0
ILB 795-76764 (F..80-13) x 77TA48	3.5	0.0	2.0	0.0
ILB 795-77058 (FL..80-12) x 77 5D 11	2.25	0.0	2.4	0.0
ILB 795-7863 (FL..80-8) x 75 TA 146	1.6	0.0	2.0	0.0
ILB 795-77914 (FL..80-3) x 75 TA 4	4.0	0.0	1.0	0.0
ILB 795 79068 (F..5) x 75 TA 14	2.75	0.0	1.0	0.0
ILB 795-8264 (FL..88-9) x 75 TA 146	1.0	0.0	3.0	0.0
ILB 795-78978 (FL..80-11) x 75 TA 146	2.2	0.0	3.25	0.0
ILB 795 78978 (FL..80-10) x 75 TA 146	3.75	0.0	2.0	0.0

Index: 0 = no galling or eggmass production.
5 = maximum galling or eggmass production.

Table 13. Response of weed plants to *Meloidogyne incognita*

Weeds	Galling*	Eggmass*
Amaranthus gracilis Desf.	2.0	1.75
Amaranthus retroflexus L.	1.8	1.8
Anthemis palestina Reut	3.0	2.6
Calendula arvensis L.	0.6	0.0
Chenopodium album L.	4.2	4.2
Chrysanthemum coronarium L.	1.25	1.0
Datura metel L.	2.6	2.6
Daucus carota L.	3.2	3.2
Diplotaxis erucoides (L.) DC.	2.6	2.6
Echium judaeum Lacaita.	1.25	1.0
Emex spinosus (L.) Campd.	1.0	1.0
Eruca sativa Mill	0.4	0.0
Hippocrepis unisiliquosa L.	3.75	3.75
Lactuca serriolo L.	3.0	2.8
Medicago litoralis Rohde	0.0	0.0
Melilotus indica (L.) All.	2.8	2.8
Notobasis syriaca (L.) Cass.	3.8	3.8
Octhodium aegyptiacum (L.) DC.	2.6	2.6
Onobrychis crista-galli (L.) Lam.	5.0	5.0
Peganum harmala L.	5.0	5.0
Polygonum sp	2.75	2.75
Raphanus sp	1.2	1.2
Rhodolphia segetum (L.) Moris	4.3	4.3
Rumex dentatus L.	3.8	3.8
Setoria viridis (L.) Beauv.	3.8	3.6
Silene sp.	5.0	5.0
Sinapis alba L.	2.0	2.0
Sisymbrium irio L.	4.2	4.2
Solanum nigrum L.	4.3	4.3
Sonchus oleraceus L.	0.0	0.0
Texiera glastifolia Jaub. et sp.	4.0	4.0
Vicia peregrina L.	5.0	5.0

*Index: 0 = no galling or eggmass production, 5 = maximum galling or eggmass production.

THE INTERNATIONAL MELOIDOGYNE PROJECT ACTIVITY IN EGYPT

M. F. M. Eissa*

THE IMPORTANCE OF THE ROOT-KNOT NEMATODES

History of Nematology in Egypt

Preyer in 1901 described a nematode disease of banana near Alexandria, Egypt, which caused root-galls. Thirty years later Fahmy, Fikry, Melchers and Doss of the plant protection administration, Ministry of Agriculture (MOA), reported the root-knot nematodes on several hosts.

Present Status and Crop Losses Estimates

Active nematological work started in Egypt after Oteifa returned from the USA (1953). His trilateral activity in MOA, The National Research Centre (NRC), and teaching load in the Faculty of Agriculture, Cairo University, constructed a solid base of nematologists serving Egypt and neighboring Arab countries. Oteifa estimated the horticultural crop losses due to nematode parasitism as E.L. 2,-Millions in 1965, which is, according to the common inflation ratios, almost E.L. 20,-Millions in 1982. The Nematology Research Centre of Cairo University has been operating for 15 years, providing research objectives for undergraduate and post-graduate students and running academic and applied research. Several manuscripts of M.Sc's and Ph.D.'s Theses in Nematology have been granted until now.

The major widespread species of the root-knot nematodes in Egypt, *Meloidogyne javanica* and *M. incognita*, have been studied mainly on horticultural crops. *M. hapla* and *M. arenaria* are also present in lower proportions.

On a continental base, 24.87% of the total abstracted articles (141 from 567 articles) in the 1968 publication "Plant Nematology In Africa South of The Sahara" by P. R. Thomas and C. E. Taylor deal with the root-knot nematodes.

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Losses due to the root-knot nematodes in Egypt measured 25% of the total estimated losses due to plant-parasitic nematodes, that is, almost E.L. 5,-Millions in 1982.

RESEARCH PROGRAM UNDERWAY

Extension Type of Research

Partial soil sterilization for rice nurseries to increase rice production in Dakahlia, Egypt, is underway. An experimental area of about 2000 acres is supervised by NRC and MOA.

Partial soil sterilization in newly reclaimed sandy soil for nematode control and increased peanut productivity is also being conducted. The experimental area of about 400 acres is supervised by NRC and MOA.

Egypt-California Agricultural Developmental Systems (ADS), Horticulture Sub-Project

Contribution of nematologists in ADS-Horticulture sub-project. Seven nematologists are contributing with the ADS-Hort. sub-project under Professor Oteifa, the ADS and MOA consultant. The writer is assisting the Hort. Co-Director, Professor M. El-Sherief, who is engaged presently in controlling the *Zeuzera* borers by insect-parasitic nematodes; Professor A. H. Taha and Dr. G. Yousef are working under garlic and citrus activities, respectively. Drs. A. Kheir and A. S. Ghorab were partially engaged in grape and mango activities, respectively.

Tomato activity. Professor A. A. Hasan, Hort. Dept., Fac. Agric., Cairo University, is supervising the tomato breeding program which covers several objectives including the root-knot nematode resistance.

Studies conducted: Screening a world-wide collection of the root-knot nematode resistant tomato cultivars for resistance to the root-knot nematode species and strains present under field conditions in Egypt.

Current research: Transfer of root-knot nematode resistance in to the most promising, high-yielding tomato cultivars in Egypt by the back-cross method of breeding.

Zeuzera borer sub-activity. Control of *Zeuzera* borers using nematodes which parasitize insects was successful in Egypt. Professor

Moustafa El-Sherief, Nematologist, Fac. Agric., Cairo Univ., reported up to 75% control of this pest by using this new biological technique through the activities of olives and deciduous fruits, under Hort. sub-project, ADS. Despite the success of Neoaplectana carpocapsae in controlling the present Zeuzera borers, an introduced Heterorhabditis sp. will be tested in the next season as reports confirm its good results under sub-tropic and arid conditions.

Current Nematode Control Procedures in Egypt

Sheraki (fallow). Natural fallow practice was followed during the Nile-flood era. Several reports revealed the efficacy of "Sheraki" practice in increasing crop yield. Presently, fallow is prohibited in our agricultural land by law to fulfill our increasing food-insufficiency-gap.

Crop rotation. Since dawn of history, this crop rotation was practiced in Egypt by the obligatory alternating Nile-flood and fallow. After construction of several dams to control the Nile water, regulations by MOA were practiced to organize our export of the national main crops (early in the 20th century). Until now, crop rotation has been valid for the field crops only, while horticultural crops are not under governmental rotation regulations.

Organic manure. This practice has been followed even until now in specific areas of Egypt under specific crops. Traditional plantings of cucurbits in Egypt, the ditch planting system in Abbasa area, the tomato cultivation system in Edco and Rashid, and classical planting of nurseries for horticultural crops utilize a natural system. Organic acids which act as nematicides, nematophagous fungi and nematovorus organisms are present in high density in the organic manure used on these crops, and therefore, satisfactory yield production results.

Use of nematicides. In the last decade, 900 tons of commercial nematicides were imported and used in Egypt at an average of 90 tons annually. The total use of pesticides in Egypt for 1981 was 9200 tons; i.e., nematicidal use represents less than 1% of the present pesticide use. All the new plant material introductions (date-palm, grapes, deciduous fruits, olives, etc.) were planted in partially

sterilized soil (mainly MB fumigation). In Egypt, the newly reclaimed sandy soils are generally planted with horticultural crops to compensate the high reclamation costs; therefore, the amount of nematicides needed during the next decades can be expected to multiply successively.

RESULTS OF OUR RESEARCH COMPLETED AS COOPERATOR IN THE IMP

Eissa and Hyder recorded both M. javanica and M. incognita race 2 on each of the range crops Atriplex semibaccata and A. muelleri.

Eissa and others reported that soil application of nematicides increases wheat, rice, maize, bean, date-palm, citrus and potato yields.

To compare nematicidal chemicals, a new criterion, known as the "Nematistatic Index," was established. This index is defined as the percentage of the rate of nematode population increase in treated soil over the rate of nematode population increase in untreated soil.

The pathogenicity of M. javanica to early growth of squash is such that the threshold level for M. javanica is one larva/500 ml soil.

The root-knot nematode species and races in four locations of the Kingdom of Saudi Arabia were identified and the susceptibility of 46 grapevine cultivars from the Saudi, Lebanese and Iraki cultivars to M. javanica was investigated. The commercial tomato cultivars available on the Saudi market were also tested against M. javanica.

Weeds of the eastern Nile-Delta were classified for their susceptibility to M. javanica which causes damage to the susceptible weed tissues.

Nematicidal trials were conducted to improve date-palm and vegetable production in Saudi Arabia and Egypt. Nematicide consumption in Saudi agriculture reached 500 tons in 1981/82, while it was 100, 80, 60 tons in 1980/81, 1979/80, and 1978/79, respectively.

FUTURE RESEARCH PLANS

1. To investigate the dominant root-knot nematode species in the remote areas and oasis of Egypt, e.g., Siwa, Farafra, Dakhla, Kharja, Baharia oasis and Saint Katherine in Sinai.

2. To continue testing the available and experimental horticultural crop cultivars against the dominant root-knot species in Egypt.

3. To collaborate with Egypt-California tomato breeding program carried out by Professor A. A. Hasan for disease resistance.

4. To collaborate with an economist (to be nominated in time) in studying the feasibility of nematicidal use in Egyptian crop production.

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SPECIES AND RACES OF ROOT-KNOT NEMATODES AND THEIR RELATIONSHIPS TO ECONOMIC HOST PLANTS IN NORTHERN EGYPT

I. K. A. Ibrahim*

INTRODUCTION

Egypt is one of the African countries that has a relatively large population (approximately 44 million) and a very limited area of agricultural land, about 6 million feddans (feddan = 4200 m^2).

It has been observed that the agricultural production in certain fields of northern Egypt has decreased in the last few years. One of the possible causes of this reduction could be due to soil infestation by root-knot nematodes (RKN), Meloidogyne spp. A clear example of this problem is in Rosetta county, Behera governorate, which has a light sandy soil and a heavy infestation of RKN. Crops grown in this area are mainly vegetables (tomato, eggplant, squash, watermelon, etc.), but due to the RKN problem the production has decreased 30-50%. Other examples are areas of Tahreer province and Sharikia governorate. In both localities, peanut and other legume production is the most important activity. The attack of RKN on these legume crops causes great economic losses. Nematode infestation to the grown plants is responsible for poor growth, low yields, and low quality of the produced crops; consequently, the commercial value decreases.

The above-mentioned examples are repeatedly found in many other locations in northern Egypt where important crop plants are cultivated, and as a result of RKN infestation and attack to agricultural crops, the yield and quality are reduced and thus substantially affecting the national economy.

Accumulated results of previous survey studies have shown that RKN were of widespread occurrence and becoming a real threat to

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agriculture in certain localities of northern Egypt. The RKN species M. incognita, M. javanica and M. arenaria were found in the surveyed agrarian areas. The first two species are widely distributed while M. arenaria is of limited occurrence.

Previous results of the differential host test have shown that some populations of RKN reacted as M. incognita race 2 and race 4. However, these populations were tested by the same differential hosts at North Carolina State University and were segregated as race 1 and race 3, respectively. In light of these results and personal communication and discussion with the scientists of the International Meloidogyne Project, it has been suggested that the resistance of tobacco 'NC 95' could be broken under high temperature conditions as in the summer months of Egypt. Therefore, all RKN populations previously designated as M. incognita race 2 and race 4 will be treated as M. incognita race 1 and race 3, respectively.

Items of this research work included survey study, host range, identification of RKN, differential host test, reaction of certain plant cultivars to RKN, and control of RKN by chemical nematicides and crop rotation systems.

RESEARCH PROCEDURES AND RESULTS

Survey Study

A nematological survey on the occurrence and distribution of root-knot nematodes was run in 12 governorates (Alexandria, Behera, Dakahlia, Fayoum, Gharbia, Giza, Ismailia, Kafer El-Sheikh, Kaliobia, Matrouh, Menoufia, and Sharkia) and in Tahreer province. A total of 1600 soil and root samples were collected from the rhizosphere of suspected host plants and processed for extraction and detection of the root-knot nematodes.

Results of this survey revealed that the root-knot nematodes infested 70% of the examined samples. The most infested areas were those of Tahreer, Sharkia, Giza and Behera (Rosetta county), while the least infested ones were those of the arid Matrouh governorate. In considering the host plants, soil samples with highest nematode occurrence frequency (80-92%) were those of tomato, kenaf, okra,

watermelon, almond, eggplant and cowpea, whereas samples with least per cent of occurrence (26-33%) were those of citrus, pear, mango and cotton. The nematode density ranged between 90 larvae/100 ml of citrus soil samples to 1200 larvae/100 ml of tomato soil samples. It was observed that some soil samples of citrus contained RKN larvae while the root samples did not show gall formation. Thereon, the prevailing nematode larvae were due to the existence of weeds.

Host Range of RKN

Host range investigations included field, vegetable and horticultural crops as well as wood trees, weeds and ornamentals. Root systems of the suspected host plants were dug and examined for the detection of nematode galls, adult females and egg masses. Adult females were morphologically identified to species level.

Results of these investigations showed that about 112 plant species were recognized as hosts of the root-knot nematodes (Table 1). Out of this number, the following host plants: black mustard, casuarina, common balm, date palm, guamia, London rocket, mint, pudding-pipe tree, sowthistle, sedge, sugar beet, sugarcane, Washington palm, wheat and willow may be considered new hosts in Egypt for the genus Meloidogyne. Root-knot nematode recovery from naturally infested hosts revealed that M. incognita was isolated from 103 host plants while M. javanica and M. arenaria were obtained from 61 and 20 host plants, respectively.

Differential Host Test

Some morphologically identified populations of RKN were subjected to Sasser's differential host test. The nematode inocula for this test were secured from cultures established by single egg masses of morphologically identified females and reared separately as definite populations on Prichard tomato plants. Seedlings of the differential host plants were inoculated with 2500 eggs per seedling, and the plants were harvested 45 days after nematode inoculation. Root systems of the harvested plants were indexed for both galls and egg masses and the tested RKN populations were identified to species and/or races as described by Taylor and Sasser (1978).

Table 1. Detected host plants of *Meloidogyne incognita* (MI), *M. javanica* (MJ) and *M. arenaria* (MA) in northern Egypt.

	Host Plant	Nematode species
Acacia	*Acacia* sp.	MI
Almond	*Prunus amygdalus*	MI,MJ
Amaranthus	*Amaranthus caudatus*	MI,MJ
Anise	*Pimpinella anisum*	MI,MJ,MA
Apple	*Malus* sp.	MJ
Asparagus bean	*Vigna sesquipedalis*	MI
Banana, dwarf	*Musa cavendishii*	MI,MJ
Banana, maghrabi	*Musa sapientum*	MJ
Begonia	*Begonia* sp.	MI
Bellflower	*Campanula* sp.	MI
Black mustard	*Brassica nigra*	MI,MJ,MA
Broadbean	*Vicia faba*	MI,MJ,MA
Camellia	*Camellia japonica*	MI
Canna	*Canna indica*	MI,MA
Carrot	*Daucus carota sativa*	MI,MJ,MA
Castor-oil	*Ricinus communis*	MI
Casuarina	*Casuarina glauca*	MI
Celery	*Apium dulce*	MI,MJ,MA
Cereus	*Cereus* sp.	MI
Chrysanthemum	*Chrysanthemum* sp.	MI,MJ
Clover	*Trifolium alexandrinum*	MI,MJ
Common balm	*Mellissa officinalis*	MI
Common caraway	*Carum carvi*	MI,MJ,MA
Common fennel	*Foeniculum vulgaris*	MI
Common sowthistle	*Sonchus oleraceus*	MI,MJ
Coriander	*Coriandrum sativum*	MI,MJ,MA
Corn	*Zea mays*	MI,MJ
Copperleaf	*Acalypha wilkesiana*	MI
Cotton	*Gossypium barbadense*	MI,MJ
Cowpea	*Vigna sinensis*	MI,MJ

Table 1 continued

	Host Plant	Nematode species
Cucumber	Cucumis sativus	MI,MJ
Dahlia	Dahlia sp.	MI,MJ
Date palm	Phoenix dactylifera	MI
Dill	Anethum graveolens	MI,MJ,MA
Dishcloth-gourd	Luffa cylindrica	MI,MJ
Dolichos	Dolichos lablab	MI,MI
Dracena	Dracaena sp.	MI
Eggplant	Solanum melongena	MI,MJ
Egyptian mallow	Malva parviflora	MI,MJ,MA
Fig	Ficus carica	MI
Freesia	Freesia refracta	MI
Garden grass	Lepidium sativum	MI
Garden stock	Matthiola sp.	MI
Gloryflower	Clerodendron sp.	MI
Goose-foot	Chenopodium amaranticolor	MI,MJ
Grape	Vitus vinefera	MI,MJ
Great snapdragon	Antirrhinum majus	MI,MJ
Guamia	Myporum pectum	MI
Hollyhock	Althaea rosea	MI
Iris	Iris sp.	MI
Jasmine	Jasminum sp.	MI
Jute	Corchorous olitorius	MI
Kenaf	Hibiscus cannabinus	MI,MJ,MA
Kidney bean	Phaseolus vulgaris	MI
Lavender	Lavandula officinalis	MI
Lesser bird weed	Convolvulus arvensis	MI,MJ
Lettuce	Lactuca sativa	MI,MJ
Lily	Lilium sp.	MI
Lima bean	Phaseolus limensis	MI
Mint	Mentha sp.	MI
Nightshade	Solanum pseudocapsicum	MI

Table 1 continued

	Host Plant	Nematode species
Ocimum	*Ocimum basilicum*	MI
Okra	*Hibiscus esculentus*	MI,MJ,MA
Pansy	*Viola tricolor*	MI
Parsley	*Petroselinum sativum*	MI,MJ,MA
Peach	*Prunus persica*	MI,MJ
Peanut	*Arachis hypogea*	MJ,MA
Pea	*Pisum sativum*	MI,MJ
Pepper	*Capsicum frutescens*	MI
Periwinkle	*Vinca rosa*	MI
Petunia	*Petunia* sp.	MI
Pick-tooth	*Ammi* sp.	MI,MJ
Pigweed	*Ameranthus caudatus*	MJ
Poinsettia	*Euphorbia pulcherrima*	MI
Potato	*Solanum tuberosum*	MI,MJ
Pot-marigold	*Calendula* sp.	MI
Primrose	*Primula* sp.	MI
Pudding-pipe tree	*Cassia fistiola*	MI,MJ
Pumpkin	*Cucurbita moschata*	MI,MJ
Rice	*Oryza sativa*	MI,MJ
Rose	*Rosa* sp.	MI,MJ
Rose-mallow	*Hibiscus rosa*	MI,MJ
Saintpaulia	*Saintpaulia ionantha*	MI
Sedge	*Cyperus rotendus*	MI
Senna	*Cassia* sp.	MI
Sieva bean	*Phaseolus lunatus*	MJ
Snapdragon	*Antirrhinum majus*	MI
Sorrel	*Rumex dentatus*	MI
Soybean	*Glycine max*	MI,MJ
Spinach	*Spinacia oleracea*	MI,MJ
Squash	*Cucurbita pepo*	MI,MJ
Storksbill	*Pelargonium* sp.	MI

Table 1 continued

	Host Plant	Nematode species
Strawberry	*Fragaria grandiflora*	MJ
Strawflower	*Helichrysum bracteatum*	MJ,MA
Sugar beet	*Beta vulgaris*	MJ
Sugarcane	*Saccharum officinarum*	MI
Sunflower	*Helianthus annus*	MI,MJ
Sweet peas	*Lathyrus odoratus*	MI,MJ
Sweet potato	*Ipomoea batatus*	MI
Sweet violet	*Viola odorata*	MI
Sword lily	*Gladiolus gandavensis*	MI,MJ
Termis	*Lupinus termis*	MI,MJ,MA
Tickseed	*Coreopsis* sp.	MA
Tomato	*Lycopersicon esculentum*	MI,MJ,MA
Turnip	*Brassica rapa*	MI
Washington palm	*Washingtonia lilifera*	MI
Watermelon	*Citrullus vulgaris*	MI,MJ,MA
Waybread	*Plantago major*	MI,MJ
Wheat	*Triticum vulgare*	MI,MJ
Wild chicory	*Cichorium pumilum*	MI,MJ,MA
Willow	*Salix* sp.	MI
Yellow mallow	*Abutilon darwinii*	MI,MJ

Results of the differential host test (Table 2) confirmed the morphological identification conducted in advance. The 86 tested RKN populations comprised 36 M. javanica, 33 M. incognita (27 race 1 and 6 race 3) and 17 M. arenaria race 1. The differential host test witnessed the presence of two races (races 1 and 3) within M. incognita species group and race 1 in M. arenaria. This test also made it obvious that M. incognita race 1 and M. arenaria race 1 were the most prevalent host races within the populations of these two nematode species.

Reactions of Plant Cultivars to RKN

Reactions of 8 tomato, 3 casuarina, 11 corn and 9 umbelliferous plant cultivars to populations of M. incognita (races 1 and 3), M. arenaria race 1 were studied in greenhouse experiments. Nematode inocula were secured from pure cultures maintained on 'Prichard' tomato. Seedlings of the tested cultivars were established in pairs into clay pots 20 cm in diameter and filled with autoclaved sandy loam soil. Nematode inoculation was accomplished by 5000 eggs per pot in 6 replications. The experiments were terminated 8 weeks after nematode inoculation, except in the case of Casuarina which was harvested after 4 months. Root systems of the harvested plants were indexed as in the differential host test. Plant resistance or susceptibility was determined in a manner that plants with ratings 0-2.0 of both galls and egg masses were considered resistant (R), 2.1-3.9 moderately susceptible (MS), while those having average ratings of 4 and above were considered susceptible (S).

The results revealed that the tomato cultivars 'AMEX-VFN,' 'Monita,' 'Patriot,' 'VFN-Bush' and 'VFN-8' were resistant to the four tested nematode populations while 'Prichard,' 'CPC' and 'VF-270' were susceptible to them. The timber tree Casuarina glauca was resistant to all nematodes except M. incognita race 1. On the other hand, C. cunninghamiana was resistant to M. incognita race 3 and M. arenaria, whereas C. equesitifolia was susceptible to all nematode populations except M. arenaria (Table 3).

Table 2. Prevailing species and host races of root-knot nematodes in 86 populations collected from northern Egypt.

Governorate	*M. arenaria* Race 1	*M. incognita* Race 1	*M. incognita* Race 3	*M. javanica*	Total
Alexandria	-	9	3	8	20
Behera	-	6	2	2	10
Giza	2	1	-	6	9
Ismailia	2	2	-	1	5
Kafer El-Sheikh	-	2	-	-	2
Matrouh	-	-	-	2	2
Menoufia	-	-	-	1	1
Sharkia	5	4	1	9	19
Tahreer	8	3	-	7	18
Total	17	27	6	36	86

Table 3. Reaction of eight tomato and three casuarina plant cultivars to *M. incognita* races 1 and 3, *M. javanica* and *M. arenaria* race 1.

Cultivars	*M. incognita* Race 1			*M. incognita* Race 3			*M. javanica*			*M. arenaria*		
	G	EM		G	EM		G	EM		G	EM	
Tomato:												
AMEX-VFN	0	0	R	0	0	R	0	0	R	0	0	R
CPC	5	5	S	5	5	S	5	5	S	5	5	S
Monita	0	0	R	0	0	R	0	0	R	0	0	R
Patriot	0	0	R	0	0	R	0	0	R	0	0	R
Prichard	5	5	S	5	5	S	5	5	S	5	5	S
VFN-Bush	0	0	R	0	0	R	0	0	R	0	0	R
VFN-8	0	0	R	0	0	R	0	0	R	0	0	R
VF-270	5	5	S	5	5	S	5	5	S	5	5	S
Casuarina:												
C. cunninghamiana	4	4	S	0	0	R	5	4	S	0	0	R
C. equesitifolia	5	5	S	5	4	S	5	5	S	0	0	R
C. glauca	4	4	S	0	0	R	0	0	R	0	0	R

Gall and egg mass indices: 0=0, 1=1-2, 2=3-10, 3=11-30, 4=31-100, and 5=over 100 galls or egg masses. R=resistant. S=susceptible.

The tested corn cultivars 'Alexandria,' 'Alex X Opaque,' 'DC 186,' 'Frensh,' 'Giza 2,' 'Giza 4,' 'Pioneer 514,' 'Pop corn,' 'Sabaeny,' 'VC 80,' and 'X 5505' were susceptible to all nematode populations. Also, the tested umbelliferous plant cultivars were all susceptible to the four RKN populations except the common fennel which exhibited a resistant reaction to M. incognita race 3, M. javanica and M. arenaria (Table 4).

Control of Root-Knot Nematodes

The control of these nematodes was planned to be undertaken through two channels: chemical and crop rotation systems.

Chemical control. The efficiency of the granular nematicides Temik 10G, Vydate 10G, Vydate G-DPX5577, Vydate G-DPX4702 and liquid formulation Vydate L 24% as control measures for RKN was evaluated in both pot and field experiments.

The pot experiment was conducted on soybean cultivar 'Calland' to control M. incognita race 3. Nematicidal treatments were made in 4 replicates at the same time of nematode inoculation, except Vydate L 24% was applied a week after nematode inoculation. Two dosage rates of each nematicide were applied on the basis of 0.014 and 0.028 g per pot of two plants (2.1 and 4.2 kg a.i./feddan). The experiment was terminated 75 days after nematode inoculation, and the assessed data are presented in Table 5.

The field experiment was run on tomato plants to control M. incognita race 1. Before transplanting took place, the four granular nematicides were incorporated into the soil as row treatments at the rate of 12 and 15 kg/feddan. The liquid formulation was sprayed once 3 weeks after transplanting at the rate of 3 and 5 L per feddan. The nematicidal treatments were replicated 4 times. Data of this experiment (final nematode population and total yield) were assessed about 4 months after nematicide treatments (Table 6).

Results of the pot experiment disclosed that all the applied chemical treatments significantly reduced the number of nematode galls. Treatments at the level of 0.028 g/pot were more effective than 0.014 g/pot. The two applied levels of Temik 10G and Vydate G-DPX5577 induced a high reduction in the number of galls as compared with the other chemical treatments. The dry weight of infected plant roots was appreciably increased with Vydate 10G at the higher level

Table 4. Reaction of nine umbelliferous plant cultivars to *M. incognita* races 1 and 3, *M. javanica* and *M. arenaria* race 1.

Plant Cultivar	*M. incognita* Race 1			*M. incognita* Race 3			*M. javanica*			*M. arenaria*		
	G	EM		G	EM		G	EM		G	EM	
Anise (*Pimpinella anisum* L.)												
Baladi	4	4	S	4	4	S	4	3	MS	3	3	MS
Carrot (*Daucus carota* L.)												
Red Cored Chanteny	5	4	S	5	4	S	4	4	MS	4	4	MS
Baladi	4	4	S	4	3	MS	4	4	S	4	4	S
Celery (*Apium graveolens* L.)												
French Breakfast	4	4	S	4	4	S	5	5	S	4	3	MS
Common caraway (*Carum caravi* L.)												
Baladi	4	4	S	5	4	S	4	4	S	4	3	MS
Common fennel (*Foeniculum vulgare* Hill)												
Baladi	3	3	MS	2	2	R	2	2	R	2	2	R
Coriander (*Coriandrum sativum* L.)												
Baladi	3	3	MS	4	4	S	4	4	S	4	3	MS
Dill (*Anethum graveolens* L.)												
Baladi	4	4	S	4	4	S	4	4	S	4	3	MS
Parsley (*Petroselinum sativum* Hoffm)												
Baladi	4	3	MS	3	3	MS	3	3	MS	3	3	MS

G=galls. EM=egg masses. R=resistant. MS=moderately susceptible. S=susceptible.

Table 5. Effect of five nematicides on *Meloidogyne incognita* race 3 on soybean cultivar Calland.

Treatment	Level per pot	No. of galls	Plant dry weight g Root	Shoot
Temik 10G	0.014 g	131.3**	6.98**	15.04*
	0.028 g	66.3**	6.85**	15.99**
Vydate 10G	0.014 g	218.8**	4.03	9.96
	0.028 g	156.3**	6.09*	13.15
Vydate G-DPX 5577	0.014 g	98.8**	4.49	10.73
	0.028 g	42.5**	5.16	11.29
Vydate G-DPX 4702	0.014 g	231.3**	3.58	11.77
	0.028 g	212.5**	5.30	13.25
Vydate L24%	0.014 g	612.5**	6.10*	11.91
	0.028 g	212.5**	8.85**	13.93
Control		737.5	3.43	11.32
LSD 0.05		92.2	2.34	3.17
0.01		124.3	3.15	4.27

Data are average of 4 replicates of two plants each.

*Significant at P 0.05 from comparable control.

**Significant at P 0.01 from comparable control.

Table 6. Effect of five nematicides on *Meloidogyne incognita* race 1 on tomato plants.

Treatment and level per feddan		No. of larvae per 250 ml soil IP	FP	Root gall index	Average No. of fruits per plant	Total yield kg per plant
Vydate L24%	3 L	850	165**	2	115**	10.47**
	5 L	780	120**	2	150**	14.25**
Vydate 10G	12 Kg	760	390**	3	98**	9.11**
	15 Kg	820	360**	3	122**	10.98**
Vydate G-DPX 5577	12 Kg	900	475**	4	100**	8.50**
	15 Kg	760	450**	4	105**	9.66**
Vydate G-DPX 4702	12 Kg	820	443**	4	102**	9.18**
	15 Kg	770	420**	4	110**	9.68**
Temik 10G	12 Kg	800	655**	4	84	6.30
	15 Kg	720	628**	4	95**	6.94*
Control		700	1340	5	78	4.13
LSD 0.05			39		10.5	2.60
0.01			62		16.2	3.80

IP: Initial nematode population. Fp: Final nematode population.

Data are average of 32 plants.

*Significant at P 0.05 from comparable control.

**Significant at P 0.01 from comparable control.

Root gall index: 2 = 3-10, 3 = 11-30, 4 = 31-100, and 5 = over 100 galls.

of treatment and the two levels of Temik 10G and Vydate L24%. The shoot dry weight of infected plants was significantly increased under Temik 10G treatments.

Results of the field experiment revealed that all tested nematicides gave significant control of root-knot nematode. Vydate L24% was the best of the tested chemicals followed by Vydate 10G and Vydate G-DPX 4702, while Temik 10G was the least effective one. In general, all nematicide treatments promoted tomato plant growth and yield. The two levels of Vydate L24% maintained the best results in comparison with the other tested chemicals.

Crop rotation systems. Two crop rotation systems (Tables 7 and 8) were proposed for the control of *M. javanica* and *M. incognita* race 1, these being the most frequently detected root-knot nematodes in northern Egypt. The two proposals were based on results of a population dynamics study which showed that root-knot nematodes are less active during winter months. The proposals were also based on the reactions of plant cultivars tested under weather conditions of northern Egypt, and on the general crop pattern adopted by local farmers. These two proposals are now underway to adoption.

CURRENT AND FUTURE RESEARCH PLANS

1. Root-knot nematode survey and host range detection.
2. Morphological and biological identification of root-knot nematodes.
3. Testing resistance of crop plant cultivars to identified species and races of root-knot nematodes.
4. Root-knot nematode control with special emphasis on crop rotation systems.

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Table 7. Proposed 3-year crop rotation system for the control of root-knot nematode *Meloidogyne javanica* in northern Egypt.

Period	Suggested crops and their reactions
1st year:	
March-July	Potato
	Sweet potato
August-October	Common bean cv. Mengatot (R)
	Carrot
November-February	Tomato cvs. AMEX-VFN, Monita, Patriot, VFN-Bush and VFN-8, all of which are high resistant
	Potato, Peas
2nd year:	
March-September	Cotton cvs. Bahtim 110, Giza 67, Giza 68, Giza 70 and Giza 75, all of which are highly resistant
October-February	Clover
	Potato
	Tomato cvs. AMEX-VFN, Monita, Patriot
	VFN-Bush and VFN-8
3rd year:	
March-June	Okra
	Pumpkin
	Watermelon
July-September	Common bean cv. Mengatot (R)
	Corn, pepper
October-February	Tomato cvs. AMEX-VFN, Monita, Patriot, VFN-Bush and VFN-8
	Potato

Crop reaction: R = resistant, MS = moderately susceptible.

Table 8. Proposed 3-year crop rotation system for the control of root-knot nematode *Meloidogyne incognita* race 1 in northern Egypt.

Period	Suggested crops and their reactions
1st year:	
October-April	Broadbean barley, clover, wheat
	Susceptible cultivars of these crops can be grown successfully in this period as nematode activity is usually low.
May-July	Soybean cvs. Hutton (R), Bragg (MS), Coker 488 (MS), Forrest (MS), and Mitchell (MS).
	Corn
August-October	Lima bean cv. Burpees Bush (R).
	Sieva bean cv. Hundersons Bush (R).
2nd year:	
November-February	Tomato cvs. AMEX-VFN, Monita, Patriot, VFN-Bush and VFN-8, all of which are highly resistant .
	Potato and peas.
March-September	Cotton cvs. Giza 68, Giza 70 and Giza 75, all of which are highly resistant.
	Rice cvs. IR28, IR459 and P 24, all of which are highly resistant.
3rd year:	
October-April	Barley, broadbean clover, wheat
May-July	Corn, soybean cvs. Hutton (R), Bragg (MS)
August-September	Pepper, squash

Crop reaction: R = resistant, MS = moderately susceptible.

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

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The status of the root-knot nematodes, Meloidogyne species, in some cultivated areas of Morocco was reported in the two previous Research Planning Conferences on root-knot nematodes for Region VII (1, 2). The present communication is a contribution in completing data on the distribution of Meloidogyne species and their importance in the country.

SURVEY STUDY

A nematological survey is being conducted in all the principal agricultural regions of Morocco (Fig. 1): the Atlantic littoral (Larache, Kenitra, Rabat-Sale, Casablanca, El Jadida, Agadir, Foum El wad), the Gharb (Sidi Slimane), the Sais (Fes, Meknes), the Midle Atlas (El Hajeb, Azrou), the Low Moulouya (Berkane), the Zemnour (Khemisset, Tiflet, Maaziz), the Tadla (Beni Mellal, Fquih Ben Salah, Afourer), and the Haouz (Marrakech).

A total of 600 samples were collected from these zones. The results obtained on the major crops (Table 1) showed 32% root-knot nematode-infested crop samples. The frequency of occurrence of Meloidogyne spp. varied from 4% in sugar beet to 70% in peach and french bean. Nematological analysis revealed no root-knot nematode attack on cereals (wheat, barley, oat, maize) and broadbean. The most important infestations were noted essentially along the Atlantic littoral where vegetables are conducted intensively.

IDENTIFICATION OF MELOIDOGYNE SPECIES

Thirty-nine Meloidogyne populations were selected and reared separately on tomato (Marmande) in the greenhouse for identification studies.

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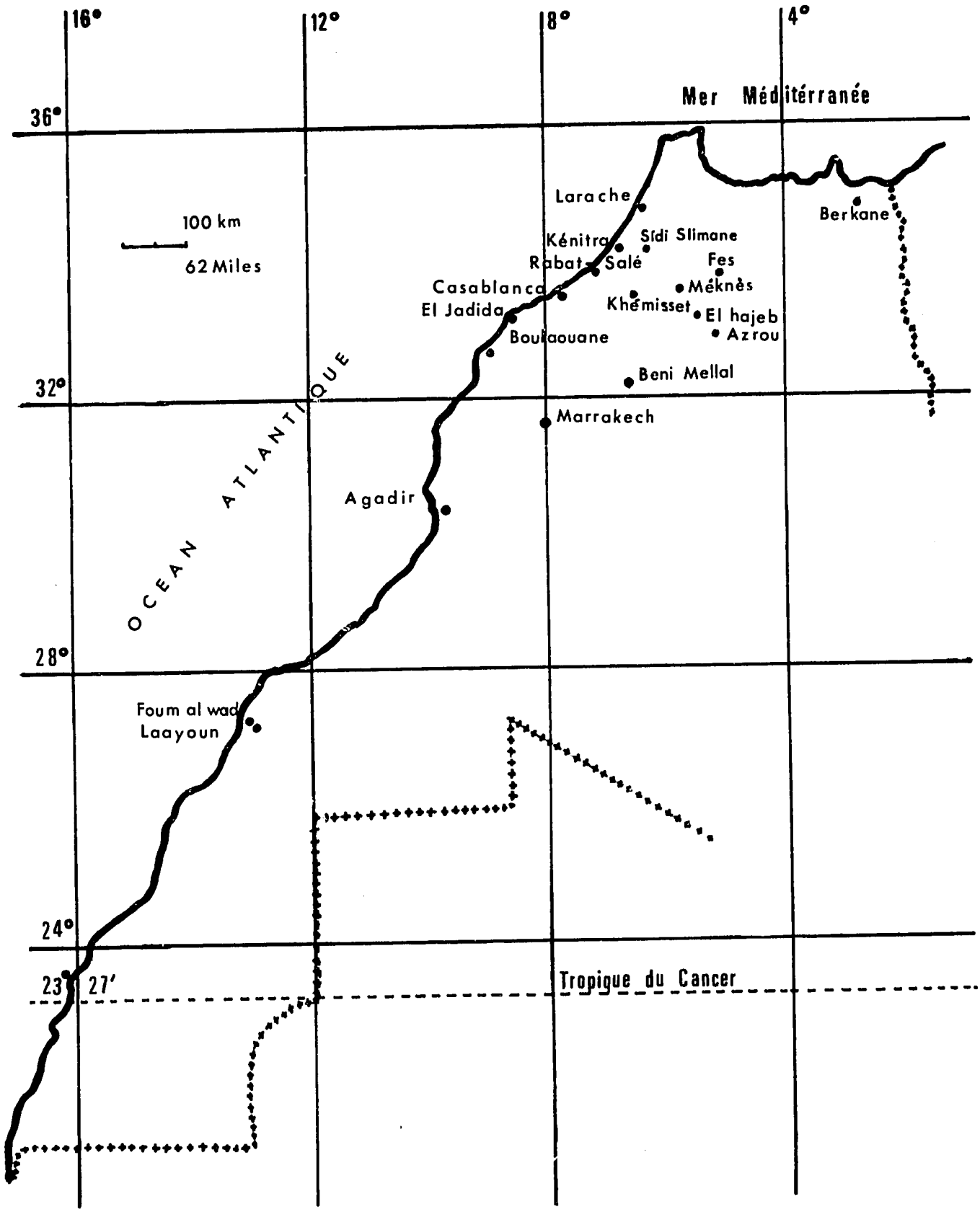

Figure 1. Map of Morocco : The surveyed areas.

Table 1. List of the major crops sampled during the survey study with the frequency of occurrence of root-knot nematodes.

Crops	No. Samples	No. Infested Samples	Frequency of Occurrence
Peach*	26	18	69%
Almond*	32	18	56%
Tomato	48	31	65%
Eggplant	28	15	54%
Carrot	43	24	56%
French bean	40	28	70%
Tobacco	30	15	50%
Potato	37	4	11%
Sugar beet	45	2	4%
Broadbean	70	0	0%
Wheat, Maize, Barley, Oat	85	0	0%

*In nurseries.

Morphological Study

Identification based on perineal pattern examination revealed the presence of the four common species: M. javanica, M. incognita, M. arenaria and M. hapla. The distribution and the host plants of these species are reported in Table 2. The data analysis showed that 61% of the selected populations belong to M. javanica, 29% to M. incognita, 7% to M. arenaria and 3% to M. hapla.

Physiological Study

The differential host plant test was conducted only on 10 populations. The results (Table 3) confirmed those obtained with perineal pattern observations. Both M. arenaria, found in mixture with M. javanica (population D 3), and M. incognita (population C 5) biotypes were defined as belonging to race 2 of each of these species.

Cytogenetic Study

So far, 19 populations were examined by means of the chromosome staining method described by Triantaphyllou (3). We determined chromosome numbers and the mode of reproduction of these populations (Table 4). The chromosome numbers relative to biotypes of M. javanica (43, 45, 47, 48), of M. incognita (32, 43, 46), of M. arenaria (36) and M. hapla (16) are similar to those mentioned by Triantaphyllou (3). According to the terminology adopted by Triantaphyllou, M. incognita (population C 4), M. arenaria (population D 3) and M. hapla (population E II) belong respectively to the races B, B and A.

DISCUSSION

These data, in comparison with those of other plant-parasitic nematodes found in Morocco (unpublished data), demonstrate that the root-knot nematodes are particularly important in vegetable-cultivated areas which play a significant role in the agricultural production in Morocco.

Among the Meloidogyne species encountered, M. javanica is the predominant and the most widespread species.

Table 2. Occurrence of *Meloidogyne* species, according to location and host plant.

Population	Location	Host plant	*Meloidogyne* species
C1	Larache, El Aouamra	French bean	*M. javanica*
C2	Laracha, El Aouamra	French bean	*M. javanica*
C3	Larache, El Aouamra	French bean	*M. incognita*
C4	Larache, Oulad Laghmari	French bean	*M. incognita*
C5	Larache, Rhamna	French bean	*M. incognita*
C6	Larache, Rhamna	Eggplant	*M. incognita*
C7	Larache, Oulad Laghmari	*Solanum sodomacure*	*M. javanica*
C8	Larache, Lahchaicha	French bean	*M. javanica*
C9	Larache, Oulad Laghmari	French bean	*M. javanica*
D1	Méknès, Ain Taoujdate	Almond	*M. arenaria*
D2	Méknès, Ain Taoujdate	Almond	*M. javanica*
D3	Méknès, Ain Taoujdate	Almond	*M. arenaria* & *M. javanica*
D4	Kénitra, Benmansour	Tomato	*M. javanica*
D5	Salé, Bouknadel	Potato	*M. incognita*
D6	Rabat, Guich	Soybean	*M. incognita*
D7	Casablanca, Soualem	Tomato	*M. javanica*
D8	Salé, Bouknadel	*Abutilon striatum* & *Oxalis corniculata*	*M. arenaria*
D9	Méknès, Sbâa Ayoun	Peach	*M. javanica*
D10	Méknès, Sbâa Ayoun	Almond	*M. javanica*
D11	Salé, Bouknadel	Celery	*M. incognita*
D12	Méknès, Azrou	Peach	*M. javanica*
D13	Méknès, Ait Yazem	Peach	*M. javanica*
D14	Khémisset, Mâaziz	Turnip	*M. incognita*
D15	Méknès, El Hajeb	Tobacco	*M. incognita*
D16	Rabat, Guich	Hemp	*M. incognita*
E1	El Jadida, Oualidia	Tomato	*M. javanica*
E2	El Jadida, Oualidia	Eggplant	*M. javanica*
E3	El Jadida, Oualidia	Cucumber	*M. javanica*

Table 2 continued

Population	Location	Host plant	Meloidogyne species
E4	El Jadida, Oualidia	Tomato	*M. javanica* & *M. incognita*
E5	El Jadida, Oualidia	Tomato	*M. javanica*
E6	El Jadida, Boulaouane	Sugar beet	*M. javanica*
E7	El Jadida, Boulaouane	*Solanum nigrum*	*M. javanica*
E8	Beni Mellal, Fquih Ben Salah	Watermelon	*M. incognita*
E9	Beni Mellal, Oxlad Ayad	Carrot & Almond	*M. javanica*
E10	Agadir, Melk Zhar	Tomato & Eggplant	*M. javanica*
E11	Agadir, Oulad Taima	Tomato	*M. hapla*
E12	Berkane, CMV 105	Peach	*M. javanica*
G1	Foum Elwad	Tomato & Melon	*M. javanica*
G2	Laayoun	Melon	*M. javanica*

C,D,E,G: Annual rainfall; C = 600-800 mm; D = 400-600 mm; E = 200-400 mm; G = less than 100 mm

Table 3. Response of the differential host plants to some selected populations.

Population	Response of the differential host plants* 1	2	3	4	5	6	Identified species & races	Perineal pattern type
C1	+	-	-	+	-	+	*M. javanica*	M.J.
C5	+	-	+	+	-	+	*M. incognita* R2	M.I.
C7	+	-	-	+	-	+	*M. javanica*	M.J.
D3	+	-	-	+	-	+	*M. javanica* or *M. arenaria* R2	M.J. & M.A.
D4	+	-	-	+	-	+	*M. javanica*	M.J.
E1	+	-	-	+	-	+	*M. javanica*	M.J.
E2	+	-	-	+	-	+	*M. javanica*	M.J.
E3	+	-	-	+	-	+	*M. javanica*	M.J.
E5	+	-	-	+	-	+	*M. javanica*	M.J.
E6	+	-	-	+	-	+	*M. javanica*	M.J.

*Differential host plants: I = Tobacco NC 95; 2 = Cotton Deltapine 16; 3 = Pepper California Wonder; 4 = Watermelon Charleston Grey; 5 = Peanut Florunner; 6 = Tomato Rutgers.

Table 4. Results of the cytogenetic study of some collected populations

Population	Species	Chromosome No.	Mode of Reproduction
C1	*M. javanica*	43	O.M.P.*
C2	*M. javanica*	47	O.M.P.
C4	*M. incognita*	32	O.M.P.
C5	*M. incognita*	46	O.M.P.
C6	*M. incognita*	43	O.M.P.
C7	*M. javanica*	43	O.M.P.
C8	*M. javanica*	43	O.M.P.
C9	*M. javanica*	47	O.M.P.
D2	*M. javanica*	45	O.M.P.
D3	*M. arenaria*	36	O.M.P.
	& *M. javanica*	45	O.M.P.
D4	*M. javanica*	47	O.M.P.
D9	*M. javanica*	48	O.M.P.
D10	*M. javanica*	43	O.M.P.
D11	*M. incognita*	32	O.M.P.
E1	*M. javanica*	43	O.M.P.
E2	*M. javanica*	43	O.M.P.
E3	*M. javanica*	43	O.M.P.
E5	*M. javanica*	45	O.M.P.
E11	*M. hapla*	n=16	F.M.P.**

* = Obligatory Mitotic Parthenogenesis
** = Facultative Meiotic Parthenogenesis

Meloidogyne species distribution seems to be correlated with the annual rainfall. In locations with 600 to 800 mm, the proportions of Meloidogyne species are 56% for M. javanica and 44% for M. incognita. In areas with 400 to 600 mm, 47% are M. javanica; 35%, M. incognita; and 18%, M. arenaria. In zones with 200 to 400 mm, 77% are M. javanica; 15%, M. incognita; and 8%, M. hapla. In regions of less than 100 mm only M. javanica occurs.

The presence of M. hapla, which was detected only once in the region of Agadir, can be traced back to strawberry plants introduced from Europe.

Continuation of the ecological studies on the root-knot nematodes will allow us to better understand the factors that condition the species distribution and will help us to define a control strategy adapted to the local conditions.

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MELOIDOGYNE IN PORTUGAL: A CENTENNIAL LANDMARK

L. G. L. Reis*

One hundred years ago, M. C. Rodrigues de Moraes, an agricultural scientist, reported in an official publication the occurrence of root-knot nematodes in Portugal (1). In the spring of 1881, Moraes found Meloidogyne in grapevine roots sent to him by a winegrower from Paredes county, Oporto district, who wanted to know whether the roots were parasitized by the grape phylloxera.

The grapevine, Vitis vinifera L., thought to exist in Portugal since the time of the Romans, occupied already in the 19th century an area estimated to be of 200,000 ha and possessed great socio-economic importance. An epiphytotic of powdery mildew Uncinula necator (Schw.) Burrill by 1850, the introduction of the grape phylloxera Viteus vitifolii (Fitch) by 1860, and an epiphytotic of downy mildew Plasmopara viticola (Berk. & Curt.) Berl. & De Toni by 1870 ravaged the European vineyards, causing economic chaos all over the winegrowing countries. The phylloxera reached Portugal by 1863. To detect the phylloxeric foci and to eradicate the aphid, antiphylloxeric commissions were established in Portugal through the years. In the reports of those commissions, many fundamental observations were made and recorded in first hand without their significance being fully realized. Not only the grape phylloxera but also any unusual disease or pest found in the surveyed vineyards was to be reported by the inspectors. Among his other duties, Moraes was an inspector in one of the first Portuguese antiphylloxeric commissions. He acted as a mycologist (he first reported the occurrence of grape downy mildew in Portugal), as an entomologist and finally as a nematologist. He was a truly dedicated pioneering scientific worker during his time. Moraes described the symptomatology caused by the root-knot

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nematodes, differentiating it from that caused by the grape phylloxera (1). He also described the morphology, colour, and localization and gave measurements of the adult females of Meloidogyne, but did not make a clear reference to the giant-cells or to the egg-masses, and in his report, the root-knot nematode is described and named Vibrio anguillula L. and Anguillula vitis. Moraes mentioned heavy crop losses due to the root-knot nematodes in the vineyards, many of them not yet affected by the grape phylloxera.

To the best of our knowledge, the first and most extensive and detailed surveys of Meloidogyne ever made in a single country are those found in the reports of the Portuguese antiphylloxeric commissions issued after 1882. In most of those reports, special tables present data regarding to the distribution of Meloidogyne by districts and localities, specifying the vineyard areas lost due to the action of root-knot nematodes. In one of such reports, a special map is included showing the distribution of Meloidogyne in the Viseu winegrowing district (2). The potential of root-knot nematodes for causing plant damage was surely then realized. It is perhaps noteworthy that it was also Moraes who first reported chemical trials aimed to control meloidogynosis in Portuguese vineyards (2). In such trials, potassium sulfocarbonate, iron sulfate, carbon disulfide and a mixture of calcium hydroxide and ashes were utilized.

So the pursuit of the grape phylloxera contributed to the discovery of root-knot nematodes in Portugal. The reports of the Portuguese antiphylloxeric commissions published in 1882 and afterwards indicate clearly that Meloidogyne was already well established in the country.

I hope this brief communication, given on the occasion of the centennial anniversary of the first report on the occurrence of a phytoparasitic nematode in Portugal, will stimulate greater awareness of the root-knot problem in this country and cause more funds and people to be devoted to this area of study.

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RESEARCH ON ROOT-KNOT NEMATODES IN PORTUGAL

M. Susana N. de A. Santos and Isabel M. de O. Abrantes*

It has long been recognized in Portugal that root-knot nematodes, Meloidogyne spp., are widely distributed throughout the country and infect important crops (2).

RESEARCH PROGRAMS

Identification of Species and Races of Root-Knot Nematode Populations

M. Susana N. de A. Santos and Isabel M. de O. Abrantes

Since 1978, in line with the IMP objectives, we have 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 that study have already been published (1, 3, 4) and are summarized in Table 1. Some other results are presented in this report.

Materials and Methods

The populations were separately cultured on potted tomato plants in the greenhouse for population increase. Later the species and race identification of each isolate was made based on studies of perineal patterns and larvae, and on results of tests using the IMP standard host differentials (5, 6).

Results and Discussion

Four populations (Table 2) were studied and, out of these, three were identified as M. incognita and one as M. hapla. Race identification showed the existence of two races of M. incognita, races 2 and 4. The present findings confirmed that Portuguese root-knot nematodes affect various crops in different parts of the country. M. incognita race 4 has been found for the first time.

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Table 1. Species and races of root-knot nematodes identified in Portugal (1978-1981)

Population	*Meloidogyne* species & race	Host Plant	Locality
001	*M. arenaria* race 2	Tomato	Coimbra
002	*M. hapla*	Carrot	Bencantaa (Coimbra)
004	*M. javanica*	Tomato	Vila Real Sto. António
006	*M. hapla*	Corn and squash	Barranco do Banho (Monchique)
007	*M. incognita* Race 2	Corn and bean	Barranco do Banho (Monchique)
018	*M. javanica*	Potato and bean	Espinheiro (Celorico da Beira)

Table 2. Species and races of root-knot nematodes identified in Portugal (1982)

Population	*Meloidogyne* species & race	Host plant	Locality
019	*M. incognita* race 4	corn	Corte Pereiro (Monchique)
020	*M. incognita* race 2	corn	Barranco do Banho (Monchique)
023	*M. hapla*	alfalfa	Barcelinhos
024	*M. incognita* race 2	melon	Oeiras

Studies on Root-Knot Nematodes, Meloidogyne spp. From Olive Trees in Portugal

Isabel M. de O. Abrantes and M. Susana N. de A. Santos

We are conducting a study to determine the species and races of root-knot nematodes affecting olive trees in different parts of the country. One of the populations did not reproduce on tomato. Perineal patterns of females differ somewhat from those of *M. incognita* and *M. hapla*. We are studying some morphological and biological aspects of this population.

Reaction of Corn Hybrids to Populations of Meloidogyne spp.

M. Teresa S. Craveiro and Célia S.Pais

Biochemical Studies of Root-Knot Nematode Populations

Célia S. Pais, Isabel M. de O. Abrantes, M. Teresa S. Craveiro and M. Susana N. de A. Santos

The first author has started this project at the Imperial College, London, U.K., using different populations of *M. naasi*.

Identification of Species and Races of Root-Knot Nematode Isolates From República de Cabo Verde E

M. Susana N. de A. Santos and Isabel M. de O. Abrantes

We are studying three populations of root-knot nematodes associated with banana, papaya and pepper plants.

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ROOT-KNOT NEMATODES IN TURKEY

Hasan S. Yüksel*

Turkey is divided into different regions having a very wide range of ecological conditions. Among these, Central and East Anatolian climatic conditions are not favorable to the survival of root-knot nematodes. Central Anatolia has low rainfall (300 mm), dry summers and cold and snowy winters. It is at an intermediate altitude (1000 m). East Anatolia occurs at a high altitude (1500-2300 m) where the winters are very cold; sometimes the temperature drops to -40°C. The mean annual temperature is 5-7°C, and the summers are short and cool. This region has the heaviest snow.

The Mediterranean sea, Black sea and Aegean sea regions are warm and suitable for the survival of root-knot nematodes. In the Mediterranean Sea region, the summers are hot and dry, and the winters warm and rainy. The mean annual rainfall and temperature are 890 mm and 18.5°C, respectively. This region is low in altitude and has a subtropical climate and crops. No snow falls here.

The Aegean Region has a mild climate with dry, hot summers. The mean annual temperature is 10-16°C. The mean temperature is 25-30°C in summers and 5-10°C in winters. The precipitation amounts to 400-600 mm; snow accounts for some of this precipitation but does not last long. The agricultural potential of the region is very high, and most of the crops are exported.

In the Black Sea region, the distribution of rainfall is very good and it rains even in summer. Sometimes it snows but the snow does not last long. The mean annual temperature is 10-14°C. The rainfall in the eastern part of the region is 400-2000 mm, and in the western part, it is 400-1000 mm.

Turkey is a wide country having ecologically different regions. As a result, the crops and the status of agriculture vary according

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to the regions. Therefore, the research concerning nematode species distribution, damage, and control requires a sufficient number of well-qualified persons.

So far, five species of the root-knot nematodes, Meloidogyne Goeldi, have been found attacking cultivated plants in Turkey.

The Mediterranean Sea region is well developed from the point of vegetable production. Apart from vegetables, cotton is an important crop of the region, grown both under irrigated and dry conditions. In some irrigated areas, Meloidogyne incognita was found to be very destructive on cotton. Some vegetable species, such as tomato, eggplant, okra, celery, squash and cucumber, are highly susceptible to Meloidogyne incognita and M. javanica while radish, pepper, spinach, leek and lettuce are not. M. incognita is especially destructive to fig and mulberry, and likewise M. javanica to banana. No root-knot nematodes were encountered on olive, apricot, citrus strawberry or peanut. In general, a susceptible plant can be infected by one or more Meloidogyne species. In the south, the most widely distributed species is M. incognita. Economic damage has been recorded on vegetable species, cotton and banana.

In the Aegean region, various crops are grown and the most of them are exported. The main crops are vine, fig, olive, cotton, tobacco and sugar beet. Other fruits, vegetables and cereals are also economically important. Tobacco, sultana vine, cotton and fig are grown both under irrigated and dry conditions. There is no important root-knot nematode problem on plants grown without irrigation; on the other hand under irrigated cultivation, these plants suffer a lot from root-knot nematodes. Most of the fruits and vegetables are infected with these nematodes. In this region, 138 populations were studied and 2/3 of them contained M. incognita populations. In this region in October, four times as many root-knot nematode larvae were counted (179-763) in the soil samples (100 ml) from the tobacco plot as from the tomato plot in the same field.

Most of the prevailing root-knot species of Turkey are found in Marmara Region. The most important crops of the region are vegetables, fruits, tobacco and sugarbeet. Table grape species are very rich in the region. Canning and fruit juice industries are well developed. Canning products and fruits are exported. For this reason, root-knot nematodes play important role in Turkish agricultural economy. Around Istanbul and Kocaeli, M. arenaria is common. In most provinces, M. arenaria and M. incognita are equally distributed. M. hapla and M. javanica also occur in high numbers.

It is better to consider the Black Sea region in two parts: as coastal and interior areas. In the coastal area, hazel-nut, tea, rice, corn, fruits and vegetables are the most important crops. In the interior area, fruits, sugarbeet, vegetables and cereals are grown. In the coastal area, M. incognita is present except in Samsun province where M. thamesi is found on fig and celery. In the interior area, M. arenaria is present. Meloidogyne spp. are not destructive to hazel-nut and tea which are the most important crops of the region.

The root-knot nematodes are usually found in the regions where the most economic crops are grown.

Studies have shown that temperature and rainfall affect the distribution of Meloidogyne species; soil structure and host plants determine type population density.

Effective results were obtained from the application of most nematicides to Meloidogyne spp; however from an economic standpoint, the additional cost often prevents the farmers from using nematicides. In this region there are about 47,000 decares greenhouses. Soil fumigants are sometimes applied in these greenhouses and the seed beds.

Root-knot nematodes sometimes cause important temporary damage to tomato in the Central Region which is not suitable for the establishment of the root-knot nematodes. In hot regions, seedlings are raised for colder regions. These seedlings are particularly infected. In this region, seedlings are planted to get early and more abundant produce. As a result, the severity of the damage varies according to the degree of infection of the seedlings. However,

root-knot nematodes which are introduced in contaminated soil do not survive the winter because of the cold climate.

Nurseries are also established in the regions having root-knot problems, but the infected saplings from these nurseries can be grown safely in the Central Region of Turkey since the nematodes are destroyed during the first winter.

In plant-parasitic nematode surveys conducted on twenty banana plantations in the Mediterranean sea region, nematode species infecting bananas have been detected. In all these plantations, M. javanica and some M. incognita were recorded. Besides root-knot nematodes, high populations of Helicotylenchus multicinctus have been found. In the same region, 248 cucurbitacea out of 700 growing in greenhouses were found to be infected with root-knot nematodes (M. incognita and Meloidogyne javanica). Cucumber and squash have been infected, but not melon and watermelon.

Variations in Root-Knot Nematode Populations and Inoculation Tests on Bananas

The variation in the populations of root-knot nematodes from month to month was determined in the following manner. During the growing season from April to September, 50-g samples were taken from the roots and soils of bananas in infested plantations.

Inoculations were carried out according to the method followed by Blake (2) in order to determine the morphological changes and the degree of damage caused by root-knot nematodes to banana roots. For that reason, the buds taken from midget rhizomes were sterilized in 5% sodium hypochlorite for one minute and then planted into beds already fumigated by methyl bromide. After two months these young plants, which were about 30 cm high, were removed and planted into big drums filled with soil which had been sterilized with methyl bromide. Before the inoculation, root-knot nematode larvae were surface sterilized in 5% hydrogen peroxide for two minutes, and then transferred to a 325-mesh sieve. After they were rinsed under running tap water, 3000 larvae were poured around the roots of the plants in each drum. Four and one-half months after inoculation, the

plants were removed from the drums and the roots checked for degree of infection. At the same time, populations were determined in soil and roots.

The population changes of Meloidogyne by month are shown on Figs. 1 and 2. In soil, the population drops significantly during July and August, but increases in September. In roots, the population increased in April, dropped in June and July, increased again in August, and then dropped in September. In general, the populations in roots are higher than those in soils from April through September (Fig. 1). The total number of larvae in roots and soil is highest in April, August and September (Fig. 2). Therefore, nematicide application should take place in April and September when the populations are very high.

In the observations made 3.5 months after inoculation, no differences in diameter, height and color were seen between infected and control bananas. Also no abnormal growth was observed during this period. However, 4.5 months after inoculation, infected plants exhibited a yellowing of leaves and a slowing down of development. The control plants showed normal growth. Damage to plant roots was assessed at 3% for control plants and 77.6% for inoculated plants.

At the termination of the experiment, numbers of second-stage larvae recovered from the roots and soil were recorded (Table 1). According to the table, an average reproduction rate of 519% was calculated for active larvae.

The observations show that if the plants are well managed, fertilized and irrigated, even under fairly high root-knot nematode populations, then damage visible on above-ground plant parts of banana will not be very severe. The injuries to roots caused by root-knot nematodes are superficial, so under normal cultivation conditions they do not result in important crop losses.

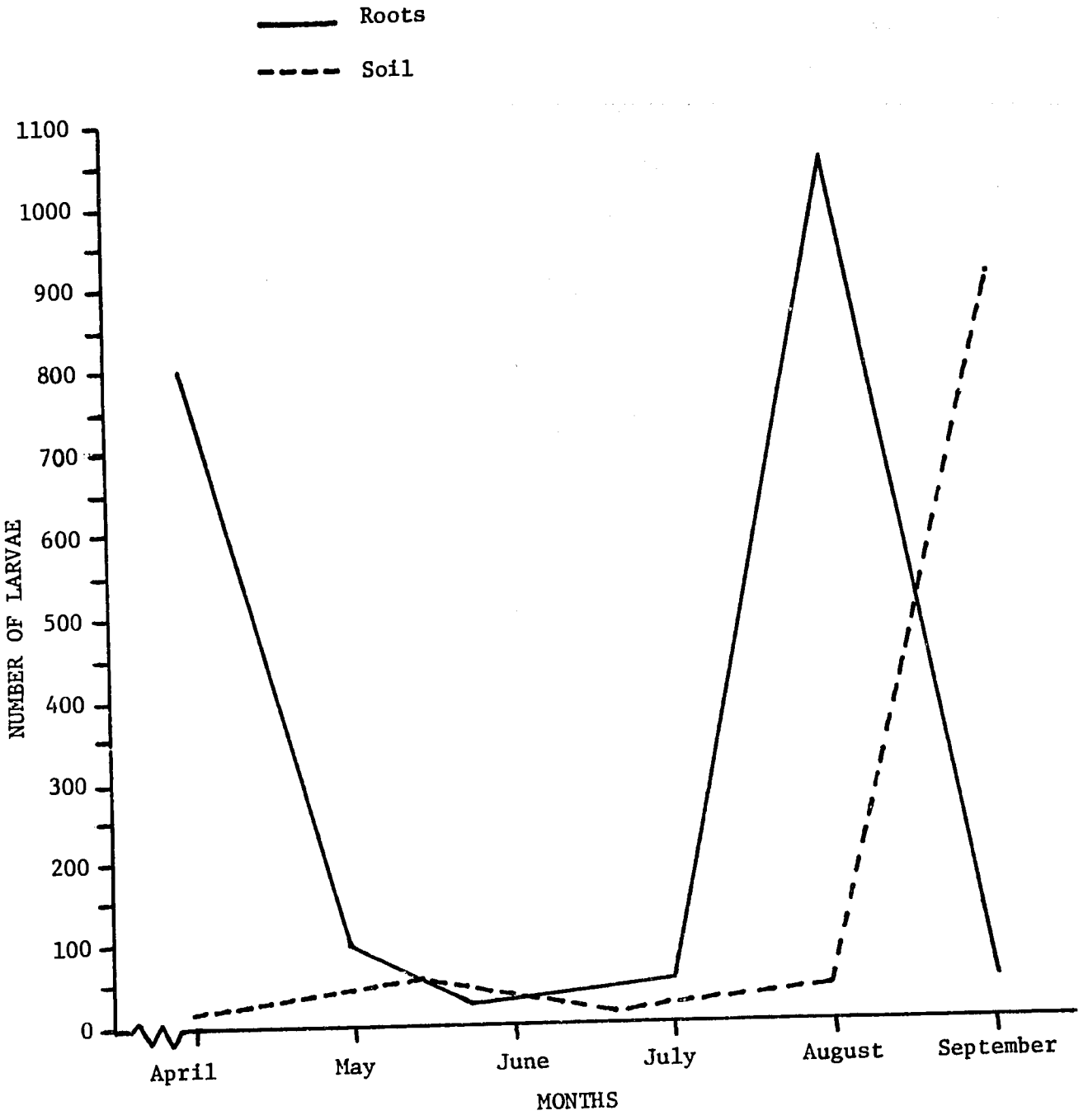

Figure 1. Month-by-month population density of second-stage *Meloidogyne* juveniles in soil and roots.

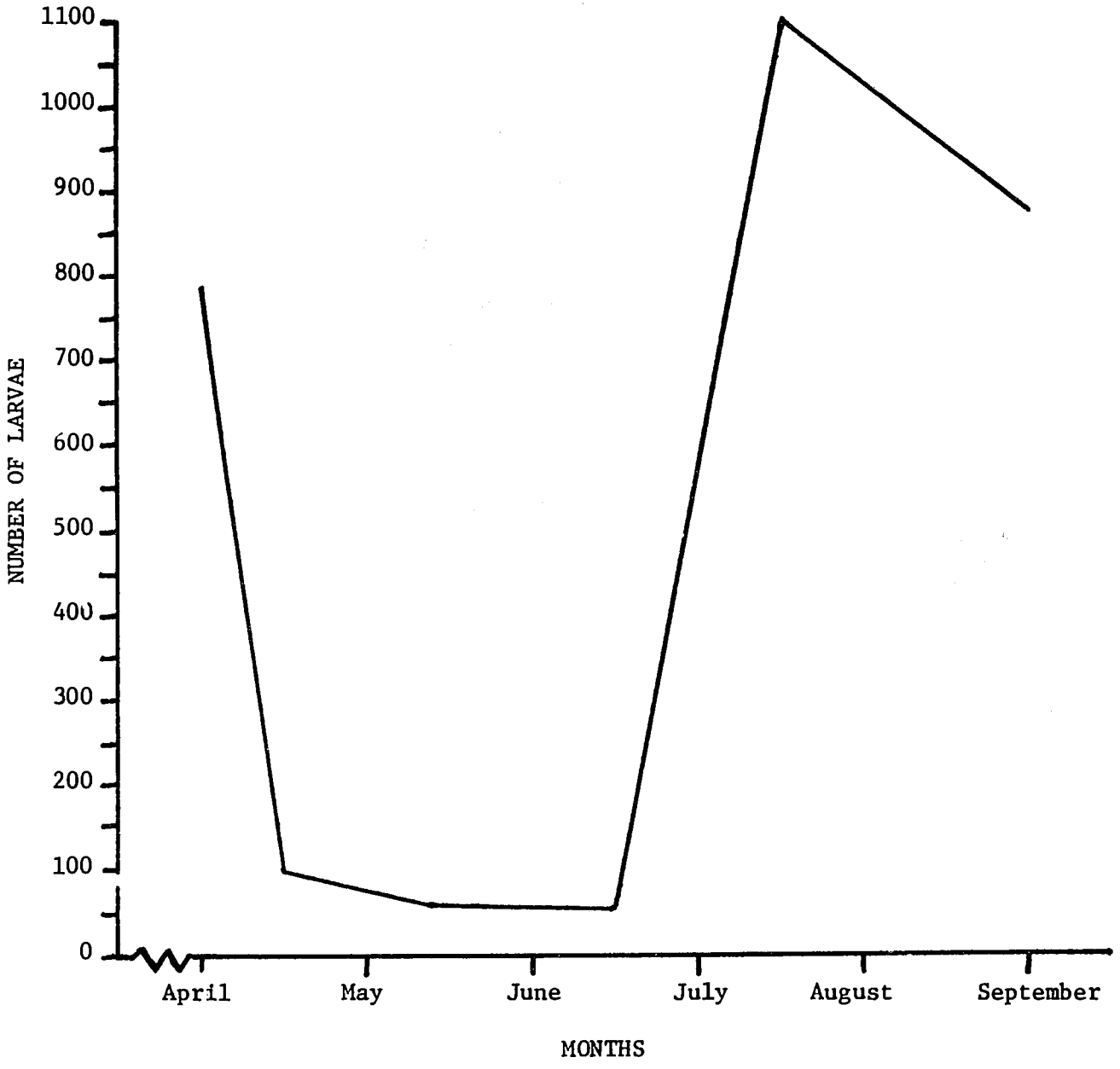

Figure 2. Total month-by-month population densitv of second-stage *Meloidogyne* juveniles in roots.

Table 1. Reproduction rates of second-stage *Meloidogyne* larvae over a 4.5 month period.

Drum	Initial population (larvae/drum)	Final Population In Soil	Final Population In Roots	Final Population Total	Reproduction rate as active larvae Percent
I	3.000	400	18756	19159	639
II	3.000	175	17980	18155	605
III	3.000	355	16900	17255	575
IV	3.000	394	8152	8546	285
V	3.000	397	14275	14675	489
Mean	3.000	344	15213	15557	519

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ROOT-KNOT NEMATODES IN THE SUDAN

M. A. Siddig and M. G. Mohamed*

INTRODUCTION

The root-knot nematodes are widely distributed in the central, eastern, western and southern parts of the Sudan. The importance of these plant-parasitic nematodes has been neglected despite the fact that they cause severe damage on many cultivated plants. Only in the last twelve years, has the attention of a few workers in the field of crop protection science been drawn to work on this problem. From 1960 to 1970, *Meloidogyne* spp. were reported on vegetables, fruit trees and field crops (1, 2, 3, 4, 5).

M. arenaria, *M. incognita* and *M. javanica* were all found in association with the roots of various plant species, but the most important *Meloidogyne* spp. were the last two (5). It has also been found that these nematodes are most severe on plants grown in the light soils. Among the most susceptible host plants to root-knot nematodes are tomato, potato, eggplant, pepper, cucurbits, okra, sweet potato, carrot, banana and papaya. In addition, root-knot nematodes were found to be a serious problem in vegetable and ornamental nurseries in Shambat and Bara. However, reliable estimates on their losses have not yet been made.

Although there are a number of methods to control the plant-parasitic nematodes, the use of cultural practices can still considerably increase the yield by reducing the damage caused by these nematodes. In general, over the last few years, some aspects on root-knot nematodes were discussed and some research has already been done by several workers, but considerable amount of work is still waiting especially in the field of resistant varieties.

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The Response of Various Species of Plants to the Root-Knot Nematode Meloidogyne javanica in Shambat

This nematode was chosen for this work because the preliminary investigations and the survey work revealed that M. javanica is associated with the roots of various plants collected from the most important cultivated areas of the North regions such as Khartoum, Gezira, Kassala, North Kordofan and White Nile provinces (3).

The purpose of this study is to determine the resistance and susceptibility of some commonly grown crops to M. javanica.

MATERIALS AND METHODS

A preliminary pot experiment was undertaken to investigate the response of 17 test plants belonging to different families including some solanaceous varieties to M. javanica. The nematode test organism was obtained from stock cultures and extracted into a water suspension containing about 100 second-stage larvae per ml.

Two seedlings of each test plant were grown in 14-cm diameter pots containing sterilized light soil. Three weeks from the date of planting or transplanting, each plot was inoculated with 1000 nematodes and kept at 25 to 30°C. The experiment consisted of three replicates. Treated and untreated pots were regularly watered. After 6 weeks the plants were carefully uprooted and washed free of soil.

Assessment of the reaction of the test plants to M. javanica was measured by the gall rating index which is shown in Table 1.

RESULTS AND DISCUSSION

The results shown in Table 1 illustrate that 7 crops as well as tomato variety VFN Bush were found to be resistant to M. javanica, while the rest of the test plants showed high susceptibility as indicated by the gall index. However, our attention was drawn by the indication that the tomato variety VFN Bush showed a resistant reaction to M. javanica while four test tomato varieties were highly susceptible. If it is proved that the above finding is correct under Shambat conditions, then this could be developed to gain resistance for the other susceptible tomato varieties.

Table 1. The status of test plants as host of *M. javanica* measured by gall rating (mean of 3 replicates)

Common name	Scientific Name	Variety	Gall rating index
Cotton	*Gossypium hirsutum*	-	0
Garden Rocket	*Eruco sativa* Mill.	-	0
Onion	*Allium cepa* L.	-	0
Radish	*Raphanus sativus* L.	-	0
Red pepper	*Capsicum annum*	-	0
Sorghum	*Sorghum vulgaris*	-	0
Wheat	*Triticum aestivum*	-	0
Cucumber	*Cucumis sativus* L.	-	3
Eggplant	*Solanum melongena*	Black Beauty	4
Jute	*Corchorus olitorius*	-	3
Muskmelon	*Cucumis melo* L.	-	4
Okra	*Hibiscus esculentus*	-	3
Pumpkin	*Cucurbita moshata*	-	3
Purslane	*Portulaca oleracea*	-	3
Snapbean	*Phaseolus vulgaris*	-	3
Squash	*Cucurbita pepo* L.	-	4
Tomato	*Lycopersicon esculentum*	-	4
	Lycopersicon esculentum	Combo C_2VF_2	4
	Lycopersicon esculentum	Moneymaker	4
	Lycopersicon esculentum	VFN Bush	0
	Lycopersicon esculentum	Strain B	4

N.B.: - = Local Variety

CHEMICAL CONTROL

In small-scale pot experiments, Nemacur-p and Terrcur-p in granulated formulations were incorporated to the top 5 cm of the soil to control M. javanica infecting eggplant variety 'Black Beauty.' The nematicides were applied at the following rates: 0, 0.25 and 0.5 g/pot. The results obtained indicate that chemical treatments were highly effective in controlling the nematodes and increasing the weight of the test plants.

FUTURE PLANS

-Survey work and evaluation of damage caused by root-knot nematodes Meloidogyne spp. will continue.

-More emphasis shall be laid on field cultural practices in crop rotation, fallow and weed control.

-Study on the use of nematicides against these nematodes.

-Further experiments shall follow in cooperation with plant breeders to identify plants resistant to root-knot nematodes.

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NATIONAL COUNCIL FOR RESEARCH[1] AND INTERNATIONAL *MELOIDOGYNE* PROJECT[2]

THIRD PROGRESS REPORT ON ROOT-KNOT NEMATODES IN THE SUDAN, 1979/80

A. M. Yassin* and A. B. Zeidan**

GLASSHOUSE AND LAB EXPERIMENTS

Identity of Root-Knot Nematodes

Western Sudan (Region No. V)[3]. An investigation was undertaken for Region V, Western Sudan, during 1979-80. Soil and root samples from severely infested eggplant and tomato naturally grown in the field at El Obeid and El Ban Gadeed areas, were collected in the usual way and used in the extraction of various stages of root-knot nematodes, using the standard techniques. Identifications of *Meloidogyne* species extracted were then carried out by means of both the standard N.C. Differential Host Test and perineal pattern morphology. Details of the results, especially those of the N.C. Differential Host Test, are shown in Table 1.

Both *M. javanica* and *M. incognita* were found, but *M. javanica* was much more prevalent. The two species occurred in a ratio of about 4:1, *M. javanica* to *M. incognita* respectively. No further investigations were undertaken to tell which races existed in either species.

Central Sudan (Region No. I)[3]. As already stated, both *M. javanica* and *M. incognita* could infect field crops in this locality, in an approximate ratio of 2:1, respectively. Universally speaking, *M. javanica* is rarely known to occur in more than one race (though there

[1]NCR = National Council for Research, D.R. Sudan.

[2]IMP = International *Meloidogyne* Project; sponsored by the USAID, through the North Carolina State University.

[3]For details of regions, reference is made to map of the Sudan, 2nd progress report, June 1979.

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Table 1. Glasshouse Experiment (1979-80). Initial identity of root-knot nematodes* from Region No. V, Western Sudan, using the standard N.C. Differential Host Test.

Standard differential host	R.I.** Mean	(and range)
Watermelon (Charleston Grey)	4.8	(4-5)
Tomato (Rutgers)	4.2	(4-5)
Tobacco (NC 95)	4.2	(3-5)
Pepper (California Wonder)	1.1	(0-2)
Cotton (Deltapine 16)	0	(0-0)
Peanut (Florunner)	0	(0-0)

*Further identifications by perineal pattern morphology showed the occurrence of *M. javanica* and *M. incognita* in the ratio of 4:1, respectively.

**Root-knot index (R.I.) on a scale of 0-5, where 0 = no infection, 1-3 = mild to moderate, and 4-5 = heavy infection.

is an indication that it can exist in 2 races, in literature). M. incognita, on the other hand, is known to exist in 4 races. The commonest, universally speaking again, is race 1 followed by race 2. Both races 1 and 2 are differentiated from each other by the use of 'NC 95' tobacco. Thus, while this host plant is tolerant to race 1, it is susceptible to race 2. According to investigations undertaken in the Headquarters of the IMP at the North Carolina State University, on our samples of root-knot dispatched from Region No. 1, Central Sudan, the identity of our race was 2 since 'NC 95' tobacco was susceptible. On the other hand, in another M. incognita sample examined at the ARC nematology laboratory at Wad Medani, this differential tobacco cultivar was immune. Therefore, we are likely to have a mixture of M. incognita races 1 and 2.

Host Range of M. javanica

The host status of M. javanica, which was originally isolated from a mixture of M. javanica and M. incognita taken from root samples in Region No. 1, Central Sudan, during 1979-80, was investigated. In this test, two sets of plants were included. The first set contained the major crops of economic importance in the Gezira locality, and the second consisted of some of the predominant weed flora from the same locality.

As before, a total of 5 seedlings of each plant species in each set were raised in the glasshouse at the GRS and subsequently inoculated with a total of 10 egg masses, each near the root zone in the usual way. All were then kept under frequent observation and regularly watered in the usual manner. After the standard period of 8 weeks, the roots were analyzed for the presence of infective females, as well as egg masses, in the standard manner. The results are summarized in Table 2.

The M. javanica isolate tested reacted differently to the various plant species. However, up to 18 of the cultivated crops were good hosts of the nematode isolate from Region No. 1. Among these were sorghum millet (cv. 'Feterita' and 'Dabar'), okra, eggplant, Haricot bean, squash, tobacco (cv. 'NC 95'), tomato (cv. 'Pearson', 'Strain B'

Table 2. Glasshouse Experiment (1979-80). Host range of *Meloidogyne javanica** from Region No. I, Central Sudan, using (a) crops of economic importance and (b) major weed species, in the Gezira locality.

Plant species	Infestation level (R.I.)
a) Crop plants:	
Arachis hypogaea L. (Peanut, C.V. M.H. 383)	0 Immune
Gossypium barbadense L. (cotton, C.V. Barakat)	
Allium cepa L. (Onion, C.V. Nasie)	
Capsicum annuum L. (Green Pepper, C.V. Cal. Wonder)	
Cajanus cajan L. (Pigeon pea)	
Glycine max. L. (Soya bean C.V. Semes)	1-3 Moderately susceptible
Glycine max. L. (Soya bean C.V. Williams)	
Oryza sativa L. (Rice C.V. IR 2053-206-1-3-6)	
Pennisetum typhoideum Strap (Finger millet)	
Cucurbita maxima Duch. (Vegetable marrow)	
Cucurbita pepo L. (Squash)	
Cucumus sativus L. (Cucumber)	
Citrullus vulgaris Schral (Watermelon)	
Corchorus olitorius L. (Jute)	
Lablab vulgaris L. (Lubia bean)	
Lycopersicon esculentum Mill (Tomato C.V. Pearson)	
Lycopersicon esculentum Mill (Tomato Money Maker)	
Lycopersicon esculentum Mill (Tomato Strain B)	4-5 Highly susceptible
Nicotiana tabacum L. (Tobacco NC 95)	
Phaseolus vulgaris L. (Haricot bean)	
Portulaca oleraceae L. (Purslane)	
Hibiscus esculentus L. (Okra)	
Solanum melongena L. (Eggplant)	
Sorghum vulgare Pers (Sorghum millet C.V. Dabar)	
Sorghum vulgare Pers (Sorghum millet C.V. Feterita)	
Triticum vulgare H.C. (Wheat C.V. Giza 155)	
Triticum vulgare H.C. (Wheat C.V. Mexicani)	

Table 2 continued

Plant species	Infestation level R.I.)
b) Weed species:	
Acalypha indica L.	
Datura metel L.	
Phyllanthus niruri L.	
Abutilon gluacum Webb.	
Sida alba L.	
Cynodon dactylon L. (Bermuda grass)	
Cyperus rotundus L. (Sedge grass)	1-3 Moderately susceptible
Brachiaria sp. (Trin) Griseb.	
Dicanthium annulatum Forsk	
Ischaomum afrum Jameel	
Eragrostis sp. (Jacq.) Nees.	
Echinochloa colonum L.	
Sorghum sudanenses Piper (Sudan grass)	
Heliotropium sudanicum Andr.	
Corchorus trilocularis L. (wild Jute)	
Solanum dubium Fresen.	
Ipomoea kordofana Choisy.	
Merremia emarginata Burm.	
Ocimum basilicum L.	
Rhynchosia memnonia (Del.) D.C.	4-5 Highly susceptible
Hibiscus sp. L. (Wild okra)	
Phaseolus trilobus L. (Phillipesara)	
Sonchus cornutus Hochst.	
Calotropis procera Ait.	

*M. javanica was originally isolated from a mixture of M. javanica and M. incognita from root samples at a site at Region No. I, Central Sudan, during the season 1978-79.

**Root-knot index (R.I.) on a scale of 0-5, where 0 = no infection, 1-3 = mild to moderate, and 4-5 = heavy infection. Unless otherwise stated, the plant cultivar is from a local source.

and 'Money Maker'), and watermelon (cv. 'Charleston Grey'). By comparison, finger millet, pepper (cv. 'California Wonder'), onion (cv. 'Nasei'), soya bean (cv. 'Semes' and 'Williams'), rice (cv. 'IR 2053-206-1-3-6') and pigeon pea were moderately infected. Those immune to nematode attack were cotton (cv. 'Barakat') and peanut (cv. 'M.H. 383') (Table 2a).

As regards the predominant natural flora tested, some of them were severely attacked by the nematode as indicated by numerous distinct galls, i.e. high root-knot index as well as abundant reproductive females. These were Solanum dubium, Ipomoea kordofana, Hibiscus sp., Phaseolus trilobus, Merremia emarginata, Ocimum basilicum, Rhynchosia memnonia, Sonchus cornuts and Calotropis procera (Table 2b). It is thus highly likely that those weed species might serve as alternate hosts of M. javanica in the Gezira locality along the Nile bank.

Effect of Watering Interval on Infestation Levels

In these tests, the effects of the different watering regimes on the infestation levels of M. javanica were investigated. As before, the same nematode inoculum from Region No. 1 was used. The materials and methods and the rest of the experimental procedure were all as before. Treatments included complete flooding and heavy, conventional, and light waterings. However, in order to avoid heavy loss of seedlings due to complete flooding, the latter was made to precede planting by about a week. A total of 40 3-inch pots were used. Each was filled with 1:1 (v/v) sterilized sand and river silt. A single 3-week-old eggplant seedling, cv. local, was then planted in each pot and inoculated with a total of 10 egg masses of nematode isolate as before. All of the pots were then wrapped with polythene sheeting as before. They were then divided into 4 lots of 10 each. The plants in each lot were watered as follows: (1) = light watering (once/2 days), (2) = conventional (twice a day), (3) = heavy (3 times/day), and (4) = complete flooding. All were then kept under regular observation. After about 8 weeks, the roots were analyzed for infection levels in the standard manner. The results are summarized in Table 3.

ble 3. Glasshouse Experiment (1979-80). Effect of watering interval on the infestation levels of root-knot nematode, *M. javanica** from Region No. I, Central Sudan.

Watering Regime	R.I.** mean (range)
Complete flooding	2.6 (0-5)
Heavy watering (once/day)	4.0 (3-5)
Conventional watering (once/day)	4.9 (4-5)
Light watering (once/2 days)	4.8 (4-5)

*This *M. javanica* culture was originally isolated from a mixture of *M. javanica* and *M. incognita* from root samples at a site at Region No. I, Central Sudan, during 1978-79.

*Root-knot index (R.I.) on a scale of 0-5, where 0 = no infection, 1-3 = mild to moderate, and 4-5 = heavy infection.

The results were largely in agreement with those of the previous season. Thus, the lowest infection level, represented by a mean R.I. of 2.6, was associated with the completely flooded treatment, and was followed respectively by those of heavy, conventional, and light waterings (4.0, 4.9, and 4.8 mean R.I., respectively).

The Life Cycle of M. javanica

The life cycle of the M. javanica isolate from Region No. 1 (Central Sudan) was studied under glasshouse conditions (ambient temperature, 25-40°C) at the GRS using three of the region's best known host plants: namely, tomato (cv. 'Money Maker'), and local varieties of lubia bean and eggplant. A total of 300 10 x 15-cm polythene bags each were filled with about 50g pure river sand. Seedlings of tomato, lubia bean and eggplant cultivars on hand were then planted in the sand and divided into lots of 100 each. Each of these three sets was then divided into two 50-bag groups as follows: (a) the first set received egg masses in lots of 10 each, in the usual way; (b) the second received newly hatched infective larvae, instead of egg masses, in lots of about 300 each; (c) the third set served as an uninoculated control. All were then kept on the glasshouse bench so that normal watering could be provided and the soil temperature noted during the duration of the 9-10 week experimental period. Thereafter, the contents of the bags were examined at intervals of 24 hr so the progressive development of the nematode within the root tissue could be noted. This was accomplished by staining the infected root pieces with acid-fuchsin-lactophenol in the manner adopted by McBeth, Taylor and Smith (4), and then examining them under the microscope. During such observations, detailed camera lucida illustrations were made.

In the set of bags inoculated with larval forms, and in all cases of the three host plants tested, root penetration took place within 24 hr of inoculation. By comparison, in the set in which egg masses were introduced in place of the larvae, such larval penetration took place within a longer period of 48 hr. Irrespective of the inoculum source or host plant, however, the penetration site was at or near the root cap, or else only a few mm away from the root tip.

Afterwards, and again irrespective of type of inoculum or host plant, the progressive developments were almost identical and could be quoted as follows:

(a) 3-6 days after inoculation, the larvae remained sedentary within the cortex tissue, but still retained the thread-like form. They were situated along the root axis with their head regions towards the vascular cylinder. Some of the roots started to swell;

(b) 7 days after inoculation, on the other hand, some of the larvae started to swell and small galls started to develop;

(c) 8-13 days after inoculation, the swollen larvae started to enlarge and well-developed galls were seen;

(d) on the 14th and 15th days, some of the swollen larvae started to take a pear-shaped form;

(e) on the 16th day, fully formed females started to develop;

(f) 18 days after inoculation, fully developed females started to exhibit maturity as indicated by the secretion of gelatinous matrix; at this stage, fully developed males were also observed within the root tissue;

(g) 20 days after inoculation, mature, gravid, females were detected;

(h) on the 22nd day, most of the females laid eggs in substantial numbers of about 500 eggs/female.

From these observations, it might be drawn that, (a) the life cycle of M. javanica from Central Sudan, Region No. 1, from egg to mature female, took about 3 weeks to complete. This was the case at an ambient temperature of 25-40°C, at a soil temperature of 24-36°C, and on tomato (cv. 'Money Maker'), lubia bean or eggplant, local varieties, as hosts. These results largely agree with those of previous investigators (1, 2, 3, 5, 7). (b) Fully developed knots could be detected in about two weeks time under the conditions of the experiment stated above.

FIELD EXPERIMENTS

During this season, the field experiments were conducted in one of the two sites chosen in the previous season, namely at a site near Hillat Hassan (the other site at Umm Sunut was abandoned because of difficulties arising from heavy weed infestation and irregular water supply). Both of the experiments on nematicidal tests, as well as on the performance of resistant tomato lines, were repeated this season.

Experiment 1A - Nematicidal Tests

This experiment was set up on half of the area. As before, the same tomato cultivar, Strain B, and the same nematicides, Bunema 40 E, Furadan 10G, Nemacur 5G, Temik 10G and Vydate 10G, were all included. They were applied at standard gross rates per feddan* of 40 gal, 10 kg, 1 kg, 6 kg and 25 kg, respectively. Control plots received no nematicidal treatments. The experimental set up, as before, was a randomized block design of 4 replicates of 5 x 3 m subplots each. The standard cultural practices in the planting of tomato were followed, as before. The plants received 16 kg/feddan urea as fertilizer, and were weeded by hand 5 times. Towards the end of the season, the following data were considered as before: (1) plant size as measured by circumference and height (cm), (2) yield of mature fruits, and (3) root-knot index as measured by heaviest attack of up to 5 R.I. level. The results were then summarized in Table 4.

Generally speaking, all of the nematicidal treatments resulted in lower root-knot infestation levels (9-46%), larger plant size (30 x 36 - 34 x 73 cm), as well as higher fruit yield (135-184 kg/1000 plants). By comparison, control plants exhibited higher root-knot infection levels of up to 51%, smaller plant size (30 x 59 cm), and lower fruit yield of only 73 kg/1000 plants. Vydate again, as in the previous season, behaved best in all of the aspects considered, followed respectively by Nemacur, Bunema, Furadan and Temik (Table 4).

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*One feddan = 1.038 acres.

Table 4. Field Experiment I (1979-80). Nematicidal tests in tomato, Strain B, against root-knot nematodes from naturally infested soil at a site at Hillat Hassan, Region I*, Central Sudan.

Treatment	% Heavily infested plants	Plant size (cm)	Yield (kg/1000 plants)
Vydate	9 (0-25)	34 x 73	184 (153-243)
Nemacur	22 (20-28)	33 x 68	157 (137-192)
Bunema	30 (21-44)	32 x 67	155 (135-178)
Furadan	33 (16-53)	30 x 63	152 (132-164)
Temik	46 (32-62)	33 x 67	135 (87-171)
None	51 (45-57)	30 x 59	73 (55-107)

*Previous investigations in the season 1978-79, showed a possible mixture of *M. javanica* and *M. incognita* in the ratio of 2:1, respectively.

Experiment 1B - Tests of Resistant Tomato Lines

As in the previous season, the other half of the plot was used in these tests. Six tomato varieties, bred especially for resistance against M. javanica in various parts of the world, were imported as seeds and included for the first time in the tests. These were 'Nemared,' 'Kalohi,' 'Healani,' 'Royal Chico,' 'VFN-8,' and 'Manalucie' (6). Together with these, tomato cultivars previously tested were also included: namely, 'Rossol,' 'Marsol,' 'Piersol,' and 'Romano NR.' In addition, both 'Strain B' and 'Money Maker' cultivars were also included for comparison as they are known to be highly susceptible to root-knot attack in the locality. As before, all of the cultivars were planted in succession, in 5 x 3 m subplots, and replicated 3 times. The usual cultural practices were followed in their cultivation. Towards the start of the season, the same three sets of data, i.e. root-knot infection level (R.I.), plant size, and fruit yield, were considered. The results are summarized in Table 5.

Generally speaking, five of the six newly planted varieties, i.e. 'Nemared,' 'Healani,' 'Kalohi,' 'Royal Chico' and 'VFN-8,' were immune to root-knot infection, while the sixth variety, 'Manalucie,' was as susceptible as those previously tested (R.I. 2.0-3.8). Also, as in the previous season, there was no clear-cut correlation between yield data and plant size of various cultivars on the one hand, and root-knot infestation level (R.I.) on the other (Table 5).

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Table 5. Field Experiments (1979-80). The performance of selected tomato lines under natural conditions of root-knot infestation at a site at Hillat Hassan, Region No. I*, Central Sudan.

Tomato variety	% Heavily infested plants	Plant size (Ht. x circum.) (cm)	Yield (kg/1000 plants)
Kalohi	0 (0-0)	47 x 103	272 (271-281)
Nemared	0 (0-0)	44 x 94	220 (179-239)
Royal Chico	0 (0-0)	46 x 94	179 (159-220)
VFN-8	0 (0-0)	39 x 79	151 (131-181)
Healani	0 (0-0)	41 x 85	146 (119-182)
Marsol	20 (16-29)	50 x 90	257 (174-374)
Manalucie	23 (21-27)	52 x 108	102 (85-134)
Rossol	27 (24-31)	48 x 83	283 (166-388)
Romano NR	27 (21-33)	54 x 107	234 (163-362)
Piersol	38 (30-46)	52 x 91	159 (127-204)
Strain B	71 (52-85)	36 x 79	168 (139-225)
Money Maker	84 (76-100)	50 x 94	125 (96-176)

*Previous tests, 1978-79, showed a possible mixture of *M. javanica* and *M. incognita* in the ratio of 2:1, respectively.

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APPENDIX I

Glasshouse Temperature Range 1979-80, GRS

Month	Mean Max. °C	Mean Min. °C
June 1979	39.0	27.4
July 1979	37.0	26.0
Aug. 1979	33.0	25.2
Sep. 1979	37.1	25.0
Oct. 1979	39.0	25.0
Nov. 1979	36.0	20.6
Dec. 1979	34.0	15.0
Jan. 1980	34.2	17.0
Feb. 1980	37.0	19.0
Mar. 1980	40.0	21.1
Apr. 1980	41.0	25.0
May 1980		

ROOT-KNOT NEMATODES IN THE SUDAN, 1982 ROUND-OFF REPORT

A. M. Yassin* and A. B. Zeidan**

GENERAL INTRODUCTION

Status of Nematology in the Sudan, A Bird's Eye-View

Not more than a few qualified nematologists are at present engaged in nematological studies. Since serious nematological investigations started about a decade ago, some 70 species of plant-parasitic nematodes were detected in and around the roots of many cultivated and weed plants in various localities throughout the country (1, 2, 3, 5). Among the most important by far, however, are the root-knot nematodes.

Species and Distribution of Root-Knot Nematodes

Universally speaking, root-knot nematodes are considered among the most important tropical parasites; the Sudan is not an exception. They were thus found to be widely distributed in this vast country in river silt along the Nile bank and also in light alluvial soils, e.g. of western and southern sectors, but not under the Gezira heavy clay. In these localities they can infest many crop and weed plants (see also results of completed research), but those most severely affected are vegetables and tobacco. A total of 5 species are thus far identified. These are *Meloidogyne africana*, *M. arenaria*, *M. incognita*, *M. javanica* and possibly also *M. megadora* (2) (see also attached Table), but the most common are *M. arenaria*, *M. incognita* and *M. javanica*. The most economically important are, however, the last two (4). While *M. javanica* can inflict heavy damage especially in tomato and tobacco, in the northern sector, *M. incognita* is more prevalent in the south, both on tomato and eggplant (4).

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Table 1. Checklist of root-knot nematodes in the Sudan and host plants (Yassin, 1974; Decker, Yassin and El Amin, 1980)

Nematode species	Species and locality of economically infested plants
Meloidogyne arenaria (Neal) Chitwood	Dolichos bean (*Lablab* vulgaris Savi)[1]
	*Tomato (*Lycopersicon esculentum* Mill.)[3]
	French bean (*Phaseolus vulgaris* L.)[2]
	Eggplant (*Solanum melongena* L.)[1]
M. incognita (Kofoid & White) Chitwood	Jute (*Corchorus olitorius* L.)[1]
	Squash (*Cucurbita maxima* Duch.)[1]
	Dolichos bean[1]
	Tomato[1]
	French bean[2]
	Eggplant[3]
M. javanica (Treub) Chitwood	Jute[1]
	Squash[1]
	Carrot (*Daucus carota* L.)[2]
	Okra (*Hibiscus esculentus* L)[1]
	Dolichos bean[1]
	*Tomato[1]
	*Tobacco (*Nicotiana tabacum* L.) var. White Gold 1-2
	Sida alba L.[1]
	Eggplant[1]
Others: *M. arenaria*	*Ageratum* sp.[1]
	Amaranthus sp.[1]
	Calotropis procera R. Br.[1]
M. africana and *M. megadora*	Pepper (*Capsicum annuum* L.)[1]
	Fennel (*Foeniculum vulgare* Mill.)[1]
	Lettuce (*Lactuca sativa* L.)[2]
	Guava (*Psidium guajava* L.)[1]
	Phyllanthus sp.[1]
	Euphorbia atropurpurea Bronss.[1]

[1]Central Sudan: (Blue Nile and part of Khartoum Province).

[2]Western Sudan: (Darfur and part of Kordofan Province).

[3]Southern Sudan: (Wau District).

Their Economic Importance

It is difficult to assess damage due to root-knot invasion under the existing system of peasant farming along the Nile bank. On the other hand, up to 70-100% of the tobacco and tomato plants in pilot farms around Zalingei might be completely devastated by M. javanica. Likewise, in southern Sudan, e.g. around the canning factory in Wau District, M. incognita is a limiting factor in the production of vegetable crops to supply the factory. In fact it was responsible for the failure of pilot experiments in the locality.

RESEARCH PROGRAMS UNDERWAY AND FUTURE PLANS

1. Continued identity of root-knot species especially in western and southern Sudan, and especially as regards races.

2. Continued investigations of the host range of major species, e.g. M. javanica and M. incognita especially in central Sudan.

3. Etiology and ecology: continued study of the effect of soil type on infestation levels, especially of M. javanica in central Sudan as to cast light on the observed phenomenon of freedom of the Gezira heavy clay from any natural infestation.

4. Control strategies:

   a) continued tests of resistant tomato varieties, such as 'Nemared,' the VFN Series (8, 10, Bush, etc.), 'Marsol,' 'Rossol,' 'Ronita,' etc., against local races especially of M. javanica and M. incognita in central Sudan.

   b) use of nematicides, e.g. Furadan, Vydate, Bunema, Temik, Nemacur, etc.

   c) use of cultural practices, e.g.

      i. effects of soil amendments using different carbohydrate and leguminous straw on control.

      ii. effects of watering regime on infestation levels.

      iii. planning of a suitable crop rotation in light of results in areas 1 & 2.

RESULTS OF INVESTIGATIONS WITHIN IMP

Two detailed progress reports have already been published and are available from the Principal Investigator. A third one will be delivered at this present third conference. The following might, however, be extrapolated from these three reports:

1. Various aspects of the ecology and biology of root-knot nematode species within the Sudan have been studied, with particular emphasis on Meloidogyne javanica as it was found to be the predominant species:

a) Generally speaking, natural infestation was confined to lighter soils, e.g. along the Nile banks, or in those of volcanic origin in the west or south.

b) The Gezira heavy clay, on the other hand, was absolutely devoid of infestation by any of the major species, e.g. M. javanica or M. incognita, under natural conditions, although it was found to be receptive in pots.

c) Among the plants that were experimentally susceptible under glasshouse conditions were several field crops (more than 20), as well as 24 predominant weeds, especially in Central Sudan (see 3rd progress report).

d) Both cotton and groundnut, by contrast, exhibited absolute immunity, both experimentally as well as naturally.

e) On the other hand, 9 of the 24 weed species tested were highly susceptible (3rd progress report).

2. Various control practices, especially against M. javanica in tomato, have been investigated. Among the most important of these are:

a) Use of resistant cultivars, e.g. 'Nemared' and 'Healani' (USA), 'Rossol' and 'Marsol' (France) and 'Ronita' (Italy);

b) Planting in heavy clay, e.g. of Gezira or eastern Sudan rainlands, whenever possible;

c) Use of suitable rotation in light of host range results and according to local need;

d) Use of cultural practices, e.g. deep ploughing and dry fallow to kill nematodes by desiccation and starvation;

e) Use of nematicides as last resort under peasant farming system.

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ROOT-KNOT NEMATODES IN TUNISIA

Maurice Moens and Bechir Ben A'icha*

Among the plant-parasitic nematodes, the root-knot nematodes are the most important in Tunisia. They can be found from the north (Bizerte) to the south (oasis of Tozeur and Gabes) on various crops.

Vegetables appear to contain the greatest number of hosts for these polyphagous nematodes. Tomato, pepper, cucurbits (melon, watermelon, and a local cucumber) and cauliflower frequently present severe galling. Also carrot, spinach, beet, onion, radish and potato are sometimes attacked. As different types of the same culture exist, damage caused by root-knot nematodes depends principally on climatic circumstances. In a tomato culture, the following list (in order of decreasing importance of the root-knot nematodes on the yield) is applicable:

- post-season culture (planting: August-September)
- plastic tunnel culture (planting: October-December)
- season culture (planting: March-April)
- early culture (planting: November under low plastic tunnel)

Almost all fruit species are good host plants for root-knot nematodes. Almond, peach, pomegranate and olive trees are often found infested. Several times nurseries are infested, and young trees have been destroyed.

Weeds maintain root-knot nematodes on non-cultured land. Solanum nigrum is frequently found infested.

Research Program at San Monastir

The Station d'Appui Nebhana was created by the Tunisian and Belgian governments in 1976. The goal of the project is the improvement of the vegetable culture in the Nebhana region by different techniques including: cultivar choice, climate improvement in plastic tunnels,

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irrigation schemes and material, and control of plant parasites and pests. The Nebhana region is the principal post-season and early culture centre of Tunisia covering 16,000 ha in the governorates of Sfax, Mahdia, Monastir and Sousse.

During the next few years the plant protection division will spend the majority of its time on Meloidogyne spp. that attack vegetables. Approximately 100 populations of different origins have been collected up to now, and species determination has started. It is too early to give detailed information, but Meloidogyne incognita and Meloidogyne javanica are predominant.

Species determination is done by observation of perineal patterns of females from single egg mass cultures. Morphometric measurements of females, males and juveniles will also be carried out. When possible, biochemical determinations will complete this study.

Shortly, studies will start which deal with the pathogenicity and the reproductive capacity of different Meloidogyne species and races to different vegetable cultures (with emphasis on tomato, pepper and cantaloupe). We hope to determine in this way the tolerance and the root-knot nematode host capacity of the principal vegetable cultures. When possible, different cultivars and nematode population levels will be examined.

Special attention will be given to the adaptation of the root-knot nematode to the host plant. An "in vitro" study will try to determine the influence of different host plants and their sequence on the perineal pattern, aggressiveness and multiplication of different root-knot nematode populations.

The influence of the temperature on the relationship of root-knot nematode to host plant will be examined in controlled conditions. Different parameters and histological studies of the root will form the basis for the interpretation.

Screening of the sensitivity of a great number of cultivars of the most important cultures to different Meloidogyne spp. and races will be done "in vitro." The most promising ones will be checked for field resistance and agronomic qualities.

Meanwhile, microplot rotat'.on experiments have been started. The first experiment set up in a root-knot nematode-infested field is composed of the following 4-year crop patterns:

A. 1. Postseason tomato
   2. Strawberry
   3. Pepper-onion
   4. Potato-cucurbit

B. 1. Postseason tomato
   2. Strawberry
   3. Pepper
   4. Fennel-eggplant

C. 1. Early tomato
   2. Fodder culture
   3. Cauliflower-potato
   4. Fennel-cucurbit

D. 1. Early tomato
   2. Strawberry
   3. Pepper
   4. Potato-cucurbit

The second experiment has been set up under a plastic tunnel and consists of different sequences of tomato, pepper and cantaloupe. In both experiments a root-knot resistant tomato cultivar is used when agronomically possible.

AN OVERVIEW OF THE TAXONOMY OF THE ROOT-KNOT AND CYST NEMATODES WITH EMPHASIS ON THE GENUS MELOIDOGYNE

Hedwig H. Triantaphyllou*

Earlier, the root-knot and cyst nematodes were included in the family Heteroderidae Filipjev, 1934, and the two subfamilies Meloidogyninae and Heteroderinae were recognized. According to the present classification, the root-knot and cyst nematodes are members of the superfamily Heteroderoidea, and thus the subfamilies Meloidogyninae and Heteroderinae were raised to family rank (Table 1). Thirteen genera are now included in the Heteroderidae, three genera in the Meloidogynidae.

The family Meloidogynidae differs from the family Heteroderidae by a number of characters:

a) the usually wider lateral sectors of the head region in females, juveniles and males;
b) the more anterior position of the excretory pore in females;
c) the larger, slitlike amphidial openings in juveniles and males;
d) the smaller stylet in juveniles; and
e) the absence of a stylet in third- and fourth-stage juveniles.

THE GENUS MELOIDOGYNE

Root-knot nematodes were first named in 1879 by Cornu (5) who gave the name Anguillula marioni to the nematodes inhabiting galls on sainfoin in France. In 1884, Müller found worms in galls on the roots of Dodartia orientalis (16), and recognized that they belonged to the genus Heterodera. He mistakenly took them to be the same as those described by Greeff in 1872 (15) as Anguillula radicicola and called them Heterodera radicicola. Thus in the early 20th century, the name Heterodera radicicola (Greeff, 1872) Müller, 1884, was wrongly used for the root-knot nematodes. In 1924, Cobb claimed that there were morphological differences between root-knot nematodes and the cyst-forming Heterodera species and erected the genus or subgenus Caconema to receive H. radicicola (4). In 1932, T. Goodey pointed out Müller's

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Table 1. Classification of Heteroderoidea

Superfamily	Family	Subfamily	Genus
Heteroderoidea (Filipjev & Schuurmans Stekhoven, 1941) Golden, 1971	Heteroderidae (Filipjev & Schuurmans Stekhoven, 1941) Skarbilovich, 1947		*Heterodera* Schmidt, 1871
			Bidera Krall & Krall, 1978
			Cactodera Krall & Krall, 1978
			Globodera (Skarbilovich, 1959) Mulvey & Stone, 1976
			Dolichodera Mulvey & Ebsary, 1980
			Punctodera Mulvey & Stone, 1976
			Sarisodera Wouts & Sher, 1971
			Meloidodera Chitwood, Hannon & Esser, 1956
			Verutus Esser, 1981
			Cryphodera Colbran, 1966
			Atalodera Wouts & Sher, 1971
			Thecavermiculatus Robbins, 1978
			Hylonema Luc, Taylor & Cadet, 1978
	Meloidogynidae (Skarbilovich, 1959) Wouts, 1973	Meloidogyninae Skarbilovich, 1959	*Meloidogyne* Goeldi, 1887
			Meloinema Choi & Geraert, 1974
		Nacobboderinae Golden & Jensen, 1974	*Meloidoderella* Khan, 1972
		Meloidoderellinae Husain, 1976	

error (14). He replaced the specific name by Cornu's earlier specific name, so that the root-knot nematodes became Heterodera marioni (Cornu, 1879) T. Goodey, 1932. Goodey felt it unjustified to erect a new genus to separate root-knot nematodes from the existing Heterodera species.

Christie and Albin, 1944 (2), and Christie and Havis, 1948 (3), studied H. marioni and for the first time proposed the existence of physiological races based on differences in host susceptibility. In 1949, Chitwood (1) showed that there were morphological differences, particularly in the cuticular markings of the perineal region of adult females, of four of the races recognized in the work by Christie and Albin and Christie and Havis. Chitwood re-erected the genus Meloidogyne Goeldi, 1887, to receive all root-knot nematodes. He briefly redescribed the type species M. exigua and described four other species and one subspecies. He gave a generic diagnosis for Meloidogyne and differentiated it from Heterodera A. Schmidt, 1871. Whitehead, 1968 (17), in his comprehensive review redefined the genus and confirmed the morphological distinctness of 23 species of Meloidogyne. Franklin, 1971 (11), discussed the Meloidogyninae in relation to other Heteroderidae and summarized the most useful characters for identification of Meloidogyne species. In her 1972 review, Franklin included 32 species and treated critically the most recent developments of the systematics of Meloidogyne with emphasis on the distinguishing characters of the various life stages (12). Esser, Perry and Taylor, 1976 (10), presented morphometric and morphological data and illustrations to facilitate the identification of 32 species of the genus in their compendium of Meloidogyne. Franklin, 1979 (13), lists 36 valid Meloidogyne species and summarizes the historical background of the genus and the means of identification based on females, juveniles and males. By July 1982, 50 species and two subspecies were included in the genus (Table 2).

DIFFERENTIATING CHARACTERS OF SPECIES OF MELOIDOGYNE

Females (9)

The most characteristic feature of the females is the perineal pattern which comprises the tail terminus, phasmids, lateral fields, anus and vulva surrounded by cuticular folds and striae. Qualitative

Table 2. Species of *Meloidogyne*

1. *Meloidogyne acronea* Coetzee, 1956
2. *M. africana* Whitehead, 1960
3. *M. ardenensis* Santos, 1968
4. *M. arenaria* (Neal, 1889) Chitwood, 1949
5. *M. artiellia* Franklin, 1961
6. *M. bauruensis* (Lordello, 1956) Esser, Perry and Taylor, 1976
7. *M. brevicauda* Loos, 1953
8. *M. cameliae* Golden, 1979
9. *M. carolinensis* Fox, 1967 (redescribed by Eisenback, 1982)
10. *M. chitwoodi* Golden, O'Bannon, Santo and Finley, 1980
11. *M. coffeicola* Lordello and Zamith, 1960
12. *M. decalineata* Whitehead, 1968
13. *M. deconincki* Elmiligy, 1968
14. *M. elegans* da Ponte, 1977
15. *M. ethiopica* Whitehead, 1968
16. *M. exigua* Goeldi, 1887
17. *M. grahami* Golden and Slana, 1978
18. *M. graminicola* Golden and Birchfield, 1965
19. *M. graminis* (Sledge and Golden, 1964) Whitehead, 1968
20. *M. hapla* Chitwood, 1949
21. *M. incognita* (Kofoid and White, 1919) Chitwood, 1949
22. *M. incognita acrita* Chitwood, 1949
23. *M. incognita wartellei* Golden and Birchfield, 1978
24. *M. indica* Whitehead, 1968
25. *M. inornata* Lordello, 1956
26. *M. javanica* (Treub, 1885) Chitwood, 1949
27. *M. kikuyensis* de Grisse, 1960
28. *M. kirjanovae* Terenteva, 1965
29. *M. litoralis* Elmiligy, 1968
30. *M. lordelloi* da Ponte, 1969
31. *M. lucknowica* Singh, 1969
32. *M. mali* Itoh, Ohshima and Ichinohe, 1969
33. *M. megadora* Whitehead, 1968
34. *M. megatyla* Baldwin and Sasser, 1979

Table 2 (continued)

35. M. megriensis (Pogosyan, 1971) Esser, Perry and Taylor, 1976
36. M. microtyla Mulvey, Townshend and Potter, 1975
37. M. naasi Franklin, 1965
38. M. nataliei Golden, Rose and Bird, 1981
39. M. oryzae Maas, Sanders and Dede, 1978
40. M. oteifae Elmiligy, 1968
41. M. ottersoni (Thorne, 1969) Franklin, 1971
42. M. ovalis Riffle, 1963
43. M. platani Hirschmann, 1982
44. M. poghossianae Kirjanova, 1963 - species inquirenda
45. M. propora Spaull, 1977
46. M. querciana Golden, 1979
47. M. sewelli Mulvey and Anderson, 1980
48. M. spartinae (Rau and Fassuliotis, 1965) Whitehead, 1968
49. M. subarctica Bernard, 1981
50. M. tadshikistanica Kirjanova and Ivanova, 1965
51. M. thamesi (Chitwood, 1952, in Chitwood, Specht and Havis) Goodey, 1963
52. M. cruciani Garcia - Martinez, 1982

characters (e.g. shape of pattern, form of striae), as well as quantitative characters (i.e. certain measurements), of the pattern are useful in species identification. The stylet length can be a good supporting character, although the ranges of most species overlap. Stylet knob shape, as well as the ratio of knob height/knob width may also be useful. Position of the excretory pore may be helpful in differentiating some species.

Second-Stage Juveniles (6, 7)

Several morphometrical and morphological characters are useful in species identification. The morphometrical characters most frequently used include body length, stylet length and tail length. These measurements obviously overlap in many species, but the extreme values may be different. Stylet length is difficult to determine, and measurements from the stylet knob base to the head end may be more reliable. Stylet knob shape seems to differ among the species. Tail length is one of the most useful measurements, because it varies considerably among species. Body width at anus and the ratio of tail length/body width at anus are also important characters. Tail shapes vary greatly but are helpful to some extent. Rectal dilation and position of hemizonid can be useful in diagnosis.

Males (8)

Since males vary greatly in size, morphometrical characters are subject to large coefficients of variability. Although there occur some differences in stylet length, dorsal esophageal gland orifice distance, and spicule and gubernaculum length, there is also considerable overlap. Head shape and stylet morphology, however, can be considered as good supporting characters in the identification of species. Head morphology differs in size and shape of the head cap, number of head annulations and width of head region relative to the first body annule. Differences in stylets occur in size and shape of the cone, shaft and knobs. The lateral field is only occasionally of diagnostic value. The number of incisures usually varies within the same specimen in different body regions, and the same is true for areolation.

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

J. N. Sasser*

Approximately 1,300 live populations of Meloidogyne species, forwarded to project headquarters from approximately 100 cooperators representing more than 70 developing nations, are being studied. To date, 914 have been identified and frequency of species encountered is as follows: M. incognita, 52%; M. javanica, 31%; M. hapla, 8%; M. arenaria, 7%; 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 472 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 70 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

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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 world-wide market, is open to producers of seed of resistant cultivars.

MORPHOLOGICAL CHARACTERS USEFUL IN THE IDENTIFICATION OF *MELOIDOGYNE* SPECIES

J. D. Eisenback and H. H. Triantaphyllou*

An accurate identification of the *Meloidogyne* species present in a given field is necessary for the effective control of root-knot nematodes. Some crops are susceptible to some species but not others, and resistant cultivars are generally not effective against all species of *Meloidogyne*. Even chemical usage is enhanced by correct species identifications because application is not necessary if the crop to be planted is not a host for the species infesting the soil.

Often the identification of root-knot species is difficult because the morphological characters commonly used to distinguish species are quite variable. Other techniques useful for species identifications are either time consuming or require sophisticated equipment and highly trained personnel.

An important goal of the International *Meloidogyne* Project has been to elucidate new and more reliable morphological characters that would make the identifications of species practical and more rapid in laboratories with limited equipment and personnel. Morphological characterization of the four most common species, *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*, has been emphasized. Because these nematodes are extremely small, the scanning electron microscope (SEM) has been utilized to examine critically second-stage juveniles, males, and females. The SEM 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 often 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--

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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 level and in exact lateral position.

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 (1).

References

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CYTOGENETIC AND BIOCHEMICAL STUDIES AS AN AID TO IDENTIFICATION

A. C. Triantaphyllou*

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 3n=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

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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 3n=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.

ECOLOGICAL STUDIES -- PROGRESS TO DATE

A. L. Taylor, L. A. Nelson, and J. N. Sasser*

Over the past several years, the International *Meloidogyne* Project has been conducting a survey of root-knot nematodes. In conjunction with this survey, pertinent ecological information and a soil sample have been gathered for each population sample. Data on 662 of these samples from 64 countries have been analyzed. From the preliminary results of this ongoing study, some basic relationships between ecology and the geographical distribution of *Meloidogyne* species in agricultural soils have been elucidated.

Sample populations were increased at the Project Center and then subjected to the North Carolina Differential Host Test. Identification of samples was based on this test, morphological characters, chromosome counts, and electrophoresis. The soil samples were analyzed physically and chemically. Ecological information accompanying each sample included temperature extremes and medians; average precipitation; cropping history, latitude, longitude, and elevation of the collection site; host plant; and a subjective estimate of crop yield loss.

Species Distribution

Although more than 50 species of root-knot nematodes have been described, about 99% of the populations collected and identified by the IMP from cultivated crops around the world belong to one of 4 species: *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*. The first two species are widely distributed in tropical, subtropical, and warm temperate climates. Though less common than these species, *M. arenaria* also occurs in the same type of climates. *M. hapla*, on the other hand, is found primarily in cool to warm temperate climates.

Temperature

M. incognita, *M. javanica*, and *M. arenaria* occur in areas with an average temperature of 3°C or higher in the coldest month or 36°C or

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lower in the warmest month. The average temperature of the coldest month of the year is apparently the principal factor limiting the occurrence of these species.

M. hapla, on the other hand, is a cold climate species, received from one location with a coldest month temperature of as low as -15°C. There is no indication that this is the coldest temperature for survival of M. hapla. Temperatures of about 24 to 27°C may limit the occurrence of M. hapla in warmer parts of the world.

Precipitation

In this survey, root-knot nematodes were collected from locations with total annual precipitation ranging from nearly zero to 5000 mm. Most populations were collected from areas with 1000 to 1500 mm annual precipitation. Less than 10% of the M. hapla and M. arenaria populations and only 17% of M. incognita populations came from areas with less than 500 mm annual precipitation. However, 42% of the M. javanica samples were received from such dry climates. These facts indicate that M. javanica is the best adapted of the four species for survival 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 80% of the M. hapla samples, 70% of the M. arenaria samples, and 48% of the M. incognita samples and 30% of the M. javanica samples came from regions with precipitation well distributed throughout the year, that is, with no dry months.

The data on precipitation indicate that 1) M. javanica is best adapted to survive in climates with distinct wet and dry seasons, and 2) M. incognita is less well adapted to such conditions. 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 climates with well-distributed rainfall.

Soil pH

A correlation between soil pH and the frequency of occurrence of M. incognita and M. javanica has been found. Nearly 45% of M. javanica samples, and a lesser percentage of M. incognita samples, came from soils with pH values between 7.0 and 8.0. The positive correlation between high soil pH and the occurrence of M. incognita and M. javanica

reflects the prevalence of these two species in dry climates since areas with low rainfall tend to have a higher soil pH.

Soil Texture

Sand, silt, and clay analysis of infested soils has failed to reveal a high correlation between percentage of sand and severity and occurrence of root-knot nematode infestations. However, a significant inverse relationship appears to exist between infestation and percentages of silt and clay. Very few Meloidogyne populations have been collected from soils with more than 40% clay or 50% silt, probably because these small particles reduce soil pore space and, therefore, limit nematode dispersal through the soil.

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 15°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 12-15°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.

RELATIVE SUSCEPTIBILITY OF CERTAIN COMMERCIALLY IMPORTANT CULTIVARS TO EXISTING BIOTYPES OF *MELOIDOGYNE INCOGNITA* AND *M. JAVANICA* IN NILE-DELTA, EGYPT

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Control of plant-parasitic nematodes aims to maximize the efficient and effective use of arable lands to meet the increasing need for agricultural commodities. Chemical control agents, while effective, are too expensive; therefore, in a developing country like Egypt, other means of economic control measures must be practiced. As a control alternative, the management approach through the use of proper crop rotation schemes including resistant cultivars is the appropriate method. Very often, however, the employment of such cultural methods is confronted by the existence of additional races which enable the pathogen to overcome host resistance as well as by populations of other species which may infect the alternate crops. An understanding, therefore, of the effects of commonly grown cultivars on the relative reproduction rates of the existing nematode species and races will aid in the coping of these changes.

Seventy-nine cultivars of 21 economic crops commonly cultivated in Egypt were evaluated for host reaction to existing biotypes of *Meloidogyne incognita* and *M. javanica* from the Nile-Delta. Parameters of host susceptibility were based mainly on the capability of the nematode-biotype second-stage larvae to penetrate, develop into adult females and produce progeny. The following index was, therefore, established:

Immune (I) = No penetration took place and hence no evidence of gall formation and/or egg mass production;

Highly Resistant (HR) = Penetration took place with little gall formation (< 20/plant) and no egg mass production;

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Moderately Resistant (MR) = Penetration took place with little gall formation (< 20/plant) and little egg mass production (< 20/plant);

Moderately Susceptible (MS) = Penetration took place with nematode gall formation and/or egg mass production (20-200/plant);

Highly Susceptible (HS) = Penetration took place with more gall formation and egg mass production (200-600/plant);

Very Highly Susceptible (VHS) = Penetration took place with extensive gall formation and egg mass production (> 600/plant).

Data indicate in general the following host reaction to the specific tested biotypes (Table 1):

1. All tested peanut, Arachis hypogea, cultivars were rated as immune to all M. incognita biotypes, while they were rated as highly resistant and immune to M. javanica biotypes 1 and 2, respectively.
2. Most cultivars of sugar beet, Beta vulgaris, reacted as moderately susceptible hosts of all M. incognita biotypes, except the 'Viveka' cultivar which was rated as a highly resistant host of biotypes 1 and 2. Likewise, such cultivars were all rated as moderately susceptible hosts when tested against M. javanica biotypes.
3. Cultivars of watermelon, Citrullus vulgaris, reacted as highly susceptible hosts of M. incognita biotypes 1 and 3, whereas they were rated as very highly susceptible hosts of biotype 2, except for cv. 'Crimson Sweet' which was a highly susceptible host. Also, they were ranked as very highly susceptible hosts of biotype 4 except cv. 'Giza 1' and 'Crimson Sweet' which were ranked as highly susceptible hosts of this nematode biotype. When the watermelon cultivars were tested against M. javanica biotypes, they all reacted as highly susceptible hosts, except cv. 'Crimson Sweet' which was a moderately susceptible host of biotype 1.
4. All tested cultivars of sweetmelon, Cucumis melo var. aegyptiacus, reacted as highly susceptible hosts to biotypes 1 and 4 of M.

Table 1. Host suitability or resistance of economic crops to existing biotypes of *M. incognita* and *M. javanica*

Scientific name	Common name and cultivar	Host suitability to M. spp. & race					
		M. incognita				*M. javanica*	
		1	2	3	4	1	2
Arachis hypogaea	Peanut,						
	Giza 4	I	I	I	I	HR	I
	No. 219	I	I	I	I	HR	I
	No. 296	I	I	I	I	HR	I
Beta vulgaris	Sugar beet,						
	Carina	MS	MS	MS	MS	MS	MS
	HH-Mono 4-16-2	MS	MS	MS	MS	MS	MS
	HH-Mono 1-74	MS	MS	MS	MS	MS	MS
	Kawemegamono	MS	MS	MS	MS	MS	MS
	Monorica	MS	MS	MS	MS	MS	MS
	Norahill	MS	MS	MS	MS	MS	MS
	Viveka	HR	HR	MS	MS	MS	MS
	(26A01x54)x 4xSPO 68	MS	MS	MS	MS	MS	MS
Citrullus vulgaris	Watermelon,						
	Charleston	HS	VHS	HS	VHS	HS	HS
	Congo	HS	VHS	HS	VHS	HS	HS
	Crimson Sweet	HS	HS	HS	HS	MS	HS
	Giza 1	HS	VHS	HS	HS	HS	HS
	Giza 2	HS	VHS	HS	VHS	HS	HS
Cucumis melo var. *aegyptiaca*	Sweetmelon,						
	Balady	HS	VHS	VHS	HS	HS	MS
	Esmaellawi	HS	HS	VHS	HS	HS	MS
	Kooz Assal	HS	VHS	HS	HS	HS	MS
Cucumis melo var. *flexuosus*	Snake cucumber,						
	Nabolci	HS	HS	HS	VHS	HS	HS

Host response: I, immune; HR, highly resistant; MR, moderately resistant; MS, moderately susceptible; HS, highly susceptible; and VHS, very highly susceptible.

Table 1. Continued

Scientific name	Common name and cultivar	Biotype					
		M. incognita				*M. javanica*	
		1	2	3	4	1	2
Cucumis melo var. *reticulatus*	Muskmelon,						
	Amlas	HS	VHS	HS	VHS	HS	HS
	Santawi	HS	VHS	HS	VHS	HS	HS
Cucumis sativus	Cucumber,						
	Algue	HS	VHS	HS	VHS	HS	HS
	Beta Alpha	HS	MS	VHS	HS	HS	HS
	Garawani	MS	HS	VHS	VHS	HS	HS
Cucurbita sp.	Pumpkin,						
	Balady	HS	HS	VHS	HS	HS	HS
Cucurbita pepo	Squash,						
	Escandrani	HS	MS	HS	HS	HS	HS
	Dark zucchini	HS	MS	HS	HS	HS	HS
	Petro	HS	MS	HS	HS	HS	HS
Glycine max	Soybean,						
	Bragge	MS	MS	MS	HS	HS	MS
	Clark	MS	MS	MS	HS	HS	MS
	Dark	MS	MS	MS	HS	HS	MS
	Hale 7	MS	MS	MS	HS	HS	MS
	Hampton	MS	MS	MS	HS	HS	MS
	Harossy	MS	MS	MS	HS	HS	MS
	Lee	MS	MS	MS	HS	HS	MS
	Lee 68	MS	MS	MS	HS	HS	HS
	Rebel	MS	MS	MS	HS	HS	MS
	Williams	MS	MS	MS	HS	HS	HS
Helianthus annus	Sunflower,						
	Giza 1	VHS	MS	MS	HS	HS	VHS
	Mekhatt	HS	MS	MS	HS	HS	VHS
	Miak	VHS	MS	MS	HS	HS	VHS

Table 1. Continued

Scientific name	Common name and cultivar	Biotype					
		M. incognita				*M. javanica*	
		1	2	3	4	1	2
Hibiscus cannabinus	Kenaf,						
	Giza 1	MS	MS	MS	MS	MS	MS
	Giza 2	MS	MS	MS	MS	MS	MS
	Giza 3	MS	MS	MS	MS	MS	MS
	Line 5-67/84	MS	MR	MS	MS	MS	MS
	Line 1 68/80	MS	HR	MS	MS	HR	HR
Hibiscus esculentus	Okra,						
	Balady	VHS	MS	MS	VHS	HS	HS
	Romy	VHS	HS	HS	VHS	HS	HS
Hordeum vulgare	Barley,						
	Bonus	HR	HR	HR	MS	MS	I
	Giza 119	MR	MS	MS	MS	MS	I
	Giza 121	MS	MS	MS	MS	MS	I
Linum usitatissimum	Flax,						
	Abyssinian-C.I. 701	MS	MS	MS	HS	HS	MS
	Birio-0.1.1085	MS	MS	MS	HS	HS	HS
	Giza 4	HS	HS	MS	MS	MS	MS
	Victory-ACI 1170	MS	MS	MS	MS	MS	MS
	Wilden-C.I. 1193	MS	MR	MS	MR	MS	MR
Oryza sativa	Rice,						
	Giza 159	I	I	I	HR	I	HR
	Giza 171	I	I	I	HR	I	HR
	Giza 172	I	I	I	HR	I	HR
	Sakha 1	I	I	I	I	I	HR
	Sakha 2	I	I	I	I	I	HR

Table 1. Continued

Scientific name	Common name and cultivar	Biotype *M. incognita* 1	2	3	4	*M. javanica* 1	2
Phaseolus vulgaris	Common bean,						
	Contender	HS	HS	HS	MS	HS	HS
	Giza 3	VHS	HS	HS	MS	HS	HS
	Swiss Blanc	HS	HS	MS	MS	HS	HS
Triticum aestivum	Wheat,						
	Giza 155	HR	HR	HR	HR	MR	I
	Giza 156	HR	HR	HR	HR	MS	I
	Shenab	HR	HR	MR	MS	MS	I
	Stork-7	HR	HR	MR	MS	MS	I
Vicia faba	Broadbean,						
	Giza 1	MS	HS	HS	MS	MS	HS
	Giza 2	MS	HS	HS	MS	MS	MS
	Giza 3	MS	HS	HS	HS	MS	MS
	Giza 4	HS	HS	HS	HS	HS	HS
	Rebai 40	HS	HS	HS	HS	HS	HS
Vigna sinensis	Cowpea,						
	Azmerly	HS	HS	HS	HS	VHS	MS
	Balady	HS	HS	HS	HS	VHS	MS
	Black Eye	HS	VHS	HS	HS	VHS	HS
	Fitriat	HS	HS	HS	HS	VHS	MS
	Pink Eye	VHS	VHS	HS	HS	VHS	HS
Zea mays	Maize,						
	American Early	MR	MS	MS	MR	MS	MS
	Asheira 17	MS	MS	MS	MS	MS	MS
	Asheira 186	MS	MS	MS	MS	MS	MS
	Composite 108	MS	MR	MR	MR	MS	MS
	Giza 1	MR	MS	MR	MR	MS	MS

incognita. The cultivars 'Balady' and 'Kooz Assal' were ranked as very highly susceptible hosts to biotype 2, while cv. 'Esmaellawi' was a highly susceptible host to the same nematode biotype. To biotype 3, the 'Balady' and 'Esmaellawi' cultivars reacted as very highly susceptible hosts, whereas cv. 'Kooz Assal' was a highly susceptible host. The sweetmelon cultivars were ranked as highly and moderate susceptible hosts of biotypes 1 and 2 of M. javanica, respectively.

5. The snake cucumber, Cucumis melo var. flexuosus cultivar 'Nabolci,' was rated as a highly susceptible host of M. incognita biotypes 1, 2 and 3, while it was rated as a very highly susceptible host of biotype 4. The cultivar 'Nabolci' was rated as highly susceptible host of both M. javanica biotypes.
6. The cultivars of muskmelon, Cucumis melo var. reticulatus, were classified as highly susceptible hosts of M. incognita biotypes 1 and 3, while they were rated as very highly susceptible hosts of biotypes 2 and 4. Such cultivars were rated as highly susceptible hosts of M. javanica biotypes.
7. The susceptibility of cucumber, Cucumis sativus, cultivars also varied greatly according to the nematode biotypes. The cultivar 'Beta Alpha' was graded as a highly susceptible host of both biotypes 1 and 4 of M. incognita, while it was ranked as a moderately and very highly susceptible host of biotypes 2 and 4, respectively. 'Garawani' cultivar was a very highly susceptible host to biotypes 3 and 4, while it responded as a moderately and highly susceptible host to biotypes 1 and 2, respectively. Cultivar 'Algue' was ranked as a highly susceptible host of biotypes 1 and 3, and as a very highly susceptible host of biotypes 2 and 4. Such cultivars were rated as highly susceptible hosts for both M. javanica biotypes.
8. Pumpkin, Cucurbita sp. cultivar 'Balady,' was rated as a highly susceptible host to all biotypes of both species, except to M. incognita biotype 3 against which it reacted as a very highly susceptible host.

9. All squash, Cucurbita pepo, cultivars were classified as highly susceptible hosts of all M. incognita biotypes, except biotype 2, to which they all reacted as moderately susceptible hosts. Likewise, such cultivars were ranked as highly susceptible hosts of M. javanica biotypes.
10. Cultivars of soybean, Glycine max, were all rated as moderately susceptible hosts of M. incognita biotypes 1, 2, and 3. Such cultivars reacted as highly susceptible hosts of biotype 4. The reaction of the soybean cultivars to M. javanica was high and moderate susceptibility to biotypes 1 and 2, respectively.
11. All sunflower, Helianthus annus, cultivars were graded as moderately susceptible hosts when tested against M. incognita biotypes 2 and 3. Such cultivars were rated as highly susceptible hosts of biotype 4. To biotype 1, 'Giza 1' and 'Miak' reacted as very highly susceptible hosts, while Mekatt was ranked as a highly susceptible host. To M. javanica biotypes 1 and 2, all sunflower cultivars were graded as highly and very highly susceptible hosts, respectively.
12. All cultivars of kenaf, Hibiscus cannabinus, were classified as moderately susceptible hosts of M. incognita biotypes, except line 5-67/84 and line 1-68/80, which were ranked as moderately and highly resistant hosts, respectively, of biotype 2. Likewise, kenaf cultivars were found to be moderately susceptible hosts of M. javanica biotypes, except line 1-68/80 which was a highly resistant host of both biotypes.
13. Both tested cultivars of okra, Hibiscus esculentus, were classified as very highly susceptible hosts of biotypes 1 and 4 of M. incognita, while to both biotypes 2 and 3, the 'Romy' and 'Balady' cultivars were rated as moderately and highly susceptible hosts, respectively. Both cultivars reacted as highly susceptible hosts of M. javanica biotypes.
14. Cultivars of barley, Hordeum vulgare, were rated as moderately susceptible hosts of M. incognita biotype 4. Cultivar 'Bonus' was found to be a highly resistant host to biotypes 1, 2 and 3,

while cv. 'Giza 121' was ranked as a moderately susceptible host to such biotypes. 'Giza 119' reacted as a moderately resistant host of biotype 1, and as a moderately susceptible host of biotypes 2 and 3. Barley cultivars were ranked as moderately susceptible hosts of M. javanica biotype 1, while they reacted as immune hosts of biotype 2.

15. With regard to flax, Linum usitatissimum, all cultivars were classified as moderately susceptible hosts of M. incognita biotype 3. Also, cultivars 'Abyissinian C.I. 701,' 'Birio O.I. 1085' and 'Victory A.C.I. 1170' were graded as moderately susceptible hosts of biotypes 1 and 2. Cultivar 'Wilden C.I. 1193' was ranked as a moderately susceptible host of biotype 1, while it was a moderately resistant host of biotypes 2 and 4. Cultivar 'Giza 4' reacted as a highly susceptible host of biotypes 1 and 2, while it was a moderate susceptible host of biotype 4. Cultivars 'Abyssinian C.I. 701' and 'Birio O.I. 1085' reacted as highly susceptible hosts of biotype 4. All cultivars were classified as moderately susceptible hosts of M. javanica biotypes except 'Abyissinian C.I.' and 'Birio O.I. 1085' which were ranked as highly susceptible hosts of biotype 1; also, cv. 'Birio O.I. 1085' was a highly susceptible host of biotype 2. 'Wilden C.I. 1193' reacted as a moderately resistant host of biotype 2.
16. All tested cultivars of rice, Oryza sativa were immune hosts to all M. incognita biotypes, except cultivars 'Giza 159,' 'Giza 171,' and 'Giza 172' which were highly resistant hosts of biotype 4. Rice cultivars were also immune to M. javanica biotype 1, while they were highly resistant hosts of biotype 2.
17. Cultivars of common bean, Phaseolus vulgaris, were all rated as highly susceptible hosts of M. incognita biotype 2, while they were ranked as moderately susceptible hosts to biotype 4. The cultivar 'Contender' was graded as a highly susceptible host of biotypes 1 and 3. The cultivar 'Giza 3' reacted as a very highly susceptible and as a highly susceptible host of

biotypes 1 and 3, respectively. All common bean cultivars reacted as highly susceptible hosts when tested against both M. javanica biotypes.

18. Cultivars of wheat, Triticum aestivum, were found to be highly resistant hosts of all M. incognita biotypes, except cultivars 'Shenab' and 'Stork 7' which were moderately resistant and moderately susceptible hosts of biotypes 3 and 4, respectively. All wheat cultivars were immune to M. javanica biotype 2, while they were moderately susceptible hosts of biotype 1 except cv. 'Giza 155' which was a moderately resistant host of this biotype.

19. Broadbean Vicia faba, cultivars all reacted as highly susceptible hosts of Meloidogyne incognita biotypes 2 and 3. Cultivars 'Giza 1' and 'Giza 2' were ranked as moderately susceptible hosts of biotypes 1 and 4; whereas 'Giza 3' reacted as a moderately and highly susceptible host of biotypes 1 and 4, respectively. 'Giza 4' and 'Rebaia 40' were also classified as highly susceptible hosts when tested against such biotypes. Concerning the reaction of broad bean cultivars to M. javanica biotypes, 'Giza 1' reacted as a moderately and highly susceptible host of biotype 1 and 2, respectively, while 'Giza 2' and 'Giza 3' reacted as moderately susceptible hosts of the same biotypes. The cultivars 'Giza 4' and 'Rebaia 40' were graded as highly susceptible hosts of both M. javanica biotypes.

20. The cultivars 'Azmerly,' 'Balady' and 'Fitriat' of cowpea, Vigna sinensis, were ranked as highly susceptible hosts of all M. incognita biotypes. 'Pink Eye' cultivar reacted as a very highly susceptible host of biotypes 1 and 2, while it was graded as a highly susceptible host of biotypes 3 and 4. 'Black Eye' cultivar was found to be a highly susceptible host of all M. incognita biotypes except biotype 2 which was a very highly susceptible host. To M. javanica biotypes, all tested cowpea cultivars reacted as very highly susceptible hosts of biotype 1; 'Azmerly,' 'Balady Fitriat' were found to be moderately susceptible, and 'Pin Eye' and 'Black Eye' highly susceptible, hosts of biotype 2.

21. Maize, Zea mays, cultivars 'Asheira 17' and 'Asheira 186' were ranked as moderately susceptible hosts of all M. incognita biotypes. Cultivar 'American-early' reacted as a moderately resistant host of biotypes 1 and 4, while it was a moderately susceptible host of biotypes 2 and 3. Cultivar 'Composite 108' was ranked as a moderately resistant cultivar of biotypes 2, 3 and 4, while it was a moderately susceptible host of biotype 1. Cultivar 'Giza 1' was found to be a moderately resistant host to biotypes 1, 3 and 4, while it was a moderately susceptible host when tested against biotype 2. All maize cultivars reacted as moderately susceptible hosts of both M. javanica biotypes.

In general, nematode reproduction on the most suitable hosts tended to maintain the parasitic capabilities of a given population or race, whereas reproduction on less susceptible hosts tended to restrict the reproductive capacity of the population or race to a great extent. The results, therefore, given in this text are valuable information that should help to interpret field populations and predict the relative amount of damage which can be expected if certain susceptible hosts are exposed to the predominant pathotype prevailing in the area. Very often, cultivars resistant or tolerant to one race may become heavily damaged when planted in soil infested with another race. On the other hand, the presence of mixed populations and/or races of several nematode species may limit the advantages of crop rotation as a management practice. For example, the presence of certain nematode populations or races may change the parasitic capability of another pathogen.

It is, therefore, evident that such information will aid the ability to advise on proper crop sequence and maintenance of soil fertility when determinations of populations or races of pathogenic nematodes are made. With these findings in mind and more research along these lines, we can improve the present state of our knowledge of crop production and maximize economic welfare. The magnitude of food and fiber crop quality which can be saved by basic research dealing with the recognition of field population levels and existing races will save a lot of expenditures for additional land and agricultural inputs.

The accumulated information gathered from programs in which certain economic crops are screened against specific nematode pests can be utilized in the planning and execution of certain research activities and control recommendations. For example:

a) Propagation of existing biotypes on typical hosts for further experimental research work, i.e. M. incognita race 1 on okra cv. 'Balady' and M. javanica race 2 on sunflower cv. 'Giza 1.'

b) Initiation of a breeding program through the selection of crop lines immune or resistant to a specific nematode biotype for crossing with desirable susceptible crop varieties. Resistance has been noted, for example, in peanut cv. 'No. 296' for the four races of M. incognita and the two of M. javanica, respectively.

c) Drafting a crop rotation scheme in an area or areas where one of these nematode species or race exists predominately, i.e. in a sandy loam soil area where M. incognita race 2 is dominate, the following 3-year crop rotation program for the growing of a susceptible watermelon can be practiced as follows:

	First year	Second year	Third year
1/3 land	A Barley cv. 'Bonus' (w) then Peanut cv. 'Giza 4' (s)	C	B
1/3 land	B Wheat cv. 'Giza 155' (w) then Watermelon cv. 'Giza 1' (s)	A	C
1/3 land	C Sugar beet cv. 'Viveka' (w) then Maize cv. 'Comosite 108' (s)	B	A

where, w = winter crop, and s = summer crop

Future Research Needed

Root-knot nematodes will become more important to Egyptian agriculture within the next few decades because of their rapid spread through the traditional irrigation system and the practice of more intensive plant culture. On the other hand, the chances for applying cheap and safe nematicides in such a developing nation are rather small. The most effective control program, therefore, is through the development of an integrated pest management strategy where biological, cultural, crop rotation, resistant and/or tolerant cultivars and economic nematicides can be incorporated. For the fulfillment of such a goal, more research is needed along the following aspects:

1. Establishment of economic thresholds through nematode density/crop yield relationship studies and the application of such information in the nematode control scheme.
2. Evaluation of the common organic manures employed by the farmers for the detection of those which may possess a potential biological effect that may keep the nematode populations at a tolerable level.
3. Determination of the joint effect of nematicide/fertilizer response on crop yield and nematode population. It is imperative to establish the best dosage of nematicide with the appropriate rate of fertilizer which will result in an economic crop yield and a minimum nematode population density.
4. Selection of an effective crop rotation scheme in which a non-host crop, resistant or tolerant cultivars and the susceptible main crop can be successfully grown in areas where a specific nematode species or race is dominating.

GREENHOUSE TRIALS ON NEMATICIDES APPLIED BY MEANS OF A DRIP IRRIGATION SYSTEM FOR THE CONTROL OF MELOIDOGYNE JAVANICA (TREUB) CHIT. AND M. INCOGNITA (KOFOID AND WHITE) CHIT. ON CUCUMBER IN GRAN CANARIA (CANARY ISLANDS)

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INTRODUCTION

The drip irrigation system has been developed in a short time in the Canary Islands becuase of its potential for conserving irrigation water. The irrigation water deficiency in the Canary Islands is well known. Application of chemicals by means of drip irrigation offers the growers a savings of not only water but also time and labor. The application of traditional fumigant nematicides (Metam-Na, EDB, DBCP, etc.) requires prior deep tillage of the soil, a large volume of water both before and after treatment, and also an interval of at least 3 weeks before planting. For the application of the new non-fumigant nematicides which can be used while the crop is in the field neither deep tillage nor an interval before planting is necessary (2).

MATERIALS AND METHODS

The trials were carried out in a plastic greenhouse, known as Canary-type, with an approximate area of 1000 square meters. Each treatment was replicated four times in a randomized block, and each plot had 36 plants distributed in two rows. The drip irrigation system used was Double-way type, and each treatment had an independent water line to avoid mixture of nematicides. The soil had a natural infestation of Meloidogyne spp., and the injurious species were determined by the

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IMP differential host test (1) and by studies of 25 perineal patterns of adult females. The population was identified as a mixture of M. javanica and M. incognita, with the former species predominating (3). The irrigation water applied during this test was as follows: 1 liter of water/plant before nematicide application, 0.5 liter of water with diluted nematicide/plant, and 1 liter of water, post-treatment/plant. The same rates of water, but without nematicides, were used for the control. The commercial varieties used were 'Kamaron-Enza Zaden' (1980-81 and 1981-82 trials) and 'Brunex-Bruinsma' (1982 trial), which were grown at 15,000 plants per hectare.

1980-81 TRIAL

Products and Dosage

The nematicides used were:

NEMACUR 40 L (fenamiphos 400 g/L a.i.) BAYER

VYDATE L (oxamyl 240 g/L a.i.) DUPONT

MOCAP 20 L (ethoprop 200 g/L a.i.) MOBIL-OIL

FURADAN 40 F (carbofuran 400 g/L a.i.) FMC

ACCONEN 25 L (AC 64475 250 g/L a.i.) CYANAMID

The application frequency and rates are given in Table 1.

RESULTS (1980-81)

Root-knot Infection Index

The root gall index used was: 0 = no infection; 1-2 = slight infection; 3-4 = moderate to heavy; 5 = total infection, respectively (Table 2).

Nematicides Effect on Yields

The yields of each plot were measured carefully. Mean yield data are shown in Table 3.

Effect of Nematicides on Growth Index

Plant growth was measured twice during the cropping season, and the daily rate of increase is based on these data (Table 4).

Table 1. Rate of nematicide per plant

Nematicides	Initial rate* 3 days after planting	15 days after initial rate	45 days after initial rate	Total rate**
NEMACUR	0.25 ml	0.25 ml	0.50 ml	1.00 ml
VYDATE	0.41 ml	0.41 ml	0.82 ml	1.64 ml
MOCAP	0.50 ml	0.50 ml	1.00 ml	2.00 ml
FURADAN	0.25 ml	0.25 ml	0.50 ml	1.00 ml
ACCONEN	0.40 ml	0.40 ml	0.80 ml	1.60 ml

*Commercial formulation rates

**Total rate of all nematicides = 0.4 g/plant a.i.

Table 2. Effects of nematicides on infection index

Nematicides	Initial index* (after the preceding crop) 5.XII.80	2½ months** after planting 23.IV.81	End harvest* 29.VI.81
FURADAN	2.12	0.95	1.32
MOCAP	2.98	1.45	1.96
NEMACUR	4.15	2.10	2.55
ACCONEN	3.47	0.65	0.48
VYDATE	2.60	0.95	1.16
CONTROL	1.76	1.45	1.12

*Data are means of all plants/plot replicated 4 times.

**Data are means of 5 plants/plot replicated 4 times.

Table 3. Yields (kg of marketable fruit per plant)

Nematicides	Kg/plant*
FURADAN	8.40
MOCAP	7.50
NEMACUR	[illegible].90
ACCONEN	7.80
VYDATE	8.30
CONTROL	8.60

*Data are means of 36 plants/plot replicated 4 times.

Table 4. Growth mean on 4 plants/plot replicated 4 times, according to length measure on the date indicated

Nematicides	Mean length (cm) 6.III.81	Mean length (cm) 23.III.81	Daily rate (cm)
FURADAN	19.93	98.50	4.6
MOCAP	17.43	82.25	3.8
NEMACUR	19.18	96.90	4.5
ACCONEN	19.31	99.70	4.7
VYDATE	19.50	95.80	4.4
CONTROL	17.93	94.50	4.5

CONCLUSIONS (1980-81)

The best nematicidal action was obtained with ACCONEN, at the rate and application frequency pointed out earlier (see Tables 1 and 2). However, this nematicide showed a visible phytotoxic action on young cucumber plants, with yellowing and deformation of the first leaves and later the yield reduction.

The highest yield was obtained from the control plots. These plots (randomly distributed) also had the lowest infection index. In addition, low temperatures during the cropping season kept nematode population from developing as much as normal. In the first year's test, all nematicides were found to give poor control of nematodes deep in the soil. In the treated plots, root-knot galls were observed on the terminal parts of the roots.

Besides ACCONEN, other nematicide treatments seemed to cause phytotoxicity. Young plants treated with MOCAP were rather stunted (see Table 4). Young plants treated with both FURADAN and MOCAP exhibited marginal yellowing of the leaves, although this problem later disappeared.

1981-82 TRIAL

Products and Dosage

In view of the early results, the nematicide rates were slightly increased, except those of ACCONEN (Table 5). Although ACCONEN displayed good nematicidal action, its dose was decreased in order to avoid phytotoxicity damage. In the same way, the intervals between treatments were changed.

RESULTS (1981-82) (Tables 6, 7, 8, 9)

Root-Knot Infection Index

The same scale (0-5) previously mentioned was used to classify the effects of nematicides on the infection index (Table 6).

All the results finally are shown in Table 9 for a clearer correlation and interpretation.

CONCLUSIONS (1981-82)

The efficacy of the nematicides at the new application rates was again insufficient to control the root-knot galls on the terminal part of the roots.

Table 5. Products, rates and treatment intervals (rates per plant)*

Nematicides	Initial rate 15 days after planting	15 days after initial rate	30 days after initial rate	Total rate
NEMACUR	0.5 ml	0.25 ml	0.5 ml	1.25 ml
FURADAN**	0.3 ml	0.6 ml	0.6 ml	1.50 ml
VYDATE	0.4 ml	0.8 ml	0.8 ml	2.00 ml
MOCAP	0.5 ml	1.0 ml	1.0 ml	2.50 ml
ACCONEN	0.3 ml	0.6 ml	0.6 ml	1.50 ml

*Commercial formulation rates

**New formulation, Flowable 350 g/L a.i.

Table 6. Effects of nematicides on infection index

Nematicides	Initial index* (after the preceding crop) 29.VI.81#	69 days after** planting 5.XI.81	End harvest* 22.XII.81
FURADAN	1.12	1.60	1.30
MOCAP	1.69	1.75	1.78
NEMACUR	0.48	1.70	1.62
ACCONEN	1.96	1.30	1.56
VYDATE	1.32	1.40	1.21
CONTROL	2.55	3.45	3.15

*Data are means of all plants/plot replicated 4 times.

**Data are means of 5 plants/plot replicated 4 times.

#These initial indices are not the same as those of the preceding crop end harvest, because the plots were changed to obtain a better distribution infestation model.

Table 7. Yields in marketable fruits

Nematicides	Kg/plant*
FURADAN	4.63 a**
MOCAP	3.92 a
NEMACUR	3.89 a
ACCONEN	3.93 a
VYDATE	4.26 a
CONTROL	2.73 b

*Data are means of 36 plants/plot replicated 4 times.

**Means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Table 8. Growth mean of 4 plants/plot replicated 4 times, according to length measured on date indicated

Nematicides	Mean length (cm) 5.X.81	Mean length (cm) 8.X.81	Daily rate
FURADAN	121	144	7.66
MOCAP	119	138	6.33
NEMACUR	109	133	8.00
ACCONEN	117	141	8.00
VYDATE	107	132	8.33
CONTROL	113	139	8.66

Table 9. Results correlation of the 1981-82 trial

Nematicides	Root-knot mean index at the end of the preceding crop	Root-knot mean index after harvest	Daily growth cm	kg/plant
FURADAN	1.12	1.30	7.66	4.63
MOCAP	1.96	1.78	6.33	3.92
NEMACUR	0.48	1.62	8.00	3.89
ACCONEN	1.96	1.56	8.00	3.93
VYDATE	1.32	1.31	8.33	4.26
CONTROL	2.55	3.15	8.66	2.72

Table 10. Nematicides rate* and dates of the treatments

Nematicides	Rate before planting	10 days after planting**	50 days after planting@	Total rate after planting
VAPAM + EDB	150 + 10ml/m^2#			150+10ml/m^2
FURADAN	1.40ml/2L water+	1.40 ml/plant	1.12ml/plant	2.52ml/plant
HOSTATHION	0.95ml/2L water+	1.20 ml/plant	0.96ml/plant	2.16ml/plant
NEMACUR	1.00ml/2L water+	1.25 ml/plant	1.00ml/plant	2.25ml/plant
VYDATE	1.60ml/2L water+	2.00 ml/plant	1.60ml/plant	3.60ml/plant

*Formulated products rate

**Through the drip irrigation system

@Second application by drip, after the first gall-index test, when root-knot galls were observed.

#On cultivated soil only, 21 days before planting by flood irrigation.

+On the plantlets in nursery.

Among the nematicides applied after planting, the most effective were FURADAN and VYDATE; however, no significant differences resulted among these nematicides with respect to yield increase.

In the present trial, ACCONEN showed less phytotoxicity and also less effectiveness; however, the product remained phytotoxic to young cucumber plants, although it did not cause depressive effects on final growth and yield (Tables 6 and 7). MOCAP-treated plants showed the most stunted growth.

TRIAL DURING 1982

Products and Dosage

The following observations were based on the two previous trials.

1. The fractioned rates applied to the crop were insufficient for good control. Approximately two months after planting, the root-knot galls appeared on the bottom-most roots in the treated plots, and on the entire roots in control plots.

2. In all cases, poor depth of action of the nematicides incorporated by drip irrigation system was noted.

For these reasons, high rates of nematicides were applied (10 days after planting) through the drip irrigation system in the present trial (Table 10).

A new treatment, VAPAM + EDB (Metam-Na 410 g/L a.i. + Ethylene dibromide 94.5% a.i.), was introduced in the trial for comparison. This chemical is incorporated into the soil by flood irrigation three weeks before planting, according to the traditional system. On the other hand, MOCAP and ACCONEN were eliminated, and HOSTATHION non-fumigant nematicide (triazofos 400 g/L a.i., Hoechst AG) was incorporated into the experiment. A second application rate of non-fumigant nematicide was planned if the root-knot galls appeared at the first gall index check (2-2½ months after planting). In this trial, the plantlets were treated with non-fumigant nematicides in the soil-block before planting.

RESULTS (1982) (Tables 11, 12, 13)

Table 11. Effects of nematicides on infection index (scale 0-5)

Nematicides	Initial index* final preceding crop	50 days after** planting	End harvest*
VAPAM + EDB	1.56	0.15	0.43
FURADAN	1.30	0.75	1.51
HOSTATHION	1.78	1.20	2.07
NEMACUR	1.62	1.40	2.14
VYDATE	1.21	1.10	1.69
CONTROL	3.15	3.60	4.02

*Data are means of all plants/plot replicated 4 times.

**Data are means of 5 plants/plot replicated 4 times.

Table 12. Yields in marketable fruits

Nematicides	Kg/plant*
VAPAM + EDB	6.35 a**
FURADAN	5.81 ab
HOSTATHION	5.18 b
NEMACUR	5.42 b
VYDATE	5.60 b
CONTROL	3.98 c

*Data are means of 36 plants/plot replicated 4 times.

**Means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Table 13. Daily growth mean in cm from three times during crop

Nematicides	1.IV	5.IV	15.IV
VAPAM + EDB	3.2	3.2	4.9
FURADAN	3.4	4.0	5.0
HOSTATHION	2.6	3.1	4.9
NEMACUR	3.0	3.7	4.8
VYDATE	2.8	3.4	4.6
CONTROL	2.5	3.1	4.5

CONCLUSIONS (1982)

The best nematicidal efficacy, as well as yield, was obtained from VAPAM + EDB treatment. The initial high dosage with non-fumigant nematicides was insufficient for good control. The gall index increased after the 50th day of plant growth in spite of the second application rate. The efficacy failure noted for the non-fumigant nematicides seems to be related to their failure to be translocated deep in the soil when they are applied by the drip irrigation system. Differences in yield obtained between VAPAM + EDB and FURADAN, and among FURADAN, VYDATE, HOSTATHION and NEMACUR were not significant.

FINAL CONCLUSIONS

The results during the 1980-1982 trials concerning the control of *M. javanica* + *M. incognita* populations on cucumber crop, under plastic greenhouse, have shown:

1. The new, non-fumigant nematicides applied through the drip irrigation system did not give an acceptable level of efficacy in comparison with the traditional pre-planting treatments (Vapam + EDB).

2. The fractionated rates of non-fumigant nematicides applied by drip irrigation during the crop have been as effective as a single, high, initial rate.

3. Poor depth action has been confirmed for all non-fumigants applied by drip irrigation.

4. Among non-fumigants, the clearer difference in nematicidal action was shown by ACCONEN (1980-81 trial) which was phytotoxic to young cucumber plants. Among the others, both FURADAN and VYDATE showed higher yield increases than ACCONEN, MOCAP, NEMACUR and HOSTATHION, though without significant differences at the 5% level.

5. The effects of non-fumigant nematicides, assuming good depth action, did not last beyond 2 to 2½ months.

6. No systemic action at root level can be estimated for the non-fumigant nematicides since the root-knot galls were always observed on the bottom-most roots of the treated plants.

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BIOLOGICAL CONTROL WITH THE FUNGUS *Paecilomyces lilacinus*

Progress to date and possibilities for collaborative research between CIP and IMP collaborators

Parviz Jatala*

The existence of fungi that prey on nematodes has been known since 1888. In the majority of cases, the species recorded came from decaying organic matter. However in 1954, it was shown that they were also common in soil. Addition of organic matter to soil would stimulate many of the nematode trapping-fungi into saprophytic competition with other organisms. Only after intense competition and at high nematode populations would these fungi begin to feed on nematodes.

During the past several decades many attempts have been made in pots and in field trials to use predacious fungi for nematode control. Results of these trials have been inconclusive and for most cases disappointing. It was concluded that congenial conditions for the growth of the predacious fungi in soil could be produced in laboratory and sometimes in greenhouse experiments, but in the field, only sparse growth, insufficient to control nematodes to a level affecting their attack and damage to plants, could be obtained. As a result, these organisms have not as yet been used commercially due to the fact that a high percentage of kill is needed to make the effort worthwhile.

In early 1978, a fungus of the group Hyphomycetes, identified as *Paecilomyces lilacinus* (Thom) Samson, was isolated from *Meloidogyne* egg masses found on an infected potato root from a central Peruvian highland in the Huanuco Valley. Use of this fungus as a potential biological agent for controlling nematodes was investigated.

Laboratory, greenhouse and field experiments conducted in Peru confirmed that *P. lilacinus* 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.

In order to test this organism under various climatological conditions prevailing in different parts of the world, the biological control studies of the Department of Nematology and Entomology of the International Potato Center (CIP) became part of the objectives of control strategies of the International Meloidogyne Project (IMP). Therefore, it is hoped that collaborators of the IMP from different parts of the world will test this organism under their local conditions, and that the information generated from their studies be compiled and evaluated for final recommendations on biological control of Meloidogyne species. Therefore, this organism is being distributed to various IMP collaborators together with a methodology for preparation and establishment of P. lilacinus for field inoculation which is as follows:

Isolation Establishment of the Fungal Culture

To isolate the fungus from the sand culture and increase it for field inoculation, the following procedures are used:

1. Shake the vial containing the sand culture well and aseptically place the entire contents or a capful (1 gm) in a test tube containing 9 ml sterilized-distilled water.

2. Mix well and add 1 ml of this solution to another tube containing 9 ml sterilized-distilled water.

3. Repeat step No. 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 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 it loosing its effectivity to control Meloidogyne species.

Preparation for Field Inoculation

Good results have been obtained by growing the fungus on sterilized rice grains. However, similar results may be obtained using wheat, oat, barley, etc. You may need to make modifications in the procedure if you use a medium other than rice grains.

Procedure:

1. Soak rice grains 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 of 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 rice grains with several ml of this suspension. Allow the fungus to grow on rice grains at room temperature. Shake the flask every day to promote uniform growth of the fungus.

4. Fungus will grow on rice grains and can be observed within a few days.

5. Fourteen days after 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 which 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 rice grains per 40 square meter-plots at planting. Spread the inoculum evenly 10-15 cm deep in the soil and cover well before planting.

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 one plot from 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 1-5 (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 center 3 rows of each plot. In case of the 10 rows of 20 meters per row treatment, use the center 8 rows and randomly evaluate at least 20 plants per row.

11. If the crop is potato, evaluate tuber infection using the following index:

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 composite root sample per row with acid fuchsin in lactophenol and clear in lactophenol for 24 hours prior to examination.

14. Extract 20-50 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 another root of tuber crops, yield of infected and non-infected tubers or roots per plot should be recorded. For yield per hectare to be calculated accurately, it is advisable that the yield of a definite number of plants per plot be recorded.

16. If possible, the subsequent crop should be examined as described above according to the same treatment plots without further fungal or nematicide application.

Comments

There might exist a crop effect on population establishment and effectivity of the fungus. As far as it is known, sweet potatoes should not be used as the first experimental crop.

REPORT FROM THE DISCUSSION GROUP ON CROP RESISTANCE AND CROPPING SYSTEMS

Crop Resistance

1. Testing germ plasm for root-knot nematode resistance could be accomplished by the following:

   a) Testing of local cultivars, lines or entries of important crops.

   b) Testing of introduced cultivars that might be obtained from the IMP, international research center or elsewhere.

   c) Field testing of resistant cultivars which will also include studies of various other characteristics, i.e. horticultural and disease resistance.

2. Exchange of germ plasm could be accomplished by:

   a) Country to research center

   b) Country to IMP

3. Exchange of information on respective lines or cultivars which will be made available upon request.

4. Exchange of information with other regions of the IMP.

Breeding

1. Cooperation should be established with breeders to produce horticulturally sound root-knot-nematode-resistant plants.

2. Program of resistance must cover the most important species and races of Meloidogyne spp.

3. Building of resistance should be based on multiple resistance.

Cropping Systems

Evaluate nematode resistance of widely used and of economically important crops which could be introduced into a cropping system for reducing yield losses caused by Meloidogyne spp.

Emphasis should also be given for relatively resistant crops. They should be introduced in such a way that farmers could choose one of several systems that would fit their cultural practice.

J. Philis (IMP)
Special Committee Suggestions

*ROLE OF IMP IN TECHNOLOGY AND/OR ASSISTANCE TRANSFER--TECHNOLOGY TRANSFER WORK GROUP REPORT

Chairman: Professor A. M. Yassin, Sudan
Members: Professor Dr. B. A. Oteifa, Egypt
Dr. I. K. Atris, Egypt
Dr. A. Rammah Morocco
Dr. A. Janati, Morocco
Mr. B. Aicha, Tunisia
Dr. M. A. Siddig, Sudan

Minutes From Committee Meeting

-Technology to be transferred could be either a practice or a resistant crop cultivar.

-Assistance: either financial or in form of commodity.

-Regarding such terms of reference, the IMP might be of help as follows:

A. Exchange of knowledge through:
   -periodic meetings
   -publications
   -visual means: movies, slides, etc.

B. Initiate training programs:
   -long courses
   -short refresher courses
   -demonstration plots
   -adaptation research units, e.g. for the sake of farmer, i.e. in form of small demonstration plots.

C. Initiate pilot projects: targeted towards technology application: e.g. as regards use of nematicides etc.

D. Continue material assistance: e.g. in the form of up-to-date books and/or periodicals, etc.

E. "Secure" financial assistance "if possible."

F. Coordinate investigations among members e.g. within the same region, or in different regions, of the I-VIII existing regions.

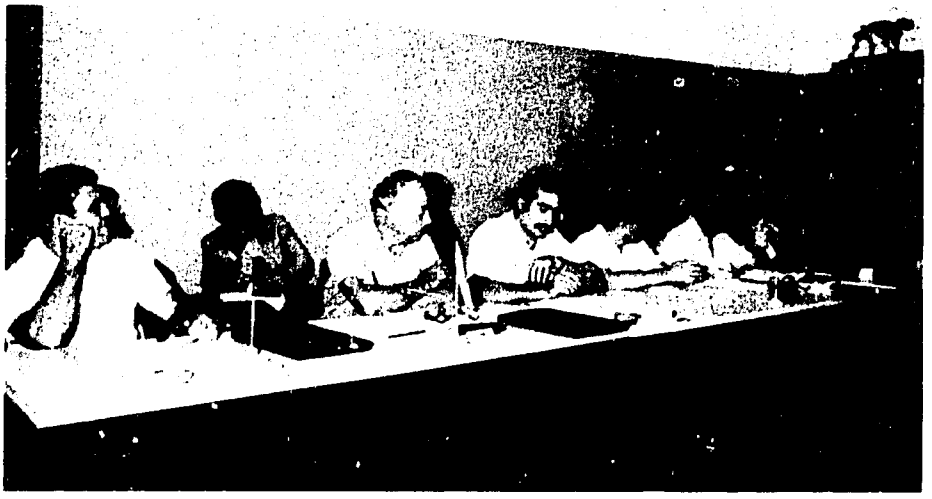
G. Secure link with other sponsoring or scientific bodies, e.g. ICRISAT, ICARDA, IDRC, FAO, etc.

*In all cases IMP should best operate through the government or legal authorities in any one region.

Portugal Delegation. L to R: Luis Gerson L. Reis; João Cláudio Martins das Neves; Maria de Fátima Serra Pacheco; Maria Susana Newton de Almeida Santos; Isabel Maria de Oliveira Abrantes; Manuel Bravo; Maria Teresa da Silva Craveiro; Maria Joana A. Vieira dos Santos; Célia dos Santos Pais.

"Birthday" Celebration

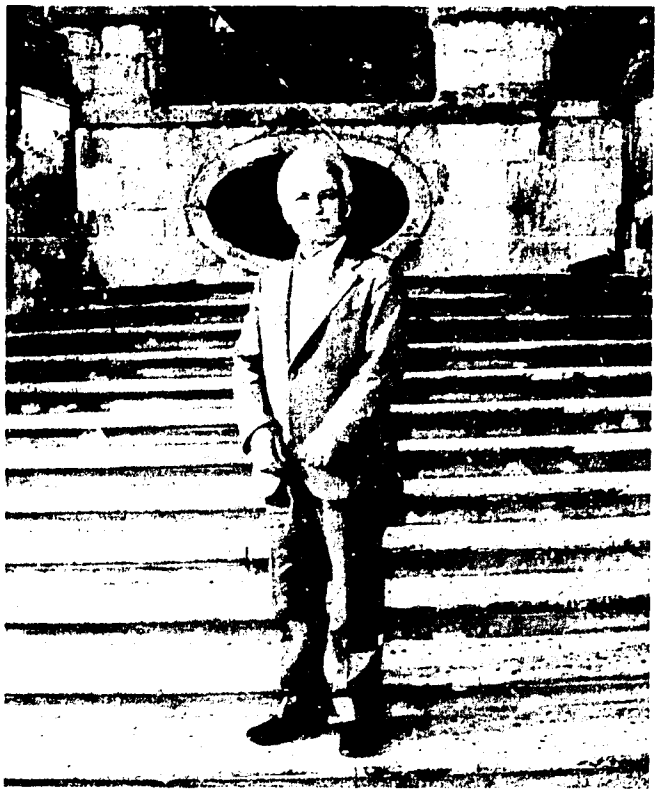
Conference in Session



MOROCCO: Ahmed Janati & Abdallah Rammah

GREECE: Ioannis Philis

ITALY: Mauro DiVito

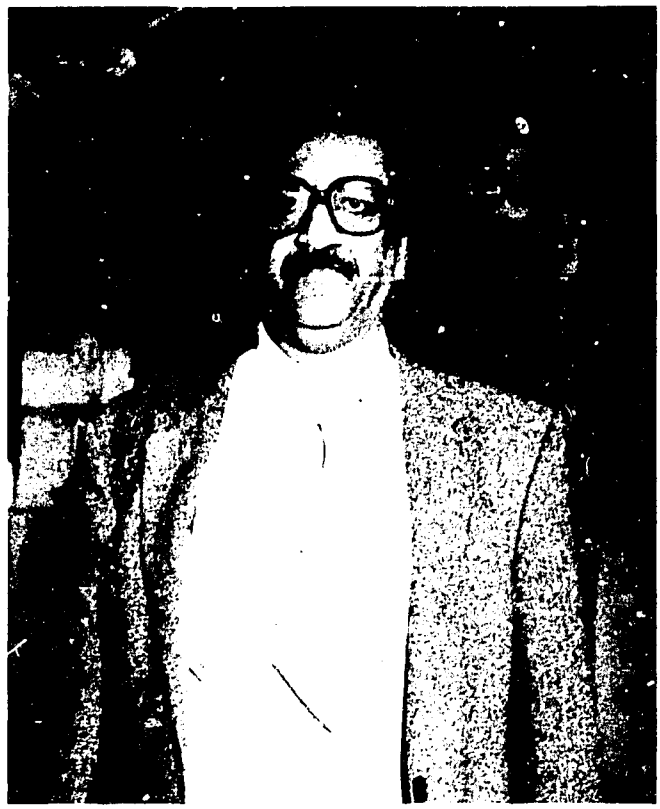


TURKEY: Hasan S. Yűksel

SPAIN: José Luís Cenis Anadon

ALGERIA: Ahmed A. Salem

TUNISIA: Maurice Moens & Bechir Ben Aicha



SUDAN: A. M. Yassin

SUDAN: M. A. Siddig

EGYPT: I. K. A. Ibrahim, B. A. Oteifa, and M. F. Eissa

JORDAN: Walid Abu-Gharbieh