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INTERNATIONAL MELOIDOGYNE PROJECT

IMP

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

Portugal	Turkey		Sudan	Cyprus	Syria
Egypt	Iran	REGION VII	Iraq	Morocco	Yemen
Jordan	Saudi Arabia		Libya	Greece	Italy

November 26-30, 1979
Athens, Greece

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PREFACE

These proceedings comprise the progress reports of cooperators from Region VII in the International Meloidogyne Project, presented at the second research planning conference on root-knot nematodes, Meloidogyne spp, Athens, Greece, November 26-30, 1979. Scientists from 15 countries representing region VII (Portugal, Egypt, Jordan, Turkey, Iran, Saudi Arabia, Libya, Greece, Iraq, Sudan, Morocco, Cyprus, Italy, Yemen & Syria) attended and participated in the conference. Region VII is one of eight regions forming a network of approximately 100 scientists from 56 nations of the world working toward a better understanding of the biology of these complex plant pests. Funds for this cooperative effort are provided by the Agency for International Development (USAID) through a contract with North Carolina State University, Raleigh, N.C., U.S.A. The major thrust of these cooperative efforts is to conduct research that will eventually enable us to devise effective and economical control of root-knot nematodes for the small farmer in developing nations. Conventional methods of control, namely, production of nematode-free planting stock, crop rotation, use of resistant cultivars, and discretionary use of nematicides cannot be maximized until we can 1) accurately identify the species and races present within each of the various regions, 2) know their pathogenic variability, 3) know the resistance and/or susceptibility of local crop cultivars to the species present, 4) identify sources of resistant germplasm for use in development of resistant cultivars, 5) understand the cytogenetic characteristic of the various Meloidogyne species, and 6) assess the influences of certain ecological factors on survival and pathogenicity. Progress is being made in all these areas and hopefully we can soon utilize what we have learned about the nematode during the first 5 years of the program in the development of effective control strategies for root-knot nematodes.

I wish to thank the cooperators for their significant contributions to our project and feel certain that research resulting from this worldwide effort on a common, but serious crop pest will lead to a substantial reduction in the damage caused by these nematodes to food and fiber crops throughout the world.

J. N. Sasser, Principal Investigator

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WELCOMING REMARKS

Dr. C. D. Pelekassis
Agricultural College of Athens, Athens, Greece

Mr. Chairman, Ladies and Gentlemen:

On behalf of myself and the Athens University School of Agricultural Sciences of which I had been pre-rector during the last academic year, I would like to express to you my warmest welcome and my sincere appreciation for the choice of Athens as the venue of the present conference on *Meloidogyne spp.* project.

Here, in this city, under the holy shadow of Parthenon and having as a guide the wisdom of the ancient spirit of the goddess Pallas Athena, an everlasting symbol of the highest ideals of freedom, liberty of human thought and the noble competition and collaboration, I wish for the success of the present conference and for positive and fruitful results, which shall be useful for a better and more efficient protection of the world agriculture from this destructive group of natural enemies.

I believe that these international conferences and meetings, which somehow remind us of the ancient amphictyonies held among the Hellenique State-cities, regardless of their scientific, technological or general character they possess a broader social and cultural significance as well.

The personal contact and the unconstrained communication among scientists of various countries could help to create a more friendly and favorable atmosphere and a better understanding among them. This would play an important role and might enable nations in seeking peaceful and civilized means in order to solve problems and existing differences among them without it being necessary to use war as the only way of solving these differences.

We are approaching the last fifth of the 20th century, and I do not exaggerate to say that even now man seems to be a frightened and hungry animal who struggles to secure the necessary food supplies for his survival and suitable space for his settlement.

It is true that in spite of the significant progress and achievements of science in the biological and technological field during the last 30-40 years, which resulted in improving or reviewing the means of protection of agricultural products, the losses caused by the pests and diseases on a world scale, amount to many billions of dollars annually. Thus a considerable

proportion of plant and animal production is destroyed by pests and diseases and thus never reach its destination.

These losses, apart from their financial significance, cause a lot of serious social and political problems, considering that about two thirds of the human population are underfed and a substantial proportion of the population even die from starvation every year.

These problems will be more critical and vital in the near future as the human population, according to Thomas Malthus' theory, increases on a geometrical progression, while the food production increases on an arithmetical one (Fig. 1).

For all these reasons it is imperative that scientists and the appropriate authorities of all countries coordinate their efforts and cooperate closer if we want to secure a better tomorrow.

Among the various pests of agricultural production, the plant-parasitic nematodes possess a considerable economic interest. In Greece, as well as in many other countries, nematodes and especially root-knot species, greatly reduce the yields of various crops or prevent the establishment and the expansion of the cultivation of more productive plant species or varieties less resistant to the nematode attack. This group of natural enemies brings back to me some memories of my early career when as a young assistant working at the Benaki Plant Pathology Institute, besides the phytophagous mites and insects, I had also to work with root-knot nematodes then known as Heterodera marioni.

At that time in Greece there were very few scientists and thus we were forced to work with various plant protection projects, including very different kinds of pests zoologically speaking.

But soon afterwards a young, very active, and vigorous scientist was appointed at the Benaki Institute and thus added to the few-membered phytopathological family of Greece. He started working especially with plant-parasitic nematodes.

That young Greek agronomist was Mr. Triantaphyllou, now professor in nematology at North Carolina State University and a well known specialist from his very important research work. He is here today with us. Professor Triantaphyllou, after his specialized training in the U.S.A., came back to Greece and pushed forward many projects regarding plant-parasitic nematodes. But unfortunately for his native country, Dr. Triantaphyllou has deprived us of his valuable presence and collaboration, since he settled permanenetly in the U.S.A. years ago.

Moreover, a few state agronomists who subsequently received specialized training in nematology abroad and who we expected to equip Plant Protection Stations have due to some reasons--professional or otherwise--diverged from the pure research work or even abardoned this group of pests.

As a result, compared with other branches of plant protection, the scientific personnel specialized in nematology appears to be quite reduced numerically these last years.

However, I have to mention here that the State Ministry of Agriculture being interested in keeping its field agronomists aware of new approaches and experiences in nematology, has since scheduled special seminars and courses. And from this point of view I might say that there is no state agronomist who is not familiar to some extent with the main nematological problems in general.

In closing, I should like to give you a brief picture of the spread and distribution of root-knot species in Greece. Among the numerous plant-parasitic nematodes found in Greece, the root-knot nematodes (Meloidogyne spp.) are considered the most abundant and destructive group.

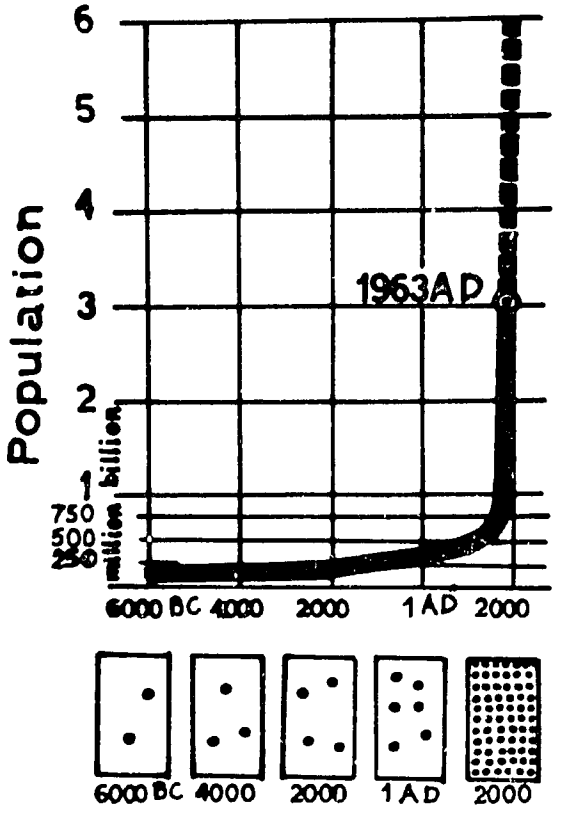
About 80 to 90 different plant species have been reported to be infected by Meloidogyne spp. in Greece. Among them tomatoes, cucurbits, eggplants, cabbage, tobacco, sugar beets, several fruit trees, olive trees and others are the most important economic plants.

The most prevailing root-knot species are: Meloidogyne javanica, M. incognita and M. arenaria distributed in the whole country. Also some other species have been reported. There is no evidence that the environmental, geographical or other factors influence selectively the distribution of the existing species. The most severely infested areas are: Peloponnesus (mainly Messinia, Achaia and Korinthe), Attica, Salonika, Rodos island and the southern part of Crete (Lassithi) (Fig. 2).

The majority of the Greek growers being unaware of the nature and the harmfulness of the nematode infestation, do not consider seriously the destructive effects of these pests to their crops.

In conclusion I would like to say that the root-knot nematode problem, which appears to be a complex one, should be tackled by setting up a more efficient and realistic strategy on an internationally research cooperative program. In such a program the participation and collaboration of both state or private scientific agencies and growers as well is necessary and should be recommended.

Finally, I hope that you will enjoy your stay in Athens, and I wish you a successful and stimulating conference.



Human population density during centuries

Figure 1.

Bulgaria
Yugoslavia
Albania
Thrace
Macedonia
Epirus
Thessaly
Lesvos
Central
Greece
Hios
Peloponissos
Paros
Naxos
Rhodes
Kriti
Distribution of Meloidogyne spp.
in Greece

Figure 2.

THE INTEGRATED PEST MANAGEMENT CONCEPT

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The most direct way to demonstrate the integrated pest management (IPM) concept is to introduce the systems approach as a basic premise of IPM. If we can agree that IPM is an holostic or agroecosystem approach to crop protection, then we must understand the systems concept if we are to understand IPM.

1. The systems approach is motivated chiefly by the desire for increased relevance in research and for a more complete understanding of complex and highly interactive physical and biological phenomena.
2. The concept arose because of a recognition that the world contains "systems" and "non-systems" and <u>that changes in one part of a system has important effects on the system as a whole</u>.
3. Thus, improvement of a system cannot be expected <u>simply</u> by making changes in one part even if this part appears to be improved. Furthermore, "improvement" of a part actually has little meaning if it does not result in improvement of the whole system.
4. We may characterize a system as an entity with a perceived or actual boundary that contains the elements of principal interest to the observer. Outside of the boundary, the elements are different either in kind or in concentration. The observer is not interested in the elements outside the boundary to the

same degree because they have a lesser impact upon the "interactive" system.

5. Thus, we characterize a system as a set of interacting components that are capable of reacting as a whole to external stimuli and which has a specified boundary based on the inclusion of all significant feedbacks.

Characteristics of agroecosystems and the role of pests in those systems

The concept of the agroecosystem is useful in visualizing crop production in ecological terms. The concept is also useful in organizing a research approach to the development of optimal production systems. The agroecosystem is depicted schematically in Figure 1 and may be characterized as follows:

1. Unnatural systems that persist only through energy inputs of man.
2. One species usually occurs in the system at "plague" or epidemic population levels (the cultivated species).
3. The cultivated species in agroecosystems, originally selected from natural plant communities, have been changed to meet better the production needs of man. Most of the improved cultivars of these cultivated species can no longer compete as components of natural ecosystems.
4. The crop production management practices aim at maximizing productivity of the crop species per unit of land and unit of time.
5. There are many unfilled niches; consequently, the agroecosystem is under constant pressure of invasion by "competing" organisms (pests: pathogens, insects, weeds, nematodes, and others).
6. The agroecosystem demonstrates the ecological principle that species simplicity rather than diversity is the most highly productive state for an ecosystem.

7. Agroecosystems lack the stability of natural ecosystems and they have little or no natural capacity for self-maintenance or recovery from adversity.
8. Man's role is to maintain the dynamic state of imbalance in the agroecosystem that maximizes productivity by protecting it against invading organisms (pests).
9. Consequently, invasion of the agroecosystem by pathogens, insects, weeds, and other depredating pests is the common and the expected condition.
10. Generally speaking, intrinsic vulnerability of the agroecosystem to damaging pest attacks is enhanced by many modern practices that maximize productivity.

The integrated pest management concept

The IPM approach is a concept and not a method. Stated very bluntly, those who insist that it represents nothing new do not understand the concept. It is neither a bandwagon tactic nor an environmentalist movement. IPM may be defined as a management integration of methodologies for all economic pests of the agroecosystem with the objective of optimizing productivity, net returns, stability, and environmental quality. Implementation of IPM has been stimulated by failures within the agroecosystem from over-reliance on pesticides and the associated environmental externalities.

The following principles should provide a conceptual basis for an ordered approach to pest management within the context of IPM systems*,

*These principles of disease management were adopted from the following source: Apple, J. L. 1977. Theory of Disease Management. In J. G. Horsfall and E. B. Cowling (Eds.). Plant Pathology: An Advanced Treatise. Vol. 1. How Disease is Managed. Academic Press, New York.

especially as applied to diseases caused by plant pathogens (including nematodes).

1. Identify the Disease(s) to be Managed

Diseases that are of obvious or potential economic importance in an ecosystem must be diagnosed and the causal agents identified. A problem disease is generally first seen by the farmer. If he does not recognize the cause (or causes), the farmer would seek assistance through a publically supported or private disease management service. Relevant information on the biology and ecology of the pest(s) of the crop must be assembled. Identifying the problem(s) that must be managed is the first step in developing pest management strategies.

2. Define the Management Unit -- The Agroecosystem

An agroecosystem comprises the total complex of organisms in the crop area together with all aspects of the environment as modified by the various agricultural, industrial, social, and recreational activities of man (see Figure 1). An ecosystem is a basic functional unit of nature that includes both organisms and their non-living environment, each interacting with the other and influencing each other's properties, and both necessary for the maintenance and development of the system. Ecosystem boundaries are generally determined pragmatically, but once defined the ecosystem may be visualized as connected to the surrounding environment by a system of inputs and outputs.

An agroecosystem is equivalent to an early and thus very dynamic successional stage of a natural ecosystem. As with a natural ecosystem, its boundaries often are difficult to establish. A normal ecological succession would proceed in an agroecosystem unless the farmer continuously fed energy into it through cultivation, irrigation, fertilization, and pesticide applications. The flow of organisms into the agroecosystem may be high since there are many unfilled niches in it. Such artifically

maintained ecosystems are invaded across the "system" boundary by a characteristic set of organisms that are determined by the qualities of the agroecosystem and its surrounding environment(s). Many of these invaders become co-habitants and are essential to the sustained yield of the agroecosystem (e.g., rhizosphere organisms). Some invaders may be innocuous and go unnoticed, but others that compete with, feed upon, or parasitize the cultivated species are declared "pests" when their effects conflict with man's desires.

The migrational capacity of the pathogen(s) determines the boundaries of the agroecosystem that must be managed. If these capacities for migration are limited, the boundaries of the management unit may be restricted to a single field (e.g., a soil-borne pathogen such as the nematode Heterodera), but if these potentials are high the pathogen ecosystem may include most of a continent as is the case with certain air-borne pathogens such as Puccinia graminis. Consequently, the geographic limits of the agroecosystem are determined by the migrational characteristics of the pathogen. But the size of the agroecosystem, which is the basic management unit, is determined by the outer limits of the set of subsystems (biological and physical) that comprise it.

3. Develop the Management Strategy

The disease management strategy must aim at reducing the amount of inoculum from which the disease starts, or to reduce the rate at which the disease increases in a plant population, or both. Plant pathologists traditionally have concentrated on reducing the incidence of diseases; in doing so, however, they often have neglected the relationship between disease incidence, pathogen populations, and/or the rate of disease increase. Although the study of these relationships is recieving renewed emphasis, the lack of such information is a serious deterrent to the prediction of disease

incidence and the development of dependable and long-term disease management strategies.

The disease management strategy should be based on a management tactic or combination of tactics that optimize crop productivity. Knowledge of pathogen ecology, disease epidemiology, and other fundamental ecosystem relationships is the principal basis for selecting and deploying existing disease management tactics and for the development of new ones. This requires not only a knowledge of the life cycle of the pathogen (including nematodes) and the factors that influence reproduction and survival, but an understanding of the interactions of the pathogen with all manageable components of the agroecosystem.

4. Establish Economic Thresholds

Plant diseases have been studied because they damage cultivated crops, but it is paradoxical that even today there are few reliable estimates of loss. Since the development of economic thresholds requires estimates of loss, it follows that economic thresholds have not been used extensively as management criteria for plant diseases.

The economic threshold is that level of disease intensity that produces an incremental reduction in crop value greater than the cost of implementing a disease management strategy. Although simple in definition, precise economic thresholds must reflect many complex and interacting variables. Losses due to disease must be based on measurements of both the quality and quantity of crop production. Only in this way can accurate relationships be established between amount of disease and amount of loss. As a parallel consideration, the relationships between the cost of alternative disease management tactics and their economic benefits must be established. These two determinations, plus a factor reflecting the willingness of the farmer to accept the uncertainties (risks) involved, constitute the basis for

disease management decisions. Available disease management tactics may not benefit the current season crop but would serve as the basis for a management decision applicable to the next crop (as with many soil-borne, root pathogens). Lack of effective or economical disease management tactics would justify the development of new management technologies, such as disease resistant varieties, pesticides, or environmental modifications.

The complexities of establishing economic thresholds have deterred their development and usage. However, empirical thresholds based on observations and experience have been used successfully in many pest management programs. These thresholds should be refined as additional research information becomes available.

5. Develop Monitoring Techniques

A basic premise of disease management is that it will be utilized only when actual or predicted disease loss reaches the economic threshold level. The disease problem may range from one that consistently exceeds economic thresholds each growing season to one with the potential for but low probability of causing economic loss. In either extreme, monitoring data would allow proper timing of control treatments even with some consistently severe diseases and would be the basis for determining if, when, and where treatments will be required for sporadic diseases.

Disease monitoring has not been utilized extensively by plant pathologists. The apparent success of this approach with *Venturia inaequalis* on apples in Michigan, when combined with environmental data, demonstrates that forecast models can be utilized in managing certain diseases. Progress in understanding population dynamics of nematodes and in developing population sampling techniques and economic thresholds has provided the basis for nematode advisory services. Some soil-borne fungal and bacterial pathogens may also be detected by soil-sampling methods but many of these are more

qualitative than quantitative. Consequently, lacking monitoring techniques for pathogens, the plant pathologist has relied mainly on "symptom" monitoring which provides little or no basis for action decisions during the current season but which is useful in developing long-term management strategy. Systems for monitoring symptoms have been useful with diseases caused by soil-borne pathogens; however, quantitative population techniques are also needed for these types of pathogens in order to study population dynamics in response to management tactics.

Some disease prediction models do not involve pathogen monitoring but monitor only environmental conditions on the assumption that inoculum is always present and that an epidemic will develop under favorable conditions. These are very useful approaches and may be applicable to a number of diseases of high value crops, but they can result in conservative forecasts and excessive treatments when their basic assumptions are not satisfied.

Better methods for the measurement of inoculum potential must be developed and coupled with environmental data since the latter are so critical to the onset of disease and epidemics. This will permit development of disease forecast models for additional diseases as the basis for chemical treatments and will facilitate development of more reliable long-term disease management strategies based on measurements of predicted loss rather than on amount of disease.

6. Evolve Descriptive and Predictive Models

The ultimate objective of pest management is the development of predictive models for agroecosystems through which management decisions can be optimized for maximum benefits to the producer, consumer, and the public at large. This process entails the collection and integration of several sets of complex data, with each set relating to a dynamic biological, physical,

meteorological, or socio-economic sub-system. This process can be facilitated by systems analysis and mathematical modeling.

It is possible to develop practical disease management systems without the use of formal modeling and systems analysis, but development of a valid system is not possible without a good understanding of the agroecosystem and the ecology of the principal pathogens. Developing a disease management system is a dynamic process, evolving to reflect the dynamics of the agroecosystem and man's increased knowledge of that system. Ideally the system (including its modeling component) will evolve only to that level of sophistication required to achieve practical utility and reliability. There are undoubtedly many ecosystems for which development of sophisticated models would not be the optimal management approach because their descriptive and predictive worth would not justify the cost necessary for their development, maintenance, and utilization.

Epilogue

The application of IPM principles will provide the conceptual framework, the ecological perspective, and the incentive to study mechanisms basic to biological interactions in the agroecosystem. Such studies will not only improve our deployment capability for existing management tactics but will lead to the development of new ones. For example, understanding the mechanisms of antagonism could provide new insights for use of biological control for both soil-borne and foliar pathogens. The allelopathic characteristics of some cultivated plants may give them competitive advantage over certain weeds, and this mechanism may also be important in host-parasite relationships. The development of a new generation of systemic fungicides and nematicides that are more target specific and that may be curative in function provide powerful new tools that enhance the feasibility of applying

the IPM concept to plant pathogens. The role of mycorrhizae in protecting roots against invasion by parasitic fungi holds potential as a disease management tool. Likewise the role of the resident flora of plant foliage in conditioning susceptibility or resistance to pathogens is little understood but is potentially a very important host defense mechanism that can be managed. Application of the IPM concept can both direct our attention to these promising opportunities for disease management and coordinate their utilization into an optimized resource management strategy. This strategy must reflect not only the crop protection and crop production interactions within the agroecosystem but also be cognizant of the impact of the agroecosystem processes on other ecosystems. The overall objective is to achieve a highly efficient, sustained-yield agroecosystem that is ecologically sound, economically productive, and environmentally acceptable.

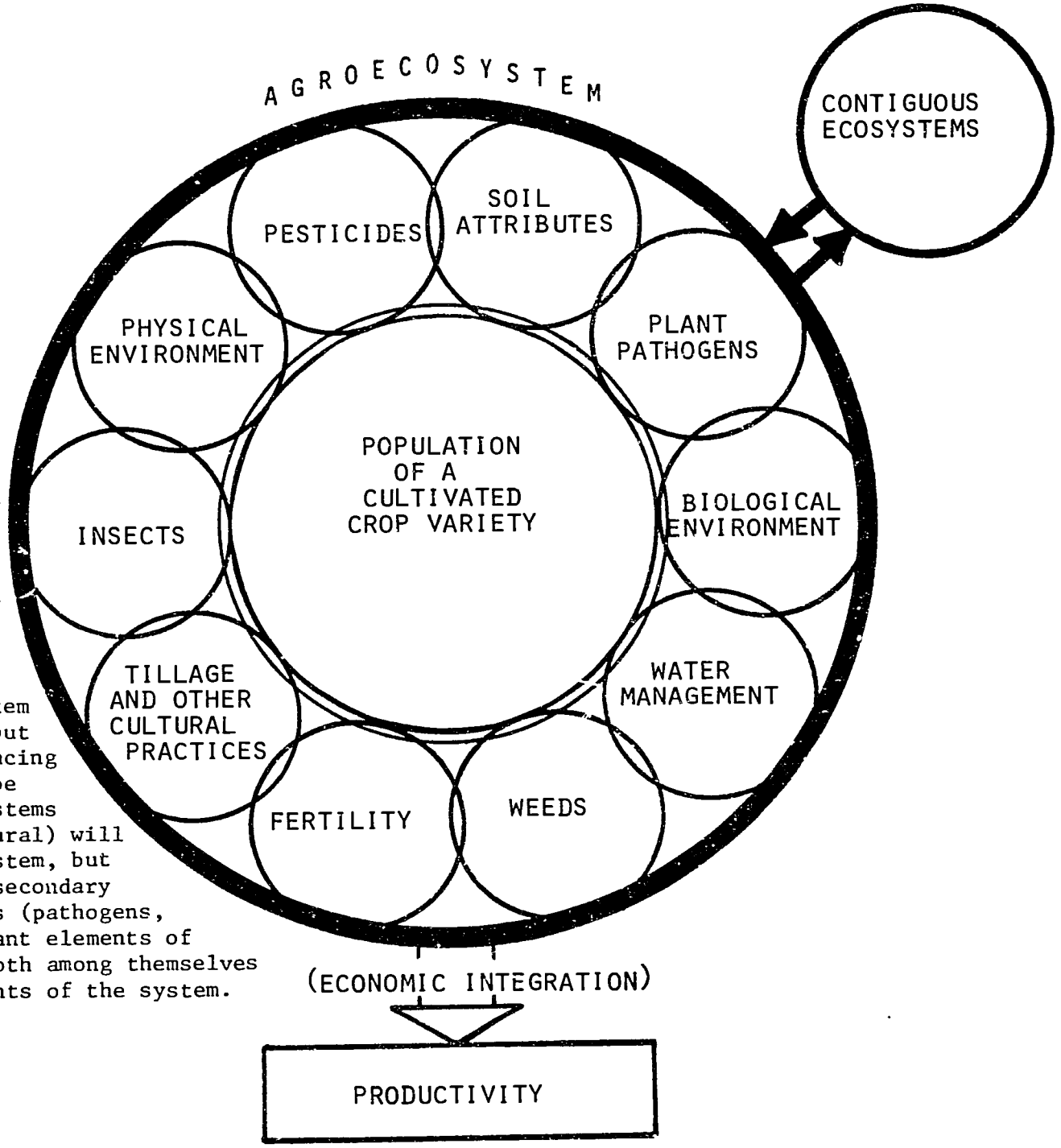

Figure 1. Conceptualization of an agroecosystem as a series of interlocking physical, biological and management functions interacting to determine the yield of a population of cultivated plants. The boundary of the agroecosystem is difficult to establish but is generally the area embracing the principal elements to be managed. Contiguous ecosystems (both natural and agricultural) will interact with an agroecosystem, but these interactions are of secondary importance. The crop pests (pathogens, insects, weeds) are important elements of the system that interact both among themselves and with the other components of the system.

ROOT-KNOT NEMATODES IN PORTUGAL

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IDENTIFICATION AND DIFFERENTIAL HOST STUDIES OF POPULATIONS OF *MELOIDOGYNE* SPP.

Introduction

Eight populations of *Meloidogyne* spp. were collected in Portugal (Fig. 1). Table 1 indicates the populations which are being built up in tomato plants and have not been studied yet.

We have conducted the differential host tests by following the techniques described by Taylor and Sasser (1978).

Seeds of the different plants were soaked overnight in tap water and germinated on moist filter paper in Petri dishes in the dark at 25°C. They were then transferred individually to Jack Pots. These are composed of 75% Irish peat moss and 25% cellulose fibre; the walls are impregnated with balanced plant nutrients and sterilized during manufacture.

Tobacco seedlings were left to grow for 3-4 weeks. Plants in Jack Pots were transferred to 17 cm clay pots filled with a sterilized sandy loam soil mixed 2:1 with quartz sand. The pots were watered regularly; Hyponex plant nutrient solution was used at two week intervals.

Table 1. Populations to be tested

Population	Host	Location
P005	Sugar Beet	Coimbra
P007	Maize and Bean	Barranco do Banho
P008	Olive	Barranco do Banho

Results and Discussion

Table 2 shows the host reactions of four populations of root-knot nematodes. The conclusions that may be drawn from the results are discussed below.

P001

The initial population could be of *M. incognita* Race 2. The population reproduced on pepper with a gall index of 4. However the egg mass index has

an average rating of 2; we observed small galls with fourth-stage larvae. So it appears that P001 is a population of either M. javanica or M. arenaria Race 2.

We have inoculated tomato plants with eggs from the pepper, to build up the population for retesting on the differential hosts. At the same time, we have repeated the experiment with the initial population.

P002

The results indicate that P002 is a population of M. hapla.

P004

The initial population could be of M. incognita Race 2. The population reproduced on pepper with a gall index of 5. However, the egg mass index has an average rating of 3; we observed many necrotic areas and small galls with fourth-stage larvae. So it appears that P004 is a population of either M. javanica or M. arenaria Race 2.

We have inoculated tomato plants to build up the population for repeating the experiment.

P006

The results indicate that the initial population could be a mixture of species of M. incognita Race 3 or Race 4 and either M. arenaria Race 1 or M. hapla. The population reproduced on tobacco and peanut. However the roots showed many necrotic areas and the egg mass index has an average rating of 3. So it appears that P006 is a population of M. incognita Race 3.

We have inoculated tomato plants with the initial population to build it up for repeating the experiment.

Table 2. Response of plant species to attack by Meloidogyne spp.

Meloidogyne species	Population	Differential Hosts[1/]					
		Tobacco	Cotton	Pepper	Watermelon	Peanut	Tomato
M. spp.	P001	+	-	-(+)	+	-	+
M. hapla	P002	+	-	+	-	+	+
M. spp.	P004	+	-	-(+)	+	-	+
M. spp.	P006	-(+)	+	+	+	-(+)	+

[1/] Plant varieties include: Tobacco, NC95; Cotton, Deltapine 16; Pepper, California Wonder; Watermelon, Charleston Gray; Peanut, Florrunner; Tomato, Rutgers.

+ indicates an average egg mass rating of 4 or more.
- indicates an average egg mass rating of 0, 1, 2, or 3.
(+) indicates an average gall rating of 4 or more.

IDENTIFICATION BY MICROSCOPE

Perineal patterns of populations P001, P004, and P006 were also prepared for identification (Taylor and Netscher, 1974). The results of our observations are presented below.

P001

The ten females observed resemble *M. arenaria*.

P004

The ten females observed resemble *M. javanica*.

P006

The ten females observed resemble *M. incognita*.

Perineal patterns and larvae of one *M. hapla* population (P002) were prepared for identification using the methods described by Taylor and Netscher (1974) and Esser, Perry and Taylor (1976).

Table 3 shows some characteristics of the larvae.

Table 3. Characteristics of *M. hapla* larvae

Population	Length	Hemizonid to excretory pore	Alpha	Gamma	Spear
P002	330-430	anterior	22-30.7	6.8-8.6	7.5-13

The results of these studies are summarized in table 4.

Table 4. Species of root-knot nematodes found in Portugal

Population	Differential host test identification	Perineal patterns identification
P001	*M. javanica* or *M. arenaria*	*M. arenaria*
P002	*M. hapla*	*M. hapla*
P004	*M. javanica* or *M. arenaria*	*M. javanica*
P006	*M. incognita* Race 3	*M. incognita*

A ROOT-KNOT NEMATODE SPECIES ATTACKING OLIVE TREES

In 1978 a root-knot nematode was found heavily attacking olive trees (*Olea europaea* L.) in Miranda do Corvo. The population (P003) must have been in the field for several years. Affected trees have numerous dead branches and sparse foliage. The root-knot nematode may have contributed to this poor stand condition. Roots were galled, the galls bearing more than one female (Figure 2).

Larvae were collected from the infested soil; males and larvae were also recovered from knotted roots with egg masses using the Baermann-funnel technique and were prepared for identification (Esser, Perry and Taylor, 1976).

Table 5 indicates some characteristics of the pre-parasitic second stage larvae.

Table 5. Characteristics of larvae of *Meloidogyne* spp. attacking olive trees

Population	Length	Hemizonid to excretory pore	Alpha	Gamma	Spear
P003	352-450	anterior	20.0-26.4	9.2-11.5	8.3-12.5

Females were dissected from the roots and perineal patterns were prepared for identification using the method described by Taylor and Netscher (1974). Microscopic examination of ten patterns showed that the nematode closely resembles *M. hapla*.

Soil and knotted roots collected from the infested field in July, 1978, were used to build up the population of the nematode in tomato plants. Two months later we found that the population failed to reproduce on tomato.

A year later soil was collected again and we have tried to build up the population in different plant species: tobacco, cotton, sugar beet, *Impatiens wallerana* and also tomato. Two months later we did not observe any galls in any of those plants.

Soil and knotted roots will be collected again next spring. Tomato plants will be inoculated with soil, egg masses and larvae.

REFERENCES

Esser, R. P., Perry, V. G. and Taylor, A. L. (1976). A diagnostic compendium of the genus Meloidogyne (Nematoda: Heteroderidae). Proc. Helm. Soc. Wash. 43:138-150.

Taylor, D. P. and Netscher, C. (1974). An improved technique for preparing perineal patterns of Meloidogyne spp. Nematologica, 20:268.

Taylor, A. L. and Sasser, J. N. (1978). Biology, identification and control of root-knot nematodes (Meloidogyne species). Raleigh, North Carolina, North Carolina State University Graphics. 111 pp.

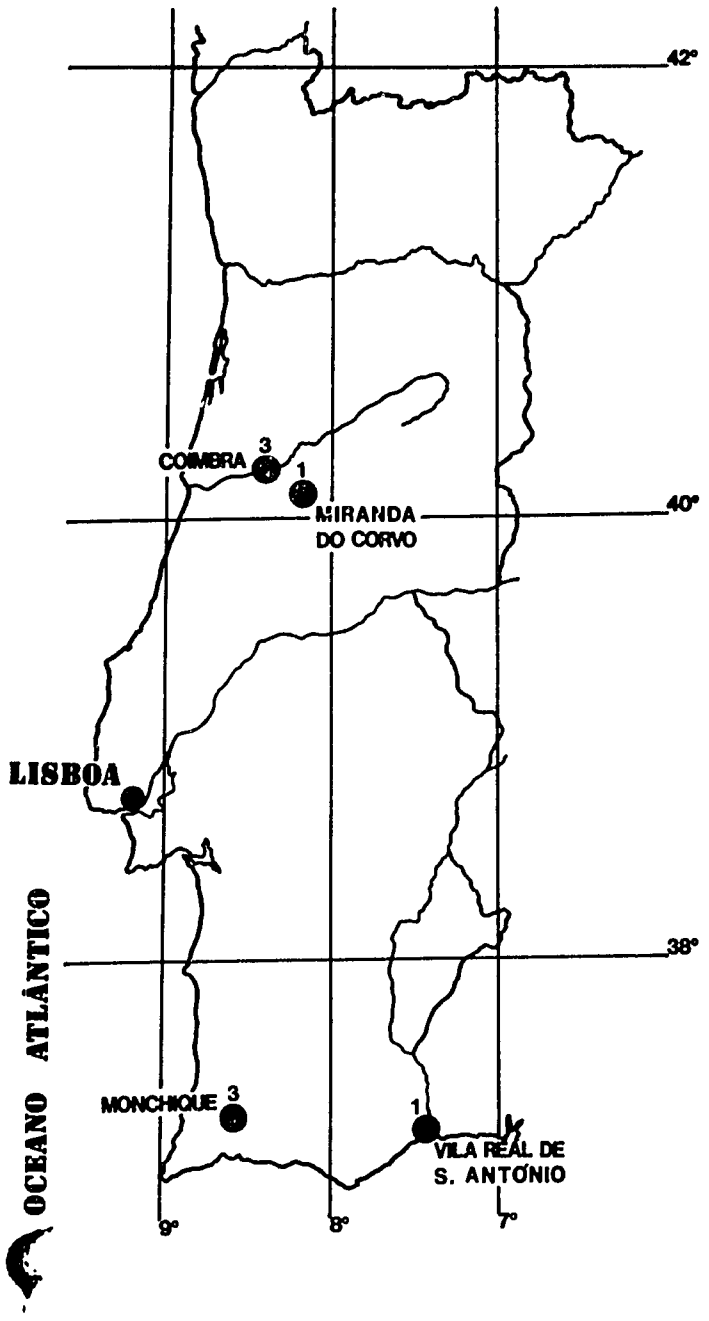

Figure 1. Sites and number of samples from which root-knot nematode populations have been collected.

Figure 2. Portion of olive tree roots infected with root-knot nematode.

THE ROOT-KNOT NEMATODES, MELOIDOGYNE SPP. IN JORDAN

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Faculty of Agriculture, University of Jordan

INTERNATIONAL MELOIDOGYNE PROJECT
(W. I. Abu-Gharbieh and Z. Hashim)

Soil and root samples were collected, one from each area, from South Shuna, North Shuna and Ghor Safi, while two samples were collected from Jerash. All samples were obtained from tomato (*Lycopersicon esculentum* Mill.) fields, except one from Jerash (Jerash 1) which was from eggplant (*Solamum melongena* L.). Egg masses, or root pieces with egg masses, were used to inoculate healthy tomato (cv. "Rutgers") seedlings so as to build up the nematode populations in a glasshouse. Perineal patterns were prepared from several females from each sample. This usually enabled identification to the species level.

In order to confirm species identification and, in some cases, to evaluate the occurrence of "races," the five nematode populations maintained in the glasshouse were used separately to conduct a "Differential Host Test". For this, seedlings of tomato (Rutgers), pepper (California Wonder), tobacco (NC 95), watermelon (Charleston Grey), cotton (Deltapine 16) and peanut (Florrunner) were grown in methyl bromide - fumigated soil contained in 4" pots, with 1-2 plants per pot. Each pot was subsequently infested with an estimated 10,000 nematode eggs of the respective population (test plants were generally more than two months old). There were five replications. Eggs were obtained from the stock population by a method involving separation of the eggs with 0.525% sodium hypochlorite solution (Hussey and Barker, 1973). After about 45 days, plants were removed from the pots and the number of galls/pot counted. Gall rating was made according to the following scale:

0 = 0, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100 and 5 = more than 100 galls.

Results

Examination of perineal patterns of the females revealed the presence of two species of *Meloidogyne*,: *M. incognita* and *M. javanica*. Their distribution was as follows:

South Shuna	M. javanica
North Shuna	M. incognita
Jerash 1	M. javanica and M. incognita
Jerash 2	M. javanica
Ghor Safi	M. javanica

The response of the plants used in the Differential Host Test confirmed the identity of the nematodes. The results of this test are presented in Table 1. From these results, it would appear that the M. incognita population from North Shuna belonged to "Race 1," since neither tobacco nor cotton were infected. The M. incognita population from Jerash 1 may have belonged to either "Race 1" or "Race 2," since it was mixed with M. javanica and cotton was not infected. In order to determine to which race this population belonged, egg masses should have been collected from the infected pepper plants and put on tomato to build up the population for retesting of the Differential Hosts.

Table 1. Gall rating to indicate response of plant species to five populations of Meloidogyne from Jordan.

Source of nematode population	Tobacco NC 95	Cotton Delta-pine 16	Pepper California Wonder	Watermelon Charleston Grey	Peanut Flor-runner	Tomato Rutgers
South Shuna	5	0	0	4	0	5
North Shuna	2	0	5	5	0	5
Jerash 1	5	0	4	5	0	5
Jerash 2	4	0	0	4	0	5
Ghor Safi	5	0	0	5	0	5

Discussion

The results reported herein indicated that M. javanica and M. incognita were the dominant species of root-knot nematodes in Jordan, with the former being the more common. Since only a few samples were studied, it is rather difficult to draw conclusions concerning the distribution of these parasites within the country. However, these conclusions were in general agreement with earlier findings that depended upon the morphological characteristics of many root-knot nematode samples collected from different areas of Jordan. And, although M. javanica was found in almost all areas investigated, M. incognita was found in the relatively cooler areas of the Jordan Valley (North Shuna) and on the rather low mountains of Jerash.

EVALUATION OF APPLICATION METHODS OF "VYDATE" FOR CONTROL OF *MELOIDOGYNE INCOGNITA* ON TOMATO SEEDLINGS

(W. I. Abu-Gharbieh and A. Ghayadha)

In a pot experiment in the greenhouse, Vydate (G-10% or L-24%) was used in various methods of soil treatments. These included: granular mix (0.23 gm/L. soil), liquid mix (0.11 ml/L. soil) and liquid drench (240 ml of 0.12% Vydate/L. soil). Separate treatments of these were supplemented by subsequent Vydate L. spray (4 ml/L. water) when the 'Claudia Raf' tomato seedlings were 5 cm high. Other treatments included: spray alone, Vydate nontreated and a control of nematode-free and Vydate nontreated soil.

The experiment was terminated three months after planting. The results showed that the liquid drench followed by a foliar spray treatment was most effective and significantly reduced root galling (67%). And, while effectiveness of Vydate drench alone was medium (52% reduction), all other treatments ranged from slightly effective (30%) to almost ineffective (13%).

EFFECT OF SOAKING TOMATO SEEDS IN VYDATE L. SOLUTION FOR ROOT-KNOT NEMATODE CONTROL

(W. I. Abu-Gharbieh and Z. Hashim)

Tomato seeds 'Claudia Raf' were soaked in the following concentrations of Vydate L. 24%: 0, 100, 500, 1000, 2500, 5000, 7500 and 10,000 ppm. In each concentration, the seeds were soaked for 5, 30, 60 or 300 minutes. Transparent plastic boxes were filled with soil infested with *Meloidogyne javanica* larvae, in which the treated seeds were sown. The experimental boxes were placed in the greenhouse for a month. They were then taken down and seedlings were examined for root galling.

The results showed that none of the treatments gave any significant reduction of root galling over the nontreated. Also, no phytotoxic effects, even at the higher concentrations, were observed. These results may indicate that seed treatment is ineffective or possibly higher concentration of the chemical should be used.

SCREENING OF LOCALLY GROWN EGGPLANT, HOT AND BELL PEPPER VARIETIES TO MELOIDOGYNE JAVANICA

(W. I. Abu-Gharbieh and Maisarah Karajah)

Several cultivars, lines or collections of locally grown eggplant, hot and bell (sweet) pepper from different sources were tested for resistance to M. javanica under greenhouse conditions. Nematode-free seedlings of all cultivars were transplanted to the soil of 10 cm pots that received 6 egg-masses of the nematode. After two months, the seedlings were removed and examined for root-galling.

The results showed that all hot and bell pepper cultivars tested exhibited no gall symptoms and presumably resistant to the nematode. The hot pepper cultivars included: Anheim Chili/Clause, Anheim Chili/Asgrow, Anheim M/Burpee, Anheim M/Petoseed, College 64 L/Peto-seed, De Cagenne/Tezier, Long thin Cagenne/F. Morse, and Rouge Long Ordinaire/Tezier. The bell pepper cultivars included: 77 B/Asgrow, 772/Asgrow, Beliare/Niagara, B.S. Fordhook/Purbe, Calif. Wonder/Peto-seed, Calif. Wonder/Ohlsens, Calif Wonder/Tezier, Calif. Wonder/300 TMR/IPB, Fancy/Asgrow, Murcury/Peto-seed, 1/0/0 Wonder/Ohlsens, 1/0/0 Wonder TMR/IPB, and 1/0/0 1/ / Niagara.

All eggplant cultivars tested were infected but to varying degrees. The most severely infected ones being Baren FI/Clause and Black Beauty/Abundance. Black Beauty/Tezier, Special Hilbush/Asgrow, Viscerba 77357/Asgrow and Large Black were moderately susceptible, while Black Beauty/Hurst, Black Beauty Shobak Sta. and Long Black/Egypt seemed to be least susceptible to the nematode.

BIOLOGY OF MELOIDOGYNE JAVANICA ON TOMATO IN THE JORDAN VALLEY

(H. M. Saleh and W. I. Abu-Gharbieh)

Certain aspects of the biological activities of Meloidogyne javanica were studied on tomato var. Claudia Raf, in the Central Jordan Valley, throughout the 1978-1979 growing season (Sept. to March). In this study, nine isolated concrete bins (1 x 2m) were artificially inoculated with egg-masses of the nematode. Each bin received 285 egg-masses. The study comprised three main treatments: (1) planting nematode-infected tomato seedlings, (2) planting nematode-free tomato seedlings, and (3) direct seeding of tomato. Each treatment was replicated randomly three times. Weekly samples were taken randomly from each replicate. Each sample comprised one plant root with the soil around it. Soil samples were used

to assess numbers of second stage larvae in the soil. Stained lateral roots were used to count root galls and numbers and stages of nematode development in the root tissue. Soil temperatures throughout the season were recorded.

The results showed a significantly lower larval counts from the soil, galls and nematodes numbers per unit of root weight were found in the direct seeding treatment than when nematode-infected or nematode-free seedlings were used. However, the direct seeding treatment had significantly higher numbersof eggs per egg-mass than the other two treatments. Also, significantly lower larval counts, galls and nematodes per unit of root weight were found when nematode-free seedlings were planted in comparison with the nematode-infected ones.

Nematode activity, differentiation and reproduction, were found to be much related to soil temperature. Faster development, higher egg laying, rapid increase in soil population of the larvae and subsequently root infection were found in the Sept. - Nov. period and in March when high temperatures (between 20-30°C) prevailed. On the contrary, retardation in these activities were found in the Dec. - Feb. period, when lower temperatures prevailed (15-18°C).

Four generations of the nematode were completed in the season. Generation time ranged from 3-8 weeks depending mainly on soil temperature.

EFFECT OF METHYL BROMIDE SOIL FUMIGATION AND BLACK PLASTIC MULCHING ON CUCUMBER GROWN UNDER PLASTIC TUNNELS

(M. Khtoom and W. I. Abu-Gharbieh)

Cucumbers planted in about November in the Jordan Valley are grown under plastic covers for protection against the low temperatures of the subsequent winter months. Latest technologies involved the use of drip irrigation and black plastic mulching. Continuous culture of cucumber in the same land successively for several years resulted in a progressive decline in productivity. The root-knot nematode was largely blamed for the short growing span of the crop.

The objective of this study was to test the effectiveness, rates (1 or 2 lb/10 m^2), and pre-sowing periods (1 or 2 weeks) of methyl bromide fumigation against Meloidogyne javanica in a field in the Central Jordan Valley. Methyl bromide was introduced under the black plastic tarp, and after the fumigation period (72 hrs), holes were made in the tarp for aeration and subsequent sowing of seeds (3 days later).

The results showed that methyl bromide fumigation gave, in all cases, excellent nematode control, and larvae and galls were almost undetectable throughout the growing season. This was contrary to the nonfumigated whether mulched or non-mulched. The average yield per plot (10 m^2) was approximately 23, 42, 52, and 61 kg in the nonmulched- nonfumigated control, mulched, nonmulched-fumigated, and mulched-fumigated treatments, respectively. The effects of rates of application and pre-sowing aeration periods on the yield were not pronounced.

DISTRIBUTION AND CONTROL OF ROOT-KNOT NEMATODES ON CRETE

Emmanuel Pyrowolakis
Iraklion Crete, Greece

A field survey conducted to determine the presence of root-knot nematodes in vegetable and banana production on Crete, showed that four species of Meloidogyne were of economic importance. The distribution of these four species is shown in Figure 1. Whereas, M. javanica, M. incognita and M. arenaria were detected throughout the coastal region at elevations below 200 meters, M. hapla was only found in one location at an altitude above 450 meters (Pyrowolakis 1975).

The infestation level, the type of vegetable attacked, and the species of Meloidogyne detected are presented in Table 1. The level of infestation was determined using an index developed by Daulton et al. 1961.

Index

Level	Description
0	Free of galling
1	1 - 5 galls
2	6 - 25 galls
3	26 - 100 galls
4	100 + galls, singly produced
5	Many galls fused together into compound galls
6	Mainly compound galling, light reduction in secondary root growth
7	Secondary root growth strongly retarded
8	Main roots in advanced state of decay, secondary roots deformed

Root-knot nematodes in general reproduce slowly during the months of December through March due to low soil temperatures. Starting the end of April up until the end of June or the beginning of July, when the soil temperatures are high (Table 2), nematode reproduction increases drastically causing high losses in yield. The high degree of crop loss relegated to M. javanica was shown to be directly correlated with soil temperature. The type of host plant played an insignificant role in crop loss (Pyrowolakis 1977).

Vegetable production methods in the coastal regions have changed drastically in the years following the survey. The majority of fields studied in 1975 have been covered with plastic greenhouses, allowing tomato, cucumber,

eggplant and okra production in the period between September and July. The presence of host crops for this extended period of time and the higher soil temperatures in the greenhouse have resulted in increased nematode damage. The amount of crop loss due to root-knot has increased to the extent that without chemical control little to no yield can be expected.

The presence of fungi causing damping-off (Pythium spp.) and wilt (Fusarium and Verticillium) in combination with the root-knot problem have forced growers to incorporate soil fumigants in their control programs.

The soil fumigants used in the greenhouses on Crete are listed in Table 3 along with the results of experiments conducted over a two-year span on the efficacy of these fumigants against M. arenaria, soil-borne fungi, and Orobanche. The yield increases in these tests, conducted in greenhouses on tomato and cucumber, are also presented in Table 3. In addition to chemical control, studies are underway to determine whether resistant varieties are climatically adaptable and able to produce the quality fruit and high yields desired by the growers on Crete.

REFERENCES

Daulton, R. A., C. J. Nusbaum. 1961. The effect of soil temperature on the survival of the root-knot nematodes Meloidogyne javanica and M. hapla. Nematologica 6:280-294.

Pyrowolakis, E. 1975. Studien uber die Verbreitung der Gattung Meloidogyne auf der Insel Kreta. Ztschr. PflKrankh. 82:750-755.

Pyrowolakis, E. 1977. Einfluss von Bodentemperatur und Wirtspflanzen auf die Generationsdauer von Meloidogyne javanica. Nematologica 23: 47-50.

Pyrowolakis, E. 1978. Einfluß von Bodenentseuchungsmitteln und Nematiziden auf Kulturen unter Folien und auf ihre Bodenorganismen. Greek Agricultural Research, II, 344-354.

Table 1. Host plant, location, and infestation level of 4 species of Meloidogyne in a field survey on Crete.

LOCATION / HOST	Paläochora	Kandanos	Omalos Hochebene	Voukolies	Platanias	Vrisses	Stavromenos	H. Gallini	Messaraebene	Arvi	Lassithi Hochebene	Malia	Vianos	Kalo Chorio	Neapolis	Hierapetra	Makris Jialos
	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H	J A I H
Cucumis sativus				0 0 0 0		2+	2+	4+	4X			4+			0 0 0 0		
Cucumis melo				0 0 0 0								4+					3+
Cucurbita citrulus									4+								3(+X)
Cucurbita pepo				0 0 0 0	0 0 0 0	3+											
Lycopersicon esculentus	2+			0 0 0 0	3+	6X	6(+X)	4+	5+	0 0 0 0		8(+ *)	0 0 0 0	3(+ *)	0 0 0 0	3*	3+
Solanum tuberosum			0 0 0 0		0 0 0 0	2+	2(+X)		0 0 0 0		0 0 0 0	0 0 0 0			0 0 0 0		
Solanum melongena												4+					
Phaseolus vulgaris				0 0 0 0	0 0 0 0	4(*X+)	5*	2*	3(*X)	0 0 0 0			0 0 0 0		0 0 0 0	0 0 0 0	
Hibiscus esculentus							8(+X+)		4+							4(+ +)	
Cichorium endivia		2X						0 0 0 0			0 0 0 0						
Allium cepa		2X			0 0 0 0	3(+X)											
Atriplex hortensis					2+			2+							0 0 0 0	0 0 0 0	
Apium graveolens					2+	6(+X)											
Beta vulgaris ssp. *cicla*								4(+X)									
Brassica oleracea						0 0 0 0											
Musa cavendishii	2+				4+				3+	2+		3+		2+		2+	2+

J: *Meloidogyne javanica*
A: *Meloidogyne arenaria*
I: *Meloidogyne incognita*
H: *Meloidogyne hapla*

X: Found for first time on Crete
+: Found for first time from this host
*: Found for second time
(): More Meloidogyne species found in the same host

Table 2. Average monthly soil temperatures in °C taken in Tybak representative of the coastal production area in 1966.

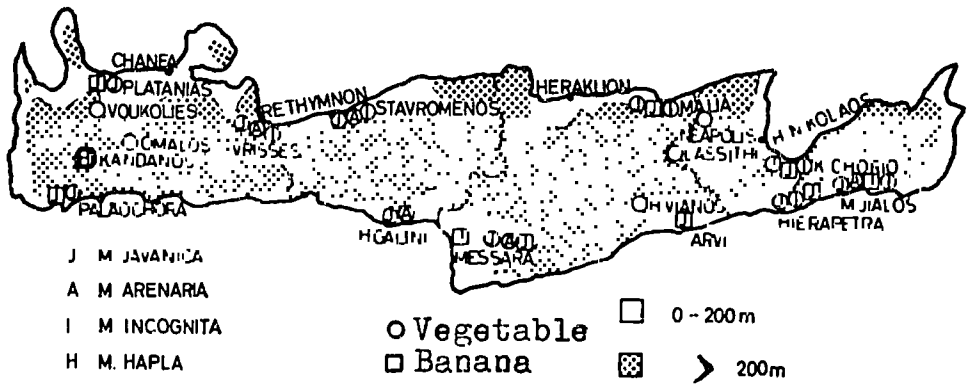
J	F	M	A	M	J	J	A	S	O	N	D
12.9	15.0	15.9	22.5	27.5	32.9	35.1	35.6	30.7	24.0	19.3	13.8

Table 3. The efficacy of soil fumigants on M. arenaria, soil-borne fungi, orobanche and the yield of tomato and cucumber under greenhouse conditions.*

Fumigant	Galling Intensity at Harvest	Number of Plants	Quality Classes			Number of Orobanche
			Tomato			
DOWFUME	0.00 a	0.25 a	111.82 ab	28.83 a	14.97 ab	0.00 a
D-D	0.00 a	1.50 a	118.23 a	20.42 abc	9.25 cd	0.50 a
DI-TRAPEX	0.08 a	0.25 a	107.90 ab	28.29 ab	10.62 bc	0.25 a
BASAMID	1.06 b	5.00 a	105.12 ab	23.56 abc	15.96 a	2.00 a
VAPAM	0.93 b	4.50 a	90.47 bc	21.52 abc	11.52 abc	5.75 a
CONTROL	2.44 c	10.00 b	58.37 d	5.85 c	4.03 e	12.75 b
			Cucumber			
DOWFUME	0.05 a	1.75 abc	188.50 a	13.30 ab	4.14 ab	-
D-D	0.83 a	1.75 abc	156.82 abc	14.75 ab	4.03 ab	-
DI-TRAPEX (liquid)	0.42 a	0.50 a	177.17 a	19.22 a	3.19 abc	-
BASAMID	2.41 bcd	2.00 abc	159.08 abc	14.26 ab	2.04 c	-
VAPAM	2.49 bcd	3.00 abcd	139.53 abcde	10.10 b	2.90 abc	-
CONTROL	4.50 d	4.00 abcd	123.48 abcde	13.88 ab	4.42 a	-

*Numbers having same letter are not statistically different

Figure 1. The presence of root-knot nematodes in vegetable and banana on Crete.



CONTRIBUTION TO THE STUDY OF THE ROOT-KNOT NEMATODE (MELOIDOGYNE SPP.) IN GREECE

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now with Dow Chemical

Nothing had been reported on root-knot nematode, Meloidogyne spp, in Greece until 1935, when Professor C. Isaakides observed galls on the root system of various cultivated plants such as tomatoes, potatoes, tobacco, almond trees and others.

Another 20 years or more elapsed until some research was undertaken by Benaki Phytopathological Institute. Not more than 10 reports have been published until today dealing with their geographic and host distribution, control and some taxonomic work.

It was not earlier than 1960 when the agronomists of the Ministry of Agriculture and some pioneer farmers were fully convinced about the importance of these nematodes on the plants and started facing them more seriously.

After examining thousands of samples from several regions of the country we could draw an outline of the economic losses of the most important crops due to this nematode (Table 1).

If we consider also the contributed losses in nurseries, perrenial trees and other cultivated plants, we may come out with an annual total loss for the whole country of more than $80,000,000.

Until today (1979), eight species have been reported from Greece, ranked according to their importance Meloidogyne incognita, M. javanica, M. arenaria, M. thamesi, M. acrita, M. artiellia, M. exigua, and M. hapla. Also there are some indications that M. acronea and possibly another species exist but some more work is needed to be confirmed.

More than 85 host-plants have been reported by the author and other scientists from all around the country (Table 2). Most of the plants are of economic importance.

Table 1.

Crop	Yield tons per year	% Loss	Loss value per year in $
Beans	105,000	5	2,800,000
Vegetables	528,000	8	11,400,000
Cucurbits	660,000	3	5,300,000
Tomatoes	1,640,000	8	28,000,000
Tobacco	82,000	1	900,000
Sugarbeets	1,500,000	1	3,200,000
Potatoes	780,000	4	8,300,000
			59,900,000

Table 2. *Meloidogyne* spp. and their host-plants reported from Greece.

Crop	*incognita*	*javanica*	*arenaria*	*thamesi*	*acrita*	*artiellia*	*exigua*	*hapla*	sp.
Cucumber	+	+	+	+	+				+
Grapes			+		+				+
Potatoes	+	+	+						+
Lettuce	+		+						
Poppy			+						+
Okra	+	+	+						+
Geranium			+						+
Snapdragon			+	+					
Tomatoes	+	+	+		+				+
Garlic				+					+
Hyacinth		+		+	+				+
Wheat						+			+
Peach	+	+					+		+
Cyclamen		+						+	+
Cotton	+								+
Tobacco	+	+			+				+
Watermelon	+								

Table 2. (cont'd.)

Crop	incognita	javanica	arenaria	thamesi	acrita	artiellia	exigua	hapla	sp.
Eggplant	+	+	+						+
Fig trees	+	+							+
Chillies	+	+							
Sugarbeets	+	+							+
Beans	+	+	+						+
Carrots	+	+		+					+
Roses	+								+
Fuchsia	+								
Almond trees	+	+							+
Gardenia		+							+
Olive trees		+							+
Melanophloeus		+							
Pistachio tree		+							+
Celery	+	+							+
Pomegranate trees									+
Begonia									+
Apricot trees									+
Lantana sp.									+
Dahlia									+
Cauliflower		+	+						+
Asparagus									+
Pear trees			+						+
Endive			+						+
Sour cherries									+
Carnation									+
Jesamin									+
Oak trees									+
Thistle	+		+						
Walnut trees									+
Cherry trees									+
Cabbage	+		+	+					+

Table 2. (cont'd.)

Crop	incognita	javanica	arenaria	thamesi	acrita	artiellia	exigua	hapla	sp.
Onion									+
Quince trees									+
Broad beans									+
Hazelnut trees									+
Poplar tree									+
Apple tree									+
Alfalfa									+
Mimosa sp.									+
Mulberry trees									+
Onobrychis sp.									+
Pine tree									+
Melon									+
Leek	+		+						+
Peas									+
Clovers									+
Lens									+
Chenopodium sp.									+
Mandarin tree									+
Petunia sp.									+
Beets									+
Squash			+						
Pistachio wild									+
Periploca sp.			+						
Violet									+
Chestnut trees									+
Kennedya sp.									+
Spinach									+
Goosefoot		+							+
Radish									+
Sau thistle			+						
Milkweed			+						

Table 2. (cont'd.)

Crop	incognita	javanica	arenaria	thamesi	acrita	artiellia	exigua	hapla	sp.
Malva sp.		+	+						
Acacia sp.	+								
Gerbera sp.			+						
Plum trees		+							
Echeveria sp.									+
Black night-shade	+								
Capsella sp.	+								
Juncus (?)	+								

RECENT STUDIES ON DISTRIBUTION AND CONTROL OF THE ROOT-KNOT NEMATODES (*MELOIDOGYNE* SPP.) IN SOUTHERN IRAN

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The status of the root-knot nematodes, *Meloidogyne* spp., in Iran was previously reported in the Research Planning Conference of the International *Meloidogyne* Project (IMP) held in Cairo, Egypt (3). This paper reports our present knowledge on the extent of distribution of the root-knot nematodes in Fars Province with special considerations on the effects of cultural practices, fallow and/or rotation, and soil types. The results of greenhouse experiments on control of *Meloidogyne incognita* are also summarized.

Materials and Methods

Distribution Studies. Tomato and/or eggplant fields in all districts of Fars Province including Abadeh, Darab, Estahbanat, Fasa, Firuzabad, Jahrom, Kazerun, Lar, Mamasani, Neyriz, and Shiraz were surveyed to determine the root-knot nematode infestations (Figures 1 and 2).

To do this, agriculturally important counties of each district were selected and the fields of each village were sampled at the end of growing season and an ecological form similar to that of IMP was completed for each field. A soil and root sample (made of 20 subsamples) was collected from each infested field with an (X) pattern and brought to laboratory as described earlier (4). Gravity-screening techniques were used to determine the nematode population in infested soils (6), and the perineal patterns were prepared for identification of the nematode species (5). Soil types were determined by Dr. Ramez Mahjoori from the Department of Soil Science.

Greenhouse Experiments. The greenhouse experiments were conducted to determine the possible application of *Artemisia cina* (a wildly grown anthelmintic plant extensively distributed in Iran, Fig. 3) in the nematode control programs, using the information reported earlier (1, 2). A population of *M. incognita* originally collected from Fasa was used throughout the experiments.

Proper conditions for seed germination were established, using different temperatures and scarification techniques. The seedlings were grown in a greenhouse and studied for the effects of the nematode on the plant and the effects of the plant on the nematode. Effects of the plant extract, dried foliage and the growing plant also were evaluated.

Results

Distribution studies: - Geographical distribution. The results of 695 samples collected from 207 villages of Fars Province revealed the presence of the root-knot nematodes in almost all districts of Fars (Fig. 4). However, the rates of infestation varied in different districts, counties, villages, and the fields.

The average rate of infestation in Fars Province was 38% of the counties, 10% of the fields and 15% of the villages surveyed. The rate of infestation in the infested fields ranged from 5%-100% with an average of 64.5%, and the population of 204 to 23,712 larvae/100 g soil. The infested villages are listed in Table 1.

The rate of infestation in different districts of Fars Province is as follows:

Abadeh District: From 9 (out of 12) counties surveyed (71 fields), only 4 fields were infested in Soormaq and Bavanat counties, resulting about 5.6% infestation for the district.

Darab District: From 2 (out of 9) counties surveyed (29 fields), only one field in Darab County (Humeh) was infested (3.4% of the district).

Estahbanat District: Fifteen fields sampled from Khir County (out of 3 counties) none was infested.

Fasa District: From 3 (out of 8) counties surveyed (15 fields), only 2 fields in Shesh Deh County were infested (over 13% of the district).

Firuzabad District: From 7 (out of 8) counties surveyed (134 fields) only 10 fields from 5 counties (Afzar, Arbaeh, Farashband, Firuzabad (Humeh) and Khajeh) were infested (7.4% of the district).

Jahrom District: From 4 (out of 8) counties surveyed (35 fields) only 5 fields from 2 counties (Jahrom (Humeh) and Ghotbabad) were infested (over 14% of the district).

Kazerun District: From 3 (out of 6) counties surveyed (76 fields), 7 fields of 2 counties (Kazerun (Humeh) and Shapour) were infested (9.2% of the district).

Mamasani District: From 2 (out of 6) counties surveyed (18 fields), only one field in Mamasani County (Humeh) was infested (5.5% of the district).

Neyriz District: From 2 (out of 6) counties surveyed (33 fields), only 2 fields in Neyriz City (Rostaq County) were infested (6% of the district).

Shiraz District: From 16 (out of 23) counties surveyed (202 fields), only 10 fields from 4 counties (Arsenjan, Gharebagh, Kavar and Shiraz (Humeh)) were infested (about 5% of the district).

A thorough survey of the fields located in Shiraz City and its vicinity revealed that over 30% of the fields (21 out of 68 fields) were infested (Figure 5). However, the rate of infestation in Shiraz County (excluding the city area) was about 5%.

Distribution Versus Soil Types. Table 2 shows the frequency of infestation of different soil types with *Meloidogyne javanica* in 65 fields of Shiraz City area. The nematode infestation was observed in Sandy Clay Loam, Silty Clay Loam and Clay Loam Soils.

Distribution Versus Cultural Practices. Table 3 shows the frequency of the root-knot nematode infestation in tomato plants, followed by fallow and/or rotation, in 420 fields of Fars Province.

Distribution of different species. Table 4 shows the known distribution of different species of the root-knot nematodes in 8 districts of Fars Province. *M. javanica* was distributed in all districts. Whereas, *M. incognita* was observed in Fasa, Kazerun, Neyriz and Shiraz. *M. hapla* was only found in Abadeh District. The frequency of occurrence of the above-mentioned species was respectively 78%, 17%, and 5%.

Greenhouse Studies. Our results of greenhouse studies on the possible control of *M. incognita* are summarized as follows:

The nematode invaded *Artemisia cina* roots and developed to gravid females. However, the rate of gall formation was very low when compared to that of the tomato seedlings (Figure 6),

The plant extract effectively controlled the nematode,

Soil infestation was highly reduced when *Artemisia* seedlings were grown for only one month.

Discussion

Although the root-knot nematodes were distributed in almost all districts of Fars Province, only 15% of villages were infested. A review of the ecological forms of the surveyed fields revealed that introduction of infested

tomato seedlings to the new areas may be an important factor for the nematode spread. Soil types is not believed to be a limiting factor. The chance of the nematode observation was more in soil types more prevalent in the region (Table 2). However, where fallow and/or rotation was not practiced, more infested fields were observed (Table 3). Although different climatic conditions in the surveyed counties did not seem to affect the presence or absence of M. incognita and M. javanica, M. hapla was only observed in cold regions.

Proper action on prevention of the nematode spread and further studies on control programs are suggested to prevent the horizontal distribution of Meloidogyne spp. and to propose an economic method of control.

ACKNOWLEDGMENTS

The authors wish to express their deep appreciations to Dr. R. Mahjoori for his valuable cooperations in determination of the soil types. Assistance of Mr. R. Kashkouli, Miss. Shirazi and Mrs. S. Atashi is also highly appreciated.

Special thanks are due to Eng. H. Azarakhsh for the drawings.

LITERATURE CITED

Abivardi, C. 1969. A study of anthelmintic natural plant products exhibiting nematocidal activity to plant-parasitic nematodes. Dissertation Abstracts Vol. XXIX, November 11, 1969.

Abivardi, C. 1971. Studies on the effects of nine Iranian anthelmintic plant extracts on the root-knot nematode Meloidogyne incognita Phytopath. Z. 71:300-308.

Abivardi, C. 1978. Status of root-knot nematodes, Meloidogyne spp., in Iran. Proc. Res. Planning Conf. (IMP), Jan. 29-Feb. 2, Cairo, Egypt. pp. 26-35.

Abivardi, C., K. Izadpanah, M. Sharafeh, and A. Saffarian. 1970. Plant-parasitic nematodes associated with citrus decline in southern Iran. Plant Dis. Reptr. 54:339-342.

Anonymous (undated). Photographs of perineal patterns of certain root-knot nematodes, Meloidogyne spp., for use in species identifications. IMP, North Carolina State University, Raleigh, N.C. Unpaged.

Ayoub, S. M. 1977. Plant nematology, an agricultural training aid. Dept. of Food and Agric. Sacramento, California. 155 pp.

Figure 1. Different Districts of Fars Province with Their Ratio of Urban and Rural Population

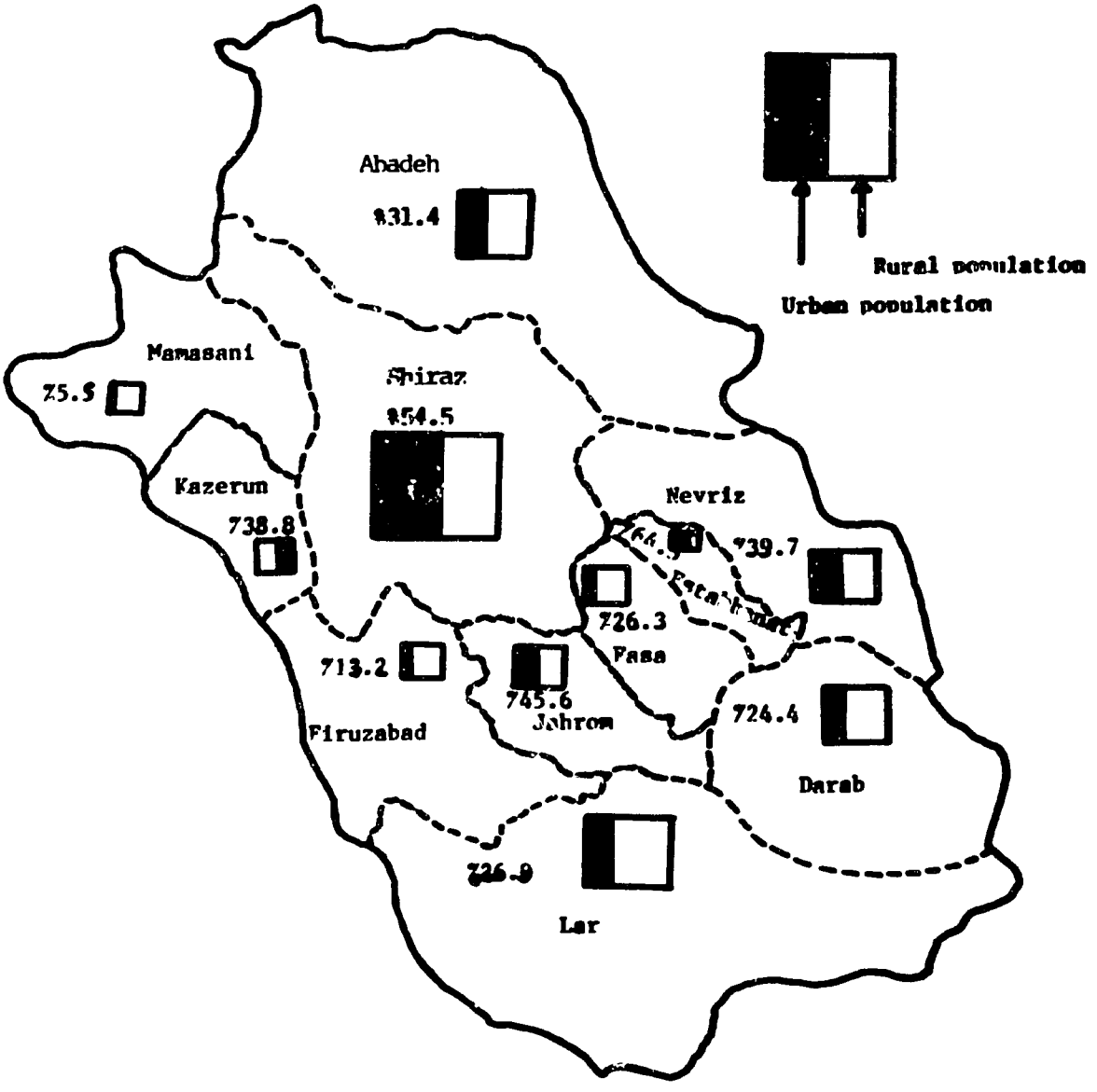

Figure 2. Population Density of Fars Province in Different Districts.

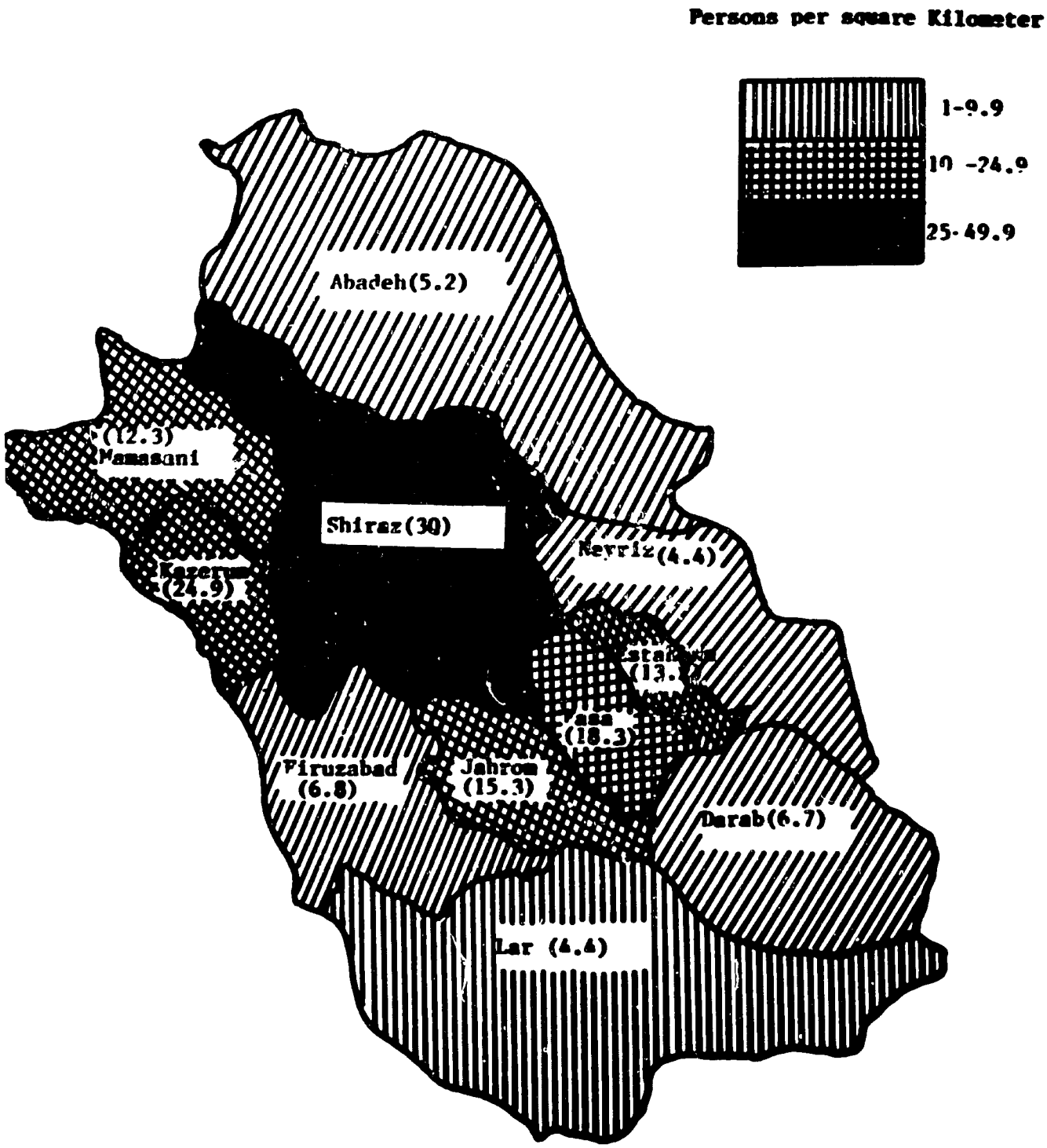

Figure 3. Artemisia Growing Areas of Iran.

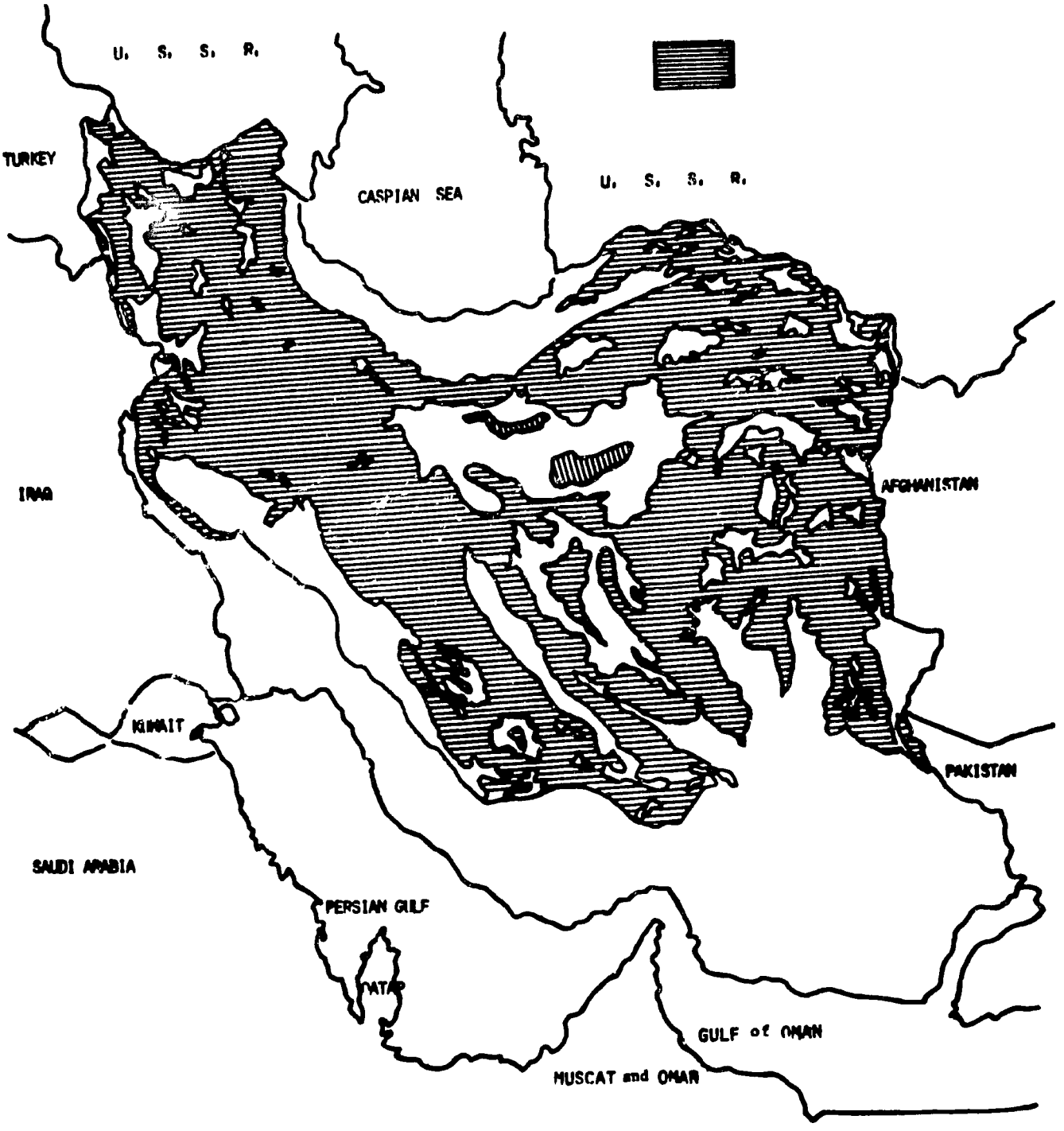

Figure 4. Pattern and Rates of Distribution of the Root-Knot Nematodes (Meloidogyne spp.) in Fars Province.

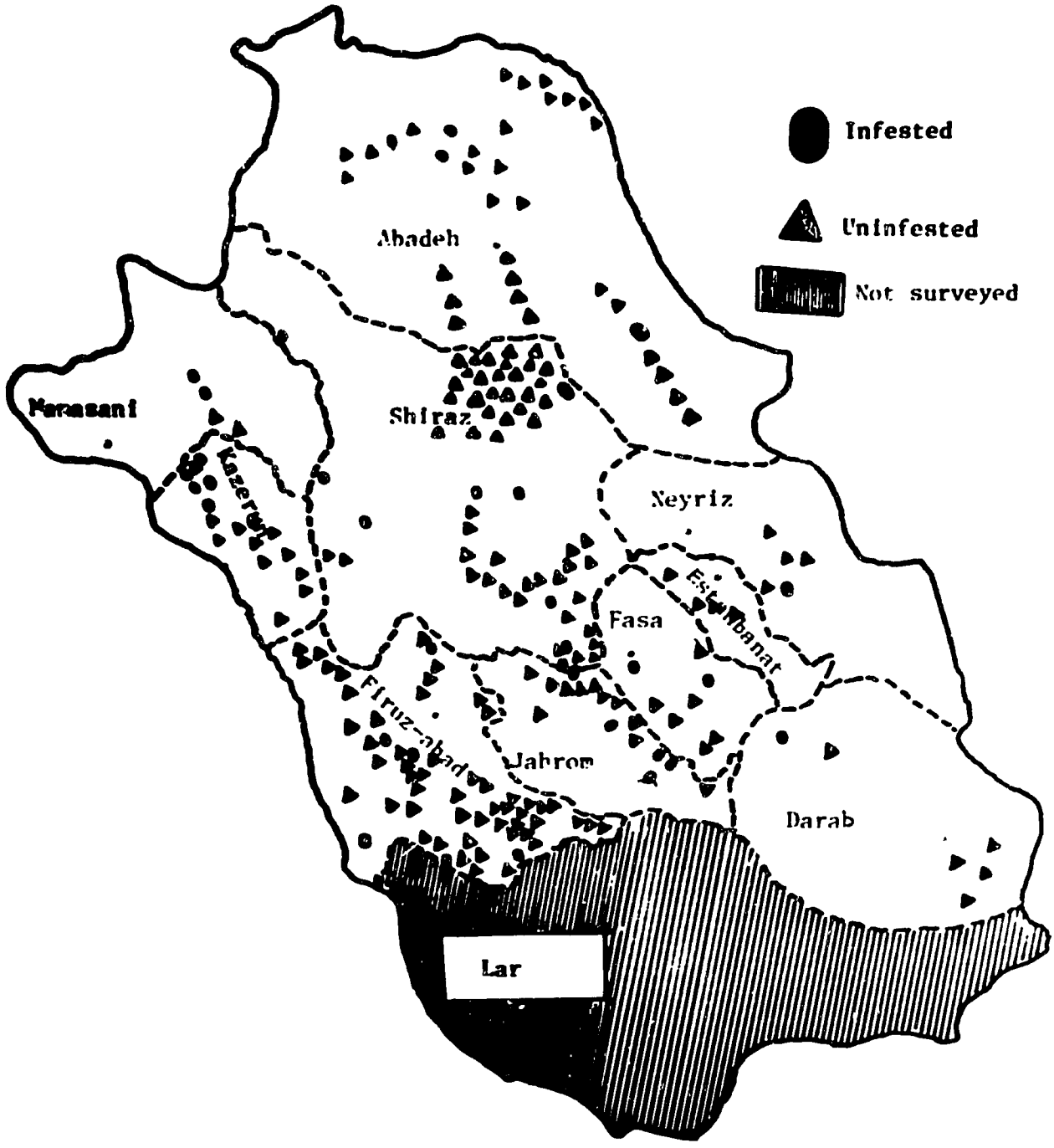

Figure 5. Distribution Pattern of the Root-Knot Nematodes (Meloidogyne spp.) in Tomato Growing Areas of Shiraz.

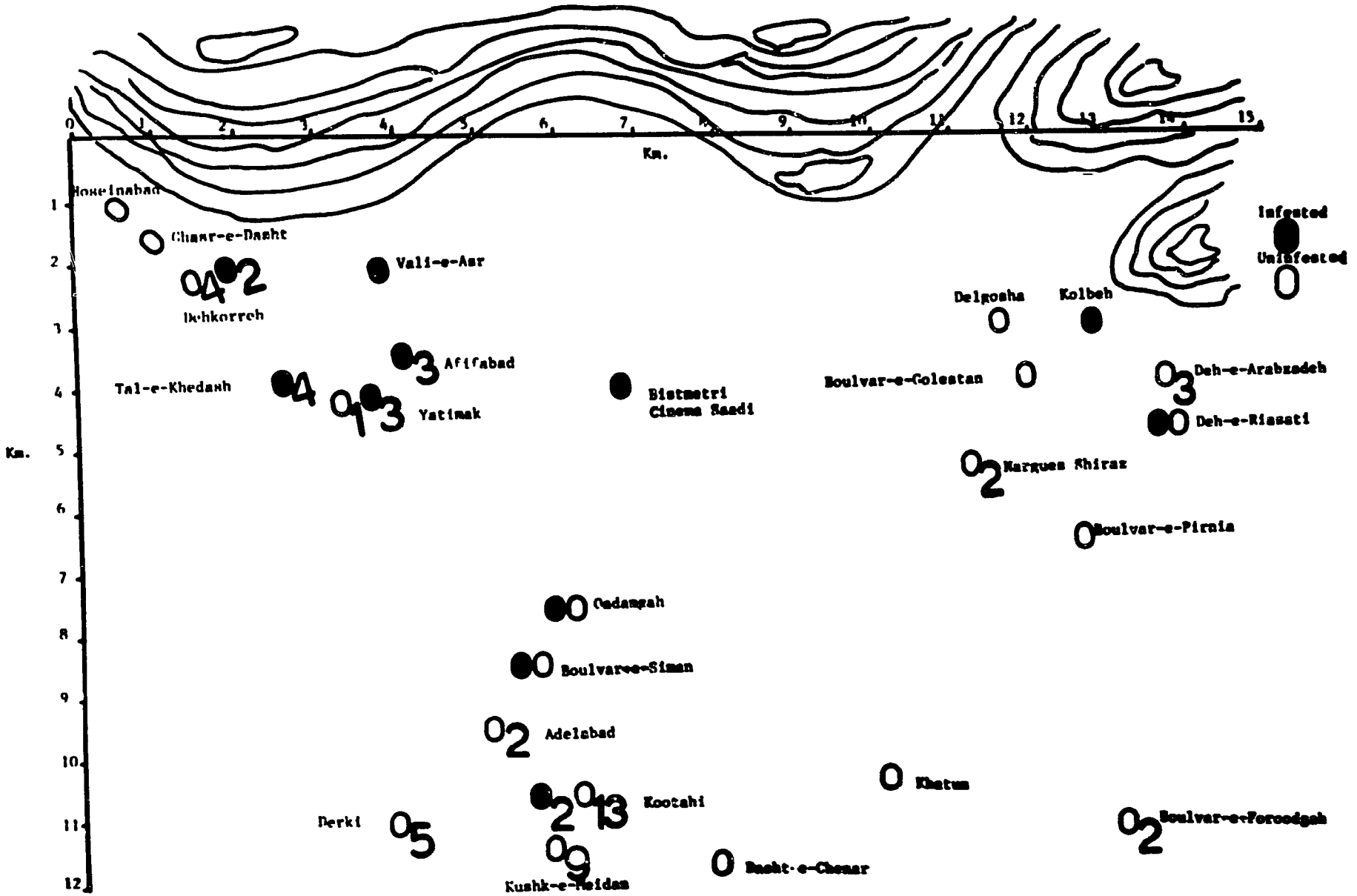

Figure 6. Rate of gall formation on roots of *Artemisia cina* (left) and tomatoes (right).

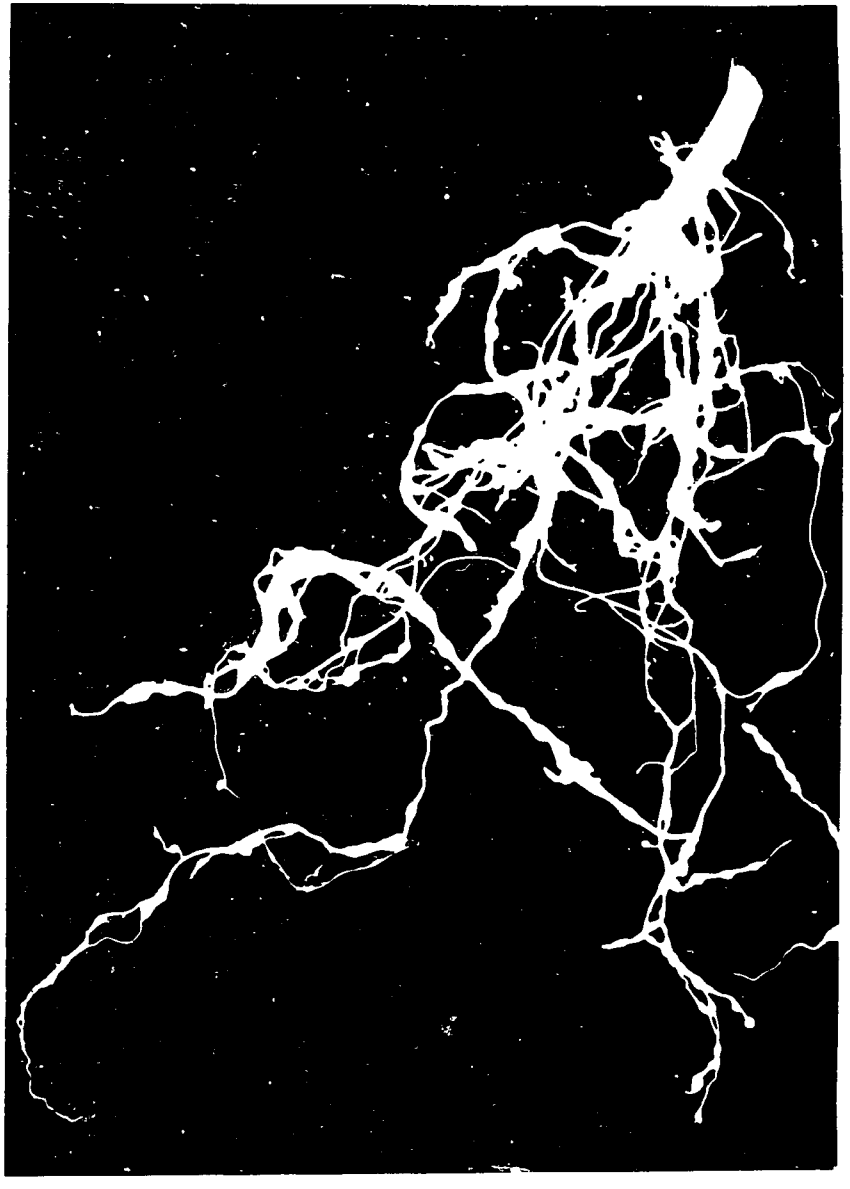

Table 1. The list of villages from different counties of Fars Province, infested with root-knot nematodes (Meloidogyne spp.)[1]

No	Name of the Village	County	District
1	Aliabad	Soormaq	Abadeh
2	Najafabad	Soormaq	Abadeh
3	Sangbor	Bavanat	Abadeh
4	Jalyan	Nowbandegan	Fasa
5	Barmeh	Farashband	Firuzabad
6	Zeinabad	Qir	Firuzabad
7	Abgarm	Afzar	Firuzabad
8	Ahmadabad	Humeh	Firuzabad
9	Zanjiran	Khajeh	Firuzabad
10	Jahrom (City area)	Humeh	Jahrom
11	Ghotbabad	Ghotbabad	Jahrom
12	Deh-e-Morvarid	Ghotbabad	Jahrom
13	Deh-e-Juyan	Humeh	Jahrom
14	Ahmadabad	Humeh	Jahrom
15	Tang Choagan	Shapour	Kazerun
16	Ahmadabad	Shapour	Kazerun
17	Jedes	Shapour	Kazerun
18	Sadrabad	Shapour	Kazerun
19	Khodabad	Shapour	Kazerun
20	Chahtala	Khonj	Lar
21	Dehak	Mamasani	Mamasani
22	Neyriz (City area)	Rostaq	Neyriz
23	Sarmoar	Rostaq	Neyriz
24	Mozafari	Kavar	Shiraz
25	Akbarabad	Kavar	Shiraz
26	Mahmoodabad	Qarebagh	Shiraz
27	Bidzard Olya	Qarebagh	Shiraz
28	Kootahi	Humeh	Shiraz
29	Deh-e-Riasati	Humeh	Shiraz
30	Arsenjan City	Arsenjan	Shiraz

[1]A total of 207 villages were surveyed.

Table 2. Frequency of infestation of different soil types with a root-knot nematode species (Meloidogyne javanica) in 65 fields of Shiraz City area.

Soil type	Infested (%)	Uninfested (%)	Total (%)
Sandy loam	none	9	6
Silty loam	none	none	none
Loam	none	none	none
Sandy clay loam	5	7	6
Silty clay loam	55	53	54
Clay loam	40	31	34
Sandy clay	none	none	none
Silty clay	none	none	none
Clay	none	none	none

Table 3. Frequency of the root-knot nematode infestation of tomato plants, followed by fallow and/or rotatior (F and/or R), in 420 fields of Fars Province.

Cultural Practice	Infested (%)	Uninfested (%)	Total (%)
R and/or R	68	90	89
None	32	10	11

Table 4. Known distribution of different species of the root-knot nematode (Meloidogyne spp.), in 8 districts of Fars Province.

District	Species	Ratio (%)
Abadeh	hapla + javanica	75 + 25
Fasa	incognita	100
Firuzabad	javanica	100
Jahrom	javanica	100
Kazerun	incognita + javanica	30 + 70
Mamasani	javanica	100
Neyriz	incognita + javanica	50 + 50
Shiraz	incognita + javanica	5 + 95
Total	hapla+incognita+javanica	5+17+78

STUDIES ON ROOT-KNOT NEMATODES IN NORTHERN EGYPT

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Introduction

About 60% of the total arable land of the country lies in northern Egypt. This region has a mild climatic condition and most of the cultivated lands are cropped twice or thrice annually with field and vegetable crops, thus ensuring a rapid build up of plant parasitic nematodes. Previous studies by Ibrahim *et al.* (1976), Oteifa (1964) and Tarjan (1964) showed the occurrence of root-knot nematodes (*Meloidogyne* spp.) on many economic crop plants grown in northern Egypt.

Two years ago, a research program was initiated in Alexandria University with the cooperation of U.S. Department of Agriculture and IMP, North Carolina State University, to study the species and races of root-knot nematodes (RKN) and their relationships to economic host plants in Northern Egypt. Research items of this program included: a nematological survey of RKN, running the differential host test on certain isolates of RKN, and determining the reaction of some plant cultivars to certain populations of RKN.

Experimental Procedures and Results

Survey Study. In the past two years, a thorough nematological survey was conducted in 10 governorates of northern Egypt. A total of 845 soil and root samples were collected from the rhizosphere of 14 host plants. Nematodes were extracted from soil and roots by sieving and Baermann funnel, respectively. The obtained results (Table 1) indicated that root-knot nematodes occurred in 79% of the collected samples. In general, frequency of occurrence varied from 47% in cotton soil samples to 94% in tomato soil samples. Counts of RKN larvae reflected a varying degree of intensity ranging from 315 larvae per 100 ml soil from eggplant fields to 1057 larvae per 100 ml soil from tomato fields.

Differential Host Test. The differential host test (Taylor and Sasser, 1978) was run on 50 different isolates of RKN which were collected from

different localities in northern Egypt and reared separately on tomato plants. The response of the tested host plants to nematode infection is based on the rating of root galls and egg masses (0=0, 1=1-2, 2=3-10, 3=11-30, 4=31-100, 5=greater than 100 galls or egg masses). The negative response is within the rating range 0 to 2 while the positive response is within the range 3 to 5.

Results of this test (Table 2) demonstrated that 23 of the tested RKN isolates belong to M. incognita, 15 to M. javanica and 12 to M. arenaria Race 1. Populations of M. incognita contained four races which segregated as: 2 belong to Race 1, 18 to Race 2, 1 to Race 3, and 2 to Race 4. In general, M. incognita populations comprised 46%, M. javanica 30%, and M. arenaria 24% of the tested isolates.

It is evident that all the studied populations of M. arenaria infected and reproduced on peanut. On the other hand, only 3 of these populations attacked pepper and produced galls and egg masses showing a typical reaction of M. arenaria Race 1, whereas the other 9 populations failed to infect and reproduce on pepper. This suggests that the latter populations might belong to a third race (Race 3) of M. arenaria.

Reaction of Certain Bean and Cowpea Cultivars to Root-Knot Nematodes. In several greenhouse experiments, the reaction of certain cultivars of asparagus bean (Vigna sesquipedalis), cowpea (V. sinensis), kidney bean (Phaseolus vulgaris), lima bean (P. limensis), and sieva bean (P. lunatus) to M. incognita (Race 2, Race 3, Race 4), M. javanica and M. arenaria Race 1 was studied. Seeds of the tested cultivars were planted in sterilized sandy clay soil in 20 cm clay pots. After emergence, seedlings were thinned to two per pot and were infested with 2500 nematode larvae/plant. Each of the used treatments was replicated four times. Plants were grown for about 8 weeks. When plants were harvested, the roots were washed free of soil and rated for galling and egg masses according to the scale: 0=0, 1=1-2, 2=3-10, 3=11-30, 4=31-100, and 5=greater than 100 galls or egg masses. Plants showed an average rating of 0, 1 or 2 were considered resistant (R) while those with an average rating of 3, 4 or 5 were considered susceptible (S).

The obtained results indicate that the kidney bean cultivars Berbouni, Contender, Menganot and Swez Blane were susceptible to the tested nematode populations, with the exception of cv. Menganot which was resistant

to M. incognita Race 3, M. javanica and M. arenaria Race 1. The cowpea cultivars Azmerli and Fetryat were susceptible to the tested RKN except cv. Azmerli which was resistant to M. incognita Race 1. On the other hand, the asparagus bean cv. Metrawi appeared resistant to M. incognita Race 3, Race 4 and M. arenaria Race 1. The lima bean cv. Burpees Bush and the sieva bean cv. Hendersons Bush were resistant to the tested nematodes except M. incognita Race 4 (Table 3).

LITERATURE CITED

Ibrahim, I. K. A., M. A. Rezk, and M. A. El-Saedy. 1976. Occurrence and distribution of plant parasitic nematodes in northern Egypt. Alex. J. Agric. Res. 24:93-101.

Oteifa, B. A. 1964. A taxonomic guide to the common genera of soil and plant nematodes with a supplement on current known economic parasitic species of U.A.R. Contribution of Nat. Res. Cent., Nematol. Unit. 32 pp.

Sasser, J. N. 1980. Root-knot nematodes: A global menace to crop production. Plant Disease 64 (1):36-41.

Tarjan, A. C. 1964. Plant-parasitic nematodes in the United Arab Republic. F.A.O. Plant Prot. Bull. 12, 1.

Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes. North Carolina State University Graphics.

Table 1. Average number of root-knot nematode larvae per 100 ml soil samples and frequency of occurrence in all tested samples.

Host Plant	Average number of larvae/100 ml soil	No. of tested samples	No. of positive samples	Frequency of occurrence percent
Almond	400	51	44	86
Banana	637	25	21	84
Broad Bean	545	75	59	79
Corn	529	108	88	81
Cotton	378	87	41	47
Eggplant	315	35	30	86
Kenaf	719	20	18	90
Myporum	594	26	23	88
Okra	1020	49	45	92
Peach	940	80	60	75
Peanut	897	62	37	60
Rice	566	68	57	84
Tomato	1057	119	112	94
Watermelon	651	40	34	85

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

No. of isolate & Host plant	Response of the differential host plants*						Identified species and races
	1	2	3	4	5	6	
E 01 Watermelon	-	-	+	+	-	+	*M. incognita* R 1
E 07 Cotton	-	+	+	+	-	+	*M. incognita* R 3
E 09 Myporum	+	+	+	+	-	+	*M. incognita* R 4
E 17 Okra	+	-	-	+	-	+	*M. javanica*
E 27 Peanut	+	-	+	+	+	+	*M. arenaria* R 1**
E 40 Kenaf	+	-	-	+	+	+	*M. arenaria* R 1***
E 50 Squash	+	-	+	+	-	+	*M. incognita* R 2

*Differential host plants: 1 = Tobacco NC 95, 2 = Cotton Deltapine 16, 3 = Pepper California Wonder, 4 = Watermelon Charleston Gray, 5 = Peanut Florrunner, 6 = Tomato Rutgers.

**Typical *M. arenaria* R 1 reaction.

***Showed different reaction (Race 3).

Table 3. Reaction of some bean and cowpea cultivars to *M. incognita* (R_2, R_3, R_4), *M. javanica* and *M. arenaria* (R_1).

Plant cultivar	Average gall (G), egg mass (EM) indices and host response (Res)														
	M. incognita R_2			*M. incognita* R_3			*M. incognita* R_4			*M. javanica*			*M. arenaria* R_1		
	G	EM	Res	G	EM	Res	G	EM	Res	G	EM	Res	G	EM	Res
Asparagus Bean (*Vigna sesquipedalis*)															
cv. Metrawi	5	5	S	1	0	R	2	1	R	5	5	S	1	0	R
Kidney Bean (*Phaseolus vulgaris*)															
cv. Berbouni	3	3	S	3	3	S	5	5	S	5	5	S	5	4	S
cv. Contender	3	3	S	5	5	S	5	5	S	4	3	S	4	5	S
cv. Menganot	5	4	S	3	2	R	5	5	S	3	2	R	2	0	R
cv. Swez Blane	4	4	S	5	5	S	5	5	S	5	5	S	5	5	S
Lima Bean (*Phaseolus limensis*)															
cv. Burpees Bush	0	0	R	1	0	R	5	5	S	1	0	R	2	0	R
Sieva Bean (*Phaseolus lunatus*)															
cv. Hendersons Bush	3	2	R	1	0	R	4	3	S	0	0	R	0	0	R
Cowpea (*Vigna sinensis*)															
cv. Azmerli	5	5	S	3	2	R	5	5	S	3	3	S	4	3	S
cv. Petryat	5	5	S	4	3	S	5	5	S	3	3	S	4	4	S

S = susceptible R = Resistant

DISTRIBUTION AND IDENTITY OF MELOIDOGYNE SPECIES AND THEIR BIOTYPES IN EGYPT

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In Egypt, as well as in many warm countries, the root-knot nematodes Meloidogyne spp. are serious pests to many field and vegetable crops. Literature concerning these pests in Egypt indicates that they are widespread in many localities and different soil types. They are found in both the alluvial soils of the Nile Valley and the newly reclaimed sandy soils of the desert, with different population densities. In the calcareous sandy soils of Tahreer region and in the heavy clay soils of Northern Delta, their frequencies of occurrence and population densities are much lesser than in the other sandy or loamy soils. These high infestations of such soils were, in many instances, responsible for considerable plant growth damage and yield losses.

Controlling such nematode pests in developing countries by using nematicides is impracticable due to the high costs of chemicals and their hazards to soil and people. Therefore, the non-chemical control, especially through the cultivation of resistant cultivars and practicing proper crop rotation programs, is believed to be the most effective and economic means of control and of increasing yield. The efforts of the IMP towards the contribution of good knowledge concerning these aspects are, of course, of great benefit for developing as well as developed countries to solve many problems of these pests.

Since the Cairo Meeting, a progressive survey work on the occurrence and distribution of Meloidogyne spp. and their host range was initiated. The cultivated area of the country was divided into five geographical regions; the Mediterranean Coastal Plain, Nile Delta, Upper Egypt, Red Sea Coastal Plain and the New Valley. These regions seem to have different environments that affect nematode build up and probably each region has certain nematode populations and biotypes. The survey work accomplished during the period of the report covered the Mediterranean Coastal Plain region. From eighteen localities in this region (Figure 1), roots infected with the root-knot nematodes were collected and processed for nematode

extraction and identification. Results on the occurrence and distribution of Meloidogyne spp., generally indicate that they are widespread in many localities. Three species and one subspecies were identified as Meloidogyne arenaria, M. arenaria thamesi, M. incognita and M. javanica. They differ in their occurrence and distribution according to soil texture and vegetation. M. incognita and M. javanica are dominant in most of the examined fields; however, M. arenaria and M. arenaria thamesi were recovered from few localities, especially fields of alfalfa, broad bean, clover, peanut, peas, sweetmelon and vegetable sponge.

Results on their host range indicate that 150 plants were reported as hosts for these nematodes. These hosts represent fruit trees, field and vegetable crops, weeds and ornamental plants. 120 hosts were recorded for M. javanica. Most of them were also recorded as hosts for M. incognita. However, certain plant species and cultivars were recorded as hosts for only one of these two species such as cotton, pepper, snake cucumber and cantaloupe for M. incognita. Hosts of M. arenaria and M. arenaria thamesi were very limited. Eighteen and twelve hosts were recorded for each of these two species respectively.

Populations of M. incognita from 18 localities in this region were collected and propagated in pure cultures. These cultures were used for differential host tests and morphometric studies. For each population, microscopic preparations for the eggs, second stage larvae, and the female neck and perineal pattern were prepared and examined. Measurements of the main important morphological characters were determined and are under statistical analysis to determine the variation within the examined populations, and to test to what extent they are correlated with their physiological response to differential hosts.

Tobacco cv. NC 95, cotton cv. Deltapine 16 and tomato cv. Rutgers were used as differentials to define the different biotypes of Meloidogyne incognita. Tests were carried out in the greenhouse according to the recommendation of the project leader. Results indicate that the eighteen tested populations are different biotypes (Table 1). The six populations from Burg Elarab, Bahr Elbakar, Edco, Rashid, Sherbien and Talkha localities did not produce on either roots of tobacco or cotton and they represent the "Race 1". Five populations from Foa, Mechanized farm, Rahmania, Salhia and West Noubaria localities developed well and deposited eggs on roots of tobacco and not on cotton roots and they represent the "Race 2". On roots

of cotton, only two populations from Faraskour and Kafr Saad localities reproduced, while failed to infect tobacco, and they represent "Race 3". Five populations developed and reproduced on roots of both tobacco and cotton which represent the "Race 4," they are from Amraya, Hamoul, Mariout, North Tahreer and Sedi Salem localities. All the populations developed well and deposited eggs on roots of tomato. Generally, these results indicate that the soils in the Mediterranean Coastal Plain Region are infested with the four races of Meloidogyne incognita. They differ in their occurrence and distribution according to locality and soil texture.

Table 1. Differentiation of eighteen populations of Meloidogyne incognita through the reaction of tobacco NC-95 and cotton Deltapine 16.

Meloidogyne incognita Races	Differential hosts		Localities of populations of Meloidogyne incognita
	Tobacco	Cotton	
Race 1	-	-	Burg Elarab, Bahr Elbakar, Edco, Rashid, Sherbien and Talkha.
Race 2	+	-	Foa, Mechanized farm, Rahmania, Salhia and West Noubaria.
Race 3	-	+	Faraskour and Kafr Saad.
Race 4	+	+	Amraya, Hamoul, Mariout, North Tahreer and Sedi Salem.

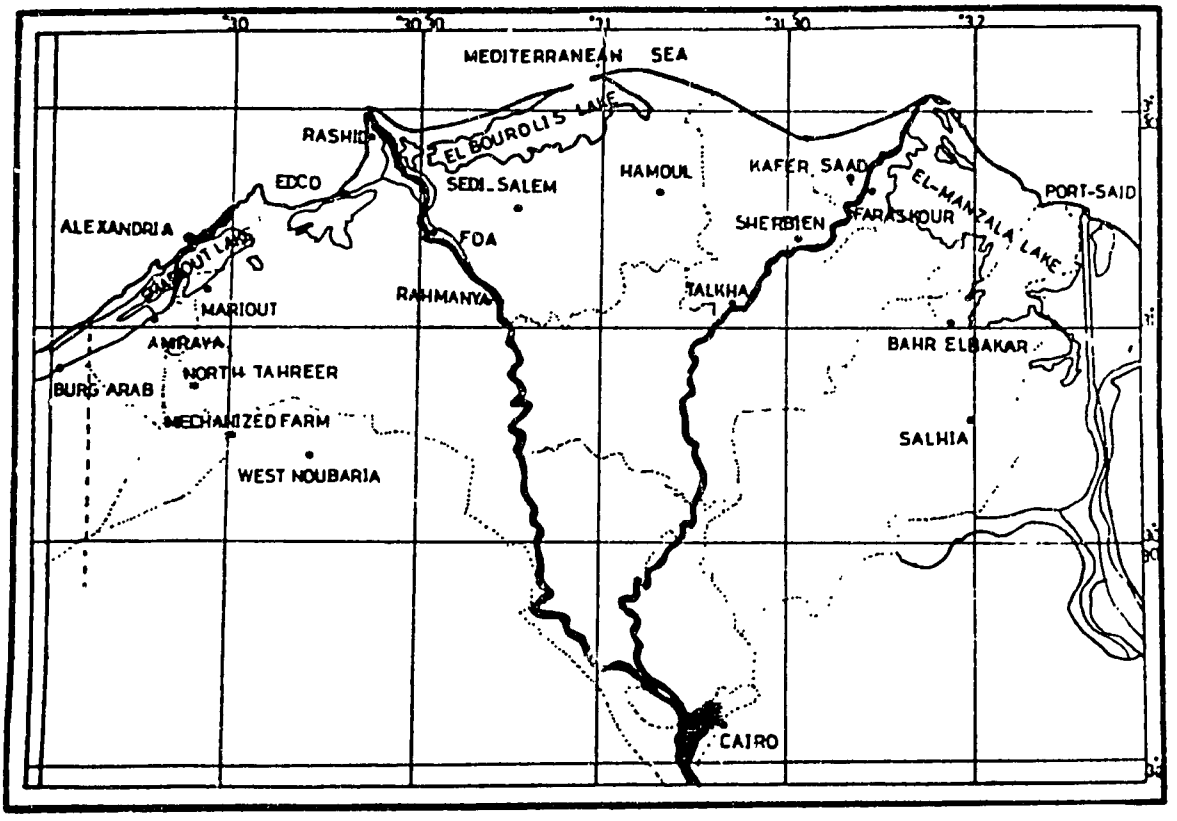

Figure 1. The surveyed localities in the Mediterranean Coastal Plain Region.

SOME STUDIES ON DIFFERENTIAL HOST TESTS FOR ROOT-KNOT NEMATODES IN TURKEY

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In Turkey according to the results obtained from the survey works, the distribution of Meloidogyne species bear speciality especially depending upon the climatic conditions. The distribution of root-knot nematode species in Turkey is not related with soil structures, but the population increment depends upon the soil structure. It shows that the combination of temperature and precipitation from the climatic conditions prevail on the coasts of North Anatolia do not favor the survival of species other than M. incognita. On the other regions of Turkey having different ecological conditions, M. incognita, M. javanica, M. acrita, M. arenaria and M. hapla are present. According to this situation, it appears that M. incognita is less susceptible to temperature and humidity from the ecological factors and so that they have a wider distribution area.

Because of the cold weather in Erzurum where I am working, root-knot nematodes do not occur. Root-knot nematodes are a problem especially in the south, north, west and Marmara Regions of Anatolia, so that samples were taken especially from these climatically different four regions during August and September, 1978, and were brought to Erzurum. Because of the unfavorable greenhouse conditions, reproduction from these samples were achieved and continued in the suitable places of the Plant Protection Department up to July, 1979, on tomato plants grown in pots. Among the samples, some are single and some are mixed populations. Cotton, pepper, tomatoes, peanut, watermelon, tobacco seedlings which were raised before hand were transplanted to small 4" pots at outdoor on July 1, 1979, and 10,000 eggs were inoculated to every pot. Later on, after two months, the galls formed on these plants in pots were examined and the following results were obtained.

Response of the Differential Hosts to
Some Common Meloidogyne species

Origin	Cotton	Tobacco	Peanut	Pepper	W'Melon	Tomato
Bursa (Tomatoes)	3	5	0	5	5	5
Balikesir (Eggplants)	5	5	0	3	5	5
Burhaniye (Tomato)	0	5	0	4	5	5
Izmir-Bornova (Tomato)	0	5	0	2	5	5
Antalya (Tomato)	5	5	0	3	5	5
Amasyo (Sugar-beet)	0	5	0	5	5	5
Amasya (Okra)	0	5	0	5	5	5

On the plants inoculated by Antalya population abundant egg masses and galls were produced in four of them except peanut. With Balikesir and Bursa populations, same results were obtained except on cotton where no egg masses were observed. When the galls on cotton were opened, 2, 3, and 4 stage larvae and very few matured males were found.

As it was known, before these researches, the reaction of North and South Anatolina populations on pepper were found to be different. Especially Amasya (North Anatolia) populations produced abundant egg masses and galls on pepper.

Although Antalya and Burhaniye populations are thought to be the same species, they differ from each other in attacking to cotton.

According to my consideration, more work will be done on Balikesir and Bursa populations, because egg masses might be obtained in these populations if the period extended more than 60 days. To repeat this research on these two populations in the same year is not possible as far as our possibilities are concerned. In Erzurum research should be done only in July, August and partly in September because of the climatic conditions prevailing here.

THE SURVEY PROGRAM OF IMP PROJECT IN IRAQ

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In Iraq, the program survey for root-knot nematode Meloidogyne sp. covered three different regions.

Northern Region. This region, with intermediate and high altitude, has high rainfall, cold and snowy winter; summer is dry in some areas and cool in others. Forest trees, vines, apple orchards, sugar beets, tobacco, tomatoes and other vegetables are the main crops in the region.

In the Sulaimaniya Province (350 km northeast of Baghdad) sugar beet fields were very heavily infected with root-knot nematode causing severe damage to the crop; some growers gave up cultivating it.

Tobacco and tomato yield reduction of up to 50% has been observed.

The most common species is M. javanica (Treub) Chitwood which is distributed through all the region; even pepper roots were infected with this species.

Central Region. In this region, winter is cool and rainy, and summer is dry, very hot, and long. The altitude is intermediate. Orchards of fruit trees, cereals, rice, tomatoes and vegetables are the most economical important crops in this region.

According to this study, root-knot nematode Meloidogyne spp. are widely distributed, generally on vegetables, and especially tomatoes and eggplants which are the most important crops.

Recently 10 acres of greenhouse area, cultivated with vegetables (tomatoes, cucumber) were highly infected with root-knot nematodes causing severe damage and yield loss to these crops.

Rice soils, heavy clay soils and salty soils were free from root-knot nematodes.

Southern Region. Cool winter but small rainfall, very hot and humid summer. The altitude is low. Fifty percent of the land of this region is covered by water. Datepalm is the most important crop, which covers about 40-50% of the cultivated area.

In sandy soils, tomatoes, onions and melons are completely damaged by the high population of root-knot nematodes. While in heavy clay soils tomato and rice fields were free of nematodes, this area is flooded for more than five months of the year.

Ten samples (soil and roots) of infected vegetables (tomatoes, eggplant, okra, cucumber and onions), and field crops were collected separately in plastic bags from the three regions.

Samples were brought to the laboratory of nematology, Department of Plant Pathology, Abu-Ghraib, Baghdad and stored at 5C.

Perineal patterns of females from the infected roots of the collected samples were examined and revealed that M. javanica was the commonest species distributed through all the country.

One hundred gm of soil from each sample were sent to the laboratory of Nematology, North Carolina State University for final identification. Five hundred gm of soil from each sample were placed in a pot and planted with three tomato seedlings (cv. Rutgers). After 60 days eggs were released from the egg masses by using NaOCl solution, number of eggs determined per ml.

Seedlings of tobacco (NC95), cotton (Deltapine 16), watermelon (Charleston Gray), pepper (California Wonder), and tomato (Rutger) were transplanted in pots containing sterilized sandy loam soil, three replications were used for each plant, and each plant was inoculated with between 9,000 to 10,000 eggs/pot.

After 70 days, roots were carefully washed and analyzed for infection levels on both the number of galls as well as the number of egg masses from each root system.

The final root-knot ratings were then defined on the basis of these two systems as: 0, 1, 2, 3, 4, and 5 or 0 - 0, 1 - 2, 3 - 10, 11 - 30, 31 - 100, and over 100 knots or egg masses respectively.

Results of this study revealed that only M. javanica was the dominant species in the cultivation areas which samples were taken, such as Baghdad, Basrah, and Anbar provinces.

Survey programs were continued on different crops, two more species of root-knot nematodes were identified by perineal patterns as M. arenaria and M. incognita in the roots of peach trees in Diyala province. Soil samples will be sent to North Carolina and differential host tests will be carried on to confirm the primary identification.

Cotton fields in the central region were free of root-knot nematodes.

Screening Tests

Tomato Cultivars Test. Seedlings of 71 different cultivars of tomato were transplanted into 4" clay pots containing sandy soil in the greenhouse.

The plants were inoculated with second stage larvae of M. javanica. After 8 weeks, roots of each cultivar were washed and examined to study the susceptibility/resistance of tomato against root-knot nematodes. Results are summarized in Table 1.

Table 1. Susceptibility/resistance of tomato cultivars to M. javanica.

Resistant cultivars	Slightly susceptible	Highly susceptible
VFN - 8	Small fry VFN	66 cultivars
Rossol	Marglobe P.V.	
Marmar		

These results indicated that only three tomato cultivars were resistant to root-knot nematode M. javanica and the rest of the cultivars were varied in their susceptibility to this species. The resistant cultivar Marmar was recommended to be used instead of the local susceptible cultivars.

Sugar beet cultivars. Nineteen cultivars of sugar beet were tested against root-knot nematode M. javanica. Results revealed that all the tested cultivars were highly susceptible to this nematode species.

IMP: TECHNICAL RESEARCH REPORT - REGION VII

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At the International Meloidogyne Project (IMP) conference held at Cairo University, Nematology Research Center, January 29 - February 2, 1978, all participants agreed to work on the efficiency of a "Host Differential Test," as this was proposed by Dr. J. N. Sasser, Principal Investigator, IMP, to identify species and races of Meloidogyne. It was also agreed that data concerning several environmental factors, which could influence the development and/or distribution of this group of nematodes in the region, should be provided to research headquarters for computer analysis (correlation studies).

AN OUTLOOK ON THE TAXONOMICAL STATUS OF MELOIDOGYNE SPP.

Nematode taxonomists in the past attempted to identify Meloidogyne species mainly on the basis of several morphological characters of the genus. Different approaches, however, concerning the value of such morphological features and the tendency of nematode taxonomists to work independently in their own and usually restricted environment resulted in a confused taxonomical status of the genus. It is well known that due to the world-wide distribution of root-knot nematodes, several environmental factors create such morphological variability on a certain species or population of the nematode that usually one is uncertain whether he is dealing with only one species of root-knot nematode. Recent findings, however, concerning the reaction of some plants to certain species and/or races of Meloidogyne, as well as important cytological studies on the genetical composition of this group of nematodes have, already, thrown enough light on the problem of correct identification.

IDENTIFICATION OF ROOT-KNOT NEMATODES IN CYPRUS

For determining the Meloidogyne species in Cyprus, twenty samples were collected from twelve different locations in the island. Eight of these samples originated from the south coastal area of the island, while the rest were taken from the inner part of the country (Figure 1).

Identification was primarily based on the Host Differential Test (Table 1). Other criteria used were: (a) larval length, (b) position of excretory pore (Table 2), and (c) appearance of perineal pattern.

ROOT-KNOT NEMATODE ACTIVITY IN CYPRUS

The warm climate of Cyprus favors the development of root-knot nematodes. Soil temperature for most of the year is very suitable for nematode activity (April-October) (Figure 2). During this period, numerous important agricultural crops are grown (Figure 3). In the coastal areas, where vegetables are grown intensively, soil temperature during winter drops down to an average minimum of about 12°C (Dec.-Feb.) its fluctuation ranging from 11.3 to 12.8°C. It may, therefore, be assumed that root-knot nematode activity during this season is extremely poor. In the case of vegetables, however, grown under cover, nematode activity will, undoubtedly, continue throughout the year.

YIELD LOSSES DUE TO NEMATODE ATTACK

Yield losses caused by Meloidogyne spp. cannot easily be assessed unless a very thorough and systematic work on this line is carried out.

Damage of sampled crops caused by Meloidogyne as determined by visual observations in the field, is indicated below:

Crop	Estimated loss in yield (%)
French Beans	50
Carnation	15
Celery	50
Cucumber	15
Eggplant	35
Swiss chard	35
Okra	35
Squash	15
Sweet Melon	50
Tomato	45

The above figures are only indicative and cannot be used for drawing any conclusions on the actual losses caused by this nematode in Cyprus. It is logical, however, to assume that losses of vegetable crops can easily reach 35%, and more, compared to non-infested fields.

Remarks

Based on the "Host Differential Test" for determining species and/or races of Meloidogyne, the present study has, so far, shown that in Cyprus

there are two root-knot nematode species, namely, Meloidogyne javanica and M. incognita race 2, the first species being the predominant one. Although previous records (1954-1958) report M. arenaria as present in the island, none of the samples examined during 1978-79 contained this species.

The criterion of larval length in distinguishing between M. javanica and M. incognita is not valid, while the position of the excretory pore can give an indication of the species involved. As far as the appearance of the perineal pattern is concerned, this undoubtedly can aid in the identification, provided that a large number of properly prepared specimens are carefully examined.

Future Outlook

Work concerning the biology (development) of the nematode in relation to soil temperature in both coastal and inland areas as well as testing the reaction of locally important crops to nematode attack will commence early in 1980.

Table 1. Species and races of root-knot nematodes found in Cyprus as determined by the Host Differential Test.

Population	Hosts[1]						Remarks
	Tobacco	Cotton	Pepper	Watermelon	Peanut	Tomato	
001	+	-	+	+	-	+	M. incognita Race 2
002	+	-	-	+	-	+	M. javanica
003	+	-	-	+	-	+	M. javanica
004	+	-	-	+	-	+	M. javanica
005	+	-	-	+	-	+	M. javanica
006	+	-	-	+	-	+	M. javanica
007	+	-	-	+	-	+	M. javanica
008	+	-	-	+	-	+	M. javanica
009	+	-	-	+	-	+	M. javanica
010	+	-	-	+	-	+	M. javanica
011	+	-	-	+	-	+	M. javanica
012	+	-	+	+	-	+	M. incognita Race 2
013	+	-	-	+	-	+	M. javanica
014	-	-	-	-	-	-	Failure to raise inoculum
015	+	-	-	+	-	+	M. javanica
016	+	-	-	+	-	+	M. javanica
017	+	-	-	+	-	+	M. javanica
018	+	-	-	+	-	+	M. javanica
019	+	-	-	+	-	+	M. javanica
020	+	-	-	+	-	+	M. javanica

[1]Tobacco cv. NC95; Cotton cv. Deltapine; Pepper cv. California Wonder; Watermelon cv. Charleston gray; Peanut cv. Florrunner; Tomato cv. Rutgers.

Table 2. Morphological characters of Meloidogyne species found in Cyprus. (IMP, Region VII, Cyprus)

Population	Species	Host	Larval length*	Position of excretory pore**
001	M. incognita Race 2	Carnation	386	1.3
002	M. javanica	Marrow	388	2.5
003	M. javanica	Tomato	384	2.4
004	M. javanica	Cucumber	360	2.5
005	M. javanica	Tomato	364	2.6
006	M. javanica	Eggplant	368	2.9
007	M. javanica	French Bean	392	2.3
008	M. javanica	Eggplant	388	2.4
009	M. javanica	Sweet Melon	436	2.5
010***	M. javanica	Tomato	-	-
011	M. javanica	Celery	392	2.5
012	M. incognita Race 2	Tomato	400	1.4
013	M. javanica	Okra	365	2.4
014	-	Eggplant	-	-
015	M. javanica	Eggplant	360	2.6
016	M. javanica	Tomato	360	2.6
017	M. javanica	Eggplant	420	3.0
018***	M. javanica	Tomato	-	-
019	M. javanica	French Bean	380	2.6
020	M. javanica	Swiss Chard	386	2.4

*Distance from head tip to excretory pore. True stylet length.

**Refers to median (microns).

***Identified by North Carolina, Nematology Center.

Figure 1. Sampling areas for Meloidogyne identification
(IMP, Cyprus, 1979)

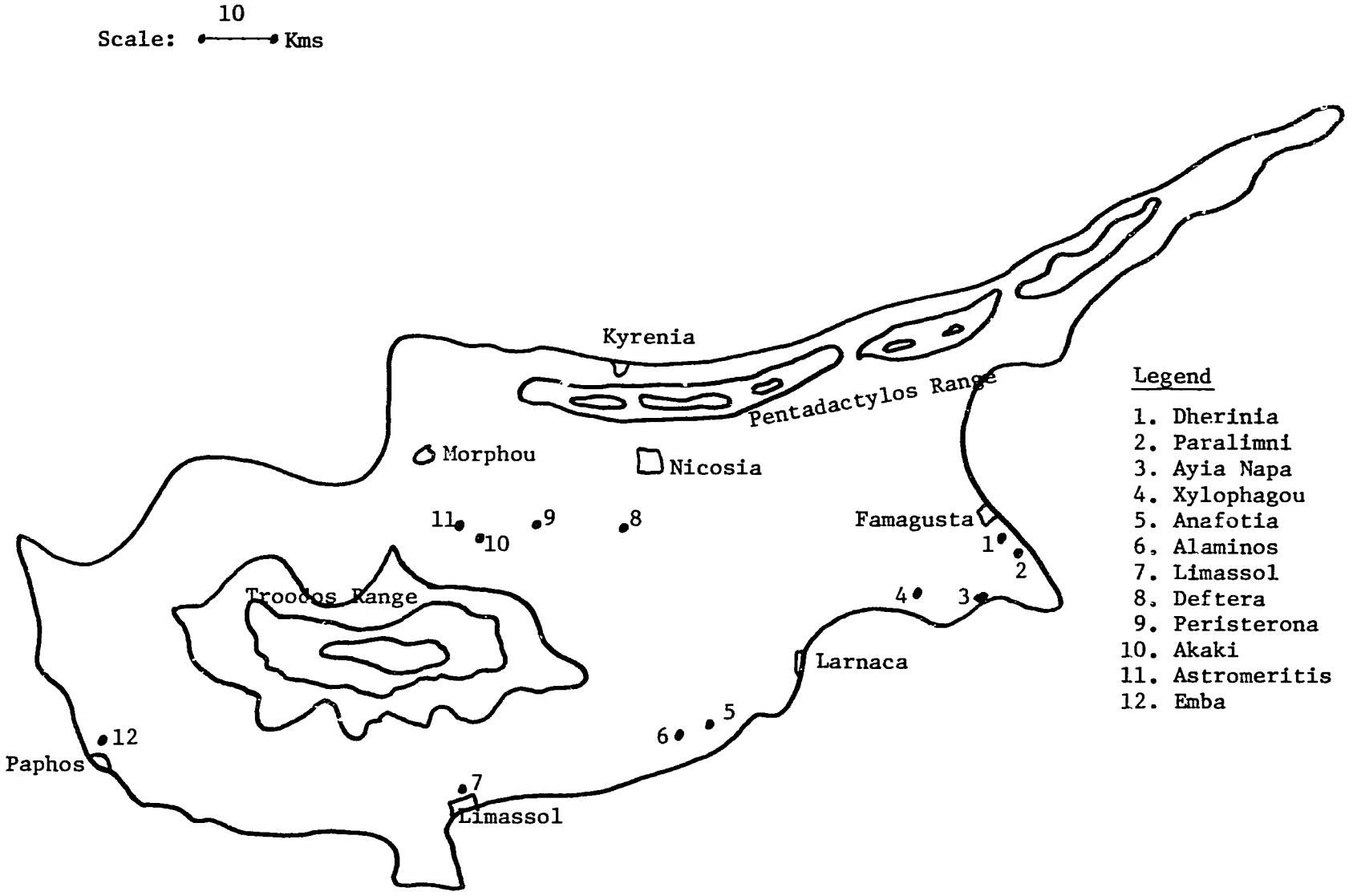


Figure 2. Mean monthly soil temperature at 10 cm depth
(Cyprus, 1966-1974)

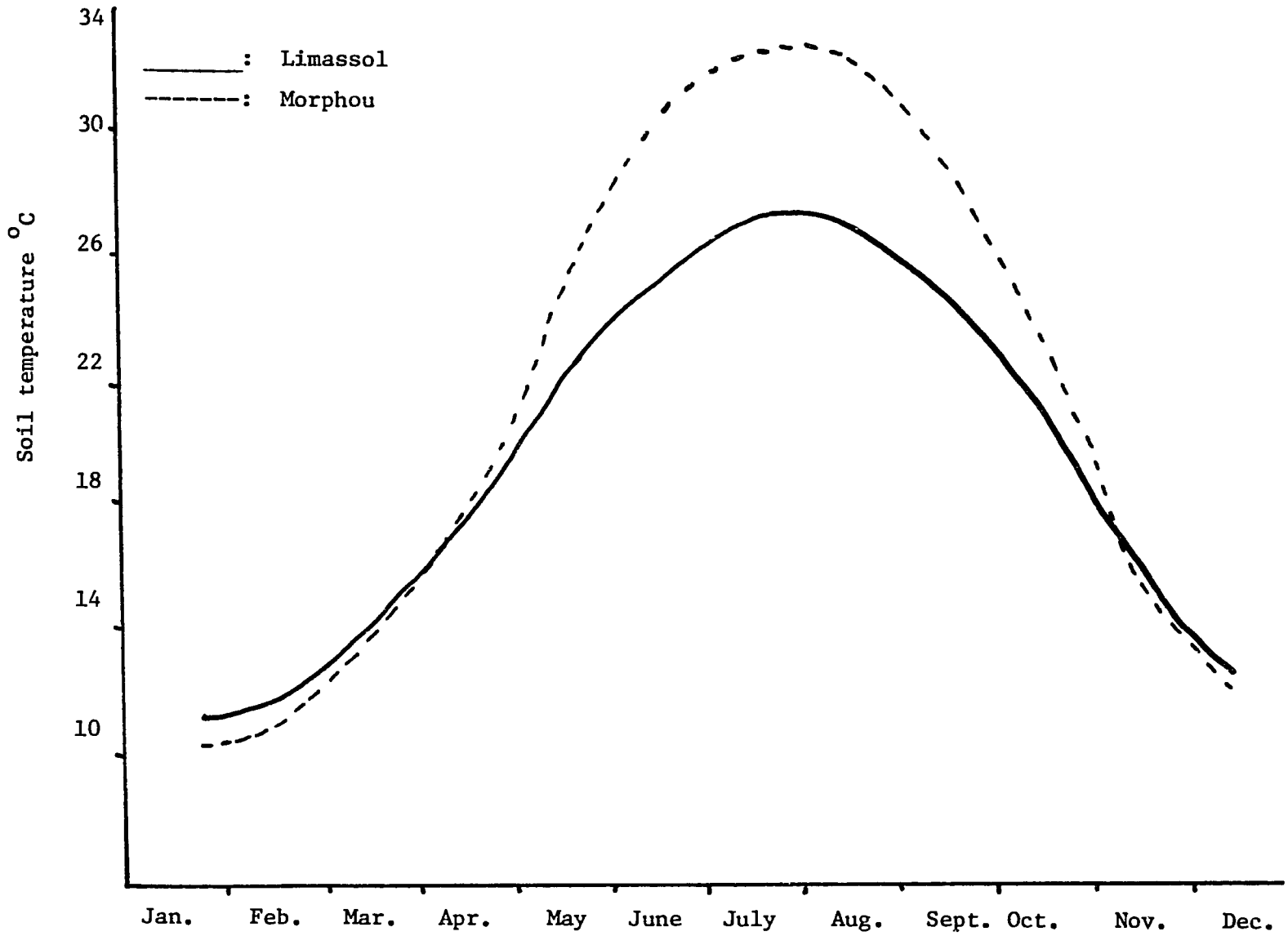
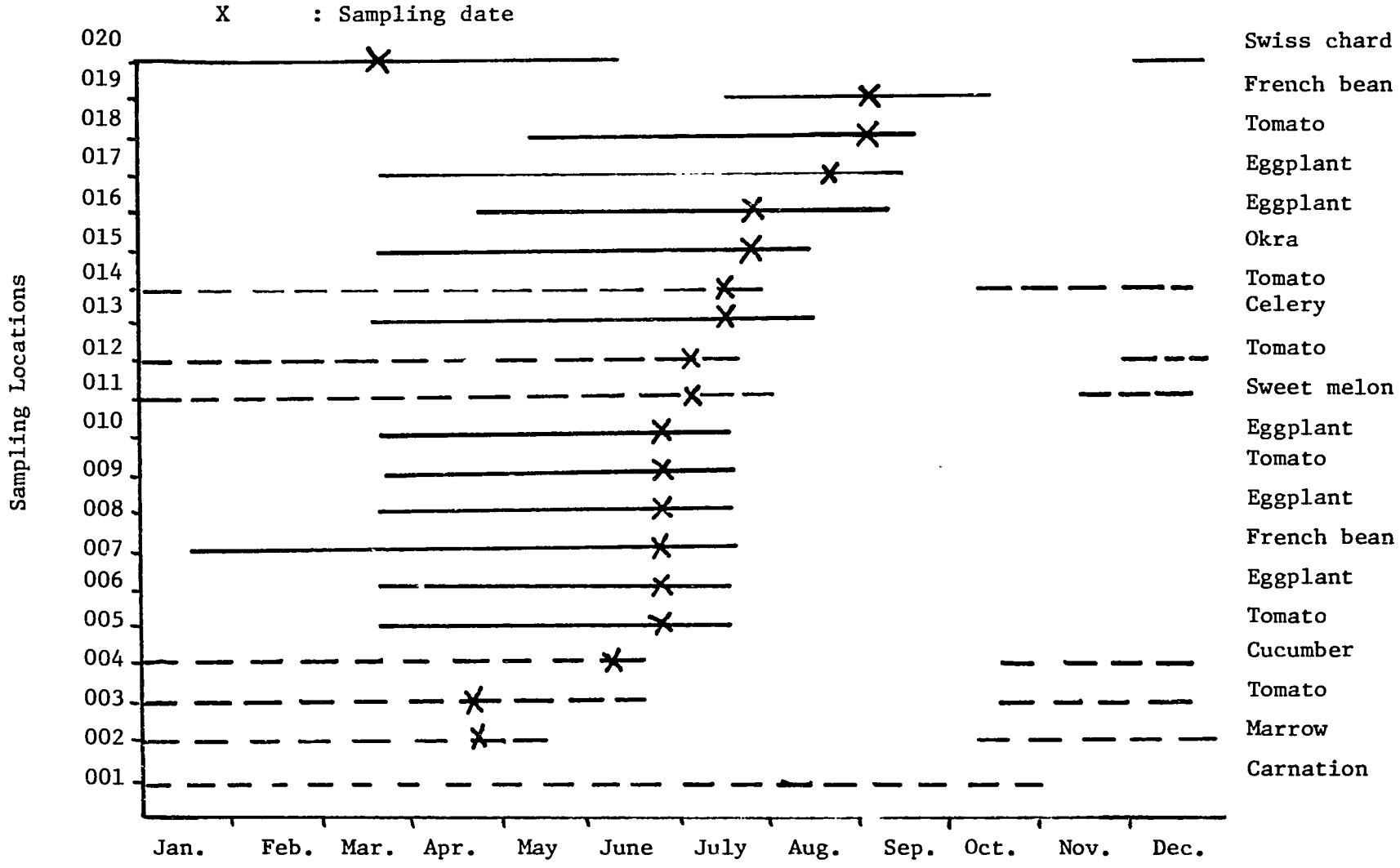


Figure 3. Growing season of sampled crops infested with Meloidogyne (IMP, Cyprus, 1979)



ROOT-KNOT NEMATODES IN THE SUDAN

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GLASSHOUSE AND LABORATORY EXPERIMENTS

Identity of Root-Knot Nematodes

Differential Host Test. This preliminary study was undertaken on nematode samples collected from various geographical regions throughout the Sudan, namely regions I - IV (see attached map). The 6 standard differential plant species were included in this study (Tobacco NC95, Cotton Deltapine 16, Pepper California Wonder, Watermelon Charleston Grey, Peanuts Florrunner, and Tomato Rutgers). For each region, each was planted into 10, 3" pots with a mixture of sterilized sand and river silt in the ratio of 1:1 (v/v). A total of 5 pots of each lot were then inoculated with 10 egg masses isolated from naturally infested roots of eggplant, C.V. local, from each of the 4 regions under test (such samples are known to comprise both *M. javanica* and *M. incognita* - see also Yassin, Loof and Oostenbrink, 1970, 1974). In the control, the other half of sets of the pots was left uninoculated for comparison. All pots were then wrapped into polythene sheetings in order to maintain a pure stand of each isolate (plants in such wrapped pots subsequently exhibited more vigorous growth; perhaps due to an improved conservation of moisture). The pots were then set up on the glasshouse bench, regularly watered and kept under frequent observation. After about 8 weeks, a period of time sufficient for maximum development of knots and reproductive females, the roots were emptied out, washed and analyzed for infestation levels based on both the number of knots as well as the number of egg masses from each root system. The final root-knot ratings, R.I., were then defined on the basis of these two criteria as: 0, 1, 2, 3, 4 and 5 R.I. = 0-0, 1-2, 3-10, 11-30, 31-100 and over 100 knots or eggmasses respectively; after Sasser. The results of R.I. were then summarized as shown in Table 1.

According to these, however, all 4 regions seemed to comprise a mixture of both *M. javanica* and *M. incognita*. This is especially so as both tobacco and pepper were infested (Table 1); thus confirming earlier investigations by Yassin, Loof and Oostenbrink. For further identity, samples from

region No. 1, Central Sudan, only, were included as they were more easily available.

"Perineal Pattern" Tests. Samples of infested roots from various sites within region I were collected in polythene bags and brought to the lab for studies within hand. Infested roots from different samples were pooled together, carefully washed and a total of 50 single egg masses, randomly selected, carefully removed by means of a picking needle and forceps. Each was kept in a water suspension in a small glass vial ready for use in the tests. A total of 50, 3" pots were then subsequently filled with 1:1 (v/v) sterilized sand and river silt, wrapped into polythene bags, as before, and planted to 3-week-old seedlings of eggplant (C.V. local) as a test host. Each pot was then inoculated with each of the single egg masses within hand. The pots were then regularly watered and left in the glasshouse under frequent observation. After the prescribed period of 8 weeks, the pots were partially emptied to detach the amount of roots necessary for the study. (Remaining, undetached, portions of samples were then removed to larger containers, labeled accordingly, and kept for relevant future use.) From such selected samples, about 15-90 females were then separated and prepared for the standard "Perineal Pattern" tests as follows. Internal contents of the females were removed and the empty bodies then transferred to cotton blue lactophenol for 24 hours to acquire the stain. The anal parts of such treated females were then severed by means of a sharp razor blade and mounted in lactophenol on a glass slide in the usual way. They were then viewed under the microscope and compared with those of standard photographs of Perineal Patterns from type specimens of M. javanica and M. incognita, and the results recorded.

Out of the total of 41 pots successfully infested, 26 were found to contain specimens comparable to those of typical M. javanica. Conversely, all of the remaining 15 exhibited P. patterns pertaining to those of classical M. incognita (the final identity of such two groups of specimens as M. incognita and M. javanica, was then confirmed by means of differential host-test, using NC-95 tobacco and California Wonder pepper - see Table 5).

Effect of Soil Type on Infestation Levels

This study was undertaken in the glasshouse at the Gezira Research Station (GRS), between October and December, 1978, using naturally infested soil under eggplant at a site at Gezirat El Feel riverside, Wad Medani.

The objective was to see whether the absence of natural infestation of root-knot under the Gezira heavy clay was associated with soil type. The following soil categories were thus included in the study: (1) Gezira heavy clay (G HC) alone, (2) GHC + river sand (RS) in the ratio of 1:1 (v/v), (3) River silt (R st) + RS, 1:1 (v/v), (4) R St, alone and (5) RS alone. Heaps of each were exposed to direct sunlight in the dry state, outdoors, and tested for freedom from root-knot infestation, in the usual way, prior to the tests. They were then distributed, each into five, 3" pots and planted to eggplant, C.V. local, which is known to be highly susceptible to root-knot attack in the locality along the Blue Nile river bank. After germination, each of the pots received a total of 10 egg masses, approximately 5,000 eggs, of root-knot nematodes from naturally infested soil *per se* containing a mixture of *Meloidogyne javanica*, predominantly, as well as *M. incognita* (no attempt was made to separate the two species in this preliminary test). These were placed near the root zones of established egg plant seedlings, and the pots then set up on the glasshouse bench with their bases covered with polythene bags to guard against escape of infective larvae from underneath. Special care was also taken to ensure an appropriate and regular watering, as the infestation level among this group of highly specialized tropical parasites is critically determined by the moisture level of the soil. After a minimum of 7-8 weeks, a period of time sufficient for the development of mature females and knots according to the temperature records within hand, the pots were emptied out and the roots carefully washed and analyzed for root-knot infestation in the usual way; using a scale of 0 (no infestation) and up to 5 (maximum infestation of > 100 knots and egg masses per plant root). The results were then summarized in Table 8.

The results of this preliminary pot experiment showed that the GHC was at least as good as RS or Rst. in the development of successful root-knot infestation; resulting in fully formed knots and reproductive females (details of the results are available for further reference). As regards the situation under natural conditions of the Gezira heavy clay, however, it seems that the absence of root-knot in the locality cannot be attributable to the physical structure of the soil alone. Other factors in the ecosystem, e.g. the strict and regular rotation adopted, might be crucial. This point will be investigated in more detail in due time.

Host Range

In these preliminary tests, a total of 21 plant species and varieties within various taxa of higher plants were put under test against unidentified Meloidogyne species collected from root samples from Central Sudan (Region I). For each, a total of 5, 3" pots were included, and each filled with 1:1 (v/v) sterilized river silt and river sand. Each was then inoculated with 10 egg masses wrapped with polythene bags, as to maintain a pure stand of each stock, watered regularly and left for a period of 8 weeks as before. Thereafter, the pots were emptied out and the roots carefully washed and tested for infestation levels as before; using root-knot ratings, R.I., of 0-5 (see experiment 1). The results of R.I. were then summarized as in Table 2.

Accordingly, all of the various plant species or varieties were categorized as follows:

1. Immune: Those with 0 R.I.: e.g. all of the six cotton CV, Barakat, V.S., Huda, Acala, Albar and Almac.; 3 C.V. of peanuts, Ashford, M.H. 383 and Libian.
2. Moderately susceptible: 1-3 R.I.: Giza 155, Wheat, Dura, C.V. Dwarf and Dabar; Adasi, Soya bean and Purslane.
3. Highly susceptible: 4-5 R.I.: Lubia bean, Okra, Squash, Cucumber, Jews mellow, Marrow, Tomato and Eggplant. In this last category, distinct aerial symptoms of poor growth and foliar yellowing were exhibited (see Table 2).

Effect of Watering Interval on Infestation Levels

In these tests, samples from Region I were used as "inoculum" source as follows: A total of 40, 3" pots, each filled with 1:1 (v/v) sterilized sand and river silt, were planted to 3-week-old seedlings of eggplant (C.V. local). Into each was then introduced a total of 10 egg masses; and, as before, all were wrapped into polythene bags. Subsequently, the pots were divided into 4 equal lots of 10 each. Each lot, then received different watering regimes by means of a small watering can as follows: (1) light watering (once/2 days), (2) conventional (once/day), (3) heavy (3 times/day) and (4) complete flooding. All were then set up on the glasshouse bench and kept under regular observations. However, in the lot in which the pots were completely flooded, almost all of the seedlings died out within the first week of planting, which incidentally, necessitated resowing. After the prescribed period of 8 weeks, the roots were then

analyzed for infestation levels in the standard manner as before. The results of root-knot index, R.I. were then summarized in Table 3.

All of the plants within the 4 lots showed infestation levels to varying degrees. For example, those in the completely flooded, showed the lowest levels of 1.8 R.I., followed, respectively, by heavy, conventional and light waterings, resulting in 2.2, 4.7 and 4.8 R.I. respectively.

Effect of Soil Amendment on Infestation Levels

In this test the standard type of soil, 1:1 (v/v) sterilized sand and river silt, was initially used. Such soil type was divided into 3 half barrels of about 20-30 kg capacity each. To the first was added Dura (*Sorghum vulgare* L.), C.V. Dabar, straw, and to the second Lubia bean (*Lablab vulgaris* L.) straw. The third was left unamended as control. All three barrels were then kept in the glasshouse and received regular watering in order to decompose the straw. After about 4 weeks, soil from each was transferred to 10, 3" pots, and these then planted to 3-week-old seedlings of eggplant (C.V. local) as before. Each was then inoculated with a total of 10 egg masses, collected from the roots of naturally infested eggplant from Region I, in the usual way. Also, as before, all pots were wrapped in polythene bags, regularly watered, and kept for subsequent observations. After a fixed period of 8 weeks, the pots were emptied out and the roots analyzed for infestation levels in the standard way. Results of root-knot ratings, RI, were then summarized in Table 4.

According to these results, there was reduction in infestation levels of plant roots maintained in the set of pots with both dura and lubia bean straw (mean R.I. 3.5 and 4.4, respectively). In the control, on the other hand, a higher infestation level of up to 4.7, mean R.I., was obtained.

Life Cycle, Etiology, Etc.

Work on these, using *M. javanica* alone, from Central Sudan, is in progress.

FIELD EXPERIMENTS

Before setting up these experiments, a pioneer survey was carried out along the Blue Nile River bank, near Wad Medani, in order to allocate pieces of land with heavily infested soil. Accordingly, two different

sites were chosen as suitable (prior to the study plots at both sites were under eggplant C.V. local; a vegetable crop highly vulnerable to root-knot attack throughout the country). The first site was near Hillat Hassan, and owned by M.M. Ahmed (about 2 feddans). The second was near Umm Sunut, covering an area of about one feddan; owned by O. M. Adlan. In the first site which is the major one, were set up two experiments. In the second, on the other hand, only one experiment was planned.

First Site (Hillat Hassan)

Experiment 1A: Nematicidal Tests. Half of the total area in this site, i.e., about one feddan, was reserved for these tests. Tomato, C.V. strain B, was chosen since it was known to be heat-tolerant, of fairly good yield and quality, and also because it is known to be highly susceptible to root-knot attack under the Gezira locality. A total of 5 nematicides were included, namely, Bunema 40 e.c., Furadan 10G, Nemacur 5G, Temik 10G and Vydate 10G. These were applied conventionally, at standard gross dosage rates per feddan of 40 gal. 10 kg; 1 kg, 6 kg and 25 kg, respectively. On the other hand, control plots received no nematicidal treatments. The experiment was set up in a randomized block design of 4 replicates of 5 x 3 m subplots each. After about 10-15 days following nematicidal applications, all of the plots were planted to 6-8-week-old tomato seedlings of the standard cultivar variety within hand, during the first week of January, 1979. This undue delay in planting date was associated with untimely preparations of the site within hand. The planting was undertaken on 80-cm wide ridges, kept 50 cm apart. The standard cultural practices for tomato cultivation were then followed; during which the plants received a rate of 16 kg/fed urea as fertilizer, applied as a single dose, and the plots hand weeded 4 times. Towards the end of the season, the following data were collected, (1) plant size as measured by circumference and height, (2) yield of mature fruits, (3) root-knot infestation as measured by the heaviest attack of 5 RI level. The results were then summarized as shown in Table 6.

Generally speaking, all nematicidal treatments resulted in lower root-knot infestation levels, higher plant size and higher fruit yield. Thus, as low as 23-57% of the plants treated with various nematicides showed severe infestation; compared with up to 63% in the non-treated, control, plants, Conversely, plants from the treated plots were 29 x 38 cm - 32 x 41 cm as compared with only 27 x 33 cm in the control. Similarly, treated

plants gave up to 44-82 kg/1000 plants fruit yield as compared with 32 kg only in case of the control. Vydate, however, behaved as best especially as regards increased fruit yield (82 kg/1000 plants) and reduced infestation (23%); followed respectively by Temik, Nemacur, Furadan, and Bunema (Table 6).

Experiment 1B: Tests of resistant Tomato Lines. The remaining portion of land in site I was used in these tests. A total of 12 tomato varieites were included. Ten of these were already known to be resistant to one species or another of *M. javanica* and *M. incognita* within hand (Yassin, 1974). They were Mon-144, VF. N-8, VF. N-Bush, 68N-144, Marsol, Motabo, Piersol, Rossol, Ronita and Romano-NR. The remaining two, namely strain B and Money Maker, were included for comparison as they were known to be heavily attacked by root-knot in the Gezira locality. The experiment was set up in alternate subplots of 5 x 3 m, each replicated 3 times. As before, there was undue delay in the planting date, i.e. January, 1979. Also, as before, the standard cultural practices for tomato planting was followed. Towards the end of the season, the three sets of data were collected as before, namely, Root-knot infestation, plant size and fruit yield. The results were summarized in Table 7.

Generally speaking, there was no clear-cut correlation between yield data of the various cultivars and root-knot infestation level. In some of the varieties, however, e.g. Marsol and Ronita, relatively higher yields of 21-23 kg/1000 plants were correlated with lower infestation rates of 3-13%. On the other hand, lower yields of 8 kg/1000 plants were sometimes correlated with very low infestation rate of less than 1%; e.g. as in case of VFN-Bush. Conversely, lower yields of 7 kg/1000 plants were associated with relatively higher infestation rates of up to 40% as in strain B. Generally speaking, however, both Money Maker and Strain B exhibited the highest rate of infestation levels, ranging between 40-53%.

Second Site: Performance of commercial tomato varieties. An observation plot was chosen in this site in which were planted a total of 10 commercial cultivars, namely, FAO-6, FAO-7, FAO-14, FAO-16, Marmand Extra O.E., Strain B, Pearson, V.F. - 144 5B, VF-13L-34 and VF.-10. Due to heavy weed infestation, in the plot, however, the results were rather erratic. Despite this, it might be concluded that all of the 10 varieties tested were highly susceptible to root-knot nematodes in the locality.

Table 1. Glasshouse Experiment (1978/79): Initial identity of root-knot nematodes from various regions throughout the Sudan, I-IV, using the standard differential host-test. The figures represent mean (and range) of root-knot ratings, R.I., as 0-5; where 0 = no infestation, 1-3 = mild-moderate; 4-5 = heavy infestation, respectively.

Region	Tobacco NC-95	Cotton Deltapine 16	Pepper California Wonder	Watermelon Charleston Grey	Tomato Rutgers	Peanuts Florrunner	Possible identity
Central Sudan* (I)	3.0 (0-5)	0.5 (0-2)	3.8 (2-5)	3.7 (2-5)	2.8 (0-4)	0 (0-0)	
Red Sea Area (II)	4.3 (4-5)	1.8 (0-3)	2.5 (0-5)	3.6 (3-5)	3.9 (3-4)	0 (0-0)	*M. javanica* & *M. incognita*
Nile Province (III)	1.0 (0-3)	1.6 (0-3)	1.6 (0-3)	3.4 (1-4)	2.3 (2-4)	0 (0-0)	
North Fung Area (Abu Naama) (IV)	3.2 (2-5)	0 (0-0)	1.4 (0-3)	1.1 (0-4)	3.9 (3-4)	0 (0-0)	

*Previous study showed that both M. javanica and M. incognita might occur in the ratio of 2:1, respectively (see experiment 1B).

Table 2. Glasshouse Experiment (1978/79): Host status or root-knot nematodes from Central Sudan, Region I*: The figures refer to mean (and range) of root-knot ratings, R.I., as 0-5, where 0 = no infestation, 1-3 = mild - moderate, 4-5 = heavy infestations, respectively.

Plant Species Tested	Infestation level (R.I.)
Cotton C.V. Barakat	
Cotton C.V. V.S.	
Cotton C.V. Huda	
Cotton C.V. Acala	
Cotton C.V. Albar	0 (Immune)
Peanuts C.V. Ashford	
Peanuts C.V. H.H. 383	
Peanuts C.V. Libian	
Dura C.V. Dwarf	
Dura C.V. Dabar	
Wheat C.V. Giza 155	
Purslane**	
Soya bean (Williams)	1-3 (Moderately susceptible)
Jews Mellow**	
Adasi** (Pigeon Pen)	
Okra**	
Tomato (Money Maker)	
Squash**	
Cucumber**	4-5 (Highly susceptible)
Eggplant**	
Lubia bean**	
Marrow**	

*Previous tests showed a possible mixture of *M. javanica* and M. incognita in the ratio of 2:1, respectively (see experiment 1B).

**Local cultivars.

Table 3. Glasshouse Experiment (1978/79): Effect of watering interval on the infestation levels of root-knot nematodes from Central Sudan, Region I⊛: The figures represent the mean (and range) of root-knot ratings, R.I., as 0-5; where 0 = no infestation, 1-3 = mild-moderate, 4-5 = heavy infestation, respectively.

Watering Regime	R.I.	S.E.±
Complete flooding (CF)	1.8***/C*/L	1.17
Heavy (3 waterings/day) (H)	2.2***/C*/L	1.19
Conventional (once/day) (C)	4.7	0.50
Light (once/2 days) (L)	4.8	1.64

⊛ Previous tests showed a possible mixture of *M. javanica* and *M. incognita* in the ratio of 2:1, respectively (see experiment 1B).

* = Significance at 0.05 P

*** = Significance at 0.001 P

Table 4: Glasshouse Experiment (1978/79): Effect of soil amendment on the infestation levels of root-knot nematodes from Central Sudan, Region I⊛. The figures represent the mean (and range) of root-knot ratings, R.I., as 0-5; where 0 = no infestation, 1-3 = moderate infestation, 4-5 = heavy infestation, respectively. A total of 10 pots were included in each set.

Type of amendment	R.I.	S.E.±
Dura straw	3.5*	0.87
Lubia bean straw	4.4	1.73
None	4.7	0.45

⊛Previous tests showed a possible mixture of M. javanica and M. incognita in the ratio of 2:1, respectively (see experiment 1B).

* = Significance at 0.05 P.

Table 5. Glasshouse Experiment (1978/79): Identity of two *Meloidogyne* species*, *M. javanica* and *M. incognita*, by means of two standard differential host plants. The figures refer to mean (and range) of root-knot ratings, R.I., as 0-5, where 0 = no infestation, 1-3 = mild to moderate, 4-5 = heavy infestation, respectively.

Suspected Meloidogyne sp.	Reaction towards differential host	
	NC-95 Tobacco	Cal. Wonder Pepper
M. javanica	3.8 (3-5)	0.6 (0-2)
M. incognita	0 (0-0)	4.2 (4-5)

Table 6. Field Experiment (1978/79): Nematicidal tests in tomato C.V. Strain B, against root-knot nematodes from naturally infested soil at a site at Hillat Hassan (Region I*): The figures refer to, % mean (and range) of heavily infested plants, mean plant size (height and circumference) in cm, and mean (and range) of fruit yield as kg/1000 plants.

Treatment	% heavily infested plants	Plant size (cm) Ht. x circum.	Yield kg/1000 plants
Vydate	23 (6.41)	31 x 39	82 (55-100)
Temik	40 (15-61)	32 x 40	51 (24-84)
Nemacur	42 (13-61)	32 x 41	44 (28-67)
Furadan	46 (15-74)	30 x 39	62 (48-102)
Bunema	57 (16-71)	29 x 38	72 (19-94)
None	63 (37-82)	27 x 33	32 (28-38)

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

Table 7. Field Experiment (1978/79): The performance of selected tomato lines under natural conditions of root-knot infestation at a site at Hillat Hassan (Region I*): The figures refer to, % mean (and range) of heavily infested plants, mean plant size (height and circumference) in cm, and mean (and range) of fruit yield as kg/1000 plants.

Tomato variety	% heavily infested plants	Plant size (cm) (Ht. x circum.)	Yield kg/1000 plant
V.F.N. - Bush	0 (0-0)	33 x 43	8 (3-14)
Marsol	3 (0-10)	34 x 44	21 (9-40)
Motabo	3 (0-10)	29 x 33	14 (4-10)
Romano NR	3 (0-10)	29 x 43	7 (4-10)
Piersol	13 (0-20)	32 x 39	13 (7-15)
Ronita	13 (0-30)	39 x 50	23 (10-36)
Rossol	17 (10-30)	37 x 38	11 (9-14)
V.F.N. - 8	17 (10-30)	37 x 46	7 (4-12)
68 N - 144	23 (10-30)	34 x 41	5 (4-9)
Mon - 144	37 (10-50)	32 x 28	4 (0-10)
Strain B	40 (30-50)	26 x 31	7 (3-13)
Money Maker	53 (40-70)	38 x 36	13 (3-30)

*Previous investigations showed a possible mixture of *M. javanica* and *M. incognita* in the ratio of 2:1, respectively (see experiment 1B).

Table 8. Glasshouse Experiment (1978/79): Effect of soil type on the infestation levels of root-knot nematodes from Central Sudan, Region I*. The figures represent the mean (and range) of root-knot ratings, R.I., as 0-5; where 0 = no infestation, 1-3 = moderate infestation, 4-5 = heavy infestation, respectively. A total of 5 pots were included in each test.

Soil Type	R. I.
River Sand (R.S.)	3.3 (2-5)
River Silt (R. St.)	4.1 (3-5)
Gezira Heavy Clay (G HC)	4.2 (3-5)
R. S. + G HC	4.5 (3-5)
R. S. + R. St.	4.5 (4-5)

*Previous tests showed a possible mixture of *M. javanica* and *M. incognita* in the ratio 2:1, respectively (see experiment 1B).

APPENDIX I

METEOROLOGICAL DATA - REGIONS OF INVESTIGATION OF ROOT-KNOT NEMATODES WITHIN THE SUDAN

I. Light river silt - Blue Nile - in the low rainfall woodland savannah (300 - 400 mm r.f.) 41.7° & 15.6°C temp.

II. Red Sea Area - in the semi desert zone (75 - 300 mm r.f.) 41.7° & 15.6°C temp.

III. Light river silt - main Nile in the desert - semi desert zone (75 mm, r.f.) 41.7° & 7.8°C

IV. Heavy clay (Fung) in the low rainfall woodland savannah (300 - 800 r.r.) 38.8°C & 18.4°C temp.

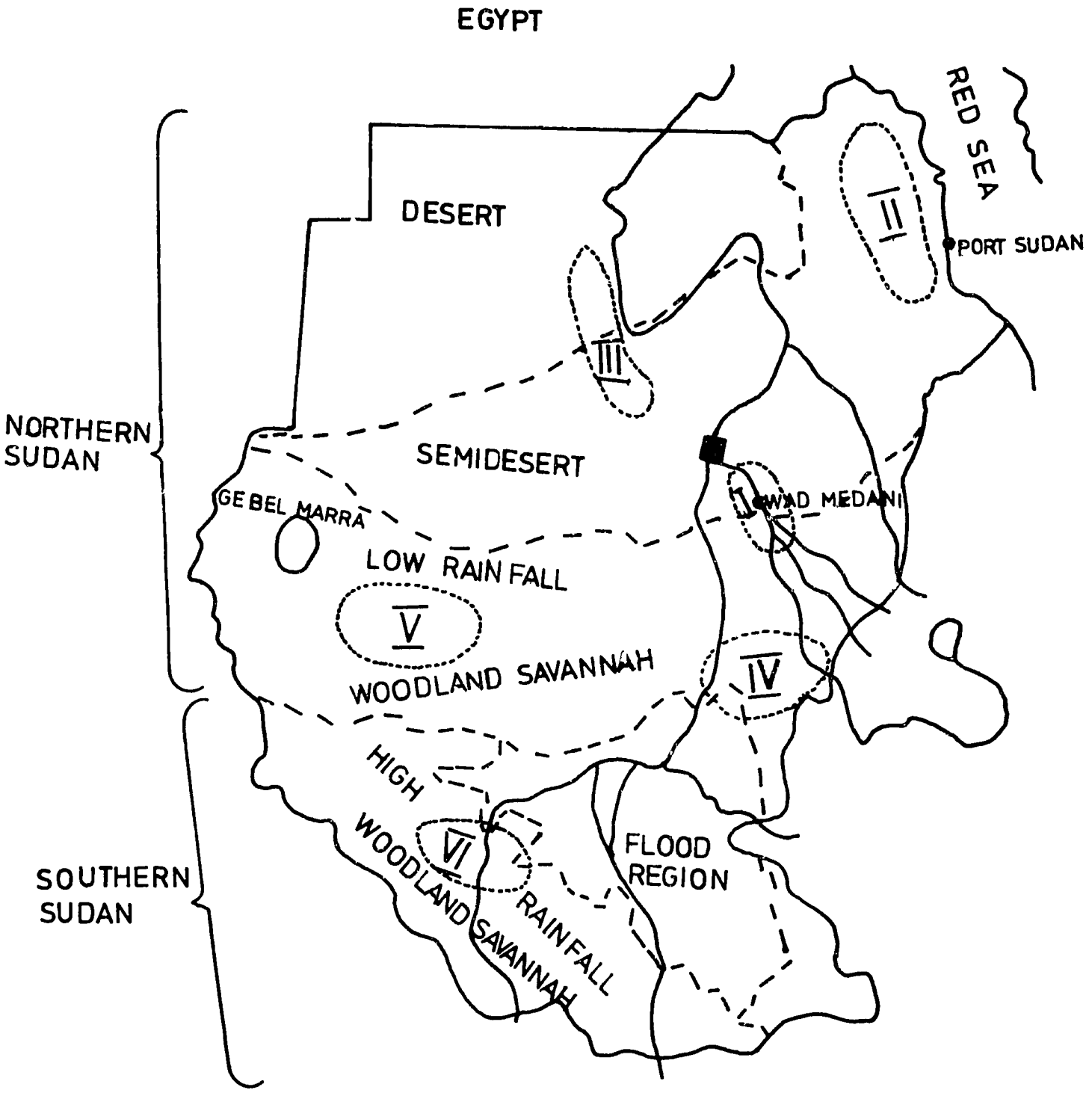
V. Light volcanic soil in the low rainfall woodland savannah (330 - 800 mm r.f.) 38.8°C & 18.4°C temp.

VI. Light river silt - Wau - in the high rainfall woodland savannah (> 800 mm r.f.) 38.8°C & 18.4°C temp.

I, II, III, IV & V fall in Northern Sudan Lat: 22°N - 10°N

VI falls in Southern Sudan Lat: 10°N - 4°N

(See map on next page)


EGYPT
RED SEA
PORT SUDAN
DESERT
II
III
NORTHERN SUDAN
SEMIDESERT
GEBEL MARRA
WAD MEDANI
LOW RAIN FALL
V
WOODLAND SAVANNAH
IV
HIGH
VI
WOODLAND SAVANNAH
RAINFALL
FLOOD REGION
SOUTHERN SUDAN

APPENDIX II

G.R.S. GLASSHOUSE TEMPERATURE RANGES (1978/79)

Month	Mean Max.	Mean Min.
Sept. 78	38.5	27.0
Oct. 78	40.0	26.7
Nov. 78	36.0	22.0
Dec. 78	35.0	20.8
Jan. 79	35.0	17.0
Feb. 79	39.0	19.0
March 79	39.0	20.9
April 79	43.0	26.0
May 79	41.2	28.8

OBSERVATIONS ON MELOIDOGYNE WITH EMPHASIS ON DISEASE COMPLEXES AND THE EFFECT OF HOST PLANT ON MORPHOMETRICS

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The field research on Meloidogyne presented here was conducted in cooperation with the Yemeni-German Plant Protection Project in Sana'a and the basic studies in the Institut fur Pflanzenkrankheiten, University of Bonn, Germany. (Studies conducted in Yemen were funded by the German Agency for Technical Cooperation (G.T.Z.), Eschborn, Germany.) The results obtained since the establishment of the Middle East Region VII of the International Meloidogyne Project will be grouped into the following categories: (1) survey, (2) species identification, (3) interaction between Meloidogyne and soil-borne fungi, and (4) host plant and morphometrics.

Survey

The results obtained in survey work conducted in Yemen in 1977 for the Yemeni-German Plant Protection Project demonstrated the importance of root-knot nematodes on crops in the warmer regions of the country (3, 6). In addition, the data showed the need for detailed research on: the economic importance of farming methods on nematode damage, interaction with other soil-borne organisms, and proper approaches to nematode control under conditions existing in the different climatic regions of the country. Additional field work was carried out in 1978 in areas of the country and on crops not examined previously (2). In Table 1 the occurrence of plant parasitic nematodes from both surveys gives some indication of the frequency with which root-knot was detected.

Species Identification

Populations of Meloidogyne collected from the field in Yemen were increased in Bonn and identified using perineal pattern, larval length and other morphological characteristics. The growing region, sample number, host plant, detection site, percent galling, estimated crop loss and species of Meloidogyne detected are presented in Table 2. Eleven populations were sent to Raleigh, North Carolina, where host differential tests were conducted. The results of the determinations from both labs are shown in Table 3. In most instances determinations were identical. Further work will be conducted where the results differ.

Interaction Between Meloidogyne and Soil-Borne Fungi

Research on complex diseases being conducted in the Institut fur Pflanzenkrankheiten in Bonn can be grouped as follows: (1) interactions involving plant parasitic nematodes, wilt fungi, and root-rotting organisms, (2) studies on the inter-relationship between plant parasitic nematodes and endotropic mycorrhizal fungi and (3) field research on the economic importance of complex-diseases.

A study was conducted in 1978 to determine the importance of nematodes and soil-borne fungi in banana decline in the coastal regions of Yemen. Although a large number of organisms have been found associated with diseased banana, effective control has not been attained. Diseased plants, exhibit a general decline in growth (1) and severe fruit rot (Figure 1).

Root and soil samples from 9 plantations were examined for nematode and root-rotting fungi. The root systems in 7 plantings were in an advanced state of decay (Figure 2). Conversely, only traces of root rot were observed in plantations at Sordud and Taiz where decline symptoms were not observed. High numbers of Meloidogyne were found in the root systems of the diseased plants along with root-rotting fungi Fusarium solani and Rhizoctonia sp. (Table 4). The root systems were heavily galled (Figure 3) and the cortex in various stages of decay (Figure 4). In many cases advanced stages of root rot prevented nematode development. In these cases rotting often caused root die-back (Figure 4). A similar study conducted in Lebanon in 1972 (5) indicated that the dual presence of plant parasitic nematodes and fungi might be responsible for banana decline (Table 5).

Banana under normal growing conditions is not adversely affected by Meloidogyne. Improper management e.g. poor fertilization, over-watering, high salt levels, and false pruning seems to have raised this nematode to its present level of importance in Yemen. The combination of these stress conditions along with high levels of Meloidogyne weaken the plant to such an extent that they are highly susceptible to root-rotting fungi, normally considered weak parasites. In addition to poor growth, severe root rot may weaken the fruit allowing the entry of fruit rotting pathogens.

Host Plant and Morphometrics

The effect of host plant on egg, gall and larval morphometrics was studied under controlled conditions as outlined in Figure 5. Measurements

were taken after the completion of one life cycle which varied with host plant. The results show that host plants have a strong influence on nematode development (Table 6). Eggs were smallest on gerbera and largest on tobacco. Galls were also larger on tobacco than on gerbera. When the root diameter was taken into consideration, the galls on tobacco were actually smaller. The smallest larvae were found on pepper followed by coleus. These differences may offer a criteria for determining host suitability. Research has also been conducted on the influence of temperature on nematode development (4).

REFERENCES

1. Hindorf, H. 1975. Pflanzenkrankheiten in der Arabischen Republik Yemen. German Agency for Technical Cooperation (GTZ) Report. 30 pp.
2. Klingauf, F. and R. A. Sikora. 1978. Additions to the occurrence, distribution, and importance of insects and plant parasitic nematodes in the Arabic Republic of Yemen. German Agency for Technical Cooperation (GTZ) Report. 66 pp.
3. Nienhaus, F. and R. A. Sikora. 1977. Distribution and importance of plant parasitic nematodes and plant viruses in the Arabic Republic of Yemen (GTZ) Report. 48 pp.
4. Schlang, J. 1979. Untersuchungen uber Wechselwirkungen zwischen Meloidogyne arenaria, Verticillium dahliae und Phytophthora cryptogea an Gerbera jamesonii. Thesis. Inst. fur Pflanzenkrankh., Univ. Bonn. 130 pp.
5. Sikora, R. A. and E. Schlosser. 1973. Nematodes and fungi associated with root systems of banana in a state of decline in Lebanon. Pl. Dis. Rept. V. 57(7)615-618.
6. Sikora, R. A. 1978. Status of root-knot nematodes, Meloidogyne spp., in the Yemen Arabic Republic. Proc. Res. Planning Conf. on Meloidogyne. Cairo. p. 50-57.

Table 1. Occurrence of nematodes in soil samples from surveys conducted in the Arabic Republic of Yemen

Genus	Percent of samples 1977	Frequency of Occurrence	Percent of samples 1978	Frequency of Occurrence
Aorolaimus	0.0	1	0.0	0
Anguina tritici	0.0	1	0.0	0
Aphelenchoides	2.7	3	9.6	4
Aphelenchus	16.0	18	42.3	22
Macroposthonia	5.0	5	11.5	6
Cryphodera	0.9	1	0.0	0
Ditylenchus	1.8	2	13.5	7
Helicotylenchus	26.8	30	17.3	9
Hemicriconemoides	0.0	0	7.7	4
Hemicycliophora	3.6	4	1.9	1
Heterodera	2.7	3	1.9	1
Hoplolaimus	15.2	17	7.7	4
Longidorus	0.9	1	3.9	2
Meloidogyne	29.5	33	21.2	11
Paratrophorus	0.0	0	1.9	1
Paratylenchus	7.1	8	32.7	17
Pratylenchus	29.5	33	36.5	19
Psylenchus	0.9	1	7.7	4
Rotylenchulus reniformis	11.6	13	3.9	2
Scutellonema	2.7	3	0.0	0
Telotylenchus	0.0	0	3.9	2
Tetylenchus	0.9	1	0.0	0
Trichodorus	0.9	1	1.9	1
Tylenchorhynchus	29.5	33	51.9	27
Tylenchulus semipenetrans	10.7	12	1.9	1
Tylenchus	44.6	50	71.2	37
Xiphinema	2.7	3	11.5	6

Table 2. Detection site, host crop, galling level and estimated loss due to species of Meloidogyne in Yemen.

Region	Sample Nr.	Crop[1/]	Location	Galling %	Estimated Loss[2/]	Species
	37 +	Tomato	W. Zabid	25-70	H	*M. incognita*
	38 +	Cotton	W. Zabid	-	-	*Meloidogyne* sp.
Tahama	43 +	Banana C	W. Zabid	10-25	H	*M. incognita*
	49 +	Tomato	W. Sordud	25-70	H	*Meloidogyne* sp.
	52 +	Banana C	W. Rima	25-70	H	*M. incognita*
	52	Squash	FAO/Farm	10-25	M	*M. javanica*
	8 +	Bell Pepper	W. Sudan	25-70	M	*Meloidogyne* sp.
	11 +	Banana C	W. Dabab	25-70	H	*M. incognita*
Taiz	19 +	Banana C	W. Birrain	25-70	M	*M. incognita*
	21 +	Tomato	W. Birrain	25-70	H	*M. incognita*
	31 +	Banana C	W. Hagda	0-10	L	*M. incognita*
	33 +	Banana M	W. Khuzaigha	25-70	H	*Meloidogyne* sp.
	42	Pomegranate	1st Village	0-10	L	*M. incognita*
Dschebel	43	Pomegranate	1st Village	0-10	L	*M. javanica*
Saber	45	Cornation	Thimirrain	0-10	L	*Meloidogyne* sp.
Terraces	65 +	Banana M	Hoedadah-Sanaa	25-70	H	*Meloidogyne* sp.
	48	Bell Pepper	FAO Farm	10-25	M	*M. incognita*
	33	Common Bean	FAO Farm	25-70	H	*M. javanica*
Ibb	32	Potato	FAO Farm	0-10	L	*M. javanica*
	30	Tomato	FAO Farm	25-70	M	*M. javanica*
	24 +	Tomato	FAO Farm	25-70	H	*M. javanica*
	19	Grape	Beni Hoshaysh	-	-	*M. incognita*
Sana'a	15	Almond	Haddah	0-10	-	*M. javanica*
	14	Almond	Haddah	0-10	-	*M. javanica*
	83 +	Weed	W. Dahr	0-10	-	*Meloidogyne* sp.

1/C = Dwarf Cavendish, M = Gros Michel
2/L = Low, M = Moderate, H = High

Table 3. Comparison of *Meloidogyne* identification results 1977-79 IMP - University of Bonn

Sample No.	Host	IMP	Bonn
Germany			
001	Carrot	-	H
002	Tomato	J	I
006	Carrot	-	H
Jemen			
003	Tomato	I(R-3)	I
004	Tomato	J	J
010	Bean	J	J
011	Pomegranate	I(R-1)	I/J
012	Pepper	I(R-1)	I
013	Tomato	J	J
014	Potato	J	J
015	-	-	J
016	Pomegranate	-	I/J
017	Squash	-	I/J
018	-	-	-
Bahrain			
019	Eggplant	-	-

J = *M. javanica*

I = *M. incognita*

H = *M. hapla*

Bonn Identification
1) Perineum
2) Larval Length
3) Female Excretory Pore

Table 4. Frequency of occurrence of plant parasitic nematodes and soil-borne fungi in banana plantations in Yemen.

	Birrain	Dabab	Hagda	Hodadal	Khuzaigha	Rema	Sordud	Taiz	Zabid	Total	% Frequency of Occurrence
Number of samples	2	2	1	1	2	3	1	1	3	16	-
Nematodes											
Aphelenchus					1					1	6,3
Helicotylenchus			1		2	3	1		3	10	62,5
Hoplolaimus		1	1		2	3			3	10	62,5
Meloidogyne incognita	2	2	1	1	2	3			3	14	87,5
Pratylenchus	1	2		1	2	1	1	1		9	56,3
Rotylenchulus reniformis	1		1					1		3	18,8
Tylenchorhynchus						6		1	1	3	18,8
Tylenchus		2	1		2	3		1	1	10	62,5
Xiphinema			1							1	6,3
Fungi											
Fusarium solani						3		1		4	25,0
Rhizoctonia spp.			1		1	1			1	4	25,0

Table 5. Plant-parasitic nematode and fungi associated with banana in Lebanon.

Location	Helicotylenchus multicinctus		Meloidogyne incognita		Rotylenchulus reniformis	Paratylenchus sp.	Tylenchus spp.	Fusarium oxysporum	Rhizoctonia solani
	soil[a]	roots[b]	soil	roots	soil	soil	soil	roots	roots
Halat	267	301	533	0	350	0	317	+[c]	-
Fidar	550	336	117	0	117	183	583	+	-
Amchiit	1400	366	0	0	500	567	117	+	-
Batroun I.	1300	1000	333	50	83	117	733	+	+
Batroun II.	617	883	200	83	317	33	267	+	+
Nahr Ibrahim I.	1917	2117	50	0	483	1450	300	+	-
Nahr Ibrahim II.	1150	1783	2933	1770	67	0	0	+	+
Tabarja	567	583	0	0	1083	2667	517	+	+
Jiye	1067	1333	967	1600	1033	2683	750	+	+
Damour I.	4017	6950	1317	450	1400	1933	267	+	+
Damour II.	1183	2433	300	17	100	900	717	-	+
Damour III.	1583	1017	333	83	50	0	67	x	x
Damour IV.	2400	3100	183	17	33	417	133	x	x
Damour V.	2767	4823	100	133	833	2383	67	x	x
Zahrani	967	1683	3633	0	0	0	67	x	x
Sarafand I.	900	1100	900	483	117	0	0	+	-
Sarafand II.	1283	1233	333	350	83	50	33	-	+
Adloun	283	833	150	83	0	0	0	x	x
Tyre I.	2950	2717	33	0	300	867	67	+	+
Tyre II.	1517	2750	483	50	0	0	0	+	-
Means	1436	1911	620	258	350	709	250		

[a]Means of three 250-ml soil samples.
[b]Means of three 7-g root samples.
[c]Symbols: + = present, - = absent, x = not checked.

Table 6. Effect of host plant on gall diameter, egg size, and larval length.

Average size of *Meloidogyne arenaria* galls on 4 different host plants and the diameter of the root section adjacent to the galls (μm)

Host	Length	Width	Root diameter
Coleus	2394	1632	330
Tomato	2304	1554	525
Gerbera	1734	1086	444
Tobacco	2149	1312	658

Relationship of gall length (a) and width (b) to root diameter (c)

Host	(a)	(b)	(c)
Coleus	7, 25	4, 95	1, 47
Tomato	4, 39	2, 97	1, 48
Gerbera	3, 91	2, 45	1, 60
Tobacco	3, 27	2, 00	1, 64

Average size (Length and Width) of *Meloidogyne arenaria* eggs in μm as influenced by host plants

Host	Length	Width
Coleus	99, 9	38, 7
Tomato	101, 8	39, 6
Pepper	100, 2	40, 9
Gerbera	98, 2	40, 7
Tobacco	106, 4	46, 1

Average *Meloidogyne arenaria* larval length ($\bar{X}$) and Standard Deviation (s) as affected by host plant

Host	($\bar{x}$)	(s)
Coleus	449,55	19, 63
Tomato	457,00	18, 05
Pepper	445,27	18, 09
Gerbera	453,19	22, 29
Tobacco	468,33	21, 41

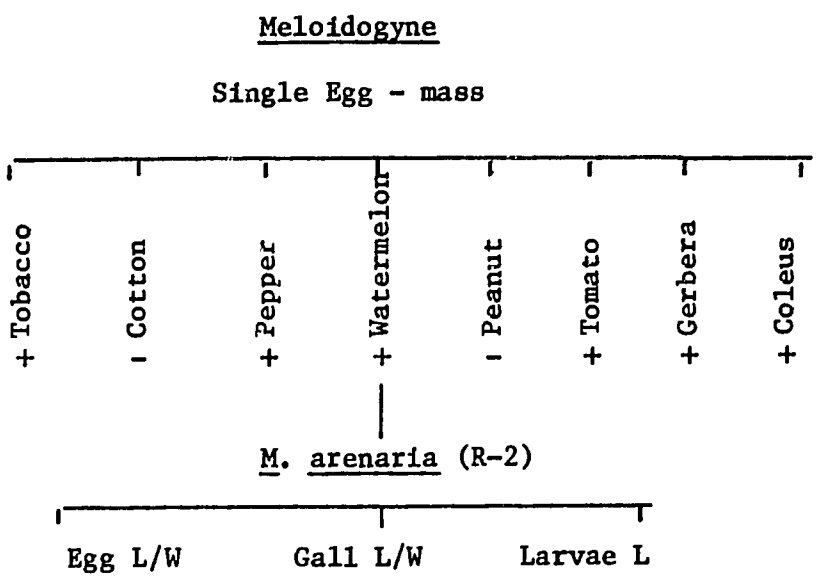
Figure 1. Symptoms of fruit rot associated with banana decline.

Figure 2. Root rot on banana.

Figure 3. Root-knot galls on banana.

Figure 4. Different stages in the decay of root-knot galls by soil-borne fungi.

Figure 5. Host plant and morphometrics.



COOPERATION WITH THE INTERNATIONAL *MELOIDOGYNE* PROJECT IN THE KINGDOM OF SAUDI ARABIA

Dr. M.F.M. Eissa, Dr. G. Beinhart, and Mr. S. Al-Uyayed

Regional Agriculture and Water Research Center of the Ministry of Agriculture and Water, Riyadh, Saudi Arabia

Root-knot nematodes are serious pests on Saudi Arabian crops. Wherever we have examined crops in the Kingdom, we have found root-knot and other nematodes; we have not found any agricultural areas to be free of such infestations, and we thus believe that nematodes are causing very great losses to production. For the past two years, collaboration with the International *Meloidogyne* Project (IMP) has increased our ability to study these pests in a systematic way, and to seek ways to control them and thus reduce their damage to Saudi crops.

In this presentation we will summarize work carried out at the Regional Agriculture and Water Research Center (RAWRC), situated near Riyadh, Saudi Arabia; this work has been collaborative with IMP. Also, we will consider needs for future work, and plans for carrying out such activities.

WHAT HAVE WE DONE?

Identifying Root-knot Nematodes in Different Regions of Saudi Arabia

Infested soils were collected from four arid localities: Al-Kharj; Gasim; Najran; and Qatif. In the RAWRC greenhouse, *M. incognita* isolates from these samples were tested on tomato (Rutgers), Pepper (Calif. Wonder), Tobacco (N.C. 95), Peanut (Florrunner), Cotton (Deltapine 16) and Watermelon (Charleston Gray). Host plants were grown in plastic pots, 18 cm. diameter, containing about 3 liters of soil, and received normal agricultural care; i.e., watering, fertilizing, weeding, etc. Results are summarized in Table 1.

We concluded that the dominant root-knot pest in the four sites is *M. incognita* Race II. Other sites in S.A. of different ecological nature; i.e., the western highlands of Taif and Abha and the Gizan valley in the extreme South, will be tested to learn which species and races of *Meloidogyne* are most important there. Practical recommendations for growing resistant cultivars should be possible after these tests are completed.

Tomato Cultivars Test

Seedlings of 29 different cultivars of tomato were planted in 12 cm. plastic pots in the RAWRC greenhouse. The potting medium was sandy soil to which was added chopped segments of galled tomato roots infested with *M. incognita* Race II obtained from Al Kharj. After 16 weeks, the plants were sacrificed, and readings made of the degree of root galling.

Table 2 shows that, based on their root gall indices (RGI), the cultivars fell into three groups of apparent susceptibility to *M. incognita* Race II nematodes: slightly susceptible, moderately susceptible, and highly susceptible.

Field Tests of Nematicides

On Tomatoes. At Hofuf, in the Eastern Province of Saudi Arabia, carbofuran and oxamyl nematicides were applied to plots i) at recommended rates, and ii) at 2 x recommended. Environmental conditions included: arid climate, coarse sandy soil, saline irrigation water.

All nematicide treatments raised yields of harvested fruits above those from untreated control plots. The percentage increases in yields for oxamyl were 29% (recommended dosage treatment) and 51% (2x recommended level). For carbofuran, the corresponding yield increases were 34% and 48%, respectively.

The favorable responses to the higher dosage rates were interesting and not expected, since low dosages usually are adequate for controlling nematodes in sandy soils because of relatively reduced surface areas.

On Beans. At Al Kharj, south of Riyadh beans (*Fasiolus vulgaris* var. Astro) were planted in sandy soil infested with *M. incognita* Race II. Systemic nematicides were applied to some plots prior to planting; some plots were untreated and served as controls. Results are summarized in Table 3.

Both carbofuran and fensulfothion considerably reduced root galling, slightly increased total plant weights, and significantly increased fruit yields; the fact that root/shoot ratios were lower in these treatments indicates that roots were active and physiologically efficient. Oxamyl-treated plants displayed vigorous vegetative growth but fruit yields were no higher than for the controls.

Susceptibility of Grape Cultivars to M. incognita

Observations have been made at Al Kharj on grapevines at differing origins, all growing in soils infested with *M. incognita* Race II nematodes,

Iraqui Cultivars. Twenty-two in number, they were examined for root galling and classified as shown in Table 4.

American, Lebanese, and Saudi Cultivars. In this experiment, 46 cultivars (7 American, 22 Lebanese, and 17 Saudi) were planted in a nursery infested with Race II *M. incognita*. Table 5 shows the names of cultivars in each of 4 categories of susceptibility based on readings of Root Gall Index.

WHERE DO WE GO FROM HERE?

Detailed plans for future collaboration between RAWRC and IMP will be discussed during these meetings. In general, we consider the following to be high priority objectives for the near future:

1) To train Saudi personnel in applied aspects of nematology research and in field control procedures; also, to encourage junior Saudi scientists to enroll in graduate programs giving full professional training in nematology.
2) To continue surveys of the susceptibility of Saudi crops to *Meloidogyne* pests commonly occurring in the Kingdom.
3) To continue, and strengthen, a program to test chemical nematicides, including determinations of most effective dosage levels, methods of application, etc.
4) To study sex-converting chemicals as potential agents for field control of nematodes.
5) To identify major nematode-caused problems confronting Saudi agriculture, and to establish priorities for studying the problems.

Acknowledgement

We are indebted to Professor Sasser and the entire IMP staff for their help in providing us with test materials, publications, and other forms of assistance.

Table 1. Response of host plants to M. incognita collected from four different Saudi Arabian sites.

Site	Tomato	Pepper*	Tobacco	Cotton	Peanut	Watermelon
Al-Kharj	+	+	+	-	-	+
Gasim	+	+	+	-	-	+
Nejran	+	+	+	-	-	+
Qatif	+	+	+	-	-	+

*Galls were fewer, and smaller in size, on Pepper than on other host species

Table 2. Susceptibility of twenty-eight tomato cultivars to M. incognita, Race II

Slightly Susceptible (RGI < 1) - 6 Cultivars	Moderately Susceptible (RGI < 3) - 6 Cultivars	Highly Susceptible (RGI > 3) - 17 Cultivars
Nemato	Meltine	Roma VF
Terrific VFN	Vine Ripe VFN	Claudia RAF
Mont Carlo VFN	Beefmaster VFN	FTVR-50
VFN-8	VFN Bush	FTVNR-3
KNVF	Red Princess	ES-58
Calmert VFN	Bonus VFN	Ace-55 VF
		VF 198
		VF 145 B 7879
		VF 145 B 7
		T VR-2
		Marmand
		Pearson A Improved
		San Merzano
		VDB Fury
		Zuiko (S-66) Cross
		Zuiko Cross
		FT VR

These results indicate that tomato cultivars commercially available to Saudi growers vary appreciably in their resistance to root-knot nematodes. Further tests should enable us to recommend varieties that will permit farmers to increase their production over existing levels.

Table 3. Growth Criteria, Fruit Yield, and Root Gall Indices (RGI) of Tomato Plants as Influenced by Treatment of Soil with Systemic Nematicides (all Tubular Data Expressed as % of Comparable Values for Plants in Untreated Control Plots)

Treatments	Average Plant Weights			Root/Shoot Ratio	Yield of Fruit	R.G.I.
	Root	Shoot	Total			
Carbofuran	103.5	114.0	112.5	66.3	176.4*	50.0
Fensulfothion	111.1	124.6	122.6	62.8	154.1*	34.5
Oxamyl	118.7	144.9	141.2	73.8	101.9	86.4
Check	100	100	100	100	100	100

*Significant at 5% level.

Table 4. Susceptibility of 22 Iraqui Grape Cultivars to *M. incognita* Race II, based on Observations at Al Kharj
Classification of Susceptibility Based on Root Galling Index (RGI)

Slightly Susceptible (RGI 0-3, $\bar{x} \leq 1.7$) - 4 cultivars	Moderately Susceptible (RGI 0-5, $\bar{x} \leq 3.1$) - 11 cultivars	Highly Susceptible (RGI 0-5, $\bar{x} > 3.1$) - 8 cultivars
Bhrzi	Abolbotol	Abbasi
Kamali	Ahmer Mawardi	Baidul Hamam
Ojimi	Shada Sawda	Black Hamburg
Sultanina	Sadani	Salobi
	Black Monukka (sl)	Kishmish-Arbeel (sl)
	Dees Alanz Alhalawi	Kozana
	Delight (sl)	Perlette (sl)
	Karn El-Ghazal	Romi Aswad
	Khalili	
	Kishmish	
	Al-Basra (sl)	

Table 5. Susceptibility of Cultivars from American, Lebanese, Saudi Sources

Slightly Susceptible (RGI = 0) - 5 Cultivars	Moderately Susceptible (RGI 0-3, $\bar{x}$ 0.5) - 9 cultivars	Highly Susceptible (RGI 0-5, $\bar{x}$ 0.5) - 20 cultivars	Unsatisfactory Cultivars (failed to survive or grow) 12 cultivars
Ahmer El-Taif (S)	Balah Beirut (L)	Almir (L)	Aasmi (L)
Aramoon (A)	Halawani Ahmer (S)	Ashkar (S)	Ainoni (L)
Kordi (S)	Jobaai (L)	Baitamoni (L)	Baidul Hamam II (L)
Masri (S)	Mokabar (S)	Berji (L)	Bony Blach (A)
Miskawi (L)	Muskat Hamburg B 41 (A)	Bizulanza (S)	Kalmashish (sl) (L)
	Soori (L)	Cardinal (L)	Karbihnon (A)
	Taifi Ahmer (S)	Farsi (S)	Khoderi (L)
	Tofaifahi (L)	Iraki (S)	Khodod El-Banat (L)
	Perlette Rijawi B 41 (A)	Khoderi El-Taif (S)	Perlette Bolson (A)
		Mariami (L)	Qaani (L)
		Moksa (L)	Qasofi (L)
		Nakhli (S)	Shokaifi (L)
		Obaidi (L)	
		Romadi (S)	
		Rozaki (S)	
		Sanso (A)	
		Sultana (s) (S)	
		Toboki (S)	
		Zaini (L)	
		Khadra (S)	

The results of Table 5 above have been summarized in a different form in Table 6 which shows susceptibility of the cultivars classified by their countries of origin.

Table 6. Susceptibility to *M. incognita* Race II

Country of Origin	Number of Cultivars	Percentage of Class of Slight	Moderate	High	Unsatisfactory
United States	7	14%	29%	14%	43%
Lebanon	22	5%	18%	36%	41%
Saudi Arabia	17	18%	18%	65%	0%
Totals	46	11%	20%	44%	26%

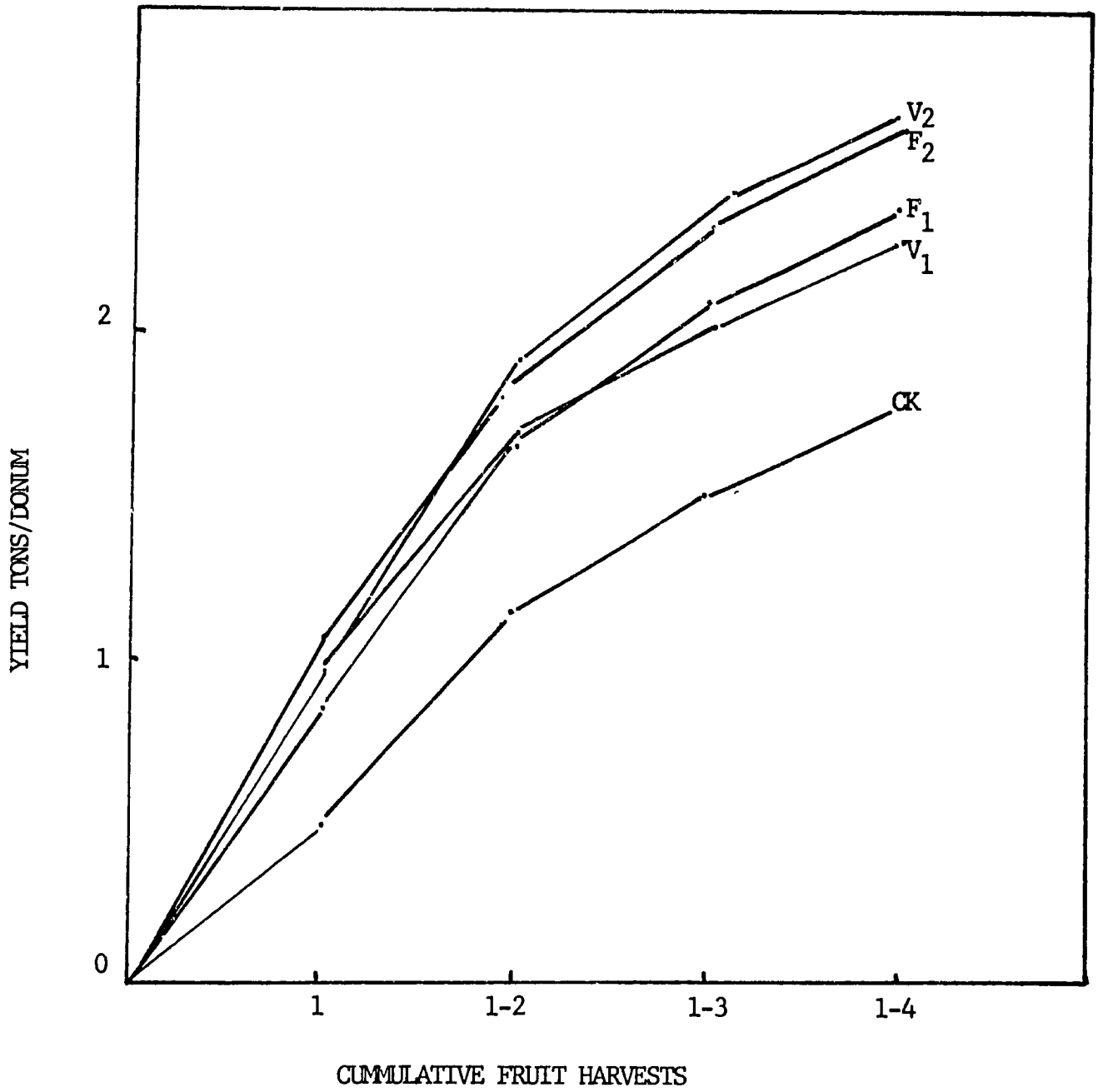


Figure 1. Effect of some systemic nematicides on tomato yield, Hofuf, Saudi Arabia

V_1 = Vydate at "standard dosage"

V_2 = Vydate at "double dosage"

F_1 = Furadan at "standard dosage"

F_2 = Furadan at "doube dosage"

CK = Untreated control

THE KINGDOM OF SAUDI ARABIA

RESEARCH ON ROOT-KNOT NEMATODES IN MOROCCO

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Institute Agronomique et Veteranaire

Diseases caused by Meloidogyne species are easily recognized by farmers because of spectacular development of galls on the root systems of many crops. Consequently, its importance among diseases caused by nematodes is well known.

In Morocco, Meloidogyne species are a limiting factor in vegetable crops production and necessitate the disinfection of infested land used for tomato production (200 ha in 1978). The Meloidogyne problem is aggravated by environmental conditions in Morocco that favor rapid completion of the Meloidogyne life cycle: we observed about 30 days per cycle, and the frequent use of plant hosts in a rotation system.

Fruit trees (peach, almond) were also found severely infected by Meloidogyne spp. Infection sometimes leads to the complete destruction of peach and almond nurseries.

We detected the presence of Meloidogyne spp on grape-vine and sugar beets also.

Work done in the Plant Pathology laboratory at the Agronomic and Veterinary Institute Hassan II was to determine different Meloidogyne species present in Morocco, their geographical distribution and control methods.

SPECIFIC DETERMINATION

Beginning in 1978 we made field trips to different areas of vegetable and fruit trees production in Morocco. Identification to species of different populations was made on the basis of patterns, the measure of the second stage larvae and the differential host done in collaboration with North Carolina State University. Some samples were identified at la Station de Recherche d'Antibes (France) by the biochemical method.

The results of the measurements of the second-stage larvae are reported in Table 1. Where they are compared to the measurements reported by CHITWOOD (1949) and WHITEHEAD (1968).

The results of the differential host test and the biochemical method are reported in Table 2 where they are compared to the pattern and the measurements of the second-stage larvae.

Results

The differential host tests done at North Carolina State University revealed the presence of only Meloidogyne javanica in the seven populations analyzed.

Another test conducted on three populations, in Morocco, revealed the presence of M. javanica, race 4, of M. incognita and M. arenaria.

The measurement of the second-stage larvae and the pattern observations on 19 samples showed that M. javanica was detected sixteen times, M. arenaria six times, M. incognita five times and M. hapla two times.

This study suggests that the association of 2 or 3 species may be common.

GEOGRAPHICAL DISTRIBUTION

The geographical distribution of the Meloidogyne species is reported in Figure 1. We found that Meloidogyne species are not confined to a single bioclimatic area. The climatic conditions of the regions sampled (Atlantic Coast, Sais Plain, and the Middle Atlas edge) are favorable to the development of different Meloidogyne species. M. hapla reported as a temperate climate species, was detected two times along the Atlantic Coast (once on the resistant tomato hybrid) and one time in a peach nursery on the edge of the Middle Atlas mountains.

METHODS OF CONTROL

Some preventive measures are often used to limit the root-knot nematodes incidence. Because of their low cost these measures can be used in Morocco. Particularly useful are the production of nematode-free plants in nurseries. The control of weeds (hosts of root-knot nematodes: Solanum nigrum, Malva sp., Chenopodiacea, Portulaca sp., Oxalis sp. . . .) the use of resistant varieties, and finally an appropriate rotation system especially for vegetable crops. Among our research activities we studied in detail in the laboratory and in the field was the effect of an appropriate rotation system on the control of root-knot nematodes. We selected 7 of the most economically important vegetable crops in Morocco and studied their influence on Meloidogyne evolution. These crops were potato (Sientje variety), tomato (Mar mande variety), carrot (Nantaise variety), bean

(Cosse violette variety), turnip (Marteau variety), lettuce (Batavia Pierre Benite variety) and melon (Jivaro variety).

Laboratory Results

The inoculum used was collected from plant residues and weeds. The species identified were M. javanica, M. incognita and M. arenaria.

For each crop 20 plants were inoculated and placed at 28°C. Every three days we applied acid fushine to one plant to examine it for nematodes. The evolution of Meloidogyne populations on each crop are reported in Figures 2, 3, 4, 5, 6 and 7. These figures show the relative percentage of different stages at different times.

We noticed that the length of the biological cycle of different Meloidogyne populations varies from one crop to another (38 days for turnip, 32 days for the lettuce, 35 days for carrots, 34 days for melon, 23 days for tomato and 29 days for beans). These results suggest that tomato and beans are more favorable to development of Meloidogyne species than turnip. To evaluate the susceptibility of different crops, it is necessary to inoculate plants with a definitive number of larvae and place the plants under homogeneous conditions. The larvae should be obtained from single species cultures and plants placed under optimal growing conditions. We should also quantify the multiplication capacities of the pathogen on each crop and the different biological stages for each generation.

Field Results

Field trials with six crops (tomato, lettuce, carrot, bean, potato and turnip) were conducted on the same type of soil and under the same climatic conditions. Melon was grown in the greenhouse. To follow the development of Meloidogyne populations, soil samples were taken before planting, soil and root samples were taken every 20 days after planting. The soil analysis was realized by sugar flotation and root analysis by the fushine acid coloration technique. The quantitative evolution of second-stage larvae in the soil, and L_2, L_3 and adult stages in the roots are reported before the appearance of egg-masses although it was difficult to quantify the length of the first generation. We estimated to be about 40 to 60 days for tomato, potato, carrot and bean; 60 to 80 days for turnip; and 20 to 40 days for melon. These results compared to those obtained in the laboratory (where the cycle was 30 days for turnip, 32 days for lettuce, 35 days for carrots, 34 days for melon, 23 days for tomato and 29 days for beans) show that turnip inhibits development of

Meloidogyne species. From these results, it seems that the root-knot nematodes may become a major problem for tomato, beans and greenhouse melon. Because of the completion of the first generation at an early stage of crop development, severe damage could result to different crops. Also, plant residues may serve as a source of inoculum for the following crops:

Turnip and carrot which favor less Meloidogyne development may also reduce the inoculum source since the roots are harvested.

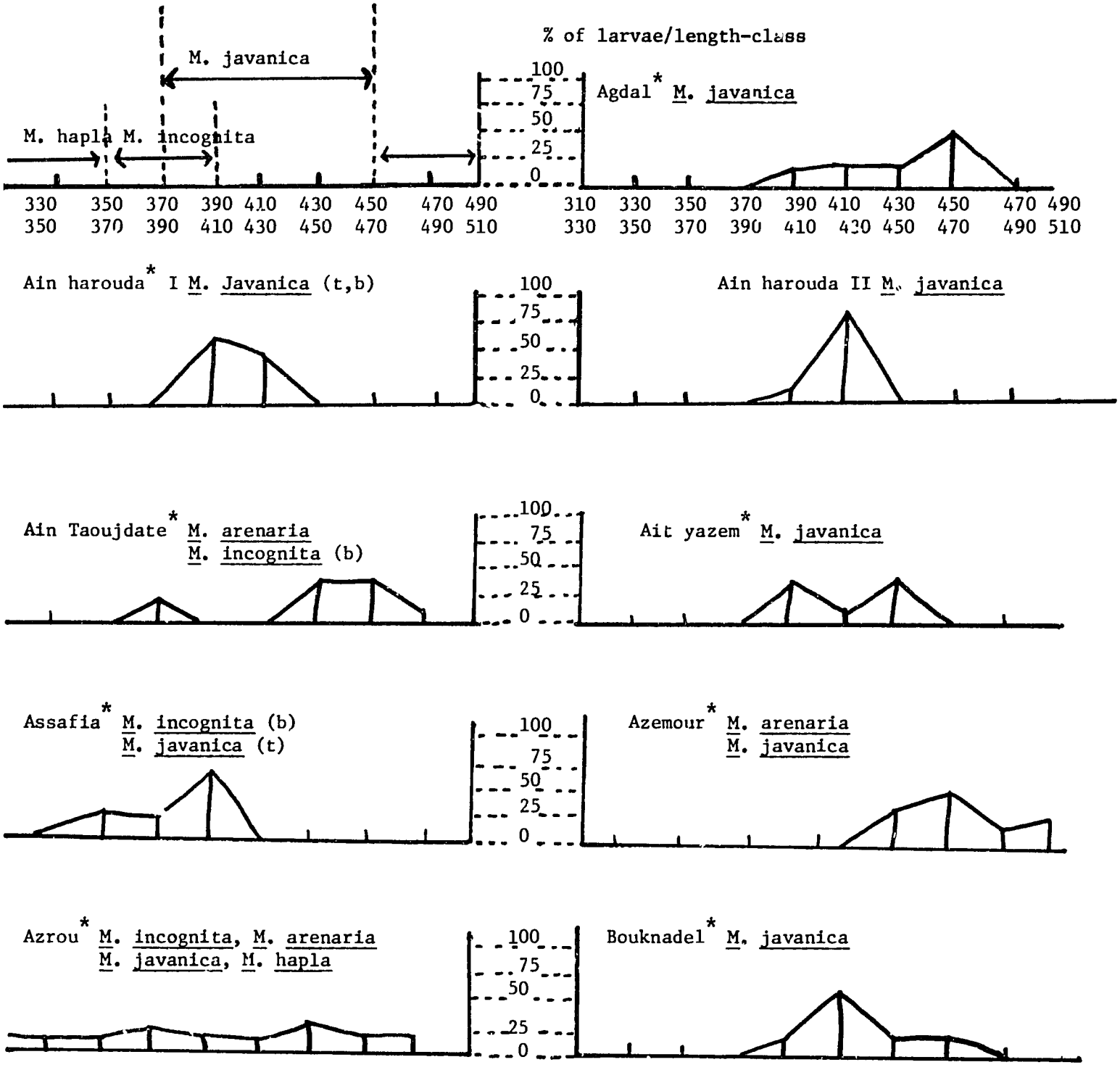
The lettuce harvested before the completion of the first generation may be utilized as a trap for nematodes.

CONCLUSION

From our studies in the field and the laboratory, we can conclude that an appropriate rotation system for spring crops is as follows:

Tomato - Turnip - Beans - Carrot - Potato - Lettuce.

Table 1. Percentage of second-stage larvae for each length-class and for each population collected.



(t): determination confirmed by the differential host test
(b): determination confirmed by biochemical analysis
* : location of sampling

Table 2. Percentage of second-stage larvae for each length-class and for each population collected

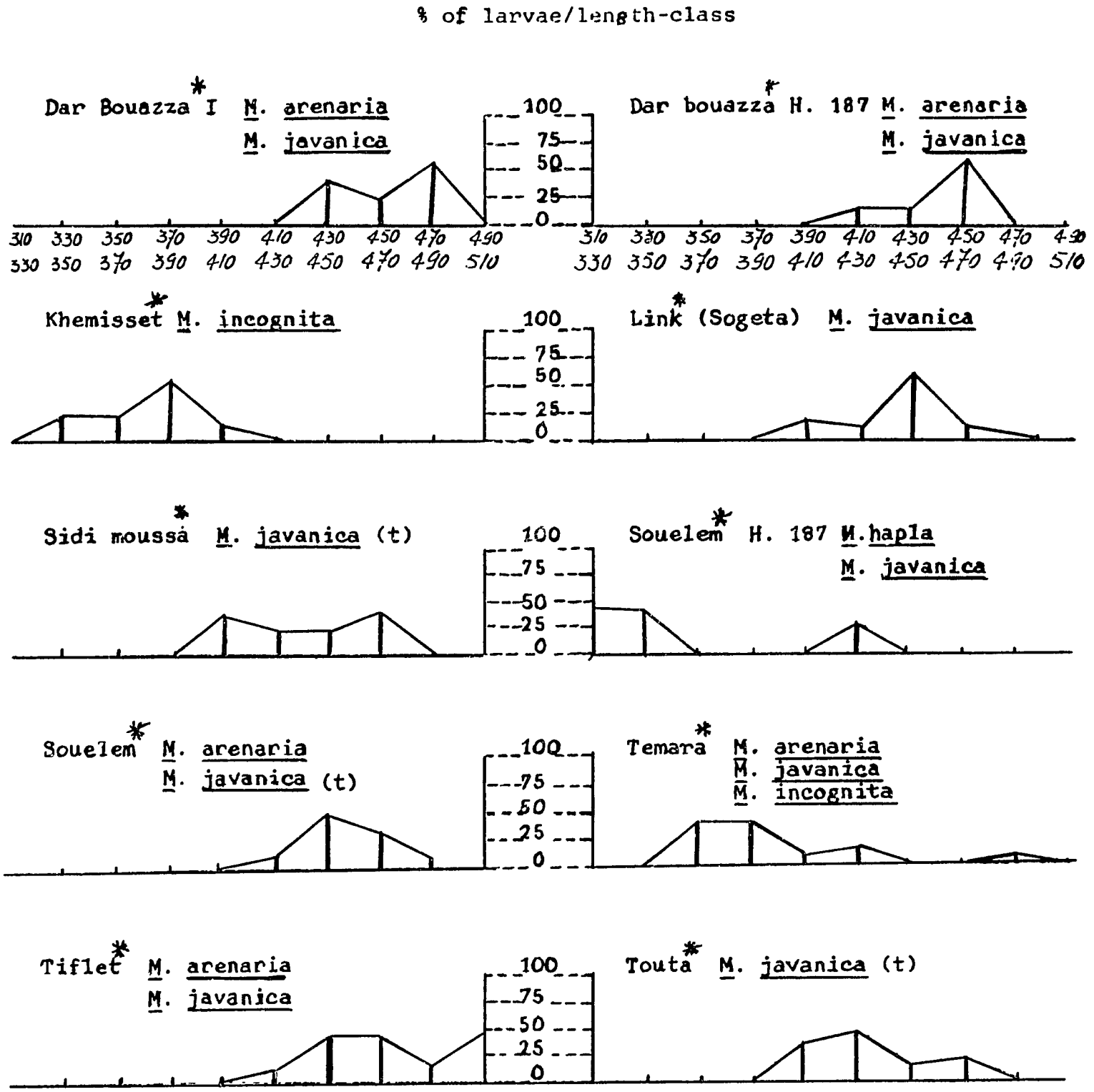
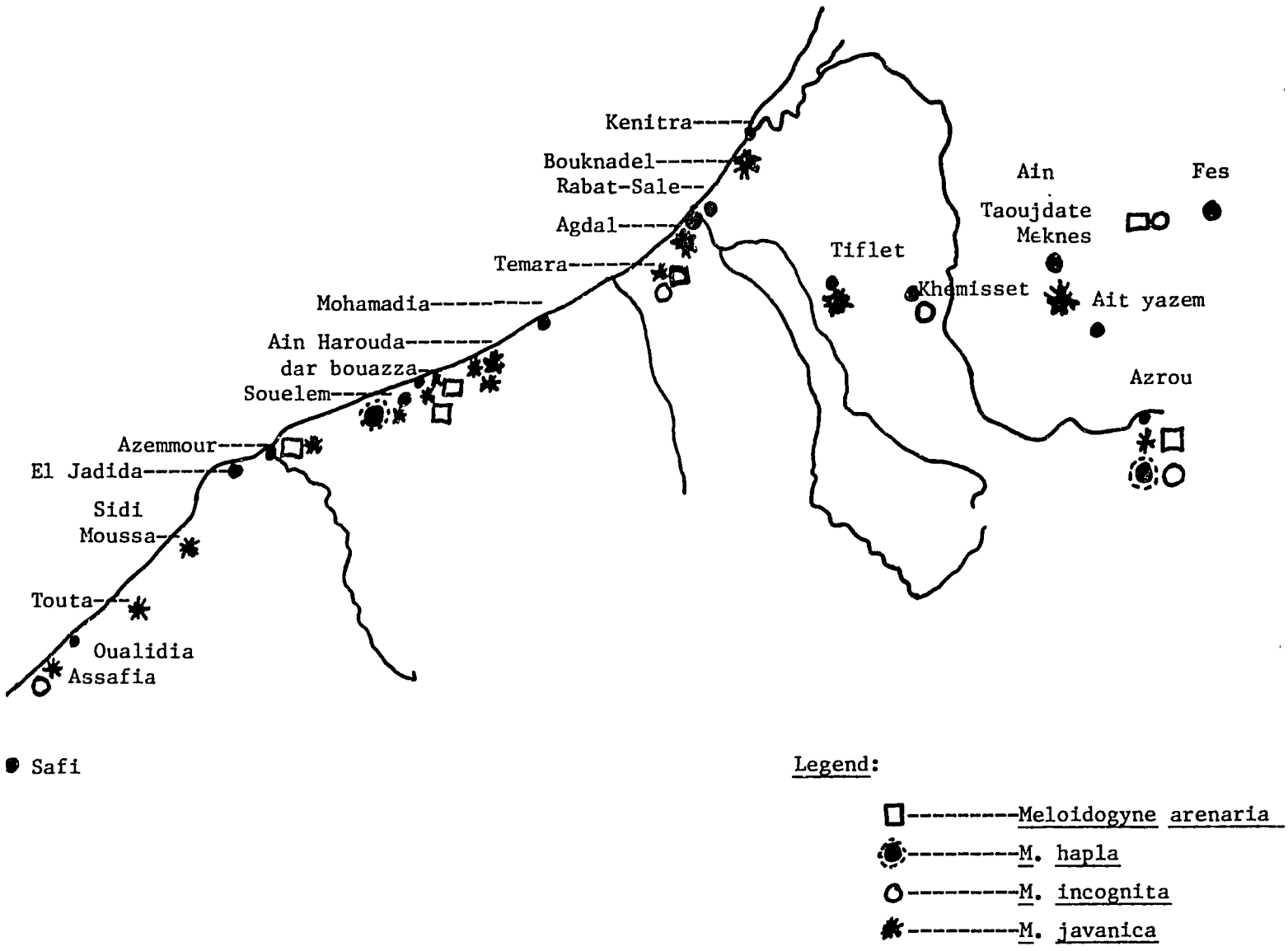


Figure 1. Geographical distribution of different *Meloidogyne* species in the area studied



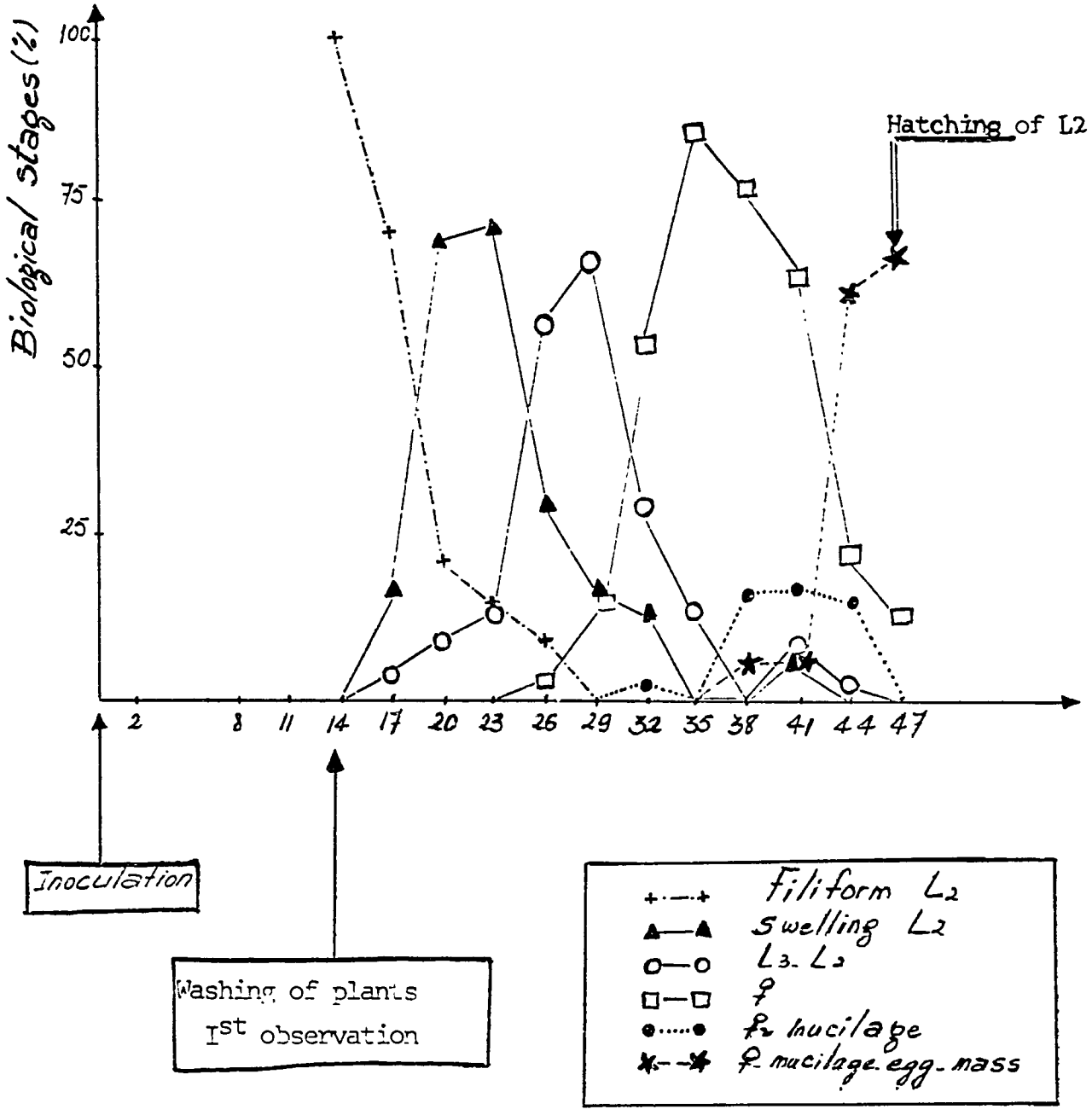


Figure 2. Life cycle of Meloidogyne spp. on Brassica napus L.

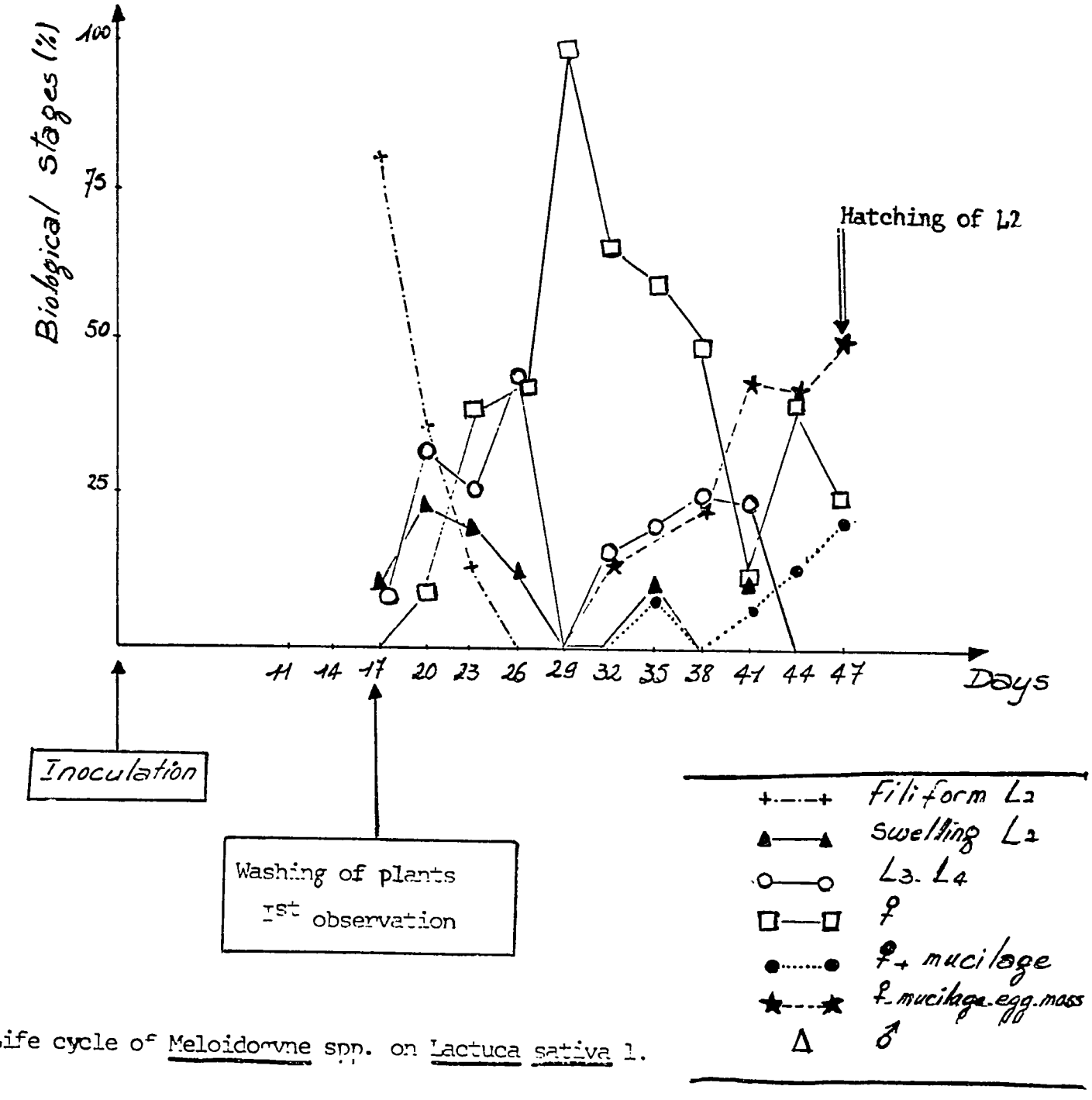


Figure 3. Life cycle of Meloidogyne spp. on Lactuca sativa l.

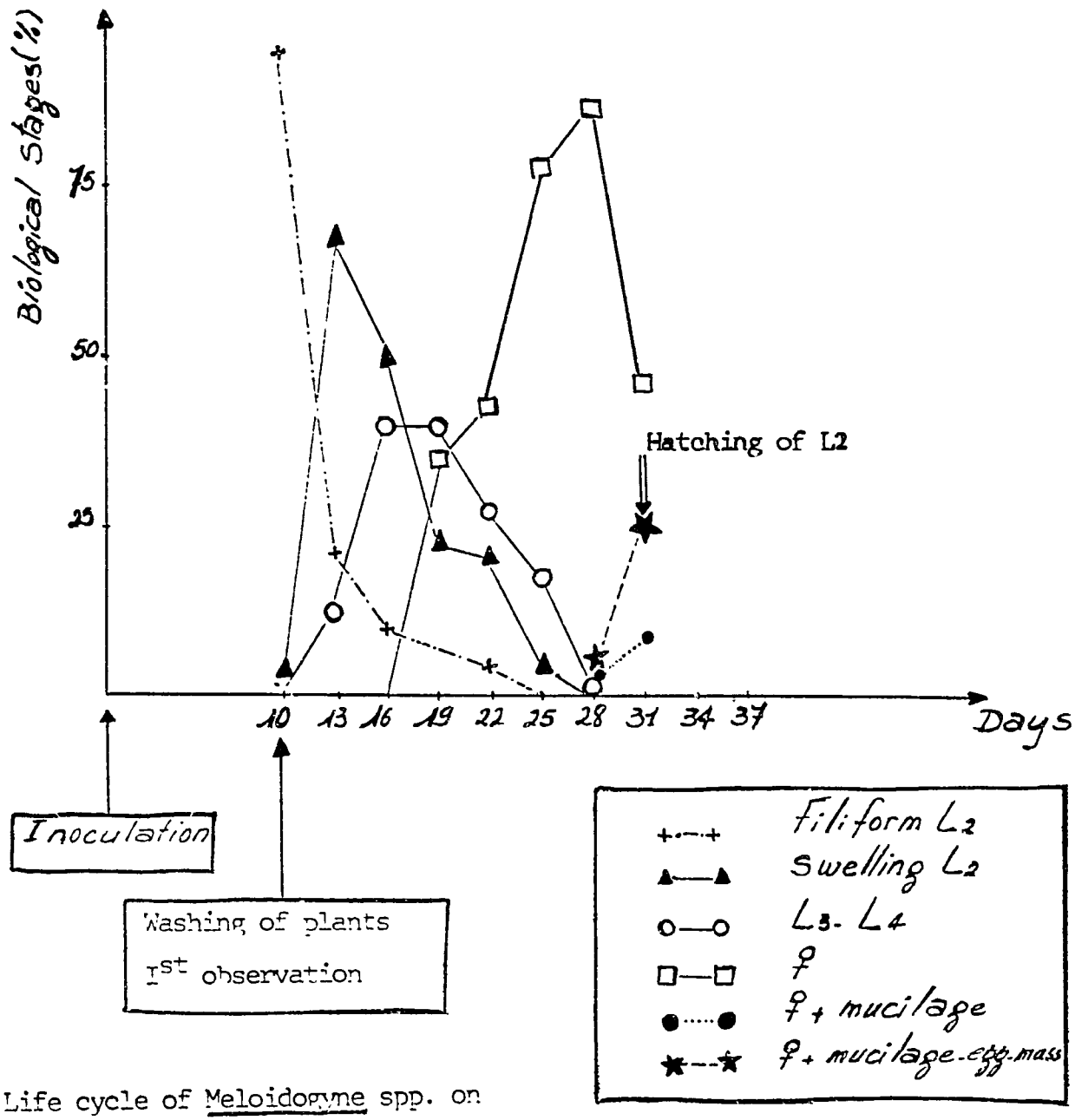


Figure 4. Life cycle of Meloidogyne spp. on Lycopersicon esculentum Mill.

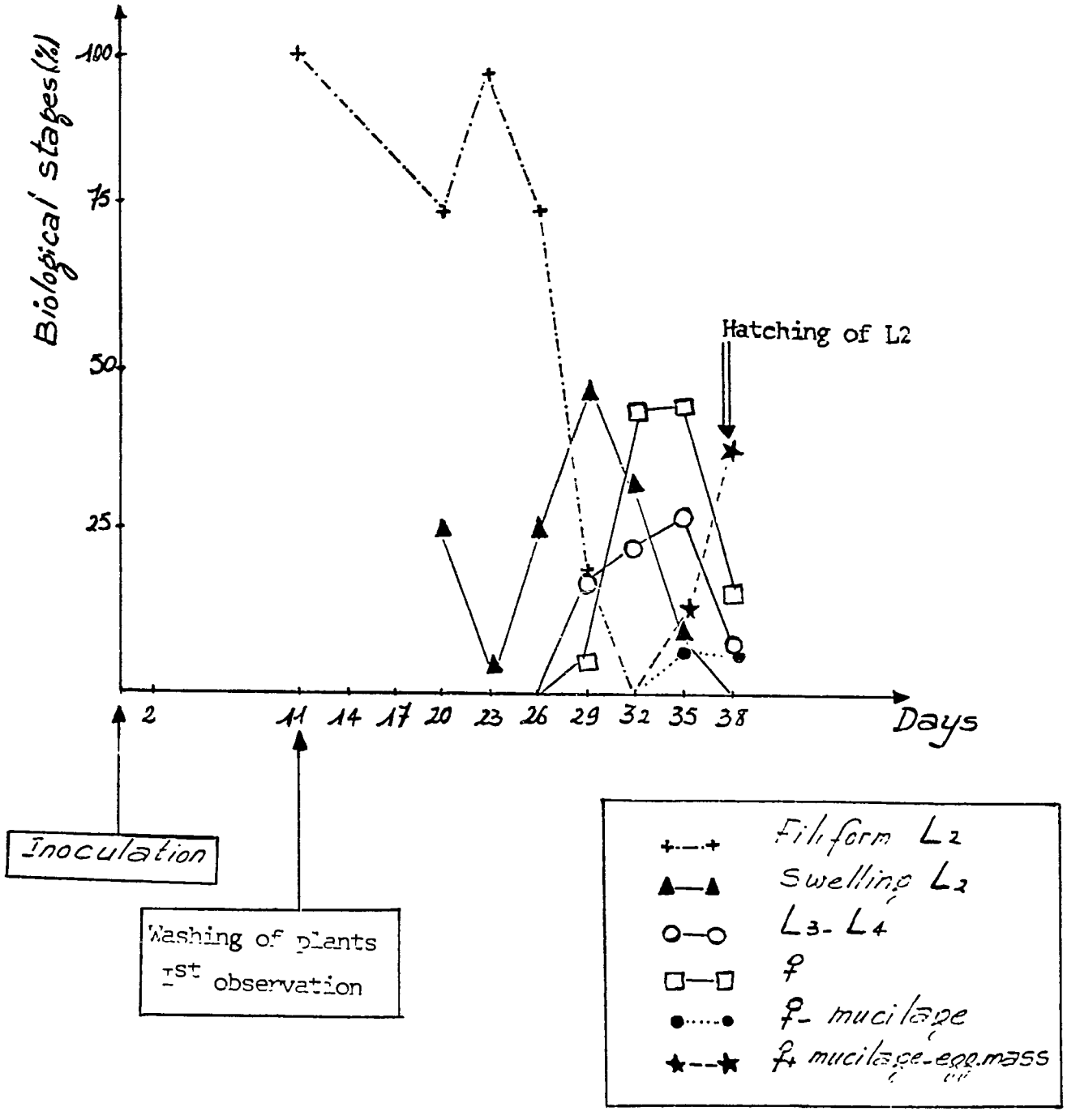


Figure 5. Life cycle of Meloidogyne spp. on Daucus carota L.

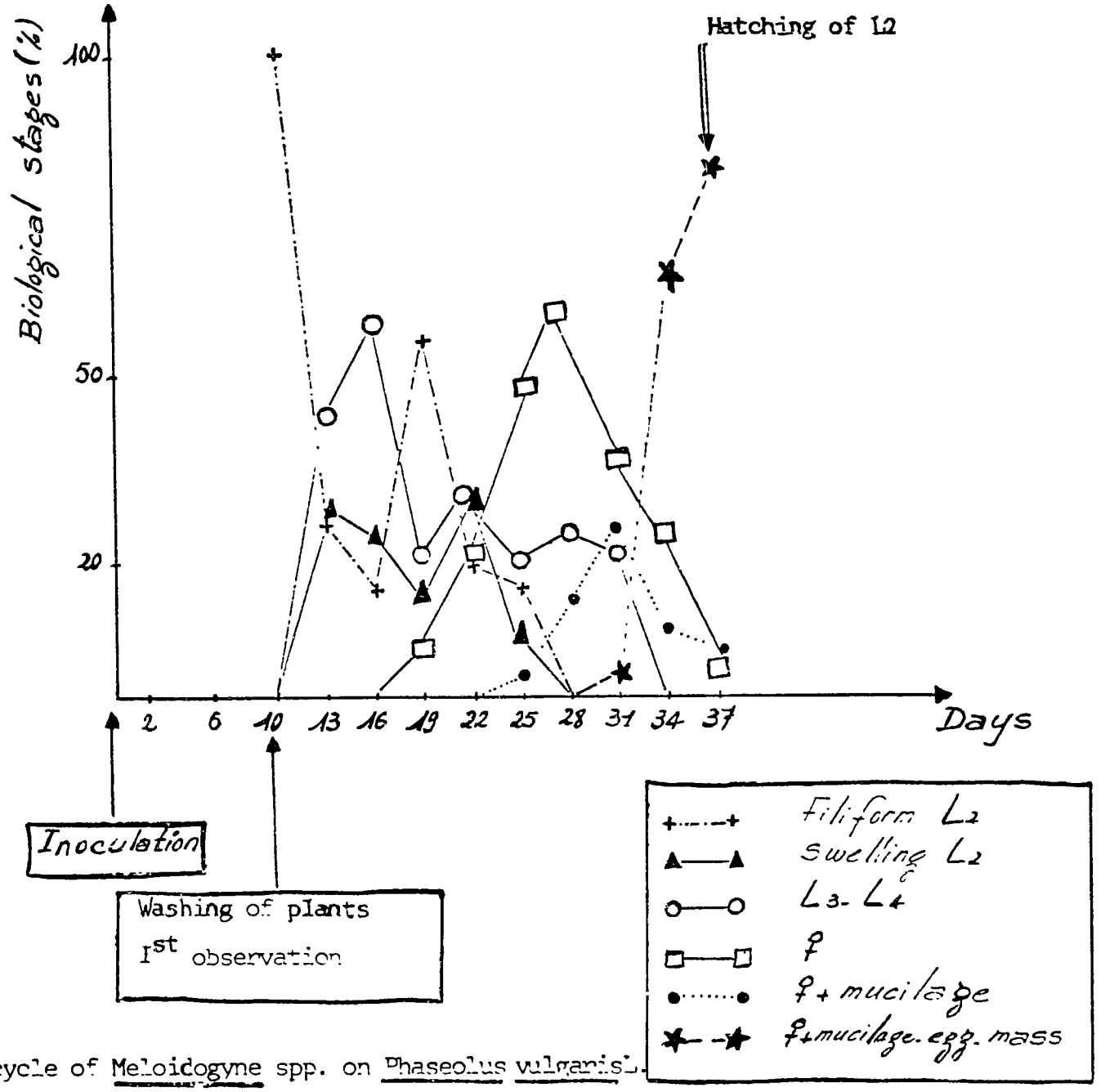


Figure 6. Life cycle of Meloidogyne spp. on Phaseolus vulgaris L.

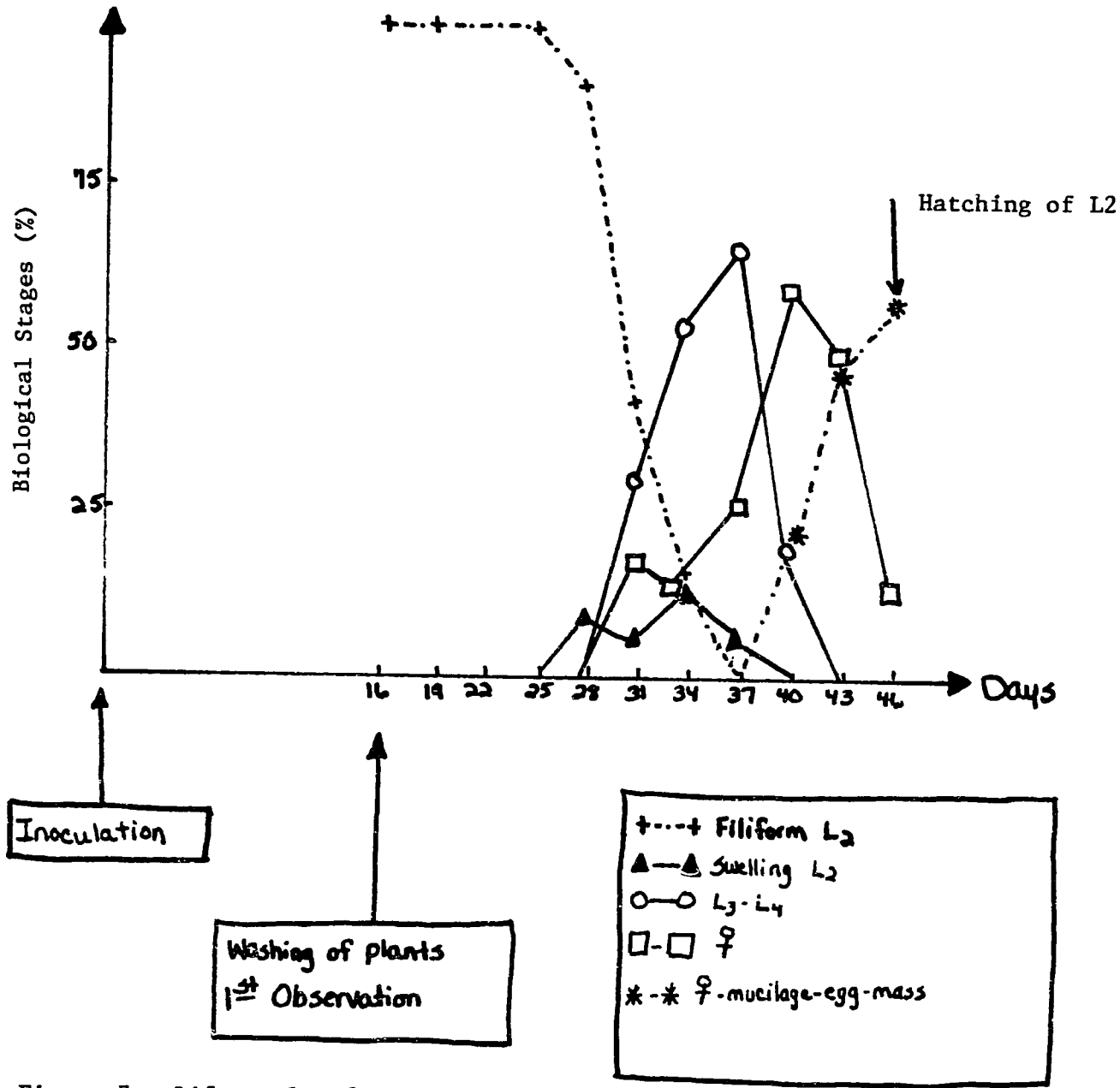
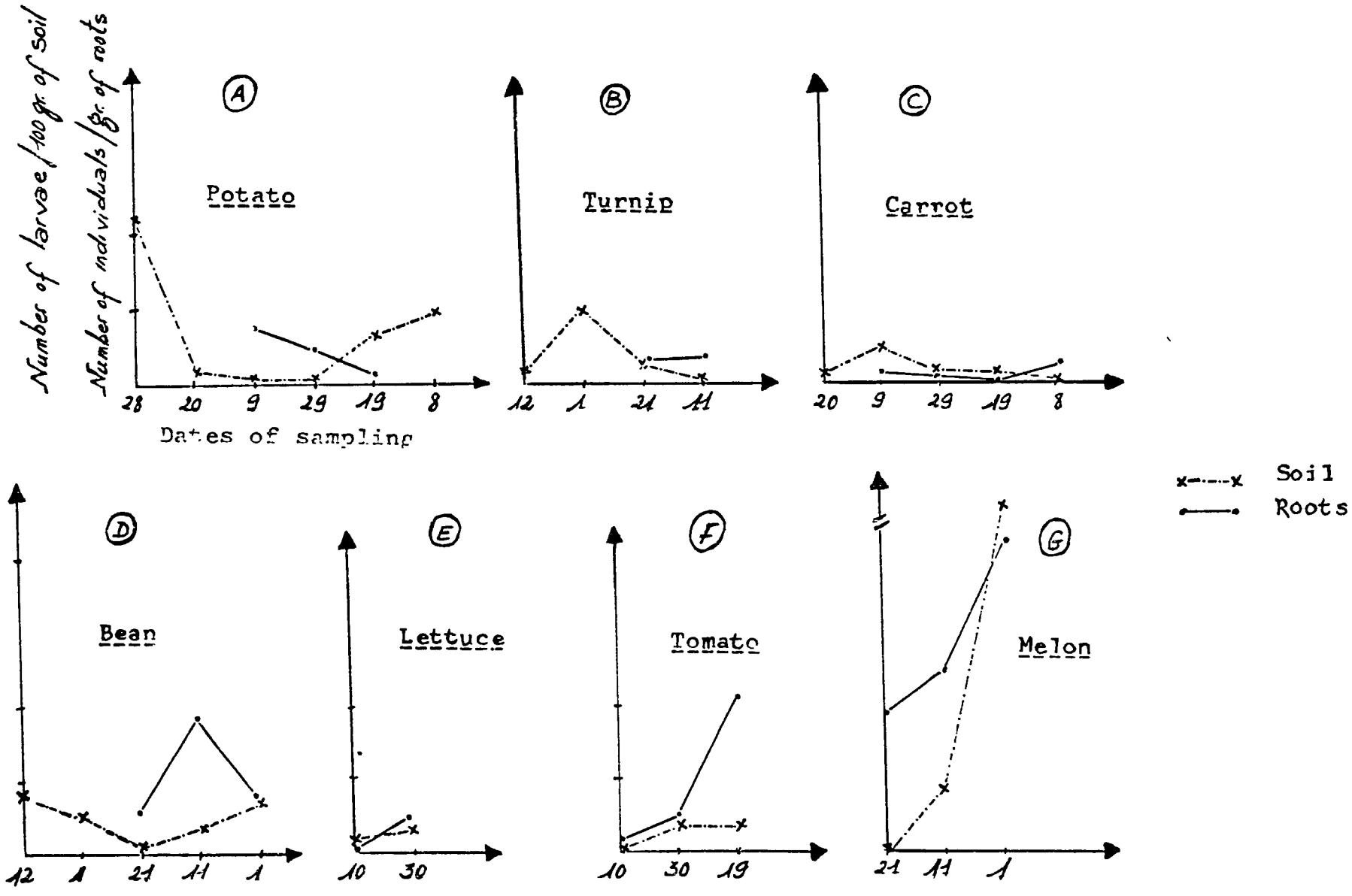


Figure 7. Life cycle of Meloidogyne spp. on Cucumis melo L.



Evolution of Meloidogyne sp on different crops

(Soil and roots)

STATE OF KNOWLEDGE OF ROOT-KNOT NEMATODES IN LIBYAN JAMAHIRIYA

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Available information regarding plant nematodes in Libyan Jamahiriya are scanty and fragmentary. Plant nematode problems of different crops have not been fully identified. Estimates of losses in different crops are not available. No survey exclusively for plant parasitic nematodes existing in the country has been done and species have not been identified and enumerated from different plants.

Earlier information available indicate that 4 species of Meloidogyne viz. Meloidogyne incognita, M. javanica, M. hapla and M. arenaria exist in the country. Kranz (1962) reported the occurrence of M. javanica on tomato, pepper, eggplant and okra and M. incognita on pepper, eggplant and okra in Cyrenaica region of the country. Pucci (1963, 1965) enlisted the diseases of plants in Libya observed during 1959-1964. Root-knot nematodes dominated in list of nematodes reported to affect different plants. M. incognita, M. javanica and M. hapla were identified from a number of hosts. M. incognita was observed to infect potato, tomato and pepper; M. javanica to peach, apricot, pepper, beans, broad bean, pea, potato and tomato; and M. hapla to peanut and carrot. The root-knot nematodes from cucurbits, cabbage, eggplant, sugarbeet, cotton, tobacco, lettuce, watermelon, apple and pear were not identified up to specific levels. The list of "Plant Diseases Recorded in Libya," presented at FAO Second Session of the Near East Plant Protection Commission contained a list of all plant disease agents and nematodes previously obtained in Libya and observed for the first time since 1965 (Anon. 1968). This list included M. incognita, M. javanica, M. arenaria and M. hapla infecting a variety of plants in different localities. The damage to plants was rated on 0-6 scale, but the basis of damage calculation was not provided. M. incognita was obtained on tomato, tobacco, pepper, peach and grapevines. Damage was reported to be from slight (+) to medium (++). M. javanica was observed on potato, tomato, tobacco, sugarbeet, alfalfa, broadbean, beans, pepper and peach. Damage was serious (++++) on tomato and potato and slight on sugarbeet, alfalfa, broadbean and beans.

M. hapla was found on peanuts, potato, tobacco, pepper, peas, beans, alfalfa, and carrot causing slight to medium damage. The list included M. arenaria for the first time from this country. It was noticed on almond, peanuts, potato, sugarbeet, tobacco and pepper. The damage ranged between slight to medium. No known reports of other species of Meloidogyne are available. The distribution of different species of root-knot nematodes on different crops in the country, their host range, levels of infestation, damage potentiality, population dynamics, etc., have not been studied. Knowledge about the existing species of Meloidogyne in the country seems to be incomplete. The identity of the species reported to exist on certain crops appears to be not well ascertained and needs reconfirmation. The root-knot problem seems to be steadily assuming greater significance in the country due to rapidly increasing intensive and extensive cultivation. There are more and more complaints of root-knot disease on increasing number of crops of economic importance from different parts of the country. The situation demands proper and urgent attention.

Recently, we have embarked upon a program to study the root-knot problems in Libyan Jamahiriya. Initially our emphasis is on vegetable crops, especially those extensively cultivated. Recent information obtained indicatesthat root-knot nematodes are serious problems on a number of plants of economic importance. Crops of tomato, pepper, potato, eggplant, cowpea, broad bean, lettuce, cauliflower, cabbage, okra, cucumber, squash, watermelon and Phaseolus spp. are affected with root-knot nematodes to a varying extent. The infestation appears to be widespread and seems to cover almost the entire coastal belt of the country where cultivated lands are mostly concentrated. Tomato, pepper, eggplant, okra and cucumber are almost invariably affected by root-knot to a varying degree. Galling on plants of tomato and cucumber grown in glasshouses and plastic tunnels has been observed to be generally higher than those cultivated in field plots.

Orchards and nurseries of peach, almonds, apricot, plums, pomegranate and vineyards have also been found to be infected to a varying extent. Banana plantation in one location was observed to be severely infected. Weeds like Solanum nigrum, common in vegetable fields, Amaranthus sp., Datura sp. and some others have been observed infected under field conditions.

The identity of the species in all the collections has not been ascertained so far. M. incognita and M. javanica have, however, been identified in a

number of collections. They appear to be prevalent species. The inocula from different hosts and areas are being maintained for identification and further studies. Root-knot on Eleusine indica was also noticed and Meloidogyne graminicola has been tentatively identified as causal organism. This, however, needs further confirmation.

REFERENCES

Anonymous. 1968. List of plant diseases recorded in Libya. Ministry of Agriculture and Animal Wealth. Plant Protection Department, Mimeograph.

Kranz, J. 1962. Plant Diseases in Cyrenaica. FAO Pl. Prot. Bull. 10(6): 121-125.

Pucci, E. 1963. Actual situation of major plant diseases in Libya. Ministry of Agriculture and Animal Wealth. Plant Protection Department. Mimeograph.

Pucci, E. 1965. Lista Preliminare delle Malattie delle piante osservate in Tripolitania. Dal 1959 Al 1964. Sintomi Danni Lotta. Rivista di Agricultura subtropicale e Tropicale. Anno. LIX No. 7-9.

SEED TREATMENT FOR CONTROL OF *M. INCOGNITA* ON COTTON*

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The principal objective of chemical control of plant-parasitic nematodes on annual crops is to reduce the preplant population to a level where little or no economic loss will occur. If seedlings are protected from nematode attack until an extensive root system has developed, ultimate damage to the crop usually will be minimal. For example, losses in yield of tobacco to *M. javanica* were found to be caused primarily by infection that occurred during the first month after transplanting. The sensitivity of tobacco to injury by *M. javanica* diminished with age of the plant. In the southeastern United States, sub-soiling under the row prior to planting cotton enhances root growth and allows penetration into the lower depths of the soil where population densities of plant-parasitic nematodes are low. Therefore, protection afforded by a nematicide is most critical during the seedling stage of cotton.

Control of nematodes with nematicides applied to seed has received little attention. In recent tests, systemic nematicides used as seed treatments were effective in controlling nematodes on several crops. Oxamyl, when applied to seed, retarded galling of watermelon by *M. incognita* and soybean and cucumber by *M. arenaria*.

The effects aldicarb and to a lesser extent its oxidation products, aldicarb sulfoxide and aldicarb sulfoue (UC-21865), on nematodes have recently been investigated. The principal effects of these carbonate nematicides are suppression of egg hatching and inhibition of migration of larvae of *Meloidogyne* spp. and *Heterodera schachtii*.

This paper reports on the effects of 2-methyl-2-(methylsulfonyl) propanal *O*-{(methylansino) = carbonyl} oxine (UC-21865 75% WP) applied as a seed treatment on penetration and development of *Meloidogyne incognita* on cotton under greenhouse conditions.

Materials and Methods

Seed of cotton (*Gossypium hirsutum* 'Stoneville 213') coated with UC-21865 75% WP at the rates of 5 g, 10 g, and 20 g, active per Kg (0.5, 1.0 and

*Work done at the University of Georgia at Athens in cooperation with Richard Hussey.

2.0 lb/100 lb). Seeds were planted three per 15 cm pot filled with bromide-fumigated sandy loam soil in the greenhouse and seedlings were thinned to one per pot after 6 days. At seeding, 12,000 eggs of Meloidogyne incognita were collected with 1.05% NaOCl as described by Hussey and Barker. Each treatment was replicated seven times in a randomized complete block design. The entire test was repeated once with data being reported from a single test.

Plants were harvested at 2, 4, and 6 weeks after seeding to study the effects of the seed treatments on penetration and progression of development of M. incognita. Root systems of plants harvested at 2 and 4 weeks were stained with acid fuchsin and examined under a stereoscopic microscope for larvae penetration and development. Numbers of larvae penetrating were counted and classified into one of five stages of development: (1) second-stage larva; (2) vermiform second-stage larva that had initiated galling; (3) swollen second-stage larva; (4) adult female with eggs; and (5) female with eggs.

Shoot height and fresh shoot and root weights were determined for plants harvested at 6 weeks. Root-knot nematode eggs were collected from root systems of 6-week-old plants with 1.05% NaOCl and counted.

Results

UC-21865 was effective against M. incognita when applied as a seed treatment on cotton. All treatments significantly suppressed the number of larvae that penetrated the roots 2 weeks after seeding (Table 1). The population of larvae in the roots was suppressed 57%, 93% and 89% by 5, 10, and 20 g active per kg seed, respectively. The population of swollen larvae (stage 3) in the roots of treated plants was suppressed from 85 to 98% compared with the population in nontreated plants. UC-21865 also affected the maturation of the infective second-stage larvae. The percentage of larvae in nontreated plants (35%) was considerably higher than for the treated plants (9 to 19%). Conversely, 52 to 82% of the larvae in the treated roots were vermiform larvae that had not initiated giant cells by 2 weeks, whereas only 21% in the nontreated roots were still in this stage.

Discussion

Many second-stage larvae in roots of treated plants were still located in the outer cortical tissue.

Nematode control was still evident 4 weeks after planting the treated seed. The population of M. incognita in the roots was suppressed from 87 to 95% (Table 1). Nematode development was also retarded, as indicated by the low percentage (10 to 24%) of females with eggs in the treated plants compared with the higher percentage (33%) in roots of the nontreated plants. Fewer nematodes and slower maturation in the treated roots was reflected in lower egg production 6 weeks after inoculation (Table 1). Egg production per plant was suppressed by 93, 77 and 59% by treatments 20, 10, and 5g/kg seed, respectively. Number of eggs per g of root tissue were also significantly reduced. Shoots and roots of cotton plants grown for 6 weeks from seed treated UC-21865 were not significantly larger than those from non-treated plants. Shoot height and shoot and root weights were 18.6 cm, 14.7 g and 10.0 g for the control plants and 20.0 cm, 17.2 g and 12.4 g for the treated plants, respectively. No phytotoxicity or inhibition of seed germination was caused by any of the seed treatments.

Sufficient quantities of UC-21865 when applied as a seed treatment are apparently absorbed by roots of cotton seeding to act systemically against M. incognita. Many second-stage larvae remained in the perphery of the cortex and failed to initiate giant cells, suggesting that UC-21865 affected the orientation of larvae similar to that described for aldicarb. Suppression of maturation of M. incognita also was manifested. Aldicarb and its oxidation products likewise retarded the development of H. schachtii larvae in sugar-beet, although UC-21865 was the least effective.

The short duration of the experiments reported here, as well as the favorable growing conditions in the greenhouse, were probably responsible for there being slight differences only in the growth of the treated and non-treated cotton plants. UC-21865 at the rates used in this study were not phytotoxic to cotton seed.

There are several advantages in using systemic nematicides for seed treatments. The principal benefit is a considerable reduction in the cost of nematicide application. For example, 454 g (a.i.) of UC-21865 will treat (at 1 lb a.i./100 lb seed) enough cotton seed for 3.2 ha. but when applied in the seed-furrow or banded in row, only 0.4 ha. (at 1 lb a.i./A) and 0.1 ha. (at 4 lb a.i./A) respectively, can be treated. Equally important, less pesticide would be introduced into the environment with fewer nontarget organisms being affected. Nematicide seed treatment, therefore, should be advantageous for nematode control for certain agronomic crops.

These greenhouse tests suggest that UC-21865 used as a seed coating is an effective and inexpensive method for providing at least 4 weeks of control of the root-knot diseases of cotton. The suppression of root invasion by second-stage larvae and egg production by the first generation of *M. incognita* should permit cotton plants to develop extensive root systems, which should result in little economic damage to the mature crop. Field trials need to be conducted to determine whether this initial suppression of *M. incognita* in the roots will in fact result in increased cotton yields.

Table 1. Effects of UC-21865 75% WP applied as a seed treatment on root penetration and development of *M. incognita* on cotton under greenhouse conditions.

Treatment g(a.i.)/kg seed	Periods of treatment									
	2 weeks				4 weeks				6 weeks	
	Nematode development[x] 1	2	3	Total nematodes penetrating	Nematode development 3	4	5	Total nematodes penetrating	Total eggs/ plant (10005)	Eggs/g root (10005)
Control	31 ab[y]	66a	53a	150a	189a	174a	178a	542a	81.2a	8.3a
UC-21865 5	34 a	24b	8 b	65 b	28 b	25 b	6 b	59 b	33.4b	2.8b
UC-21865 10	9 b	2 c	1 b	11 c	20 b	34 b	17 b	71 b	18.8b	1.6b
UC-21865 20	10 b	3 c	3 b	16 c	11 b	14 b	4 b	29 b	5.3c	0.4b

[x]Nematode development: 1 = second-stage larva; 2 = vermiform second-stage larva that had initiated galling; 3 = swollen second-stage larva; 4 = adult female without eggs; 5 = female with eggs.

[y]Column means followed by the same letter are not significantly different according to Duncan's Multiple Range Test. p = 0.05.

STATUS OF RESEARCH ON THE BIOLOGY AND CONTROL OF THE ROOT-KNOT NEMATODES IN ITALY

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Root-knot nematodes are of major economic importance in the southern regions of Italy. The most common species are Meloidogyne incognita (Kofoid et White) Chitw., M. javanica (Treub) Chitw. and M. naasi Franklin. Meloidogyne arenaria (Neal) Chitw. and M. hapla Chitw. are less common and present in limited areas (9). The crops most injured by M. incognita and M. javanica infestations are carnation, carrot, celery, cucumber, eggplant, pepper, sugar beet, tobacco, tomato and watermelon. Recently, corn and "Troyer" citrange, a citrus rootstock, were found attacked respectively by a population of M. incognita and M. javanica (Di Vito, unpublished) (8).

In 1978, heavy infestations of M. hapla were observed on sugar beet in a few fields of northern Apulia.

Meloidogyne naasi has been detected on durum wheat, barley and some leguminous weeds but not on oat (13).

PHYSIOLOGICAL RACES OF MELOIDOGYNE SPP. FOUND IN ITALY

During 1978 and 1979 attempts were made to identify the races of several root-knot species by differential host tests (12). Ten populations of M. incognita, 3 populations of M. javanica and 2 populations of M. hapla collected from different areas in Italy and Sicily were tested. Races 1 and 2 of M. incognita were identified. Race 2 appeared to be the most widespread, while race 1 was found only in Apulia and Sicily. Two populations of M. javanica from Sicily and Calabria reproduced on pepper cv. California Wonder in addition to tobacco cv. NC 95, tomato cv. Rutgers, and watermelon cv. Charleston Grey, which is not considered to be a host of M. javanica. These two populations could possibly be considered a new race of this species (Table 1). The two M. hapla populations showed the same host preference as indicated by the N. C. differential test (12).

HOST-PARASITE RELATIONSHIPS

The effect of population densities of M. incognita on the growth of corn seedlings was investigated in a glasshouse experiment at 24-27°C. Clay pots containing 500 ml of steam pasteurized sandy soil were inoculated with a geometric progression of (0, 1, 2, 4, . . . 1024) eggs and 2nd stage

juveniles/ml of soil and planted to corn. Using a method described by Seinhorst (11) the tolerance limit of corn to M. incognita in this experiment was about 10 eggs and 2nd stage juveniles per ml of soil (Di Vito, unpublished).

CONTROL OF MELOIDOGYNE SPP. BY CHEMICALS AND RESISTANT VARIETIES IN ITALY

Preplant chemical control experiments were conducted in fields infested with M. incognita and planted to tomato, watermelon, cantaloupe, sugar beet, eggplant and pepper (1, 2, 3, 5). The highest yields ranging from 28 to 196% compared to the controls were given by EDB, Phenamiphos, D-D, Di-Trapex and Aldicarb. Several Italian tomato varieties with good marketable quality were tested in M. incognita infested fields in 1978 and 1979 to check for resistance. The varieties were planted in twin plots: nematode infested, and disinfested with EDB at a rate of 130 l/ha, replicated 5 times. Only the variety IAS-1 was resistant to M. incognita. Yield of this variety was not reduced by the nematode and no galls were observed in the root system of plants grown in the nematode infested plots. A significant ($P = 0.05$) yield decrease, compared to the control, was noted in the infested plots planted with the nematode susceptible varieties. Roots of these varieties were heavily galled (4).

Several pepper lines were screened in a glasshouse at 24-26°C to check their resistance to M. incognita, M. javanica and M. arenaria. Capsicum annuum L. "P.I. 159237" and "P.I. 159256" and C. frutescens "Webb" and "Tabasco" were resistant to the three nematode species. Capsicum chinense "Surinam 4" was resistant to M. incognita and M. javanica.

In another study, the progenies obtained from interspecific hybrids F_1 of C. annuum x C. frutescens, from their back-crossing (F_1BC_1) and F_2 gave 73% and 42% M. incognita resistant plants. This confirms that resistance to this nematode is a dominant monogenic character in C. frutescens (7). From an analysis of the F_1 hybrids progenies of resistant x susceptible lines of C. annuum it has been ascertained that resistance to M. incognita is due to recessive factors because all F_1 plants were susceptible (10). Genetic studies are continuing.

REFERENCES

Di Vito, M. and F. Lamberti. 1977. Prove di lotta chimica contro i nematodi galligeni su Barbabietola da zucchero. Nematol. medit. 5:31-38.

Di Vito, M. and F. Lamberti. 1978. Prove di lotta chimica contro i nematodi galligeni del Melone. Atti Giornate Fitopatologiche 1978. pp. 405-411.

Di Vito, M. and F. Lamberti. 1978. Prove di lotta chimica contro Meloidogyne incognita su Anguria. Nematol. medit. 6:129-132.

Di Vito, M. and A. Carella. 1979. Behaviour of some industrial tomato varieties to Meloidogyne incognita infestations. Abstr. Giornate Nematol. pp. 2-4 (Nov. 28-29, 1979), Florence, Italy.

Di Vito, M., F. Lamberti, and A. Carella. 1977. Ulteriori risultati di prove di lotta chimica contro Meloidogyne incognita su Barbabietola da zucchero. Nematol. medit. 5:339-343.

Greco, N., M. Di Vito, and M. Basile. 1979. Present knowledge on the control of plant-parasitic nematodes of horticultural, flower and industrial crops. Abstr. Giornate Nematol. p. 26 (Nov. 28-29, 1979), Florence, Italy.

Hare, W. W. 1957. Inheritance of resistance to root-knot nematodes in pepper. Phytopathology 47:455-459.

Inserra, R. N., G. Perrotta, N. Vovlas, and A. Catara. 1978. Reaction to citrus rootstocks to Meloidogyne javanica. J. Nematol. 10:181-184.

Lamberti, F. 1979. Economic importance of Meloidogyne spp. in subtropical and mediterranean climates. In "Root-knot Nematodes (Meloidogyne Species), Systematics, Biology and Control" (Eds. F. Lamberti and C. E. Taylor) Academic Press, London and New York, pp. 341-357.

Saccardo, F., M. Di Vito, N. La Gioia, and A. Carella. 1979. Wild species of Capsicum as source of resistance to Meloidogyne spp. Abstr. Giornate Nematol. p. 41 (Nov. 28-29, 1979), Florence, Italy.

Seinhorst, J. W. 1965. The relation between nematode density and damage to plants. Nematologica 11:137-145.

Taylor, A. L. and J. N. Sasser. 1978. Biology, Identification and Control of Root-knot Nematodes (Meloidogyne spp.). Dept. Plant Pathology, N.C. University, Raleigh, N.C. 27650. pp. 111.

Vovlas, N. and R. N. Inserra. 1979. New host records of Meloidogyne naasi from Italy. Plant Dis. Reptr. 63:644-649.

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

Meloidogyne spp. and races	Number of populations	Differential Host Plant					
		Tobacco, N.C. 95	Cotton, Deltapine 16	Pepper, California Wonder	Watermelon, Charleston Grey	Peanut, Florrunner	Tomato, Rutgers
M. incognita							
Race 1	2	-	-	+	+	-	+
Race 2	8	+	-	+	+	-	+
M. javanica							
Race 1	1	+	-	-	+	-	+
Race 2	2	+	-	+	+	-	+
M. hapla	2	+	-	+	-	+	+

A PROGRESS REPORT OF RESEARCH COMPLETED AT THE RESEARCH CENTER OF THE INTERNATIONAL *MELOIDOGYNE* PROJECT

J. N. Sasser and A. C. Triantaphyllou

Introduction

Research on several aspects of the biology, behavior, and bio-chemistry of *Meloidogyne* spp. is being carried out at North Carolina State University in connection with the International *Meloidogyne* Project. This report will cover only a portion of the work, namely the frequency of occurrence of the major *Meloidogyne* species, pathogenic variation within these species, results of cytogenetic studies on many of the populations sent to the Research Center, biochemical studies and ecological factors influencing survival and pathogenicity of *Meloidogyne* species.

Identification of and Pathogenic Variation Within Field Populations

Seven hundred and fifty-six field populations sent to Raleigh by local country cooperators have been studied for pathogenic variation and species identification. *Meloidogyne incognita* and *M. javanica* together make up more than 80% of these populations, followed by *M. hapla* and *M. arenaria* (Table 1). Other species (*M. exigua*, *M. naasi*, *M. microtyla*, *M. graminicola*, *M. megatyla*, *M. oryzae*, and others) are only rarely encountered. Data on the distribution and frequency of these species is biased by the location and type of crops sampled; the majority of the samples being from vegetable and field crops in tropical regions. Species such as *M. hapla* and *M. naasi* would be expected to be found in higher frequencies in the temperate climates. Other species such as *M. brevicauda* and *M. mali* have very limited host ranges (tea and *Malus* spp., respectively) and would not be expected to be found unless these crops were sampled. For these reasons, those species with wide host ranges and tropical to subtropical habitats would be expected to predominate. Nevertheless, it is noteworthy that *M. incognita* and *M. javanica* are the most frequently encountered species.

During the identification of the field populations it was noted that a mixture of species was occasionally encountered. Seven percent of the field populations contained more than one species. Mixtures of *M. incognita* and *M. javanica* occurred with the highest frequency. Mixtures of other species occurred with lower frequencies.

A major portion of the work on the Meloidogyne populations sent to Raleigh has involved the study of pathogenic variation within each species. This involves tests on the ability of each population to infect and reproduce on a standardized set of differential hosts. Previous studies have demonstrated that populations of M. incognita, M. javanica, M. hapla and M. arenaria respond to the host differentials in a characteristic or "usual" way (Table 2). Deviations from the "usual" host responses, therefore, are an indication of pathogenic variation. The results of these studies are not intended to be used in developing crop rotation systems because of the limited number of host differentials used. Nor can it be inferred that the results of the studies completely characterize the pathogenic variation within a species. The limited number of host differentials used in these studies are only intended to give some indication of the pathogenic variation that exists among populations of Meloidogyne species from widely separated geographic regions of the world.

Based on the ability to parasitize cotton (cv 'Delta Pine 16') and tobacco (cv 'NC 95'), four host races of Meloidogyne incognita have been identified (Table 3). Based on the ability to parasitize peanut (cv 'Florrunner'), two host races of M. arenaria have been identified. There are no morphological differences among the host races of M. incognita or M. arenaria. The host races of these species are apparently worldwide in distribution, and for M. incognita do not appear to have developed through selection pressures. With M. arenaria, some selection pressure may be involved in the development of the two host races; Race 1, which attacks peanuts, has generally been found in regions where peanuts are frequently cultivated. Race 2 of M. arenaria, which does not attack peanuts, is generally from regions where peanuts are not grown. No host races have been detected among the different populations of M. javanica and M. hapla.

Morphological Studies

Considerable progress has been made in elucidating morphological characters which are reliable in distinguishing between species of Meloidogyne. These contributions to the project have been made by Drs. J. D. Eisenback, Research Associate, and Hedwig H. Triantaphyllou, Cooperator. Details of these studies are given in several publications (1, 2, 3).

Cytogenetic Studies

About 450 populations of root-knot nematodes from 55 countries have been studied cytogenetically. A summary of this work has been published (6) and

includes information about mode of reproduction, chromosomal complement, cytotaxonomy and methodology employed in the study of these nematodes. This extensive cytogenetic work demonstrated that evolution of root-knot nematodes has been influenced by the establishment of polyploidy and aneuploidy in association with various types of parthenogenetic reproduction. Furthermore, it revealed four possible steps in the cytogenetic evolution of root-knot nematodes (Table 4). The first step represents the evolution of meiotic parthenogenesis from amphimixis; the second involves changes in the karyotype which resulted in the reduction of the haploid chromosome number; the third step includes the evolution of mitotic parthenogenesis; and the fourth the establishment of polyploidy in mitotically parthenogenetic forms. Each step is associated with an increased level of parasitism, especially the second and fourth steps which appear to have given rise to the most successful forms of root-knot nematodes.

Biochemical Studies

A "micro" system has been developed that permits the electrophoretic analysis of very small samples of proteins. This has enhanced our ability to study the proteins and enzyme systems produced by Meloidogyne species. Several enzyme systems, including non-specific esterases, RNases, peroxidases, and β-glycosidases, have been examined using this system. Although differences in the isozyme profiles of esterases and RNases among different Meloidogyne species are evident, considerable variation within species was also evident. Studies with peroxidases (5) indicate that much of the peroxidase activity associated with adult females is of host origin; probably in ested by the nematode during the feeding process. This phenomenon may be responsible, in part, for the variation in the isozyme profiles of esterases and RNases. Other studies provide evidence for the presence of β-galactosidase and β-glucosidase activities within the nematode, with β-galactosidase activity being predominant. A portion of this glycosidase activity is undoubtedly of host origin, but the evidence also indicates the presence of enzyme activity of nematode origin. These studies have increased our knowledge of the capacity of Meloidogyne species to produce enzymes that may be involved in pathogenesis. Additionally, these studies have indicated new areas of investigation which will lead to a better understanding of the complex host-pathogen associations that exist with root-knot nematodes.

Ecological Studies

An important objective of the International Meloidogyne Project has been to gain some insight concerning those ecological factors which influence survival and pathogenicity of root-knot nematodes. Three kinds of information were collected or determined for each of 346 populations of Meloidogyne included in this study. These were 1) identification of the species using morphological, physiological (host response) and cytogenetic characteristics; 2) physical and chemical characteristics of the soil in which the nematode was surviving; and 3) information on the habitat from which the nematode was collected, including host, location, amount of damage (estimated percent crop loss and root gall index), cropping history of field sampled, and weather data. A computer program was developed to sort out various kinds of data and to make correlation analyses. The Meloidogyne species and race, as well as the estimated percent loss of the crop and severity of root galling served as a backdrop or reference point for measuring the effects of various ecological factors associated with the disease.

Survival and pathogenicity of Meloidogyne species on suitable hosts appear to be affected primarily by temperature, precipitation and soil texture. This is based on ecological data recorded for 346 populations of Meloidogyne spp. collected from 52 countries. Average annual temperatures for M. hapla, 3-15 C (this range included 87% of all M. hapla samples); M. arenaria, 15-27 C (90%); M. incognita, 18-30 C (90%) with the greatest number in the range of 24-27 C (47%); M. javanica, 18-30 C (97%). Minimum temperature, calculated as the average temperature for the coldest month of the year also affected distribution. Of the 23 M. hapla populations, 20 came from localities where the average temperature for the coldest month was 0 C or less. None of the other species were from areas where the low temperature was less than 3 C, suggesting that these species are limited in distribution by minimum temperatures above 0 C. The average warm month temperatures of the areas from which most populations of each species came were 22 C for M. hapla and 26 C for M. incognita and M. javanica. Average annual precipitation where the 346 populations were collected ranged up to 6500 mm, but nearly 94% were from areas in the range of 0-2500 mm, with the maximum number (33%) of all populations occurring in the range of 1000-1500 mm. Eighteen percent of the M. incognita and 39% of M. javanica populations came from areas with less than 500 mm annual precipitation. One-hundred samples came from dry climates (3 or more months with less than 10 mm precipitation/month). Of these, 68 were identified as M. javanica

and 32 as either M. incognita or M. arenaria. This suggests that M. javanica is better adapted to survive under dry conditions than other species, especially M. incognita. Among the 346 samples, 240 had gall indices of 3 or more on a scale of 0 to 5. Of these, 54% came from soils with more than 55% sand and 17% came from soils containing less than 35% sand. A significant correlation was found between reported gall index and crop loss, but not between gall index and number of years the land had been farmed, the number of months the land had been in susceptible crops during the 2 years prior to sampling, or the number of months of growth of the crop at time of sampling. These data from farms where little attempt has been made to control nematodes suggest that climate and soil influence Meloidogyne survival and pathogenicity more than management practices.

Table 1. *Meloidogyne* species identified from field populations sent to the IMP Research Center (Raleigh, NC) by local country cooperators.

Species	% of 756 populations studied
M. incognita	52.8
M. javanica	30.7
M. hapla	7.5
M. arenaria	7.3
Others[a]	1.7

[a]Includes populations of *M. exigua*, *M. microtyla*, *M. megatyla*, *M. graminicola*, *M. graminis*, *M. oryzae*, *M. naasi*, *M. carolinensis*, *M. querciana* and others.

Table 2. Usual response of host differentials to attack by the common *Meloidogyne* species.

	Differential hosts[a]					
Species	Tobacco	Cotton	Pepper	Watermelon	Peanut	Tomato
M. incognita	±	±	+	+	-	+
M. javanica	+	-	-	+	-	+
M. hapla	+	-	+	-	+	+
M. arenaria	+	-	+	+	±	+

[a]Plant varieties include: Tobacco, NC 95; cotton, Delta Pine 16; pepper, California Wonder; watermelon, Charleston Grey; peanut, Florrunner; tomato, Rutgers.

Table 3. Host races of *Meloidogyne incognita*

	Host response		% of 399
Race	Cotton	Tobacco	populations studied
1	-	-	71.4
2	-	+	15.0
3	+	-	11.0
4	+	+	2.5

Table 4. Cytogenetic characteristics of *Meloidogyne* spp.

Meloidogyne species	Chromosome No.	Mode of Reproduction
M. megatyla	n=18	
M. carolinensis	n=18	Amphimixis
M. microtyla	n=19	
		1st[a]
M. exigua		
M. graminicola		Facultative
M. naasi	n=18	meiotic
M. graminis		parthenogenesis
M. ottersoni		
	2nd	
M. hapla - Race A	n=17,16,15,14	
	n=34	
		3rd
M. arenaria - Race B	2n=36	
M. incognita - Race B	2n=32-36	
M. hapla - Race B	2n=30-32	Obligatory
M. querciana	2n=30-32	mitotic
	4th	
M. hapla - Race B	3n=43,45,48	parthenogenesis
M. arenaria - Race A	3n=51-56	(apomixis)
M. incognita - Race A	3n=40-46	
M. javanica	3n=43-48	

[a]Major steps of cytogenetic evolution associated with increased levels of plant parasitism.

LITERATURE CITED

1. Eisenback, J. D. and Hirschmann, Hedwig. (1978). Morphological Comparison of Second-Stage Juveniles of Six Populations of Meloidogyne hapla by SEM. Journal of Nematology 11:5-16.

2. Eisenback, J. D. and Hirschmann, Hedwig. (1979). Morphological Comparison of Second-Stage Juveniles of Several Meloidogyne Species (Root-Knot Nematodes) By Scanning Electron Microscopy. SEM III pp. 223-230.

3. Eisenback, J. D. and Hirschmann, Hedwig. (1979). Morphological Comparison of Meloidogyne Males by Scanning Electron Microscopy. Journal of Nematology 12:23-32.

4. Sasser, J. N. (1980). Root-Knot Nematodes: A Global Menace to Crop Production. Plant Disease 64:36-41.

5. Starr, J. L. (1978). Peroxidase Isozymes from Meloidogyne spp. and Their Origin. Journal of Nematology 11:1-5.

6. Triantaphyllou, A. C. (1979). Cytogenetics of Root-Knot Nematodes. In: Root-Knot Nematodes (Meloidogyne Species) Systematics, Biology and Control. F. Lamberti and C. E. Taylor, editors. Academic Press, New York. pp. 85-109.