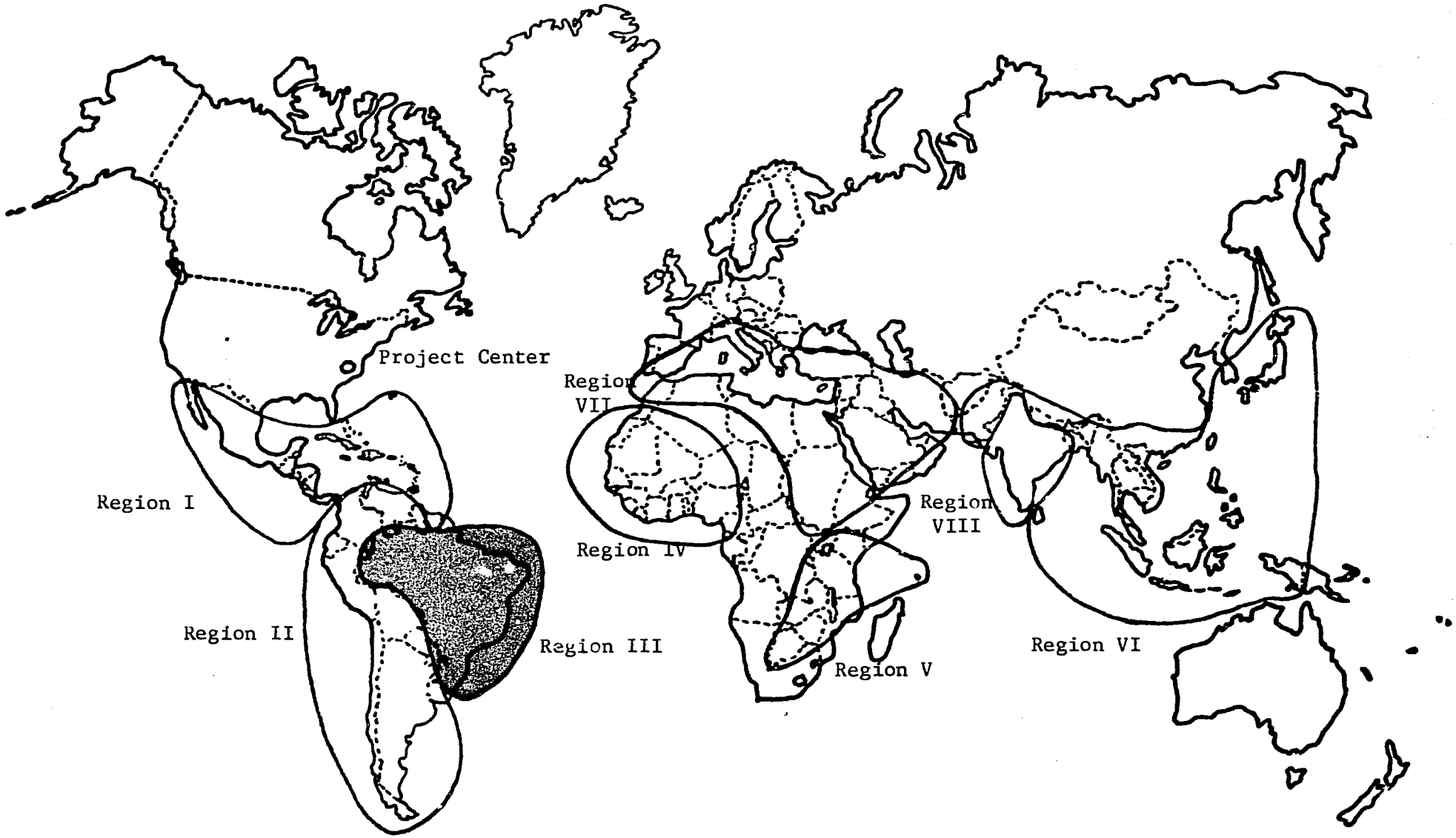

Figure 1. The eight geographical regions of the International Meloidogyne Project.

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INTERNATIONAL MELOIDOGYNE PROJECT

IMP

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Proceedings of the Research and Planning Conference on Root-Knot Nematodes Meloidogyne spp.

October 25-29, 1982

REGION III

Brazil

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PREFACE

This Region III Research & Planning Conference on Root-knot Nematodes was held October 25-29, 1982, in Brasilia, Brazil. The Department of Plant Biology of the University of Brasilia and the International Meloidogyne Project (IMP) planned this cooperative endeavor. The IMP, headquartered at North Carolina State University, Raleigh, North Carolina, U.S.A., is a worldwide network of over 100 scientists grouped into eight geographical regions. Brazil has a sufficiently large number of nematologists that it comprises an entire region in itself.

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

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

ORGANIZING COMMITTEES

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Dr. C. S. Huang, Universidade de Brasilia, Brazil

Dr. Romero M. de Moura, Universidade Federal Rural de Pernambuco, Brazil

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Juvenil H. Cares	Reception and Technical Sessions
Joao P. Pimentel	Reception and Transportations

Thanks also go to the Department of Plant Biology of the University of Brasilia for providing facilities for the conference. Finally, we acknowledge Mrs. Catherine Carter, Research Assistant, for editing and arranging the proceedings; Dr. C. S. Huang, nematologist, for proof-reading the Portugese papers; and Milly Oldham, secretary, for typing the master copy.

J. N. Sasser

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Discurso de Abertura

Dr. Ubiratan M. Serrão
Secretário Nacional de Defesa Agropecuária
Ministério da Agricultura

Por delegação do Senhor Ministro Ângelo Amaury Stabile, com muita honra, faço a abertura da Conferência Internacional de Pesquisas sobre os Nematóides, promovida pela Universidade de Carolina do Norte, Estados Unidos, Coordenadora do Projeto Internacional de Meloidogyne - IMP.

Inicialmente, apresento as boas vindas aos senhores participantes, que vieram das mais longínquas regiões do Brasil e, também, do exterior.

Desejo destacar, nesta oportunidade, a presenta do Doutor J. N. Sasser, Diretor do IMP, com sede na Carolina do Norte - USA, que participa deste evento, para enfatizar a sua importância no âmbito da comunidade nematológica internacional.

Como Secretário Nacional de Defesa Agropecuária, tenho bastante interesse na realização deste encontro, que se reveste de grande proveito para o país.

Espero, que sua realização seja proveitosa, porquanto será enriquecida com as experiências acumuladas dos membros do IMP, bem como de todos aqueles que realizam pesquisas com nematóides.

Em nome do Senhor Ministro, desejo-lhes feliz estada em Brasília e bom trabalho nesta casa, que lhes pertence, e reafirmando a elevada significação dessa reunião para os trabalhos deste ministério, declaro aberta a Conferência Internacional de Pesquisas sobre Nematóides.

Opening Speech

Dr. Ubiratan M. Serrão
National Secretary for Crop and Animal Protection
Ministry of Agriculture

On behalf of the Minister of Agriculture, Dr. Angelo Amaury Stabile, I am here with great honour to open this International Conference on Meloidogyne species promoted by North Carolina State University of the United States of America and the Braziiian nematologists.

Initially, I would like to extend our welcome to the distinguished participants who have come to Brasilia from the other regions of Brazil and from abroad.

I would like to call special attention on this occasion to the presence of Dr. J. N. Sasser of North Carolina State University who is Principal Investigator of the International Meloidogyne Project. His presence at this conference emphasizes the importance of this meeting in the international nematology community.

As the National Secretary for Crop and Animal Protection, I have enormous interest in the proceedings of this meeting because the results of the event will serve the Country greatly.

I hope that your activities in the meeting will be productive because the event is being enriched by the accumulated experiences of the members of IMP, as well as by the knowledge of all of you who have done research on nematodes.

In the name of the Minister, I wish you a happy stay in Brasilia and, especially, good work in this house, which is being made available to you for your use. Reiterating the importance of the meeting to the work of this Ministry, I hereby declare the International Conference on Meloidogyne species open.

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

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

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

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

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

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

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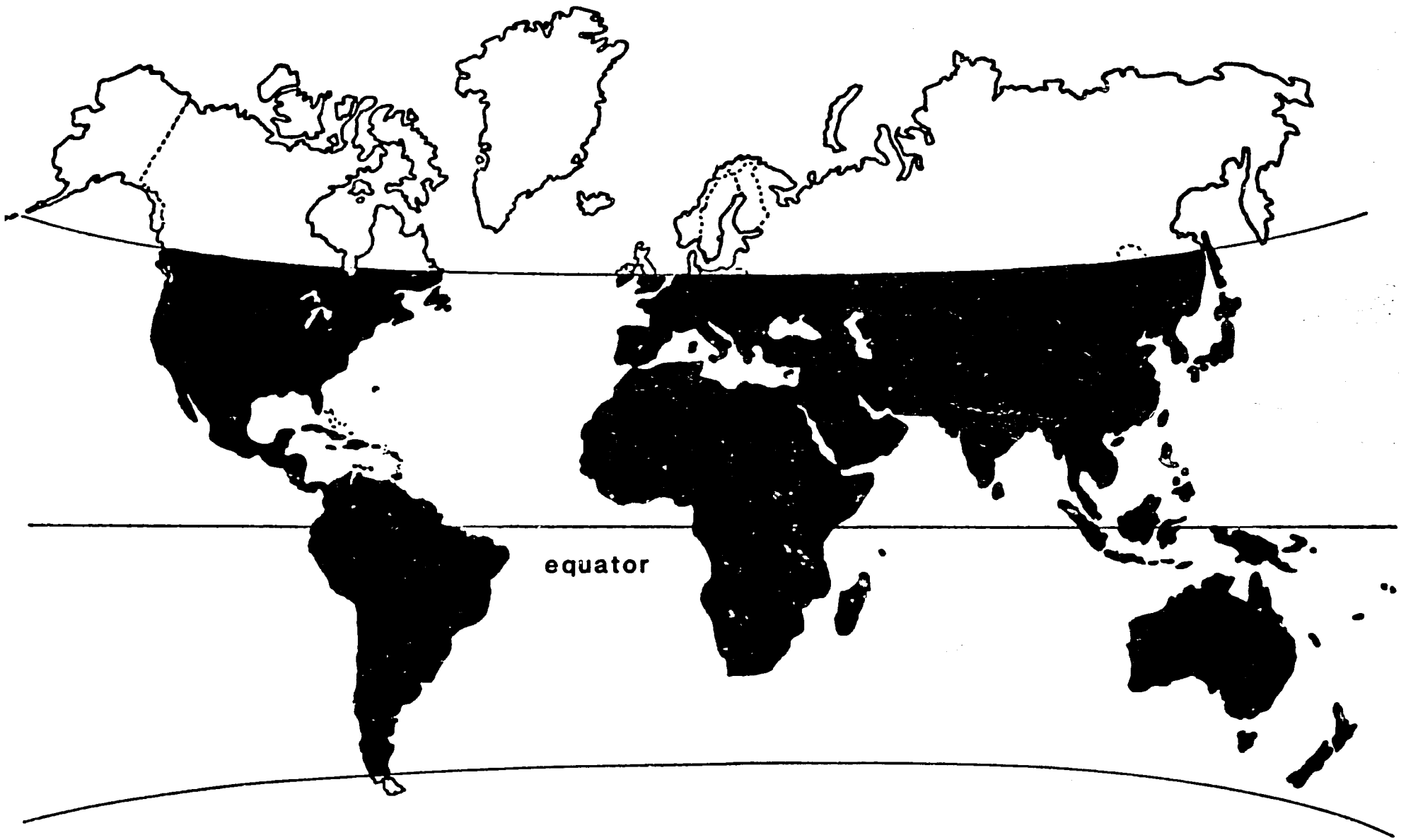
*Principal Investigator, IMP, and Research Assistant, North Carolina State University, respectively.

Figure 1. Approximate distribution of root-knot nematodes.



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

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

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

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

Root-Knot Nematode Germplasm Collection

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

North Carolina Differential Host Test (2)

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

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

Morphology (1)

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

Table 1. North Carolina Differential Host Test Reaction Chart

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

*Box indicates key differential host plants.

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

Reproductive and Cytological Characters

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

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

Biochemistry

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

Ecology

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

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

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

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

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

Management

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

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

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

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

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

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

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

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

Technology Transfer

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

Summary

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

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

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

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MELOIDOGYNE SPECIES IN BRAZIL

Ailton Rocha Monteiro*

"Invited by one of the most important farmers" of Cantagallo, in the Province of Rio de Janeiro, Brazil, in August 1877, C. Jobert studied a disease of coffee trees. He observed numerous galls in the roots of the apparently vigorous plants that he asked to be pulled out around the diseased ones. Inside the galls, he saw "cysts" and eggs, some of the last with small nematodes. Jobert's observations were published in 1878, in France, and they seem to be the first record of root-knot nematode disease in a field crop (10, 14, 32).

The Imperial Brazilian Government, worrying about the serious problem of coffee plantations, designated Prof. Dr. Emílio Augusto Goëldi, a renowned zoologist, to study the disease. In 1887, Goëldi published his known report Relatório sobre a moléstia do cafeeiro na Província do Rio de Janeiro; in 1892, it was republished in the journal Archivos do Museu Nacional, vol. 8 (11, 16, 19). In his study, Goëldi came to the same conclusion of Mr. Jobert concerning the nature of the disease of the coffee trees in Rio de Janeiro: a nematode, inciting galls in the roots, was the primary cause of disease. To this nematode, Goëldi gave the scientific name Meloidogyne exigua. The name of the new genus was derived from Greek words meaning "apple-shaped" and "female." The specific name exigua is a Latin adjective concerning the small size of the "encysted" female.

In 1879, Cornu (9) described and named as Anguillula marioni, a root-knot nematode on Onobrychis sativa Lam. from Chateauneuf-sür-Loire, France; in 1884, Mueller synonymized it with Heterodera radicicola (Greeff, 1872) (13, 26). In 1885, Treub described as Heterodera javanica a root-knot nematode from sugarcane in Java (33). In 1889, Neal identified the root-knot nematodes of various plants in Florida, USA, as Anguillula arenaria (27).

---

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In 1919, Kofoid and White gave the name Oxyuris incognito to a nematode described from eggs encountered in the feces of soldiers in Texas, USA (15). Sandground pointed out that these eggs agreed in all known characteristics with those of root-knot nematode, then known as Heterodera radicicola (30).

In 1924, Cobb ignoring the Goeldi's paper, proposed the name Caconema (nom. nov.) for the root-knot nematodes (8).

In 1932, Goodey (12) showed that Anguillula radicicola Greef, 1872 (13), a nematode from the root galls of Poa annua, Triticum repens and Sedum spp., was in fact a slender species not closely related to the cyst or the true root-knot nematodes.

Goodey considered that the correct name of the root-knot nematode should be Heterodera marioni (Cornu, 1879), and this name lasted until the revision of the Genus Meloidogyne Goëldi, 1887 by Chitwood in 1949 (4, 9, 11).

Studying the morphology of the root-knot nematodes, Chitwood was convinced that they indeed constituted a valid genus and that several species should be distinguished. Chitwood was magnanimous in reviving the genus Meloidogyne and in adopting most of the early species names because there were no type specimens and the original descriptions of the nominal species were not identifiable below generic level. Chitwood's work made it possible to distinguish as species four of the "races" of H. marioni recognized in the works by Christie and Albin (6) and Christie and Haris (7). In 1949, Chitwood (4) identified the following species: Meloidogyne exigua Goëldi, 1887 (type species); M. javanica (Treub, 1885) Chitwood 1949; M. hapla Chitwood, 1949; M. incognita (Kofoid & White) Chitwood, 1949; M. incognita acrita Chitwood, 1949; and M. arenaria (Neal, 1889) Chitwood, 1949. Later Chitwood (5) proposed the name Meloidogyne arenaria thamesi for the material that he had illustrated as M. arenaria from Boehmeria in his 1949 work.

In Brazil, like in other countries, the work of Goëldi stayed ignored or forgotten, and the root-knot nematodes were called Heterodera radicicola or Heterodera marioni until the end of 1940's.

At this time in Brazil, Dr. Olavo José Book of the Instituto Agronômico in Campinas, State of São Paulo, was concerned with the damage caused by nematodes in many crops in Brazil. He successfully convinced Dr. Carlos Arnaldo Krug, a distinguished director of that Research Institute, of the importance of nematodes to Brazilian agriculture. Therefore, the IAC invited Dr. Gotthold Steiner from the USDA to come to Brazil. The eminent nematologist arrived at Campinas on January 2, 1951, carrying a microscope that he had bought with the money left over after the purchase of his ticket (21; book, not published). Two followers of Dr. Steiner renewed the study of plant nematology in Brazil: Dr. Jair de Carvalho, of the Instituto Biológico de São Paulo, and Dr. Luiz Gonzaga E. Lordello, from the Escola Superior de Agricultura "Luiz de Queiroz," Universidade de São Paulo.

Concerning the identification of Meloidogyne species, the results came quickly. In 1951, Boock (2) reported the occurrence of M. incognita in potato tubers, Solanum tuberosum L. The species M. javanica, M. hapla and M. arenaria were first identified in 1954 by Carvalho (3) in soybean roots, Glycine max Merril.

In 1956, Lordello (17) described M. javanica bauruensis as a parasite of soybean var Abura. From the same host cultivated in Campinas, he described another new species Meloidogyne inornata (18).

In 1958, Lordello and Zamith (22, 23) found M. exigua attacking coffee trees in the State of São Paulo and studied its morphology.

In 1960, Lordello and Zamith (24) described M. coffeicola, a new species that was causing the death of coffee trees in the State of Paraná, Brazil.

The 1964 work of Lordello (20) "Contribuição ao conhecimento dos nematóides que causam galhas em raízes de plantas em São Paulo e Estados Vizinhos" was laureated with the prize "Prêmio Defesa Sanitária Vegetal (1961) of the Sociedade Paulista de Agronomia."

In 1967, Moura (25) found M. arenaria thamesi parasitizing "fruta-pão de caroço," Artocarpus incisa L., in Pernambuco.

A new species, M. lordelloi, was described by Ponte (28) in 1969 as a parasite of cactus Cereus macrogonus, in the State of Ceará.

In 1977, Ponte (29) presented his thesis in order to obtain the degree of "Docente Livre" at the Universidade Federal do Ceará." The thesis included a catalogue of plant hosts of Meloidogyne species in Brazil and the description of a new species, Meloidogyne elegans (type host: Schrankia leptocarpa D.C.). It was edited as a book in 1978 and became one of the most valuable publications to the researchers interested in Meloidogyne spp. in Brazil. We hope that supplements for the catalogue will be published from time to time.

As we can see, 11 species (and subspecies) of Meloidogyne have been identified until now in Brazil. It would be 12, but M. incognita acrita has been considered indistinguishable from M. incognita (1, 31, 34, 35).

RESUMO

Especies de Meloidogyne no Brasil

Jobert (14) fez o primeiro relato de uma meloidoginose em cultura no campo ao publicar suas observações de uma doença do cafeeiro na então Província do Rio de Janeiro. O nematóide causador de galhas radiculares dos cafezais fluminenses foi posteriormente descrito como gênero e espécies novos, Meloidogyne exigua, por Goëldi (11), trabalho que foi reeditado em 1892. Como alhures, a proposição de Goëldi permaneceu ignorada e os nematóides das galhas foram chamados Heteroderodera radicicola ou H. marioni até o fim dos anos 40. Pouco depois da revalidação do gênero Meloidogyne por Chitwood (4), a nematologia foi reavivada no Brasil graças à vinda do eminente nematologista do Departamento de Agricultura dos Estados Unidos, Dr. Gotthold Steiner. Seus discípulos e a Escola que formaram registraram a ocorrência no Brazil de M. incognita (2), M. javanica, M. hapla, M. arenaria (3), M. arenaria thamesi (25) e descreveram novas espécies ou subespécies: M. javanica bauruensis (17), M. inornata (18), M. coffeicola (24),

M. lordelloi (28), e M. elegans (29). M. exigua foi redescrita por Lordello e Zamith (22, 23). O trabalho de Ponte (29) contém um catálogo de hospedeiros das espécies de Meloidogyne no Brasil.

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ROOT-KNOT NEMATODE PROBLEMS ON BEAN (PHASEOLUS VULGARIS L.) IN BRAZIL

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Introduction

Dry beans (Phaseolus vulgaris L.) constitute the basic dietary source of proteins in many countries, including Brazil. In 1980, the world production was 14.6 million tons. China, India and Brazil are the main producers and are responsible for more than 50% of the total crop. However, production per area is quite low in Brazil. One reason for this is the occurrence of many diseases and pests, among them the nematodes. The first report of plant-parasitic nematodes attacking beans in Brazil was published in 1955 (1), when Meloidogyne incognita was observed in roots of beans and other plant species in the State of São Paulo. Since then, the occurrence of M. incognita and/or M. javanica on beans in other States has been reported (5, 6, 7, 8, 9).

Tests conducted under microplot conditions showed a yield reduction of 67% in bean plants inoculated with M. incognita or M. javanica (5).

Survey of Plant-Parasitic Nematodes Associated with Beans in the State of Minas Gerais

The state of Minas Gerais holds the second position in the country as far as bean production is concerned. The State is divided into several areas called "Zonas." The "Zona da Mata" is one of the most important bean producers in the State. In 1976, a survey was carried out there in 23 counties (5). In each county, three or more farms were surveyed. Soil and root samples were taken from areas showing plants with good, medium and poor growth. Meloidogyne species, either M. incognita or M. javanica, were found in all counties. The other species found were: Helicotylenchus nannus, Criconemella onoensis, C. ornata, C. sphaerocephala, Pratylenchus brachyurus, Hemicycliophora lutosa, Xiphinema elongatum, X. krugi and X. seteriae.

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Another survey was initiated in 1978, in order that the presence and distribution of plant-parasitic nematodes associated with the different crops in Minas Gerais could be studied (3). In the first 394 soil samples taken from the root zones of 75 plant species collected in 50 counties, 34 genera of plant-parasitic nematodes were found. Meloidogyne was found in 30.5% of all samples. Ten different bean fields were sampled, and Meloidogyne was present in four of them.

Pathogenicity Trial

The assay was conducted in concrete boxes (110 x 60 x 50 cm) filled with artificially-infested soil (5). Fourteen bean plants, cultivar 'Rico 23,' were maintained in each microplot. By planting time, the nematode population consisted of 2,900 juveniles of M. incognita/100 g of soil and 2,700 juveniles of M. javanica/100 g of soil. Each box was filled with soil containing one of the two species except in one treatment where both species were maintained by mixing the soil half and half. The results are shown in Table 1 and indicate a very strong effect on number of pods/plant, yield and plant height.

Screening Program

Considering that beans are, in Brazil, a low income crop, the search for resistant varieties is a very attractive approach in order to solve the problem of controlling root-knot nematodes. The first report on this subject came from Vieira (14). He tested 18 bean varieties against M. incognita, and none of them showed resistance. Twenty-five varieties were screened by Sharma & Mohan for their resistance to M. javanica, under greenhouse conditions (13). All of these were susceptible. The variety 'Cara suja' was considered to be less susceptible than the others. In another test, Sharma screened 25 other varieties using the same nematode species, and except for the variety 'Engorda mulher,' which was considered tolerant, all others were susceptible (11). Twenty bean lines were also susceptible in a later test with M. javanica, according to Sharma & Guazelli (12).

The screening program at the Federal University of Viçosa, MG, started in 1976 (4). Thirty-one bean varieties were inoculated with M. incognita and M. javanica under greenhouse conditions. Forty-five

Table 1. Effects of *Meloidogyne incognita* and *M. javanica*, alone or combined, on the yield and growth of bean variety 'Rico 23'

Tratamentos	NP/P*	WHS(g)*	NS/P*	SW/P*	PH(cm)*
Check	30.78**	18.75 a	5.84 a	33.70 a	88.02 a
	32.28 a	18.53 a	5.83 a	34.87 a	88.92 a
	31.73 a	18.17 a	5.95 a	34.35 a	86.32 a
M. incognita	11.42 b	17.79 a	5.55 a	10.66 bc	50.13 bc
	11.35 b	17.90 a	5.76 a	11.76 b	50.76 b
	11.78 b	18.02 a	5.72 a	12.14 b	51.36 b
M. javanica	11.57 b	18.06 a	5.57 a	11.63 bc	50.70 b
	10.64 b	17.78 a	5.67 a	10.78 bc	49.80 bc
	11.40 b	17.95 a	5.88 a	10.10 c	50.17 bc
M. incognita + *M. javanica*	11.85 b	17.80 a	5.53 a	11.45 bc	48.86 bc
	10.92 b	17.98 a	5.62 a	11.03 bc	47.96 c
	10.71 b	17.93 a	5.72 a	10.98 bc	48.87 bc

*NP/P = Number of pods per plant; WHS = weight of one hundred seeds (humidity was adjusted to 14%); NS/P = number of seeds per pod; SW/P = seed weight per plant (humidity adjusted to 14%); PH = plant height.

**Numbers followed by different letters are significantly different at 5% (Tuckey).

days later, a gall index was given to each plant, ranging from 0 (absence of galls) to 4 (heavily galled). The nematodes also were stained *in situ* with boiling lactophenol + cotton blue in order to observe the infection level. Results show that all of the varieties were highly susceptible, except '37-R' (Table 2). However, even though '37-R' had a low gall index, large numbers of females and egg masses were found in the roots.

In 1982, a second screening for resistance to *M. javanica* was conducted (10). Under greenhouse conditions, 49 bean varieties were inoculated with 10,000 eggs/pot. Fifty days later, the root systems were rated from 0 to 5 according to the number of galls. Eggs also were extracted and counted to determine reproduction. The results indicate that all the varieties were susceptible (Table 3). Four of them, namely '37-R,' 'Honduras 35,' '51051' and 'Rajado ag. 496,' had low gall indices, but many females and eggs in their roots. These varieties were checked again (Table 4).

Effect of Bean Root Exudates on Egg Hatching

The effects of root exudates from two bean varieties ('37-R' and 'Rico 23') on egg hatching at different temperatures were studied (4). Different concentrations of exudates were tested, but the results did not show any significant difference from distilled water controls. The temperature had some influence: higher number of hatched eggs were obtained at 28°C, followed by 25°C, 32°C, 20°C and 16°C, in that order.

Interaction of Meloidogyne javanica and Fusarium oxysporum f. sp. Phaseoli on Phaseolus Bean

Two tests were conducted to evaluate the interaction between *M. javanica* and *F. oxysporum* f. sp. *phaseoli* (10). In the first one, the bean varieties used were 'Pintado' and 'Roisnha G-1,' resistant and susceptible to *Fusarium* respectively. In the second test, 'Pintado' was used again and the susceptible variety was 'Costa Rica.' Plants were inoculated with nematodes (10,000 eggs/pot) at planting time, and 3 weeks later, 15 ml of a suspension containing 1.2×10^6 fungal spores/ml was added. Sixty days after planting, the plants were harvested and evaluated for vascular discoloration,

Table 2. Relative susceptibility of bean varieties to *Meloidogyne incognita* and *M. javanica*

Bean varieties	Gall Index*	
	M. incognita	*M. javanica*
'Manteigão Fosco 11'	3.6	3.8
'Manteigão Preto 20'	3.4	3.6
'Rico 23'	4.0	4.0
'Preto Sessenta-dias'	3.2	3.4
'Manteigão 87'	4.0	4.0
'Preto 132'	3.8	3.4
'Preto 145'	3.4	3.6
'Manteigão Mineiro'	4.0	3.6
'Manteigão 241'	4.0	4.0
'Baio'	4.0	4.0
'Caraota'	3.2	3.4
'Vermelhão'	3.4	3.8
'Tupi'	4.0	4.0
'1828 S 313 Venezuela'	4.0	4.0
'1841 6G'	3.2	3.4
'37-R'	2.0	2.2
'S-856-B'	3.0	3.2
'S-182-N'	3.2	3.4
'Avermelhado Raiado'	3.8	3.6
'Seleção Cuva 168-N'	3.4	3.6
'Venezuela 350'	3.0	3.2
'Mulatinho Paulista'	3.0	3.0
'Seleção 984-18'	3.2	3.4
'Seleção 984-24'	3.0	3.6
'Seleção 984-28'	2.3	3.4
'Carioca'	3.2	3.2
'Costa Rica'	3.4	3.6
'Coleção 1.63-A'	3.2	3.0
'Vermelho Rajado'	3.4	3.4
'49-242 (69-6193-N)'	3.2	3.2
'Roxo Mineiro'	3.8	3.2

*0 = no galling, 4 = highly susceptible.

Mean numbers of five replicates.

Table 3. Relative susceptibility of bean varieties to *Meloidogyne javanica*

Bean varieties	Gall index*	Egg number/ g of roots
'Rico 23'	5.0	2,750
'Preto Chumbinho'	4.5	2,085
'2025 Sacavem 176'	5.0	2,210
'37-R'	2.0	350
'S-182'	4.0	677
'Honduras'	2.5	183
'Gordo'	5.0	1,177
'Americano'	5.0	7,485
'(N-315) 61-1-5-1'	4.0	965
'732443'	4.3	1,370
'51051'	2.5	420
'Red Kloud'	5.0	5,360
'IPA-7419'	5.0	3,340
'Rajado Ag. 496'	3.5	468
'Serra Negra Ag. 497'	5.0	3,395
'Agrorrico Ag. 495'	5.0	507
'Santana'	4.3	3,850
'Palmital'	5.0	3,875
'Comp. Negro Chimalt.'	4.0	2,650
'Pintado'	5.0	3,800
'Rosinha-G-1'	5.0	2,250
'Pompadour'	5.0	5,300
'S-630-B-C-63'	5.0	5,500
'IPA-1'	4.8	4,250
'Linea 29 (P 738)'	5.0	2,650
'Rio Tibagi'	5.0	4,650
'Ouro Preto'	5.0	7,500
'10103 (ICA-Col.)'	4.5	3,250
'500 vagens'	4.8	3,500
'BAT-67'	4.0	650
'BAT-65'	5.0	4,700

Table 3 (cont'd.)

Bean varieties	Gall index*	Egg number/ g of roots
'BAT-75'	5.0	3,200
'BAT-55'	4.8	3,200
'BAT-64'	3.8	1,700
'G 1753'	5.0	3,750
'Rosinha Guaranésia'	5.0	6,300
'1810 Mex. 438'	5.0	3,400
'1934 Sacavem 307'	5.0	2,600
'Col. 123-N'	5.0	3,350
'Chumbinho'	4.8	4,150
'Mulatinho Vagem Roxa'	4.5	2,100
'Seleção 984-29'	4.8	2,500
'Veranic-2'	5.0	2,850
'Chumbinho Opaco'	5.0	1,950
'Bolinha'	5.0	6,500
'IPA-2'	5.0	2,200
'ICA-TUI'	4.5	4,400
'Brasil-2'	5.0	5,650

*0 = 0 galls, 1 = 1-2, 2 = 3-10, 4 = 31-100,
5 = more than 100 galls per plant.

Table 4. Relative susceptibility of bean varieties to *Meloidogyne javanica*

Bean varieties	Gall index*	Egg number/ g of roots
'37-R'	3.5	580
'Honduras-35'	2.6	505
'51051'	3.0	465
'Rajado Ag. 496'	3.3	445
'Agrorrico Ag.'	5.0	1,045

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

presence of the fungus at different levels in the stem, and number of galls and eggs in the roots. The results demonstrated a positive interaction between the fungus and the nematode, which was most noticeable when the variety 'Pintado' was used. The presence of the nematode clearly increased the disease severity. It also was noticed that there was a tendency for egg production to drop in the treatments where the fungus was present as compared with the ones with nematodes alone.

In another test, it was shown that vegetative growth and production of conidia by F. oxysporum f. sp. phaseoli were higher when cultured media contained extracts from plants infected with M. javanica than when it contained extracts from healthy plants (10).

Efficacy of Chemical Seed Treatment for Nematode Control on Bean

The control of plant-parasitic nematodes on bean is a rather complicated subject considering it is a low income crop and usually planted only in small farms. Resistant varieties are not available yet, and the cost of nematicides is prohibitive. Chemical seed treatment could be helpful in this case. Thus, the effects of different concentrations of oxamyl, dissolved either in acetone or ethanol, and the effects of time of immersion in oxamyl with acetone and with ethanol were studied in relation to germination percentage of the dry bean cultivar 'Rico 23' (2). Also studied under greenhouse conditions were the effects of different concentrations of oxamyl in acetone or ethanol, during two immersion times, as a seed treatment for the control of nematodes. Results from the preliminary tests showed that bean seeds treated with oxamyl at concentrations ranging from 0.25 to 8% a.i. for periods up to 90 minutes germinated normally, but when the seeds were immersed in oxamyl concentrations of 2% a.i. or more for 180 minutes, germination was reduced regardless of the solvent used. In the main test under greenhouse conditions, the parameters of plant height, weight of the aerial part of the plant, and the weight of the root system were influenced positively by the treatments with oxamyl dissolved in acetone, but no such response was shown by the treatments where oxamyl was dissolved in ethanol. On the other hand, the number of root galls and the number of Meloidogyne

javanica juveniles in the soil were reduced significantly by the seed treatments with oxamyl dissolved either in acetone or ethanol. The populations of Criconemella sp. and saprophytic species in the soil were not influenced by the application of oxamyl. There was no phytotoxic effect of oxamyl to the bean plants.

Program Underway and Future Research Plans

A general survey for plant-parasitic nematodes, initiated in 1978, is still underway. Soil and root samples have been taken from different crops, including beans, throughout the State of Minas Gerais. The States of Espirito Santo and Rio de Janeiro will be next to be surveyed. The whole idea behind this project is to know which nematode species occur in the areas and on each crop, as well as their distribution and prevalence, and also some indication of their host range.

The Bean Germ plasm Collection at the Federal University of Viçosa has more than 2,000 cultivars and lines. The screening program has a goal to test as many of these as possible for resistance to M. javanica and to the prevalent races of M. incognita. Bean varieties considered to be nematode resistant elsewhere will be introduced and tested. In order to support this, and other research programs, a project has been initiated in which the races of M. incognita in the area will be identified.

As far as nematode control is concerned, two approaches will be followed: tests will be conducted with nematicides applied at planting time (carbofuran, aldicarb, ethoprop, phenamiphos, etc.) comparing the effectiveness of the treatments and the economic feasibility of the whole operation; and, the use of antagonistic crops or poor hosts as alternatives for crop rotation will be evaluated.

RESUMO

Problemas com o nematóide das galhas em feijoeiro (Phaseolus vulgaris L.), No Brasil

O feijão constitui a dieta proteica básica em muitos países, incluindo o Brasil. Embora o país esteja colocado entre os três

maiores produtores do mundo, a sua produção por área é muito baixa. Uma das razões deste baixo rendimento é a ocorrência de muitas doenças e pragas, incluindo nematóides. Testes conduzidos em microparcelas mostraram uma redução de até 67% na produção de feijoeiros inoculados com Meloidogyne javanica e/ou M. incognita.

Em 1976, um levantamento realizado na Zona da Mata, em Minas Gerais mostrou a presença de M. incognita ou M. javanica em todos os 23 municípios visitados. Um outro levantamento iniciado em 1978, e que se encontra ainda em andamento, tem a finalidade de ver a presença e distribuição de fitonematóides nas diferentes culturas do Estado de Minas Gerais. Nas primeiras 394 amostras analisadas, coletadas na rizosfera de 75 espécies de plantas, Meloidogyne foi encontrada em 30,5% das amostras. Em 10 amostras coletadas em feijoais, Meloidogyne estava presente em 4 delas.

Como o feijão é uma cultura de baixa rentabilidade, o uso de variedades resistentes é uma das melhores opções para o controle de nematóides. Contudo, embora mais de 160 linhas e cultivares tenham sido testados para resistência a Meloidogyne, por vários pesquisadores no Brasil, nenhuma delas se mostrou promissora.

Trabalhos realizados na Universidade Federal de Viçosa mostraram que:

-Exudatos radiculares de feijoeiro não influíram na taxa de eclosão de larvas de M. incognita e M. javanica, quando comparado com a eclosão em água. A temperatura, contudo, influiu, sendo 28°C a mais favorável.

-M. javanica aumentou a incidência e a severidade da murcha do feijoeiro causada por F. oxysporum f. sp. phaseoli, quando este fungo foi inoculado 3 semanas após o nematóide.

-O tratamento de sementes de feijoeiro com oxamil em acetona ou etanol indicou ser esta uma prática viável para auxiliar o controle de Meloidogyne.

Na UFV, os esforços estão agora concentrados em continuar o levantamento de fitonematóides no Estado, prosseguir nos testes de resistência varietal do feijoeiro a Meloidogyne e estudar a viabilidade econômica do controle químico e da rotação de culturas com plantas antagonistas.

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COFFEE CULTURE PROBLEMS CAUSED BY ROOT-KNOT NEMATODES IN BRAZIL

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General Information

The first reference to problems in coffee plantations caused by nematodes in Brazil was made by Goeldi in 1892 (23). Jobert in 1878 had mentioned only an association between nematodes and coffee trees (28). Goeldi named, described and prognosticated the nematode Meloidogyne exigua as the cause of the "coffee tree disease in the Province of Rio de Janeiro." In 1929, Rahm detected M. exigua in coffee plantations in several municipalities of the State of São Paulo (40). In 1942, Silva detected coffee seedlings infected with Meloidogyne exigua and recommended not planting such material (46). In 1960, Carvalho reported M. exigua, M. incognita, and M. javanica in coffee trees of several municipalities of the State of São Paulo (7). Arruda and others, from 1957 to 1962, reported M. exigua in northern São Paulo State (2-5). These authors presented the first work about the stunting action of M. exigua on young coffee trees.

Lordello and Zamith, in 1960, described a new species Meloidogyne coffeicola on coffee trees in the State of Paraná (33). Work was conducted to determine the distribution of the different Meloidogyne species in the Brazilian coffee areas. Several surveys were carried out in different States of Brazil: Lordello et al. (31) and Curi et al. (9, 10, 15) in the States of São Paulo, Espírito Santo and Bahia; Loureiro and Cruz (34) in the State of Minas Gerais; Ponte and Silva (39) in the State of Ceará; Carneiro and Carneiro (6) in the State of Paraná; and Sharma and Sher (45) in the State of Bahia. These surveys were designed to detect the more noxious nematodes on the coffee trees.

Economical Importance

The problems caused by root-knot nematodes on coffee plant depend on several factors: age, species and cultivar of Coffea, species and race of the nematode, and type of soil and climate

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conditions. M. exigua is very important to the young coffee trees. Arruda and Reis (5) showed a significant decrease in coffee yields during the first two years after planting. Meloidogyne coffeicola, noxious to the coffee tree in the States of Paraná and São Paulo, has a limited host range and needs specific conditions for reproduction and survival. M. coffeicola tends to disappear with the death of the coffee trees.

The species Meloidogyne incognita, probably races 2 and 3, showed destructive action after the surveys of the years 1969 and 1970. M. incognita is the most serious enemy of the coffee tree. It has destroyed thousands of coffee plants of different ages. For a long time, this nematode was disseminated through seedlings, soil erosion, and soil clinging to farm tools. M. incognita has a wide host range and is a big threat to the large coffee area with more than 430 million trees in western São Paulo State. M. incognita is present in the coffee farms of the State of Paraná where it has caused big losses in yields. In the years 1976 and 1977, three million coffee seedlings were destroyed for sanitary measures in the State of São Paulo.

Other root-knot nematodes such as M. javanica, M. hapla and M. arenaria were detected, but they are not very important.

Research Work

Much work has been undertaken to find answers to coffee problems caused by root-knot nematodes. Genetic resistance has been researched (1, 8, 11, 16-22, 42). Some sources of genetic resistance have been found. Curi detected resistance of Coffea canephora var. 'Kouillou' to M. exigua (8). He also found resistance of six C. canephora cultivars: 'Robusta,' 'Laurentii,' 'Kawisari' and 'Bukobensis' (11). Some resistance was detected in progenies of C. arabica cv. 'Tafari Kela 1161-9' to the nematode M. exigua. Fazuoli found resistance of C. racemosa to M. exigua (17). Rebel and Fazuoli detected resistance in C. racemosa, C. dewevrei and C. arabica progeny 'C 1167-19 Amphillou' to M. incognita (41). Fazuoli et al. detected tolerance of C. congensis cv. 'Bangelan' and six progeny of C. canephora cv. 'Kouillou' to M. incognita (22).

Chemical control studies were developed to help solve Meloidogyne problems in coffee. Curi et al. reported the efficacies of 70 formulations of 17 nematicides in controlling M. exigua (12-14). The better treatments were prophos, phenamiphos, basamid, DD, fensulfothion, bunema and AC 64475. Curi et al. reported the efficient initial control of M. incognita under field conditions (13). Curi also reported that the behaviour of systemic nematicides was not sufficient to keep coffee trees free of the destructive action of M. incognita (14). Pereira et al. tested the nematicidal effects of fungicides and insecticides (38). Santos et al. studied the effect of nutrients on M. exigua (43, 44). Lordello et al. tested chemicals to control M. exigua and M. incognita (29, 31, 32). These works showed that the chemical control in nursery beds is possible, but under field conditions, the results were not viable.

Organic manure, crop rotation, and other means of control also have been investigated (24-27, 29, 31, 32, 35-37).

Priority for New Research

The control of the coffee nematode M. incognita is a priority for new research. Several areas must be studied:

1. Organisms antagonistic to nematodes: fungi, protozoa, etc.
2. Genetic resistance of Coffea: more research on larger number of progeny which are showing promising resistance.

RESUMO

Problemas na cultura do café causados por nematóides do gênero Meloidogyne no Brasil

São relatadas as detecções e levantamentos dos nematóides do gênero Meloidogyne parasitando cafeeiros em diferentes Estados brasileiros. São comparadas as diferentes espécies de Meloidogyne em relação a importância econômica para o cafeeiro. São mencionadas as pesquisas visando o controle através de resistência genética e do controle químico. Prioridades para novas pesquisas, abrangendo organismos antagônicos e resistência genética, são sugeridas. É apresentada uma relação de literatura abrangendo noventa e um (46) trabalhos referentes a nematóides do cafeeiro no Brasil.

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SINOPSE DA LITERATURA BRASILEIRA SOBRE MELOIDOGYNE EM ALGODÃO

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Introdução

Sobre a origem do algodoeiro, os especialistas estão de acordo: há algodões nativos tanto no Novo, quanto no Velho Mundo (Ásia).

Porém, o algodão cultivado no Brasil ó, em sua quase totalidade, do próprio continente, sendo a maioria das variedades de procedência norte-americana.

Os tipos anuais - algodão herbáceo - foram introduzidos a partir dos Estados Unidos da América, tanto que algumas variedades, máxime as de introdução mais recente, ainda conservam os nomes pátrios ('Upland,' 'Cleveland,' etc.). Botanicamente, são plantas que, no geral, filiam-se às espécies Gossypium hirsutum L. e G. barbadense L., com franca predominância da primeira sobre a segunda.

Os tipos perenes - algodão arbóreo -, atualmente cultivados no país, derivam de miscigenações acontecidas aqui mesmo no Brasil e envolvendo espécies nativas e estrangeiras, de hábitos bem diversos, tudo consequência do intenso intercâmbio de sementes ocorrido em outras épocas. Por exemplo, o algodão mocó, G. hirsutum marie-galante Hutch., o principal tipo arbóreo da cotonicultura brasileira, resultou da hibridação natural G. hirsutum x G. barbadense cv. 'Sea-Island.'

Quanto ao algodão asiático, filiado à espécie G. herbaceumm L., há evidências de sua introdução no Brasil. Todavia, por força de inadaptação, seu cultivo não floresceu no país. Com efeito, raramente se encontra, em qualquer quadrante do território brasileiro, uma planta que possa ser, com segurança, atribuida à citada espécie.

Data de meados do século passado o interesse pela cultura algodoeira em nosso país. A sua expansão processou-se com rapidez. Em função desse interesse econômico, foram muitas as variedades de

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algodão introduzidas. A dispersão destas por regiões de clima e solo variados ensejou, com o tempo, o aparecimento de tipos bem diversificados, alguns, inclusive, guindados à condição de variedades ou espécies botânicas. Tal gama de genótipos explica também a diversidade de comportamento do algodoeiro cultivado no Brasil em relação às doenças de um modo geral e, em particular, à Meloidoginose. Por esta razão, o nematóide das galhas do algodoeiro, Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949, jamais representou um problema ou ameaça de ordem geral para a cultura do algodão do país. Tem gerado problemas localizados ou regionais. Problemas resultantes não propriamente de uma ação isolada do nematóide, pois que devidos ao complexo sinérgico Meloidogyne-Fusarium.

Em linhas gerais, pode-se afirmar que os tipos derivados ou mais próximos de G. hirsutum são suscetíveis - ex. o algodão IAC-12 -, salvo, obviamente, aqueles já oriundos de trabalhos específicos de melhoramento. De outra parte, os tipos derivados ou mais próximos de G. barbadense são resistentes ao parasitismo de M. incognita. Está neste caso algodão mocó, uma variedade perene e arbórea largamente cultivada nos taboleiros semi-áridos do Nordeste, mercê de seu apreciável grau de xerofilismo.

Resenha Bibliográfica

No Brasil, é da autoria de Lordello (10) a primeira alusão ao parasitismo de nematóide das galhas em raízes de algodoeiro, G. hirsutum. Aliás, uma citação singela, inserida no rol de numerosas referências pertinentes a um levantamento geral de nematóides residentes no solo de algumas regiões do Estado de São Paulo.

Dois anos depois, em um levantamento de caráter mais específico, uma vez que envolvendo apenas nematóides do gênero Meloidogyne Goeldi, 1887, Carvalho (1) destacava o algodoeiro entre as culturas então arroladas, em São Paulo, como suscetíveis à Meloidoginose.

Ainda na mesma década, Lordello, Zamith & Arrud (14) destacavam a importância do parasitismo de M. incognita para o algodão e a soja, Glycine max Merrill, duas culturas em expansão, àquela época, no Estado de São Paulo.

Relativamente ao algodão, o problema agravou-se de tal forma, dadas, naturalmente, as implicações mais sérias do complexo Fusarium-Meloidogyne, que o Instituto Agronômico de Campinas (IAC), em Campinas-São Paulo, achou por bem iniciar, pouco tempo depois, um programa de melhoramento, objetivando a criação de variedades resistentes (4).

Neste propósito, cogitou-se, ali, da utilização de G. barbadense como fonte de resistência, não obstante a constação do parasitismo de M. incognita em determinados exemplares da mencionada espécie, segundo Ferraz & Lordello (7). Neste mesmo trabalho, os autores, com respaldo em resultados experimentais, indicam alguns nematicidas como opção de controle do referido nematóide.

Variedades resistentes seriam, assim, a solução para o problema Fusarium-Meloidogyne em algodoeiro, nas condições de São Paulo e estados vizinhos. Contudo, não uma solução a curto prazo. Assim, antes que tal solução aparecesse, houve tempo suficiente para que esse problema fitossanitário crescesse substancialmente em expressão, a ponto de desestimular o cultivo do algodão nas principais regiões produtoras de São Paulo. Algumas dessas regiões desistiram, até hoje, de cultivá-lo.

Natural, portanto, que o assunto fosse abordado, com ênfase e frequência, em diferentes meios ou veículos de divul gação técnica: em textos de extensão rural (5, 6); em periódicos científicos (11) e em compêndios didáticos (9, 12), além de o ser, repetidas vezes, na imprensa comum, mediante enfoques em sessões agrícolas de jornais e rádios.

Em São Paulo, as primeiras variedades de algodão resistentes ao complexo Fusarium-Meloidogyne, selecionadas pelo Instituto Agronômico de Campinas, apareceram em 1964, a partir da variedade 'Acala' (2). Mas, conforme se afirmou anteriormente, não surgiram a tempo de recuperar o prestígio da cultura em certas regiões paulistas, tradicionalmente afeitas à lavoura algodoeira (13).

No Nordeste semi-árido, outro grande centro produtor de algodão do país e onde se cultiva sobretudo o algodão mocó, G. hirsutum mariegalante, Ponte (19) comprovou, experimentalmente, aquilo que as observações práticas e a vivência agrícola já indicavam, ou seja, a elevada resistência da citada variedade arbórea ao parasitismo de

M. incognita - resistência herdada de G. barbadense -, fato que também explica em parte, a posição absolutamente secundária da Murcha Fusariana entre as doenças que afetam a cultura na região. Resultados semelhantes obtiveram, três anos depois, Menezes, Ramos & Oliveira (16), constatando a resistência do mocó, justo na mesma época em que Menezes, Ribeiro & Ramos (17) demonstravam, ainda no Nordeste, a suscetibilidade de tipos herbáceos (G. hirsutum) a vários isolados de M. incognita.

No Sudeste, no entanto, o problema Fusarium-Meloidogyne foi sempre mais sério em razão da predominância dos tipos oriundos, exclusivamente, de G. hirsutum. Por isto mesmo, a busca de plantas resistentes teve continuidade, em São Paulo, com o trabalho de Cia et al. (3) e, com este estudo, foi reativado o programa de melhoramento genético há anos em pauta no IAC. Esta nova fase do estudo permitiu a seleção de novas linhagens herbáceas dotadas de resistência ao complexo patogênico em questao. Ademais, o programa de melhoramento do IAC tem preocupação também com resistência simultânea a M. incognita e a outros nematóides que atacam o algodoeiro nas condições de São Paulo, como bem atesta o recente trabalho de Fuzatto, Cia & Gridi-Papp (8), relatando uma metodologia de avaliação de comportamento do algodão a nematoses em condições de campo.

A mesma preocupação de resistência, em algodoeiro, à Meloidoginose vem sendo observada também no vizinho Estado do Paraná, por parte de técnicos do Instituto Agronômico do Paraná (IAPAR), como bem demonstram as pesquisas de Ruano & Scotti (20) que culminaram com a seleção de duas linhagens (no caso, 1439/79-FN e PR-4139) de bom comportamento em relação ao nematóide.

Em reconhecimento à importância sócio-econômica do algodoeiro em termos de Nordeste semi-árido, a Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) criou, na própria região, o Centro Nacional de Pesquisa do Algodão (CNPA), com sede em Campina Grande, Estado da Paraíba. Este Centro há-se aplicado ao melhoramento dos tipos arbóreos (algodão mocó) e herbáceos cultivados na região. Em decorrência desse trabalho, novas variedades e linhagens têm sido distribuidas ou se encontram em fase de testes. Com isto, há

sempre o risco de perda do equilíbrio fitossanitário a que se aludiu anteriormente; em outras palavras, há o perigo de que essas novas variedades ou linhagens, embora mais produtivas, sejam suscetíveis ao complexo Fusarium-Meloidogyne, criando, para o Nordeste, um problema até hoje praticamente inexistente na região. Refletindo tal preocupação, Menezes, Moura, & Teixeira (15) avaliaram o comportamento de oito novas cultivares de algodão mocó, todas oriundas do CNPA, em relação à r. 2 de M. incognita. A propósito, nenhuma delas acusou suscetibilidade. Simultaneamente, os mesmos autores, em trabalho conduzido separadamente (18), testavam o comportamento das mesmas oito cultivares de mocó, bem assim de nove cultivares de algodão herbáceo do citado CNPA, em relação à raça 3 de M. incognita. Os resultados foram bem distintos, porquanto só uma cultivar herbácea - a CNPA-78/SME_4 - e apenas uma de mocó - a CNPA-80/2Br - acusaram resistência ao parasitismo.

Os resultados obtidos mediante o último trabalho comentado, envolvendo a raça 3 do nematóide, justificam, plenamente, a procedência de toda essa preocupaçao dos fitossanitaristas nordestinos, com relação às novas variedades oriundas do CNPA.

Resumo e Conclusões

No Brasil, em linhas gerais, o parasitismo de M. incognita em algodoeiro tem merecido, da parte dos pesquisadores especializados, a devida atenção, como bem atestam o razoável número de trabalhos publicados sobre o assunto e, em especial, o esforço em favor de um controle eficiente e econômico da doença, máxime mediante a obtenção de variedades geneticamente resistentes.

Uma análise geral das implicações econômicas decorrentes da incidência de Meloidogyne incognita sobre a cultura algodoeira do país, permite concluir:

1) que o problema assumiu conotações particularmente severas na região Sudeste, sobretudo no Estado de São Paulo, durante as décadas de 50 e 60, por força da constante associação Fusarium-Meloidogyne, aliada à predominância do cultivo de tipos filiados à espécie Gossypium hirsutum L. (suscetível);

2) que esse problema foi superado ou minimizado mediante o uso de variedades resistentes, selecionadas, em sua maioria, pelo Instituto Agronômico de Campinas;

3) que, no Nordeste, outro importante centro algodoeiro do país, os prejuízos devidos ao citado parasitismo foram, até agora, irrelevantes, isto em rezão da predominância de tipos de acentuado grau de consanguinidade com Gossypium barbadense L. (resistente);

4) que, em favor da preservação dessa situação privilegiada de que desfruta o Nordeste, as novas variedades ora preparadas, na região, pelo Centro Nacional de Pesquisa do Algodão devem merecer rigorosos cuidados em termos de resistência ao parasitismo em questão, sob pena de graves consequências para a economia da região nordestina.

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ROOT-KNOT NEMATODE PROBLEMS ON FRUIT CROPS IN BRAZIL

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INTRODUCTION

Root-knot nematodes have been reported to be associated with fruit crops like pineapple (Ananas comosus), banana (Musa spp.), fig (Ficus carica), papaya (Carica papaya), passionfruit (Passiflora spp.), and peach (Prunus persica).

In citrus orchards, reports of Meloidogyne spp. are extremely rare, without references to symptomatology and possible damage.

Meloidogyne infestations in field plantations commonly are related to initial attack under nursery conditions. This parasitism of fruit seedlings in nurseries plays a very important role in the dissemination of root-knot species for nematode-free areas, in plant growth reduction, and in increasing yield costs because of the adoption of additional control measures.

Pineapple

Root-knot nematode infestations (especially M. incognita) on pineapple already have been observed in most producing areas such as the states of Bahia, Minas Gerais, Paraiba, Rio de Janeiro, and São Paulo (9, 16, 27, 28). Poor growth and moderately galled roots (claviform galls) were the symptoms most evident in heavily infected plants. However, population densities of root-knot nematodes in soil and root samples from the cultivars 'Perola' and 'Smooth Cayenne' were much lower than those determined for Rotylenchulus reniformis and Pratylenchus brachyurus (29). This lesion nematode actually has been considered to be the most important species for pineapple in Brazil (16, 29).

Banana

For many years Radopholus similis and Helicotylenchus multicintus have caused extensive damage to plantations in various banana-producing countries. On the other hand, root-knot nematodes frequently are considered to be parasites of minor importance on banana.

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In Brazil, a similar situation existed until a recent study was presented (26), which will probably determine a new approach to the subject. In this work, the root-knot species (M. incognita and/or M. javanica) were reported in 48% of the samples collected during a nematological survey in 13 producing states: namely Alagoas, Bahia, Espirito Santo, Goiás, Maranhão, Mato Grosso de Sul, Minas Gerais, Paraiba, Paraná, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, and São Paulo. An average population of 1066 specimens/10 g roots was estimated. These nematodes were able to parasitize 'Nanica,' 'Nanicão,' 'Prata,' and all other cultivars of commercial value and cause evident crop losses in some cases. The author suggested that the importance of Meloidogyne on banana in Brazil, particularly in production areas where the burrowing nematode does not occur, has been underestimated and that more specific studies should be stimulated in the future to elucidate this point.

Fig

The importance of root-knot nematodes as parasites of fig (Ficus carica 'Roxo de Valinhos') in Brazil has been emphasized for more than 20 years (4, 10, 17). M. incognita is the main species involved, being frequently found under nursery conditions.

Fig cuttings inoculated with M. incognita show heavily galled roots, marked reduction in the number of rootlets, and significantly lower values of top dry weight when compared with healthy plants (6). Galls sometimes are observed also along the stems of infected cuttings, like yellowish rounded intumescences.

Studies regarding the production of healthy cuttings in nurseries have been carried out, mostly involving the use of nematicides in preventive (22) or therapeutic (7) treatments.

Fig plantations planted with infected cuttings show evident symptoms of root-knot infection a few months after transplanting.

The recuperation of infected plants seems to be possible through nematicide application in orchards not exceeding 1 to 2 years old, but is very difficult in older plantations (Ferraz et al., unpublished data).

Papaya

Several root-knot species are known to attack papaya in Brazil (19). In São Paulo State, papaya cultivation was reduced markedly by M. incognita and M. javanica infestations in the last decades. To date, root-knot nematodes are still considered as a major problem for papaya in the remaining production areas (11).

Problems with Meloidogyne species on papaya also have increased in the northeastern region, particularly in Ceará State, where annual yield losses are estimated at 20%. A nematological survey carried out in the county of Fortaleza, capital of Ceará State, showed that 65% of the papaya plants examined were infected by root-knot nematodes (20). Research regarding Meloidogyne control in papaya nurseries and plantations from Ceará State has been conducted, mainly concerning organic manure application, since the use of nematicides already has proved to be unprofitable.

Passionfruit

As observed in other countries which produce passionfruit, nematological problems of this crop in Brazil generally are related to root-knot nematodes and the reniform nematode. Most infested plantations have been reported in the states of Bahia (8, 23), Ceará (20), and São Paulo (12).

Passiflora edulis (purple passionfruit) and P. edulis var. flavicarpa (yellow passionfruit), the types of highest commercial importance, are very susceptible to Rotylenchulus reniformis (3), but are unfavorable hosts for Meloidogyne spp. (12, 21). Both types are also susceptible to Fusarium wilt, probably caused by Fusarium oxysporum f. passiflorae (2), a vascular disease which causes sudden death of plants and is not adequately controlled by chemicals. Thus, the utilization of Fusarium-resistant rootstocks was considered the best alternative for this situation (18).

In a recent screening of available rootstocks (25), Passiflora alata was found resistant to the fungus and highly compatible with P. edulis var. flavicarpa, and thus was considered to be promising material. Later, however, this species proved to be very susceptible to M. javanica (1), M. arenaria and M. incognita (5), and, as a

result, more trials will be necessary until a rootstock resistant to Fusarium and Meloidogyne can be obtained and recommended.

Regarding M. javanica parasitism on passionfruit, it also was observed that the cultivars 'Boi' and 'Silvestre' were highly resistant and susceptible, respectively (1).

When root-knot infection occurs in nurseries, passionfruit seedlings show heavily galled roots, chlorotic leaves, and poor growth. In orchards established with infected seedlings, more severe symptoms are observed such as leaf drop, stunting, and eventual death of plants.

Peach

Peach is a suitable host for several species of Meloidogyne and Pratylenchus (15, 19). Control measures against M. incognita on peach are always recommended, under both nursery and field conditions (13).

Because of the difficulties and high cost of chemical control in perennial crops like peach, the utilization of resistant cultivars or rootstocks has been recommended as the most adequate alternative for nematode control. In a trial where the reaction of 5 cultivars to M. arenaria and M. incognita was tested (15), most materials (traditionally planted in Brazil) were shown to be susceptible or very susceptible (Table 1). Only 'Okinawa' was highly resistant to both Meloidogyne species. This cultivar was introduced in Brazil approximately ten years ago at which time it was considered to be resistant to root-knot nematodes and was commonly used in the state of Florida, U.S.A. (14, 24). Its adaptation to soil and climatic conditions has been studied mainly in São Paulo State, with good preliminary results. 'Okinawa,' planted as a cultivar or used as a rootstock, will serve as an immediate solution to Meloidogyne problems on peach and, in the next years, as basic material in a breeding program for nematode resistance.

SUGGESTIONS FOR FUTURE RESEARCH

Banana (Production areas not infested by R. similis)

1. Effect of different population densities on yield

Table 1. Reaction of peach cultivars to *M. arenaria* and *M. incognita* under greenhouse and field conditions.

Cultivars	Greenhouse		Field	
	Inoculated	Non-inoculated	Inoculated	Non-inoculated
'Rei da Conserva'	2.5[a]	1.0	3.9[b]	1.0
'Talismã'	3.7	1.0	3.2	1.0
'Cristal'	2.3	1.0	2.8	1.0
'Biuti'	4.3	1.0	3.3	1.0
'Okinawa'	1.0	1.0	1.0	1.0

Obs: scale from 1.0 (not infested) to 5.0 (severe infestation).

a = mean of six replicates.

b = mean of ten replicates.

Fig

1. Control measures under nursery conditions.

2. Integrated control in young orchards, with infected plants not exceeding 1 or 2 years old.

Passionfruit

1. Screening of available species and cultivars for root-knot resistance.

2. Breeding program for resistance to Meloidogyne species and Fusarium wilt.

Peach

1. Breeding program for resistance to root-knot nematodes.

2. Some control measures for nurseries, including regulatory procedures.

RESUMO

Problemas de nematoides das galhas em fruteiras no Brasil

Diversas são as frutíferas cultivadas no Brasil que enfrentam problemas decorrentes de infestações por nematóides de galhas. Entre as culturas consideradas de maior interesse econômico e frequentemente atacadas por espécies de Meloidogyne estão no abacaxizeiro, bananeira, figueira, mamoeiro, maracujazeiro e pessegueiro.

Com relação às plantas cítricas, largamente cultivadas e de elevada importância comercial, praticamente não são prejudicadas, encontrando-se na literatura nacional apenas relatos esporádicos da presença de Meloidogyne spp. em pomares, sem quaisquer referências à ocorrência de danos.

Os ataques dos nematóides das galhas podem se dar tanto em viveiros de mudas como nas áreas definitivas de cultivo. O parasitismo em mudas recém-formadas constitui problema muito grave por favorecer a disseminação dos nematóides para áreas ainda não contaminadas, provocar redução no crescimento e até morte das plantas infestadas, além de exigir dos fruticultores a adoção de medidas de controle que irão onerar os custos de produção.

Culturas formadas a partir de mudas infestadas, particularmente nos casos da figueira, maracujazeiro e pessegueiro, apresentam sintomas de moloidoginose poucos meses após o transplante, como reboleiras, crescimento reduzido, murcha, queda de folhas, clorose, enfezamento e até morte de plantas.

Pesquisas envolvendo medidas culturais de controle dos nematóides das galhas, como emprego de cultivares ou portaenxertos resistentes e a adubação orgânica, têm sido desenvoldidas. O uso de nematicidas em culturas novas, com 1 a 2 anos de idade, ven sendo também estudado, com resultados promissores. Por outro lado, em pomares adultos, o controle parece ser muito difícil.

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BREEDING VEGETABLE CROPS FOR RESISTANCE TO ROOT-KNOT NEMATODES IN BRAZIL

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Efforts for obtaining new cultivars or breeding lines with resistance to Meloidogyne species are relatively recent in Brazil. Germ plasm introductions, screening tests, hybridization experiments, etc., have been conducted. Nematology and plant breeding training programs in Brazil and abroad have been accomplished as part of these efforts.

Research on root-knot nematodes has been carried out in a few vegetable crops: carrot, potato, cowpea, and tomato.

Carrot

Carrot (Daucus carota): Results were obtained at the Brazilian Vegetable Crops Research Center of EMBRAPA (CNPH/EMBRAPA), at Brasília, by Charchar, Vieira and Huang (7). The screening program started with 249 lines in a field heavily infested with Meloidogyne incognita, and it was possible to select 51 promising lines in the first selection cycle. After four cycles of selection in the field, six highly resistant lines of M. incognita and M. javanica were selected. The susceptible cultivars (checks) used were 'Kuroda' and 'Nantes,' which had heavily galled roots. The susceptible cultivars were sown side by side with the resistant lines. At the end of the fourth selection cycle, a high frequency of commercial carrot roots consistently free of galls was found in all six experimental lines selected. These six lines originated from the cultivars 'Rio Grande,' 'Nacional' and 'Tropical,' which were collected in Rio Grande do Sul State. These three local cultivars were introduced by European immigrants many years ago.

No nematode-resistant carrot cultivar has been reported by Sasser and Kirby in their list of crop cultivars resistant to root-knot nematodes (14).

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Potato

Potato (Solanum tuberosum): Some field screening tests have been carried out to evaluate the degree of resistance to Meloidogyne spp. in potato. Charchar (personal communication) at the CNPH/EMBRAPA found among 48 cultivars (Brazilian and European cultivars), four cultivars moderately resistant to M. incognita and M. javanica: 'Delta S,' 'Edzina,' 'Sowa,' and 'Clone 70.' The important Brazilian varieties 'Santo Amor,' 'Aracy,' and 'Baroneza' were susceptible.

Cowpea

Cowpea (Vigna unguiculata): Although it has been used as a cereal, it is also prepared green as a vegetable in several Brazilian regions. It is an important source of protein in our lower income areas.

Root-knot nematodes have been limiting crop yields. Ponte, comparing infested and non-infested crops in northeastern Brazil, estimated a yield loss of 20% due to Meloidogyne spp. (12).

The selection of germ plasm accessions and the results obtained in screening tests indicated the importance of regional tests in the selection of resistant cultivars. Among 10 cultivars grown at NE, the cultivars 'Seridó,' 'Pitiuba,' 'Quarenta-Dias,' 'CE-50,' and 'CE-212' were highly resistant to M. incognita, M. javanica, M. arenaria and M. hapla (13). Lemos & Ponte examined 15 cultivars for resistance to these four nematodes and found six to be highly resistant. Due to the use of resistant cultivars, especially 'Pitiuba,' 'Seridó' and 'Quarenta-Dias,' root-knot nematodes in the northeast are now considered a secondary disease of cowpea.

The Basic Seed Production Department (SPSB/EMBRAPA) in 1981 sold 91 tons of Basic seeds of the cultivar 'Pitiuba' and 11 tons of Basic seeds of the cultivar 'Seridó,' an amount large enough to produce about 2,260 tons of certified seed in 1982 (16).

R. D. Sharma worked in Central Brazil under greenhouse conditions with 12 cultivars inoculated simultaneously with M. javanica (30,000 eggs/larvae per pot containing 1 kg of soil) and Rhizobium japonicum. He concluded that "no cultivar was resistant to this nematode" (15). However, 'V-4 Alagoas,' 'IPEAN 69552' and 'Jaguaribe' were considered

as tolerant cultivars (high gall and egg mass indices and small growth reduction). He classified 'Pitiuba,' 'Seridó,' 'TV 1836-013J' and '4R-0267' as susceptible cultivars.

Although these results seem to contradict the ones previously mentioned (10, 13), they may suggest that the high initial inoculum level used under greenhouse conditions overloaded the biological system. This could be observed by the number of egg masses counted on roots of five cultivars 'IPEAN-V-79,' 'TUV 735-P_2,' 'Pitiuba' and 'Seridó,' which presented an average of 135 egg masses per plant representing five times fewer egg masses than the average of the remaining eight cultivars.

Tomato

Tomato (*Lycopersicon esculentum*): Dias *et al*. (9) in 1964 mentioned a tomato program to incorporate root-knot nematode resistance using the *Mi* gene from the Hawaiian line HES 6048 (9). Segregating population from the first backcross showed plants with roots completely free of galls. However, to our knowledge, no resistant cultivar was released.

More recently, the cultivars 'IPA-1,' 'IPA-2' and 'IPA-3,' which possess the *Mi* gene, were released by IPA from Pernambuco State (17). This program will be presented by Tavares during this meeting.

Camara, Araújo and Cordeiro, working with 'IPA-3' and several other cultivars in the Central Brazil, found that this dual-purpose cultivar (fresh and processing tomatoes for the NE) showed some disadvantages such as lower yield of high-graded tomato fruits, lower firmness and lower prices for the high-graded fruits when compared with the traditional Santa Cruz cultivars (6).

Charchar & Araújo at the CNPH worked in a field heavily and uniformly infested with *M. incognita*, in which the populations in some treatments were greatly reduced by crop rotation with *Crotalaria spectabilis* for 4 and 8 months (8). The results suggested that 'IPA-3' (*Mi/Mi*) is intolerant to *M. incognita* while 'Angela,' a susceptible bilocular Santa Cruz type, is tolerant to high soil populations. This finding would raise the importance in a tomato

breeding program of searching not only for resistance but also for tolerance in a given region. These experiments also indicate that in regions with night temperatures below 32 C, such as occurs in Brasília, the Mi gene could be used successfully in reducing field populations of M. incognita.

As part of their graduate course requirement, two Brazilians carried out research in California and Florida which could be useful in tomato breeding programs in our country (1, 11). Medina-Filho studied the feasibility of using starch gel electrophoresis (EP) in selecting for nematode resistance in tomato (no infection with root-knot nematode is necessary) (11). For this work, he chose the genotype of locus 1 of acid phosphatase (Aps-1) in chromosome 6. Cultivars resistant to root-knot nematodes possess $Aps\text{-}1^{+/+}$ or $Aps\text{-}1^{1/1}$ closely linked to Mi gene. $Aps\text{-}1^{1}$ was known to occur in L. peruvianum. Then, a crossing over between $Aps\text{-}1^{1}$ and Mi may have occurred in early generations of the root-knot nematode resistant cultivars derived from Hawaiian lines during the process of transferring such genes into L. esculentum. The same did not occur with 'VFN 8' and other California lines which possess $Aps\text{-}1^{1}$ (like the Hawaiian lines from which they originated, the same Smith's interspecific hybrid and Watt's first backcross of Smith's interspecific hybrid to L. esculentum).

The EP technique is useful only by using germplasm from the California Breeding Program ('VFN 8' and derivatives) or L. peruvianum with $Aps\text{-}1^{1}$.

The EP technique has several advantages over the traditional method (based on direct infection with root-knot nematodes) when transferring the Mi gene to susceptible lines or cultivars. It is time saving because no progeny test is necessary to distinguish homozygous from heterozygous resistant plants (distinct banding patterns in the zymogram), and the screening period is extended by allowing the use of several stages such as seedlings, leaflets, anthers, stored frozen leaf samples or dry anthers.

Araújo et al. (1, 2, 3, 4, 5) carried out experiments to identify new sources of resistance to root-knot nematodes effective

at high soil temperature (32.5 C). The methodology was developed to make the measurement of quantitative resistance feasible. The tomato plants were grown in controlled-temperature tanks. It was determined that the best inoculum density for screening tomato accessions at soil temperature for resistance to M. incognita and M. javanica was 200 eggs/larvae per plant. Thermoperiodism was found to play an important role in maintaining the resistance to M. incognita and explained why in many areas with high night soil temperature the Mi gene is not effective. Races may vary in aggressiveness toward tomato accessions at high soil temperature. Among 146 cultivars, PI accessions and selections of L. esculentum, L. peruvianum var. dentatum, L. peruvianum var. humifusum, L. chcesmanii var. minor, and L. esculentum x L. peruvianum, the selection 2-(Sib)-5-16 (selfed) of L. peruvianum var. dentatum 'PI 129 149' was the most resistant to M. incognita race 1 in the entire screening work at high temperature.

Now at the CNPH/EMBRAPA there is a breeding program to transfer the Mi gene into fresh and processing tomato cultivars in order to obtain isogenic lines. Another program is being carried out by the bulk population method aimed at obtaining new root-knot nematode resistant cultivars. In both programs, plant nematologists, plant breeders and other researchers are working in a multidisciplinary way.

RESUMO

Melhoramento de hortaliças no Brasil, visando resistência à meloidoginose

Trabalhos procurando fontes de resistência, de seleção e de hibridização para os nematóides das galhas Meloidogyne spp. efetuados no Brasil ou por brasileiros em cursos de pósgraduação no exterior são relatados.

Encontram-se referências nas culturas da cenoura, batata, feijão-de-corda e tomate. Novas fontes de resistência tem sido encontradas e também já foram lançadas as primeiras cultivares resistentes.

Embora promissores os programas deveriam ser dirigidos não apenas para a incorporação de resistência propriamente dita, como também para a associação de resistência com tolerância a este importante grupo de nematóides.

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ROOT-KNOT NEMATODE PROBLEMS OF SUNFLOWER

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Sunflower production in Brazil was very low until 1981 due to a lack of incentive to grow this crop. Since then the government and private companies have become interested in increasing the sunflower oil production. Some of the seed-producing private companies are stimulating the sunflower production in the State of Minas Gerais, Paraná and São Paulo.

Researchers have shown the possibility of growing sunflower late in the summer, following soybean, thereby allowing better use of the soil and avoiding interruption in supplying seeds for the vegetable oil industry.

Even though sunflower was introduced into Brazil many decades ago, producers did not become stimulated due to the great incidence of disease and the lack of research to solve the problem. The increase of sunflower production in other countries and the needs for more and better quality oil have made Brazil think again about sunflower cropping. However, past experiences with disease made the government agencies invest more in research to support and solve field disease problems.

Among disease problems caused by many organisms are plant-parasitic nematodes. In fact, nematodes can become an important problem due to the agricultural system in which sunflower is grown as a second crop planted late in the summer.

Nematode work on sunflower in Brazil has been scarce. Root knot is by far the most important nematode problem of this crop. *Meloidogyne javanica* has been cited as a common species on sunflower (2). However last year, the occurrence of *M. incognita* in Minas Gerais State was reported (1).

The incidence of *M. javanica* and *M. incognita* in sunflower is greater than published reports would indicate. As a matter of fact, there have been reports of these species in Paraná and São Paulo States.

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Present and Future Research

We have screened many cultivars and hybrids of sunflower for resistance to M. incognita and M. javanica in the greenhouse (Table 1). Plant inoculation, nematode reproduction and gall grading were done according to the procedure suggested by the International Meloidogyne Project.

None of the cultivars or hybrids showed high resistance to the two nematode species. However, cultivars which demonstrated some degree of resistance may not suffer great damage in the field. Other areas of research will be carried out on crop losses caused by Meloidogyne species and crop rotation.

RESUMO

Nematóides das galhas do girassol

A incidência de doenças tem sido uma das causas do insucesso desta cultura desde a sua introdução no Brasil há algumas décadas. Parece, entretanto, que o girassol começa outra vez a ser pensado como uma cultura promissora capaz de diminuir a ociosidade das indúdtrias esmagadoras de grãos de soja e criar alternativas para o agricultor em plantios no final do verão. Contudo, desta vez, investimentos em pesquisas do girassol têm sido realizados com o objetivo de resolver os problemas de doenças no campo.

Trabalhos em nematóides do girassol realizados no Brasil têm sido muito limitados. Até o presente momento o principal nematóide do girassol é o Meloidogyne, sendo que M. javanica parece ser a espécie mais comum nesta cultura. Entretanto M. incognita foi relatada mais recentemente atacando girassol. A incidência de M. javanica e M. incognita no girassol no Brasil parece ser bem maior do que os relatos existentes na literatura.

Presentemente, vinte e cinco, e vinte e três cultivares e híbridos de girassol têm sido testados quanto a resistência a M. javanica e M. incognita respectivamente. Nenhum deles se mostrou altamente resistente a estes nematóides.

Table 1. Screening sunflower for root-knot nematode resistance

Cultivar: Hybrid	M. javanica Gall index	M. javanica Egg mass index	M. incognita Gall index	M. incognita Egg mass index
1. 'Peredovic'	5.0	5.0	1.6	1.8
2. 'Conti GH 8121'	5.0	5.0	5.0	5.0
3. 'Stanzvella 75'	4.8	5.0	5.0	5.0
4. 'C-33'	5.0	5.0	5.0	5.0
5. 'Conti GH 8133'	5.0	5.0	5.0	5.0
6. 'IAC. EXP.'	5.0	5.0	5.0	3.8
7. 'C-22'	5.0	5.0	5.0	5.0
8. 'Airelli'	5.0	5.0	5.0	5.0
9. 'CEP G 8001'	5.0	5.0	5.0	5.0
10. 'Coex 8111'	5.0	5.0	5.0	5.0
11. 'Conti GH 7833'	4.2	2.8	5.0	5.0
12. 'Coex 7822'	4.8	4.8	5.0	5.0
13. 'Contisol'	3.8	3.8	4.0	4.0
14. 'Coex 7922'	5.0	5.0	4.4	3.8
15. 'Apolo'	5.0	5.0	5.0	5.0
16. 'Uruguai Sel.'	3.8	2.8	5.0	5.0
17. 'DK 180'	5.0	5.0	5.0	5.0
18. 'Cordobes'	4.8	4.8	4.8	4.8
19. 'DK 170'	5.0	5.0	5.0	5.0
20. 'ESAL' (?)*	3.8	3.2	4.4	3.8
21. 'Coex PH 21'	5.0	5.0	5.0	5.0
22. 'Issanka'	5.0	5.0	5.0	5.0
23. 'Guayacan'	5.0	4.8	5.0	5.0
24. 'Iac Anhandy'	4.6	4.4		
25. 'Coex 7811'	5.0	3.8		

*The correct name of the cultivar is not known.

Outras áreas de pesquisa serão exploradas tais como: estudos sobre danos e prejuízos causados por espécies de Meloidogyne e rotação de cultura.

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ROOT-KNOT NEMATODE PROBLEMS IN HORTICULTURAL AND SPECIAL CROPS IN BRAZIL

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Introduction

This review deals with studies done on root-knot nematodes in horticultural crops in Brazil. Investigations concerning the nematode problems on special plantation crops such as black pepper (Piper nigrum L.), "guaraná" (Paullinia cupana Mart.), cocoa (Theobroma cacao L.) and rubber trees (Hevea brasiliensis Arg. Muell.) also are included here since they are not treated elsewhere in the workshop.

A survey of the literature was concluded in August of 1982. No attempt was made to include papers published before 1949, when the genus Meloidogyne Goeldi, 1892, was revised. Also, works concerning breeding for resistance and chemical control were not included here since they will be reviewed by others in this workshop.

Some of the data cited in this review are original findings of the first author which have been presented in the Brazilian Phytopathological Society annual meetings but not yet published as such (10).

Incidence of Root-Knot Nematodes

The documented incidence of root-knot nematodes in horticultural and special crops in Brazil is summarized in Table 1. We believe, however, that the table does not show the actual extension of root-knot problem in Brazilian horticultural regions. Experience of the first author traveling in various regions of the country in the last seven years indicated that many outbreaks of the nematode were not reported in literature. We do not doubt that the disease is more numerous in terms of the type of plants and species of nematode involved, and more extensive in geographical distribution.

Crop Loss Due to Root-Knot Nematodes

Estimates of crop loss due to nematodes, including root-knot, are not available for Brazil. A limited number of studies have been

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Table 1. Incidence of root-knot nematodes in horticultural and special crops in Brazil

Crops scientific names (common names)	Nematodes*	State**	Author(s)
Allium cepa (onion)	M.I., M.J., M.TH.	SP	Lordello & Mello, 1971
Arracacia xanthorrhiza (apio)	M.J., M.H.	DF SP	Lordello, 1970 Ponte *et al.*, 1975
Beta vulgaris L.	*Meloidogyne* sp.	DF	Ponte *et al.*, 1975
(table beet)	M.A., M.J., M.I., M.H.	SP RS	Carvalho, 1965 Lordello & Marini, 1974
Brasica oleracea var. *acephala* (cole)	M.I.	DF	Ponte *et al.*, 1975
B. oleracea var. *botrytis*	M.I., M.H.	DF	Ponte *et al.*, 1975
("couve")		BA	Sharma, 1977
B. oleracea var. *capitata* (cabbage)	M.J.	DF	Ponte *et al.*, 1975
Capsicum frutescens (chilli pepper)	M.I.	DF	Ponte *et al.*, 1975
C. annuum (bell pepper)	M.I.	DF	Ponte *et al.*, 1975
		BA	Sharma, 1977
Celosia argentia	M.J.	SP	Paradela *et al.*, 1971
Chicorea endivia	*Meloidogyne* sp. M.J., M.I.	DF	Ponte *et al.*, 1975 Lordello & Marini, 1974
Citrullus vulgaris (watermelon)	*Meloidogyne* sp.	DF	Ponte *et al.*, 1975

Table 1 (cont'd.)

Crops scientific names (common names)	Nematodes*	State**	Author(s)
Coriandrum sativum L.	M.I.	DF	Ponte *et al.*, 1975
Cucumis sativus (cucumber)	M.H., M.I.	DF	Ponte *et al.*, 1975
C. melo var. *cantalupensis* (cantaloupe)	M.I.	SP	de Mello, 1958
Cucurbita moschata	M.J., M.I.	DF	Ponte *et al.*, 1975
C. pepo melopepo (squash)	M.I.	DF	Ponte *et al.*, 1975 Huang *et al.*, 1977
Daucus carota L. (carrot)	M.I., M.J.	DF SP	Ponte *et al.*, 1975 Ikuta *et al.*, 1976 Huang *et al.*, 1977
Dioscorea cayennensis (yam)	M.A.	PB	Leal & Ponte, 1980
Hevea brasiliensis (rubber trees)	M.I.	PA	Freire & Santos, 1978
Hibiscus esculentus (okra)	*Meloidogyne* sp.	SP	Carvalho & Zica, 1971
Impatiens balsamina L. (garden balsam)	M.A.	DF	Ponte *et al.*, 1975
Lactuca sativa L. (lettuce)	M.I., M.A.	DF	Ponte *et al.*, 1975
Lycopersicon esculentum (tomato)	M.I. M.TH. M.H.	BA SP SP DF	Sharma, 1977 de Melo, 1958 Lordello, 1970 Ponte *et al.*, 1975

Table 1 (cont'd.)

Crops scientific names (common names)	Nematodes*	State**	Author(s)
Manihot esculenta (cassava)	M.I.	BA	
		AL	Zem *et al.*, 1978
		BA	Sharma, 1977
Paullinia cupana ("guaraná")	M.I., M.J.	PA	Freire, 1978
Piper nigrum (pepper)	M.I.	PA	Lopes & Lordello, 1976
			Lordello, 1974
Pisum sativum (pea)	*Meloidogyne* sp.	DF	Ponte *et al.*, 1975
Sechium edule (chayote)	M.H., M.I., M.J.	DF	Ponte *et al.*, 1975
			Lordello & Marini, 1974
Solanum gilo ("jiló")	M.J.	DF	Ponte *et al.*, 1975
S. melongena (eggplant)	M.I.	SP	Rosseti, 1957
	Meloidogyne sp.	DF	Ponte *et al.*, 1975
S. tuberosum L. (potato)	M.I., M.J., M.A.	DF	Ponte *et al.*, 1975
	M.I., M.J.		Lordello, 1968
			Boock & Lordello, 1960
Theobroma cacao (cocoa)	M.I.	ES	Sharma & Sher, 1974
Vigna esculentum (bean)	M.I., M.J. M.H., M.A.	CE	Lemos & Ponte, 1978
Wedelia paludosa	M.H.	DF	Mattos & Rodrigues, 1980

*M.I. = Meloidogyne incognita; M.J. = M. javanica; M.A. = M. arenaria; M.TH. = M. thamesi; M.H. = M. hapla.

**AL = Alagoas; BA = Bahia; CE = Ceará; DF = Distrito Federal; ES = Espírito Santo; PA = Pará; PB = Paraíba; RS = Rio Grande do Sul; SP = São Paulo.

done, however, to show quantitative damage due to root-knot in some horticultural crops (Table 2). Although the potential crop losses demonstrated by this limited work are alarming, the published information should not be extrapolated to estimate the real loss in any given region, since additional data such as population densities and geographical distribution of the nematodes are not available.

Some of the crop loss estimates were based on nematicide field control experiments (Table 2). Since many of the nematicides used are also insecticides and possibly have other effects on the field microflora and fauna as well, it is extremely risky to attribute the improved crop production solely to their control of plant-parasitic nematodes. The risk increases even more if the beneficial effects were credited solely to the control of root-knot nematode. Interpretation of the experimental data, therefore, needs to be approached with extreme caution.

Root-Knot Nematode Densities Related to Crop Performance

Pre-planting nematode densities related to crop performance have begun to receive attentions of Brazilian nematologists. In their pot experiments in Brasília, Huang and Charchar showed that pre-planting densities of *M. incognita* were related intimately to commercial carrot yields (11). Based on their data, the critical pre-planting density of the nematode in the case of commercial carrot production was estimated at about 250 eggs/liter of soil. It was also demonstrated that the damage of the root-knot nematode lies mainly in the reduced quality, not the quantity, of the carrot roots produced. They further affirmed that the infections which contributed most to the damage in commercial carrot production took place within 45 days after carrot germination.

Similar investigations demonstrated that cucumber (*Cucumis sativus* L.) growth as well as fruit production also was related intimately to the pre-planting inoculum density of *M. incognita* (10) (Table 3). It was observed that at the high inoculum density of 10^5 eggs/liter soil, the nematode was able to cause damping-off of the infected seedlings. The results also showed that at a low

Table 2. Damage of some horticultural crops infected by root-knot nematodes under experimental conditions

Crop	Loss estimated (%)	Nematodes involved*	Methodology	Authors
Tomato	37.6 (fruit weight)	Mixture of M.I. and M.J.	Greenhouse experiment with pots of unspecified size and pre-planting inoculum of 30 eggs/pot.	Ponte *et al.*, 1977
Carrot	16.6 - 20 (root weight)	M.J.	Field plot nematicide control experiment	Brancalion and Zem, 1982
Carrot	50 (root weight)	*Meloidogyne* spp.	Field control experiment with organic matter	Silva Sena and Ponte, 1982
Potato	100 (popped tubers)	M.J.	Field observations	Zem *et al.*, 1981

*M.I. = *Meloidogyne incognita*
M.J. = *Meloidogyne javanica*

Table 3. Pre-planting inoculum density of *Meloidogyne incognita* related to the development and production of cucumber (*Cucumis sativus* L.)

Inoculum (egg/liter soil)	Height (cm) of cucumber after germination				Fruit (g/plant) in 3 months
	10 days	24 days	45 days	86 days	
2×10^4	3.1	1.9	0.0	0.0	0.0
10^4	4.5	10.5	27.6	32.2	0.0
10^3	5.3	15.5	50.0	86.8	39.0
10^2	5.8	16.6	49.1	83.1	114.0
0	5.4	17.0	50.6	84.8	100.0
$LSD_{0.05}$	0.2	1.5	8.9	15.0	23.1

inoculum density of 10 eggs/liter soil, the nematode offered stimulatory effects on the initial stages of seedling development.

Disease Complex, Histopathology and Other Studies

Lopes and Lordello found both M. incognita and Fusarium solani f. piperis to be present in wilting pepper plants (Piper nigrum L.) (15). They believed that the two were involved in, and were having synergistic effects on, the wilting of black pepper. However, controlled experiments were not carried out to show the relationship between the two pathogens in the pepper disease, which is a menacing problem in the plantations of Amazon region.

Freire and Santos showed in their histopathological studies that F. solani f. piperis invaded and destroyed not only the giant cells and other host tissues infected by M. incognita, but the egg masses and females of the nematode as well (7).

Various cultivars of tomato were simultaneously infected with M. incognita and M. javanica and F. oxysporum f. lycopersici in the greenhouse (1). Results showed that all of them, even those known to be resistant to the fungus, were susceptible to the disease complex.

Possible disease complexes involving these two root-knot nematodes also attracted attention of Brazilian nematologists. Freire (1978) showed that simultaneous infections with M. incognita and M. javanica resulted in synergistic reduction of the height of "guaraná" (Paullinia cupana H. B. K. var. sorbilis) seedlings. Independently, the two nematodes failed to produce the same effect six months after inoculation, although they invaded the plant normally.

Susceptibility of rubber trees (Hevea brasiliensis Arg. Muell.) to M. incognita was demonstrated convincingly by the histopathological work of Freire & Santos, who showed that the nematode provoked rapid formation of giant cells and produced great numbers of egg masses in the cortex region (8).

Conclusion

In spite of the fact that the number of active nematologists in Brazil is relatively few, much work has been done to investigate the root-knot nematode problems in horticultural crops, particularly in the last 15 years. Analyses of the Brazilian literature revealed

many reports of the occurrence or chemical control of the nematodes. Fundamental information such as species and race, geographical distribution, population dynamics, crop loss, density and crop performance relationship, and crop resistance to the nematodes are scarce or altogether lacking.

RESUMO

Meloidoginose em hortaliças e culturas especiais no Brasil

Esta é uma revisão dos trabalhos publicados entre 1949 e 1982, que relatam, no Brasil, a meloidoginose em olerícolas e nas culturas especiais, tais como: guaraná, seringueira, pimenta-do-reino e cacau. O resultado da análise mostrou que, a ocorrência de meloidoginose foi registrada em 30 culturas olerícolas, além das quatro culturas especiais acima citadas, em 9 Estados do território brasileiro, envolvendo cinco espécies do gênero Meloidogyne Goeldi, 1892. Acreditase, entretanto, que a ocorrência real da moléstia seja mais ampla do que registra a literatura. Embora alguns trabalhos apontem perdas alarmantes de algumas hortaliças devido à meloidoginose, em condições experimentais, estimativas científicas sobre as perdas reais atribuíveis à doença, não são disponíveis. A maioria dos trabalhos publicados tratam do registro de ocorrências da doença e/ou controle da mesma. Estudos sobre aspectos da moléstia, tais como: identificação de raças, dinamica de população, densidade do nematóide relacionando-a com a perda cultural, distribuição geográfica, doenças complexas, histopatologia, estimativa de perdas culturais e outros são recentes e poucos e até mesmo ausentes.

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ROOT-KNOT NEMATODES ATTACKING SOYBEAN IN BRAZIL

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Occurrence and Distribution

Root-knot nematodes are by far the most important nematodes infecting soybean in Brazil. Several species of root-knot nematodes have been identified attacking soybean in Brazil, but Meloidogyne javanica (Treub, 1885) Chitwood, 1949, seems to be the one most commonly found (4, 10, 12) (Figure 1).

Effects of Chemical Control and Nematode Population on Soybean Yield

Soybean losses due to nematodes in Brazil have not been measured, but Lordello (13) estimated that they can be as high as 10% of total yield.

The first reference on nematode control in soybean by chemical methods was reported by Boock (5). He applied 10 gal/ha of Dowfume W-10 and found that plots treated with the nematicide yielded 656 kg/ha as compared with 163 kg/ha yield for the check plots. The nematicide did not affect soybean nodulation, since nodule number of the treated plots was 98% of the untreated ones.

Lehman et al. (11) evaluated the effect of Nemagon (14 and 28 kg/ha) associated with granular Mocap 10% and carbofuran 5% (4 kg/ha) on yield of 'Santa Rosa' soybean infected with root-knot nematode Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949. Full control was not obtained by any treatment, but a negative correlation was found between root weight and yield.

Novaretti et al. (14) applied aldicarb 10G and carbofuran 5G to a field planted with 'Foscarin 31' soybean and heavily infested with M. javanica, Pratylenchus brachyurus (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941, and Helicotylenchus sp. The results showed significant effects in increasing soybean yields and reducing the nematode population.

In an attempt to evaluate yield reductions caused by M. javanica, Bonetti & Tragnago (4) carried out an experiment with 5 soybean

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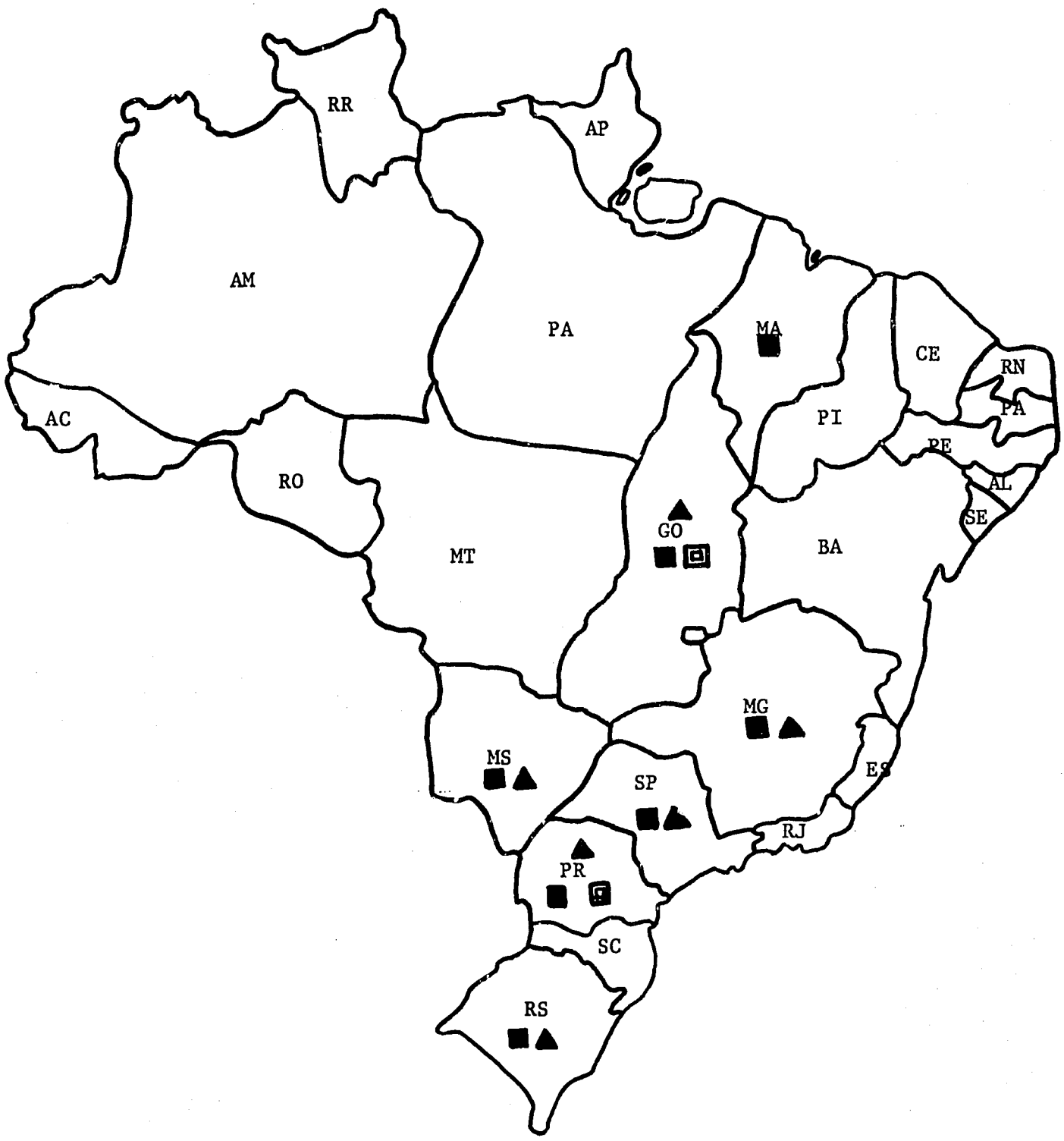

Figure 1. Distribution of Meloidogyne javanica (■), M. incognita (▲) e M. arenaria (▣), identified in soybean crops in Brazil.

cultivars ('BR-2,' 'IAS-5,' 'Paraná,' 'Pérola' and 'Década') and carbofuran 350F (365 a.i./ha). 'Década' was the only cultivar to reach maturity. Carbofuran 350F did not control M. javanica. Nodulation by Rhizobium japonicum was related negatively to root-knot number.

The effect of nematode population on soybean cv. UFV-1 was studied by Sharma and Rodrigues (22). The results indicate that initial population is related negatively to plant height, root weight, above-ground weight and leaf area at 35, 70 and 95 days after inoculation. Yield reductions were 43, 52, 82 and 98% when initial nematode populations were 2, 4, 8 and 16 larvae/g of soil, respectively.

Effect of Green Manure on Root-Knot Nematode Reproduction

Brazilian growers are considering the use of green manure practices in order to protect the soil and restore its physical and chemical properties. However, in areas infested with Meloidogyne spp., antagonistic or resistant plants should be used. Such plants can release root excretions with nematicidal properties or act on nematodes after root penetration to suppress reproduction or prevent continuation of the life cycle.

The effect of plants used as green manure on nematode reproduction is little known in Brazil. Sharma and Pereira (21) studied 15 of these plants and their capability of reducing M. javanica populations. Results showed that Tagetes erecta strongly reduced nematode density in the subsequent soybean planting. After that, the population increased due to the susceptibility of the cultivar used for two consecutive seasons. Crotalaria paulina was the most efficient plant species in controlling nematodes. Soybean yield increased by 2137 kg/ha following C. paulina compared to 2096 kg/ha following T. erecta.

Methodology for Testing Soybean Genotypes Under Greenhouse Conditions

There is little information on methodology for testing genotype reactions to root-knot nematodes. Antonio and Dall'Agnol (2) set up a greenhouse assay to study differences on the root-knot formation of two soybean cultivars ('Forrest' and 'Bossier,'

resistant and susceptible, respectively), under several inoculum levels (0, 1, 2, 4, 10, 20 and 40 thousand eggs) of Meloidogyne incognita in pots with 1,000 and 5,000 ml capacity. Inoculation was made through a syringe, and eggs were placed close to the seedling roots. The experimental design was a 2 x 2 x 7 factorial, with 8 replications. Plants were removed 69 days after planting and visually scored on a 0-5 scale, where 0 indicated no gall formation and 5 indicated roots heavily galled. Also, fresh and dry weight of the above-ground plant parts was determined.

'Forrest' showed few galls regardless of pot size or inoculum level. Gall scores for 'Bossier' were higher in small pots (2.08) than in large ones (1.65). It was concluded that the ideal rate for testing genotype resistance is close to 10,000 eggs/pot, since higher rates did not increase root-knot formation, in either pot size.

Inoculum level did not affect above-ground fresh weight of 'Forrest' or 'Bossier,' probably due to the light nematode attack and because of daily irrigation of the plants. Above-ground dry mass production on both cultivars was higher in 5000-ml than in 1000-ml pots. Despite heavier nematode attack, 'Bossier' produced larger amounts of dry mass, probably due to a longer cycle than 'Forrest.' In the smaller pots, above-ground dry mass was equivalent on both cultivars, due to space limitation for root development. Above-ground dry mass was proportional to its fresh weight, for both cultivars (r = 0.98).

Afterwards, Dall'Agnol and Antonio (9) studied effects of pot size, inoculation methods and inoculum levels upon gall formation on soybean. Resistant ('Bragg') and susceptible ('Bossier') cultivars were pre-germinated and planted one plant to each pot. Clay pots were used, with volumes of 500, 1000, and 5000 ml, while inoculum levels were 0, 1, 2, 5, 10 and 55 thousand eggs/pot. Inoculations were made by mixing the nematode egg suspension with the soil or by dispensing nematode eggs close to the soybean roots through a pipette.

Plants were collected 82 days after planting and roots were evaluated based on a 0 (no galls) to 5 (lot of galls) scale. Results showed no gall formation on roots of the resistant cultivar in any treatment. For the susceptible cultivar, differences were found depending on inoculation method, inoculum level and pot size. Gall score increased proportionally to inoculum concentration, on both methods, but the placement of the inoculum close to the roots was more efficient in inducing gall formation. Pots of 500 and 1000 ml capacity were also more efficient in inducing gall formation than the 5000-ml pots, as shown by the gall scores of 1.42, 1.31 and 0.94, respectively.

After visual evaluation, roots from 5000-ml pots were dried, for dry matter evaluation, while the roots from other pots were ground in a blender, for egg and larva evaluation. Root dry matter was not affected by the inoculation methods or inoculum levels. A high correlation (r = 0.89) was found between visual gall scores and number of nematodes recovered from the ground roots.

Despite gall absence, 1,714 nematodes/root were found on 'Bragg' for the 55,000 nematodes/pot level, while 'Bossier' showed 65,500 nematodes for the same level of inoculum.

Soybean Weeds as Hosts of Root-Knot Nematodes

Crop rotation is a reasonable nematode control measure, but can be inefficient when host weeds are allowed to grow in the rotated area.

Costa Neto (8) and Brandão (6) were the first to study nematode weed hosts in Brazil. Ponte (15), Rebel *et al*. (19), Ponte and Castro (16), Ponte *et al*. (17), Zem (23), Ponte (18), Rodrigues and Mattos (20) and Antonio and Lehman (1) reported lists of weeds as hosts of root-knot nematodes, especially of *Meloidogyne* spp.

Antonio and Dall'Agnol (3) determined the degree of susceptibility of 16 weed species, considered to be the most important in soybean fields of the state of Paraná (7), to the three most important soybean nematodes (*M. incognita*, *M. javanica*, and *M. arenaria*). The study was made under greenhouse conditions in 3000-ml clay pots. When plants were in the seedling stage, each pot was inoculated with a

suspension of approximately 25,000 nematode eggs. Plants were removed 78 days after inoculation, and nematode damage to the root system was evaluated by three different methods.

Ipomoea spp., Sida rhombifolia and Solanum sisymbrifolium were considered the best hosts for the nematode species studied. Commelina virginica was considered a good host when evaluated by the method of grinding the roots and counting the number of nematode larvae and eggs, but would be considered a poor host by the mean gall score and number of egg masses. Borreria suaveolens showed a low number of eggs and larvae, but relatively high gall scores and egg masses.

Except for Echinochloa crusgalli, other Graminae tested were considered to be non-hosts to the three nematode species, according to all three evaluation methods used. E. crusgalli and Aconthospermum hispidum were considered excellent, good and medium hosts for M. javanica, M. incognita and M. arenaria, respectively. Cassia occidentalis, Bidens pilosa and Euphorbia heterophyla behaved as non-hosts. Amaranthus hybridus and Raphanus raphanistrum were medium and poor hosts, respectively, for the three species. Considering the three nematode species, the three evaluation methods were equivalent for all the weeds studied, except for C. virginica and B. suaveolens.

RESUMO

Nematóides das galhas que atacam a soja no Brasil

Várias espécies de Meloidogyne foram identificados parasitando soja no Brasil. Entretanto, M. javanica é a espécie de maior ocorrência na cultura de soja seguida de M. incognita.

Na literatura consultada, encontram-se vários trabalhos mostrando a eficiência do controle químico na densidade populacional de nematóides e no aumento da produção de soja. No entanto, o seu uso é economicamente impraticável, devido aos elevados custos dos nematicidas.

É pouco conhecido o efeito de espécies vegetais usados como adubo verde na reprodução dos nematóides das galhas no Brasil. Trabalho realizado na região dos cerrados monstram que Crotalaria paulina e Tagetes erecta proporcionaram não apenas redução na população de M. javanica como também aumentaram a produção de soja.

Há uma sensível falta de informações quanto à metodologia a seguir em trabalhos de casa de vegetação quando se quer avaliar a reação de plantas aos nematóides formadores de galhas. O Centro Nacional de Pesquisa de Soja vem desenvolvendo algumas pesquisas nesse sentido e já obteve alguns resultados envolvendo soja resistente e suscetível com diferentes níveis de inóculo, diferentes tamanhos de vasos e diferentes métodos de avaliação. Em recente trabalho, uma cultivar de soja resistente a M. incognita não foi afetada pelo tamanho de vaso, nem pelos níveis de inóculo, enquanto que o grau médio de galhas numa cultivar suscetível foi significativamente maior nos vasos pequenos do que nos vasos grandes, e os níveis de inóculo influiram na formação de galhas com os níveis mais altos formando mais galhas que os níveis mais baixos. Os níveis de inóculo não influiram na produção de massa verde para as duas cultivares (resistente e suscetível). Também, observou-se que o método de inocular, misturando o inóculo no solo do vaso é menos eficiente na formação de galhas, que a colocação do inóculo concentrado na base da raiz. Quanto maior o tamanho do vaso maior a diferença entre os dois métodos. Com densidades muito altas (50-100.00) essa diferença tende a desaparecer.

A rotação da soja, com culturas não hospedeiras aos nematóides das galhas, seria uma excelente maneira de controlar estes parasitas, se não fossem as plantas daninhas hospedeiras dos mesmos nematóides. Corda-de-viola, guanxuma, joá-bravo e trapoeraba foram os melhores hospedeiros para M. javanica, M. incognita e M. arenaria. Com exceção de capim arroz, as demais gramíneas testadas foram péssimas hospedeiras para as três espécies de nematóides estudadas.

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ROOT-KNOT NEMATODE PROBLEMS IN NORTHEASTERN BRAZIL

Romero Marinho de Moura*

Introduction

The distribution of root-knot nematode in northeastern Brazil appears to cut across the major agricultural ecological zones. On the other hand, the heavy continuous cropping of land permits the build up of the nematode populations to very high potentially damaging levels. The effects of this parasite constitute the primary economic problem limiting production of crops, including vegetables, cereals, root crops, fruit crops and commercial crops (Figure 1). Hardly any crop or weed is free from the attack (Tables 1 & 2). As pest, it can inflict yield losses as high as 100% in several crops such as carrot, yam and sugarcane growing in highly infested fields. Frequently, interactions between *Meloidogyne* spp. and other plant pathogens such as *Fusarium*, *P. solanacearum*, and *Rhizoctonia* are observed under field conditions causing extremely high losses.

Control

Nematode control is practically nonexistent mainly due to the lack of knowledge concerning the importance of root-knot to production. On the other hand, the high prices of nematicides make chemical control for most root-knot problems almost prohibitive. Programs aimed at resistant varieties have been established recently for tomato and bean (*Phaseolus*) in Pernambuco State by EMBRAPA.

Research Activities

Most of the research work on plant nematodes including root-knot was conducted in the late 1960's and concentrated mainly on short surveys, species identification and field and greenhouse trials. More recently, with the start of the Master Programs on Crop Science at the Federal University of Ceará and Plant Protection at Federal Rural University of Pernambuco, more scientific research has been carried out.

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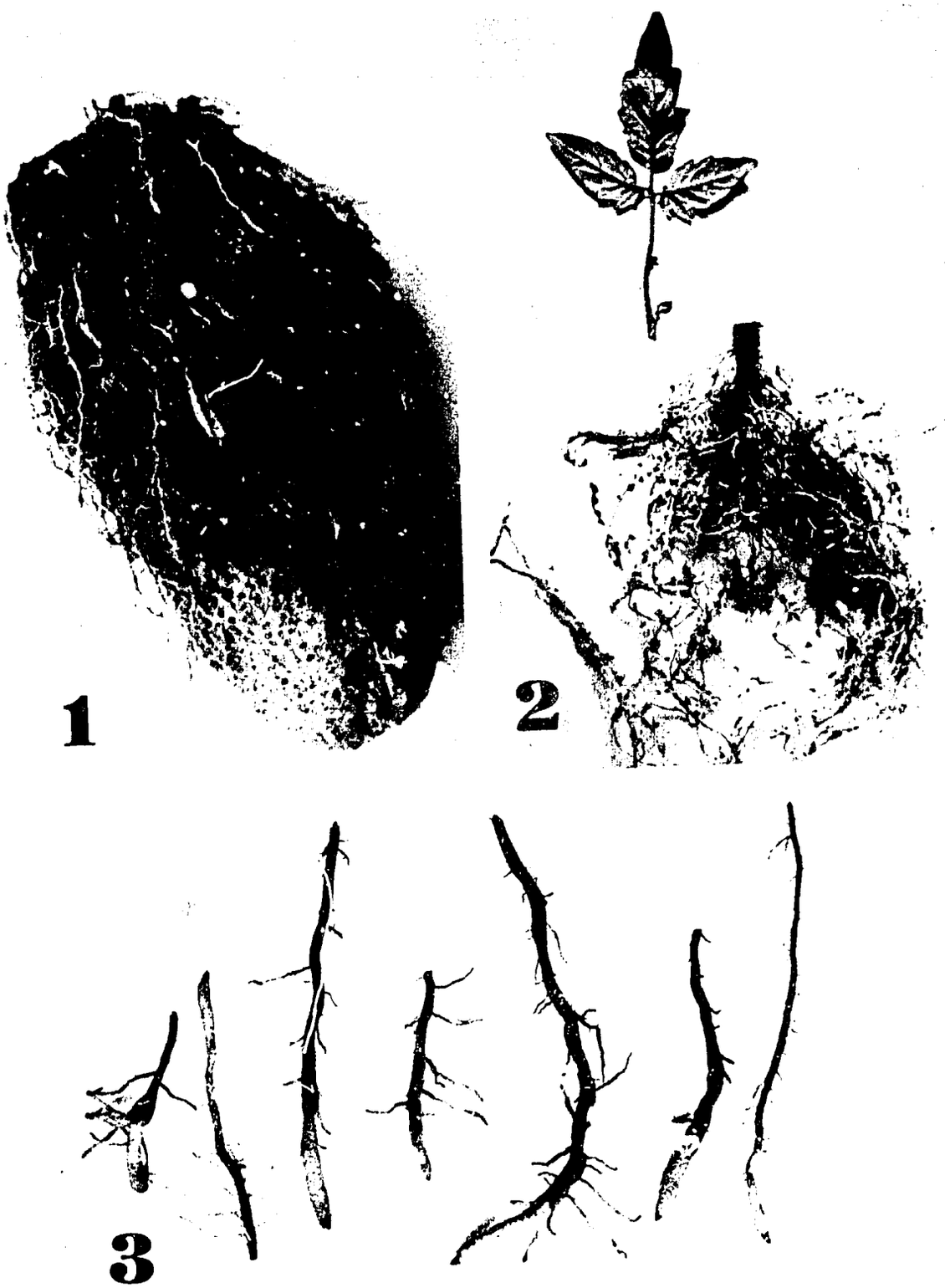

Figure 1. Root-knot nematode symptoms on three important crops in northeastern Brazil: 1) yam (Dioscorea cayenensis); 2) tomato (Lycopersicon esculentum) and 3) sugarcane (Saccharum sp. var. 'CB 45-3').

Table 1. Cultivated crop plants of northeastern Brazil subject to high losses due to *Meloidogyne* spp.

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1. Vegetable crops

   Tomato - *Lycopersicon esculentum*

   Okra - *Hibiscus esculentum*

   Melon - *Citrullus vulgaris*

   Pepper - *Piper nigrum*

   Carrot - *Daucus carota*

   Onion - *Allium cepa*

2. Food crops

   Bean - *Phaseolus vulgaris*

   Cowpea - *Vigna unguiculata*

   Yam - *Dioscorea cayenensis* and *D. alata*

   Sweet potato - *Ipomoea batatas*

3. Commercial crops

   Tobacco - *Nicotiana tabacum*

   Sugar cane (hybrids) - *Saccharum* sp. varieties 'Co 331' and 'CB 45-3'

4. Fruit crops

   Banana - *Musa* sp.

   Papaya - *Carica papaya*

Table 2. Existing species of *Meloidogyne* in northeastern Brazil

Species	Frequency (%) (Aprox.)
M. incognita	60
M. javanica	25
M. arenaria	10
*Others	5

*Includes *M. hapla*, *M. thamesi*, *M. lordelloi*, *M. elegans* odd populations.

In northeastern Brazil, there are only two laboratories for Plant Nematology: one at the Federal University of Ceará, under the leadership of Profº José Júlio da Ponte, and the other at the Federal Rural University of Pernambuco, under the direction of Profº Romero Marinho de Moura. Both laboratories have developed research and teaching activities for graduate and undergraduate students.

Future Needs

An extensive country-wide survey to find the existing species and races and to ascertain their geographic distribution is the basic need. Also, disease complexes involving plant-pathogenic nematodes and other soil-inhabiting pathogens, as well as soil deficiency programs, should be considered as basic research programs.

For control, more efforts should be concentrated on evaluation of cultivars in an attempt to attain material resistant or tolerant to root knot. Studies on crop rotation and use of nematicides are extremely important for short-term nematode control in the northeastern Brazil. The economic aspect of these control methods are important to farmers and should be included in the final reports.

Finally, the scientific staff working with nematodes in northeastern Brazil is practically nonexistent and training programs on plant-parasitic nematodes should be encouraged.

SUGAR CANE IMPROVEMENT FOR MELOIDOGYNE RESISTANCE IN BRAZIL

Hasime Tokeshi*

Due to its agroindustrial characteristics, along with the fact that its price is controlled by the State, sugar cane never renders astronomic profits which would permit the utilization of costly inputs for obtaining increased production. Since the cost of utilizing resistant varieties is practically nil, the producer always searches for sugar cane varieties that are rich, productive, widely adapted and resistant to pests and diseases.

Constant changes in ranking of the most cultivated varieties in Brazil, particularly in the State of São Paulo, are a reflection of the continuous search for new varieties (8).

The majority of producers are unaware that, for the production and release of the new varieties in the State of São Paulo in 1981, it was necessary for PLANALSUCAR to carry out work on over 1,520,000 seedlings. This work began in 1970, and only in 1981, was it possible to release these varieties. The probabilities of obtaining a new variety which surpasses the best already available is approximately 506,600:1; this is both a difficult and costly task.

In the screening for a new variety, PLANALSUCAR's sugar cane improvement program takes into consideration at least 25 agro-industrial characteristics of the crop. Each of these characteristics is controlled by one or several genetic factors, most of which are unknown. Due to these difficulties, plant breeders are obviously reluctant to introduce screening for resistance to nematodes. In addition to these difficulties, population studies indicate that at least five pathogenic genera of nematodes may occur in the same region, and within the genera, there may be several species and pathogenic strains (5, 6).

Since the genetic factors of resistance, as well as the hereditability of this resistance to nematode species, are unknown, all attempts to obtain resistant varieties have been based on

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exposing new clones to available nematode populations in naturally infested fields.

Since we do not have the predominant nematode species quantified or know the extent of their geographic distribution, all screening programs will be carried out in a rather unscientific manner. The choice of gall nematodes to be used for breeding work is based simply on the facility of symptom visualization. Thus, the need to develop work for the qualification and quantification of species distribution becomes evident. Only after these data are obtained will it be possible to carry out logical and rational screening programs which are not based merely on the facility of symptom visualization of gall nematodes.

In spite of these inconveniences, methodology errors have been minimized by selection criteria which submit clones in the final phases of selection to real conditions under which the variety will be utilized. Thus, indirectly, or even unconsciously, resistance to nematodes and other diseases has been taken into consideration. This is confirmed by the list of resistant varieties produced by different Brazilian research institutions shown in Table 1. All these varieties were produced without specific selection for nematodes (1, 3, 7, 9).

Practically all of these varieties were screened without considering nematode resistance characteristics. Only recently have COPERSUCAR and PLANALSUCAR conducted variety competition tests in an area naturally infested with nematodes and discovered that many commercial varieties have some type of resistance to gall nematodes and other genera. After this fact was confirmed, it became evident that breeders had screened for sugar cane varieties which were resistant to some nematode populations.

Nevertheless, one should not overlook the fact that the methods being employed for sugar cane breeding programs do not provide an adequate control over nematode populations which could safely isolate all the other factors that may minimize or aggravate nematode damage: for example, drought resistance, other nematode populations, ratoon stunting disease, soil management and soil fertility.

Table 1. Varieties resistant or tolerant to *Meloidogyne javanica*

Source	Brazilian varieties
COPERSUCAR	'CB53-98,' 'IAC48-65,' 'IAC52-150,' 'SP70454,' 'SP70592,' 'SP701143,' 'SP701203'
PLANALSUCAR	'IAC50-134,' 'IAC52-150,' 'RB735275'

COPERSUCAR 1982 PLANALSUCAR 1981

The specific case of variety 'NA56-79,' which in laboratory tests is considered susceptible to Meloidogyne javanica but which under field conditions often shows moderate tolerance, should be investigated further. This reaction may be attributed to the fact that this variety is tolerant to drought.

Tests carried out by Brinholi et al. (2) and Lee et al. (4) clearly showed that 'NA56-79' is more tolerant to drought than 'CB41-76.' Figure 1 shows results from tests to evaluate the resistance to drought through proline concentration in leaves. These results reveal that variety 'NA56-79' and clone 'RB745464' present high proline concentration, while the opposite holds true for 'CB41-76' which is highly susceptible to drought.

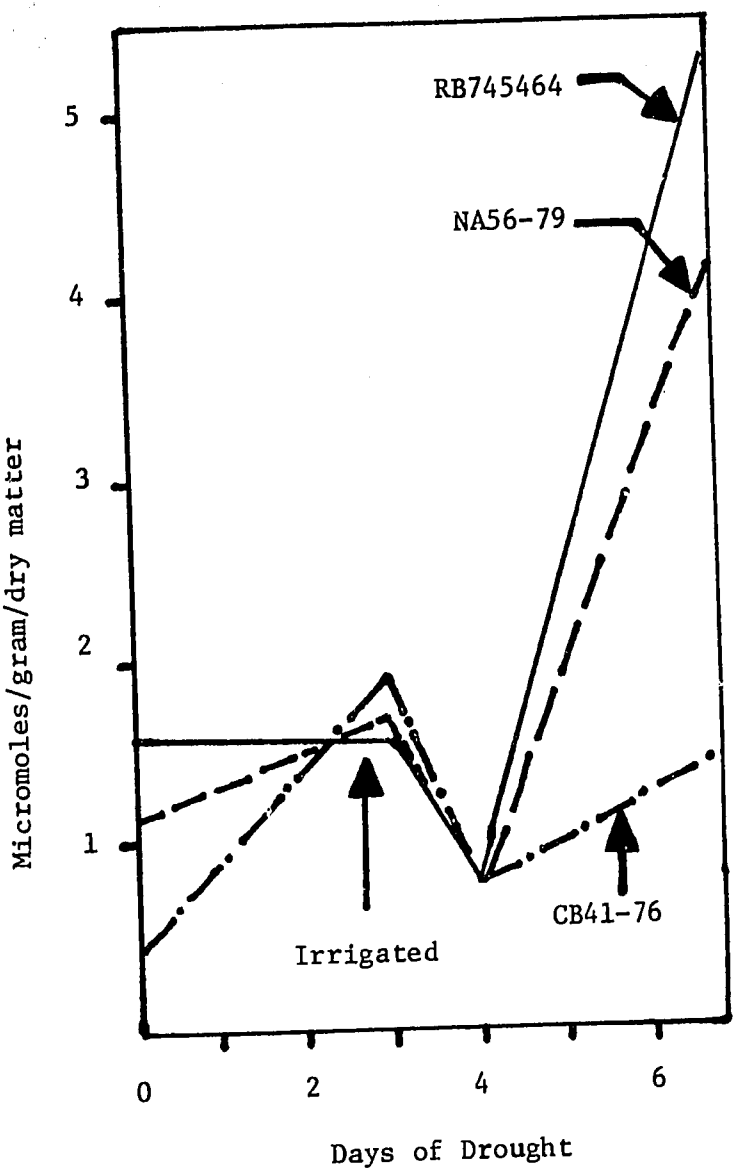
These characteristics and the capacity of nematodes to destroy the plant root system limit the volume of soil exploited by roots and, consequently, interfere in the water available to the plant. Varieties such as 'CB41-76,' which are susceptible to drought and nematodes, are more affected by this organism than varieties such as 'NA56-79,' which are susceptible to nematodes but tolerant to drought.

Tests carried out by PLANALSUCAR at the Estivas sugar mill, in the State of Rio Grande do Norte, in sandy soils infested by Meloidogyne and other genera, have shown that 'NA56-79' displays resistance to nematodes when its development is enhanced by the integrated control of nematodes. It is interesting to point out that other varieties screened for greater drought resistance are also displaying resistance to nematodes in a manner similar to that of 'NA56-79.' This fact is in agreement with the hypothesis that drought resistance interferes with nematode resistance tests.

Results from varietal resistance tests carried out by PLANALSUCAR at the Barra Grande sugar mill in the State of São Paulo indicate that an adequate control of nematode populations in experimental areas is necessary to avoid serious errors inherent to irregular nematode distribution in the areas and in the methodologies employed for nematode population analyses.

Based on previous surveys carried out at the Barra Grande sugar mill, a new varietal competition test was carried out in areas

Figure 1. Proline concentration in cane leaves (Lee *et al.*, 1983).



adjacent to those highly infested by Meloidogyne javanica (Table 2). While this test was being set up and monitored, new analyses of predominant field populations were carried out. Although these tests are still underway, changes in populations can be observed (Table 3). Results from these analyses revealed that although the areas had similar vegetation and soil, the nematode populations at the Barra Grande sugar mill were different or later became different. Previously, Meloidogyne javanica was predominant, and in the new neighbor area, a predominance of Helicotylenchus was recorded.

Although Meloidogyne populations were low, yields and percentage of yield losses of controls were compared with nematicide-treated plots. Table 4 shows the yield (in tons of sugar cane) of some varieties which were resistant and susceptible to Meloidogyne. It is observed that 'NA56-79' rendered high yields even though it is susceptible to Meloidogyne.

If the criteria of analyses used is changed, the level of resistance can be evaluated by the yield differences among untreated and nematicide-treated plots (Table 5). The variety 'NA56-79' becomes one of the most resistant varieties, even surpassing 'IAC51-205,' which is resistant to Meloidogyne. Similar comparisons can be made with other varieties. If there had not been a populational control in the latter experiment, errors of interpretation would have been unavoidable, resulting in conflicting results.

Another frequently observed problem in experiments when the application of nematicides is used for evaluating varietal resistance is the contamination of cuttings with Ratoon Stunting Disease (RSD). Matsuoka et al. (5) carried out experiments with the following treatments:

a) soil without nematodes and healthy cuttings (absolute control);

b) healthy cuttings plus soil with nematodes (NEM);

c) cuttings with Ratoon Stunting Disease plus soil without nematodes (RSD);

d) cuttings with RSD plus nematodes (NEM + RSD).

Table 6 shows the percentage of losses per variety for treatments b, c and d as compared to treatment a (absolute control).

Table 2. Population 1

	Nº of nematodes per 300 cc of soil
Meloidogyne	520
Pratylenchus	208
Helicotylenchus	214
Trichodorus	93
Others	144
Total	1,179

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Table 3. Nematodes observed in experimental areas

Genera	Usina Ester	Usina Barra Grande
Meloidogyne	+	+
Pratylenchus	+	+
Helicotylenchus	+++	+++
Trichodorus	+++	+
Criconemoides	+	+
Xiphinema	+	+
Tylenchorhynchus	++	+

+ = Low infestation, +++ = high infestation.

Source: PLANALSUCAR

Table 4. Some clones and varieties that showed highest production in nematode infested soils at Usina Barra Grande

Clones and varieties	Ton cane hectare	Ton sugar hectare
'IAC51-205'	172,52	27,91
'RB735275'	169,84	25,96
'725053'	153,67	22,94
'NA56-79'	150,30	24,88
'RB715079'	116,96	18,95
'725147'	108,34	17,50

Source: PLANALSUCAR

Table 5. Resistance to nematodes evaluated by production difference in treated and non-treated plots. Usina Barra Grande.

Clones and varieties	Difference %	Difference Weight (tch)
'RB725053'	5.32	8.63
'NA56-79'	6.13	9.82
'RB735275'	8.20	15.18
'IAC51-205'	8.86	16.77
'RB725147'	13.40	16.76
'715079'	13.67	18.46

Source: PLANALSUCAR

Table 6. Production losses in first harvest, as compared to nematode and Ratoon Stunting Disease free control.

Varieties	% losses per treatment		
	Nem	RSD	Nem + RSD
'CB41-76'	41.9	27.1	51.7
'CB49-260'	33.4	30.2	55.3
'IAC50-134'	15.2	15.0	25.4
'IAC52-326'	50.9	26.2	51.9
'NA56-79'	38.7	27.0	46.9
Average	35.0	25.1	46.2

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These data reveal that the percentage loss caused by nematodes in 'CB41-76' may reach 51.7% if th cutting has RSD. If the cutting is healthy, the loss drops to 41.9%.

Nematode damage is aggravated in all varieties if the cuttings have RSD. It is noteworthy that the damage of RSD is aggravated in ratoon crops, and in many cases, the use of healthy cuttings free of RSD disease may result in the production of an economic crop without the use of nematicides. This is because the increased yields brought about by nematicide treatments do not cover increases in cost.

From the above data, it may be concluded that the work related to the production of nematode-resistant sugar cane varieties still requires further basic scientific information to allow the selection of resistant varieties in a more scientific manner and to reduce probabilities of interpretation errors. In spite of the difficulties cited above and the frequency of nematode-resistant varieties available in the country, the number of resistant varieties is anticipated to increase rapidly with improvements introduced in Brazilian research programs.

RESUMO

Melhoramento da cana-de-açúcar para resistência à meloidoginose no Brasil

As revisões de literatura sobre programa de melhoramento da cana-de açúcar no Brasil indicam que mais de 25 características agro-industriais são levadas em consideração pelos melhoristas e estes estão relutantes em selecionarem para a resistência aos nematóides. A falta de informações básicas sobre os gêneros e espécies predominantes bem como a sua patogenicidade na cana-de-açúcar é discutida.

Testes conduzidos em campos em campos naturalmente infestados permitiram a identificação de diversas variedades comerciais com elevada resistência para diferentes populações de nematóides. A metodologia e testes de clones usada no melhoramento da cana tem sido a responsável pelo elevado nível de resistência e tolerância

encontrada em muitas variedades largamente cultivadas. Isto tem sido demonstrado mais recentemente pelos testes efetuados pela COPERSUCAR e PLANALSUCAR no Estado de São Paulo, em condições de campo e casa de vegetação.

O uso de campo naturalmente infestado, solo com fertilidade variável, mudas contaminadas com Raquitismo da Soqueira tem levado a algumas interpretações que podem suscitar dúvida sobre o grau de resistência ou tolerância varietal observado. Testes mais avançados têm mostrado elevada influência da seca, resistência varietal à seca e Raquitismo da Soqueira na produtividade de variedade cultivada em solo infestado com nematóide. Este fato não permite em muitos casos isolar a resistência ao nematóide dos outros fatores mencionados.

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CONTROL OF ROOT-KNOT NEMATODE ON SUGAR CANE IN BRAZIL

Wilson R. T. Novaretti*

INTRODUCTION

The nematodes of the genus Meloidogyne are indeed among the most important (13) sugar cane pests in Brazil.

The National Program of Alcohol has promoted a significant increase in the cane-growing areas, inevitably located on sandy soils, where the damage caused by nematodes is enhanced.

Studies were carried out under controlled conditions (12), comparing a check plot without nematodes to plots infested with three different initial levels of M. javanica. Reductions of up to 54% in the dry weight of roots and of 43% in the yield, occurred in inoculated plants as compared to healthy plants.

CONTROL

Based on present research and data, the main methods of nematode control on sugar cane in Brazil are summarized as follows.

Chemical Control

The use of nematicidal chemicals on sugar cane presents some problems, the most important being cost and toxicity. However, when they are properly used in highly infested areas, some nematicides have produced compensatory results (2, 4, 7, 10, 14, 25, 26).

For the compounds tested under Brazilian conditions, the best results were obtained with Furadan (carbofuran) as a granular formulation, with yield increases of 24 tons of cane per ha (Fig. 1). Two other products that also have shown good results are Temik (aldicarb) and Vydate (oxamyl), both as granular formulations.

The application period of these nematicides as well as the method to be employed are very important for better nematode control. Therefore, trials were performed under field conditions (11), and nematicides were applied at four different times: in the planting furrow; on the cane stems; incorporated at 30 and 60 days after

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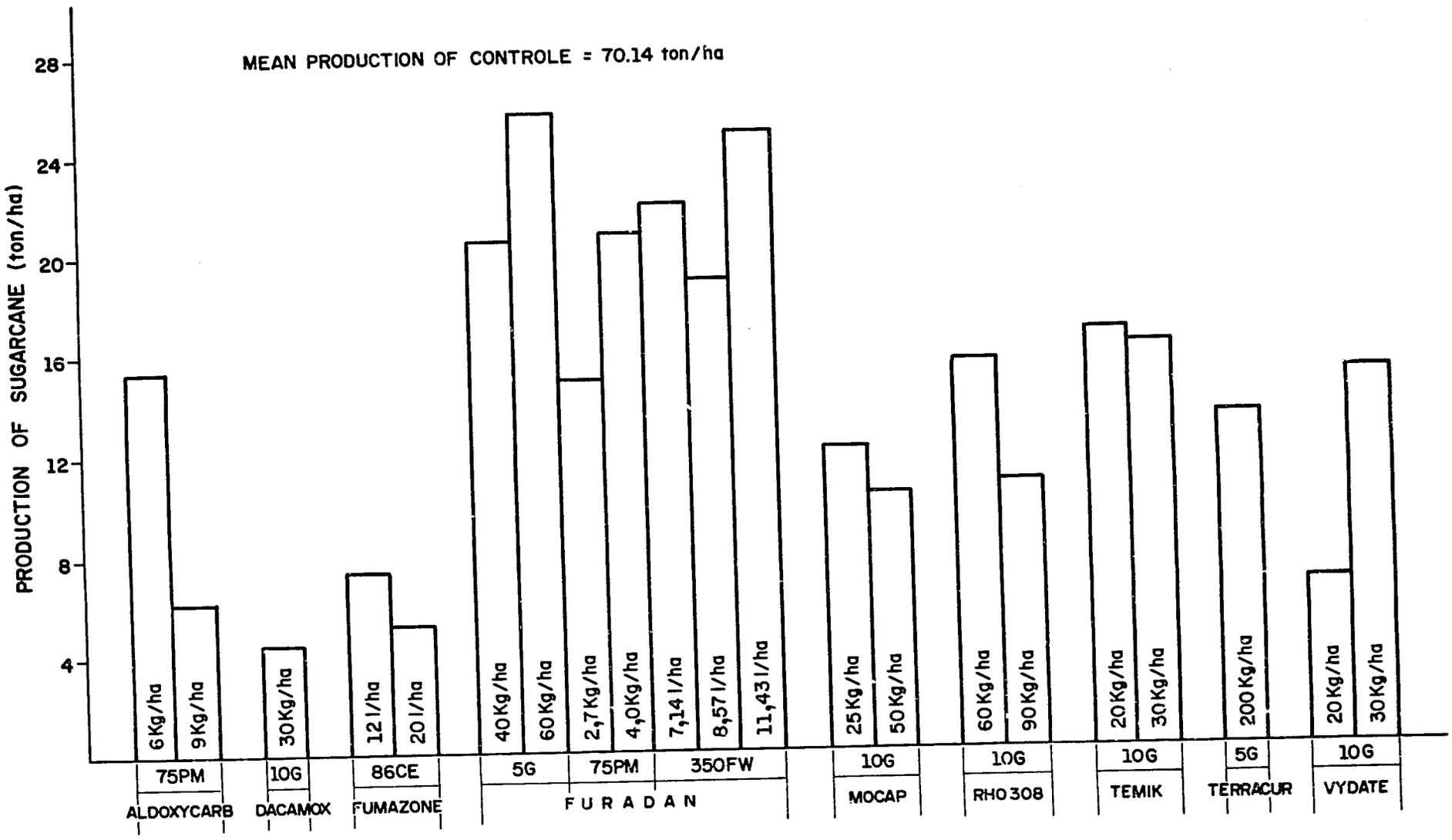
FIG. 1. INCREASE IN SUGARCANE PRODUCTION (ton/ha) BY NEMATICIDE TREATMENTS IN BRAZIL



planting; and in split applications with half of the dose applied at planting and half 7 months after planting, at the beginning of the rain season.

Analyses of the results showed that the utilization of the chemical compounds at planting gave the best results. However, the recommendation and practical utilization of nematicides in areas of commercial sugar cane production will depend mostly on the cost-benefit of using each industrial chemical compound.

For this reason, trials were performed in representative areas, comprising approximately 90.720m^2 with the purpose of studying the economical feasibility of using nematicides (16).

During the trial, all of the values necessary for the calculation of application cost of each chemical compound were considered. The following criteria were used: cost of each compound in the different formulations; cost of application equipment and yield; cost of application of these compounds; cost of harvesting, loading and transportation of the cane, in addition to the yield increases caused for each of the used treatments.

The linear formula used for calculating the profit per hectare as a function of cane yield increase, resulting from the chemical control of nematodes, is the following:

$$Ga = (P \times A) - C_s - (T \times A)$$

where:

Ga = Profit per hectare in tons of cane,

P = Cost of ton of cane,

A = Yield increase in ton/ha with the use of the nematicide,

C_s = Cost of nematicide use per hectare,

T = Cost of harvesting, loading and transportation per ton of cane.

When the nematodes were controlled with Furadan 5 G (carbofuran) at 60 kg/ha, for each Cr$1.00 invested in the cane planting, there was a reward of Cr$4.11 at harvesting. These values refer to the costs of sugar cane, nematicide and application equipment in September, 1982. The soils of the trial location were sandy in texture and highly infested by nematodes, mainly Meloidogyne javanica. The chemical treatment was made when the cane was 18 months old.

With respect to the cost-benefit ratio associated with the use of the nematicide Furadan 5 G (60 kg/ha), taking into account the present prices of cane, nematicides and applicators (October, 1982), the yield increase necessary for covering only the initial investment (compound + application) is 8.45 tons/ha.

With reference to the shooting, two aspects should be considered:

1) the effect of nematicide application on cane shooting and

2) the effect of the compound applied at planting on the yield of shootings.

In relation to the first item, the chemical control of the nematodes on shooting can promote sizeable yield increases of up to 12 tons/ha. However, at the present costs of the nematicide and cane, the use of this input has not been favorable economically (19).

With reference to the second item, trials under field conditions (22) showed that some nematicides applied at planting, on susceptible or intolerant varieties, caused significant yield increases on shooting, and contributed to the reduction of its utilization cost (Table 1).

However, this yield increase on shooting is probably caused by a 'strengthening' of the shoot during the vegetative period of the plant, and not due to a 'residual effect' of the nematicide.

Still with respect to the chemical control of nematodes, trials were performed in order to observe the influence of the nematode attack on the absorption of principal nutrients by sugar cane (21).

Analyses of leaves for N-P-K content showed that the chemical control of the nematodes had a positive effect on the absorption of nutrients, mainly N and P, probably because of the increase of root system of the plants treated with nematicide compared to those without treatment.

Research in progress and future research guidelines

1. Tests of new nematicide compounds on canes and shoots.

2. Studies of fertilizer reduction in areas where nematicides are applied.

3. Efficacy tests of nematicides applied during the planting period of sugar cane.

4. Studies of interactions between nematicides and the chief herbicides used on sugar cane.

Table 1. Yields of sugar cane treated with Furadan at planting
Barra Grande Sugar Mill, Lençóis Paulista, SP - Brazil 1976/1980

Treatments	Plant crop (ton/ha)	First ratoon (ton/ha)	Second ratoon (ton/ha)	Third ratoon (ton/ha)	Total (ton/ha)	Total response plant + ratoon (tons cane/ha)
Control	73.05	61.74	41.75	28.47	205.01	-
Furadan 5 G 40 kg/ha	94.49	71.50	48.03	31.63	245.65	40.65
Furadan 5 G 60 kg/ha	101.38	71.15	47.86	30.93	251.32	46.31
Furadan 75 PM 2.7 kg/ha	87.98	68.94	45.81	31.03	233.76	28.75
Furadan 75 PM 4.0 kg/ha	95.68	71.05	47.88	31.85	246.46	41.75

Varietal Control

Among the possible methods of controlling nematodes on sugar cane, the use of resistant or tolerant varieties is without doubt the most practical and economical (8). In addition, other advantages of this kind of control are recognized: it can be used without great knowledge on the part of the farmer, does not demand any service or attention of them, does not interfere with the other cultural practices, and does not present any problems of undesirable residues. However, the factors that give the features of high productivity and richness of sugar are in general antagonistic to those which promote hardiness, such as resistance to pests and diseases, low soil fertility requirements, etc.

In order that this kind of tactic may be employed against nematodes on sugar cane, two main kinds of work have been developed:

1. Evaluation of commercial varieties and clones SP, RB and IAC in the final phase of selection.

2. Selection of seedlings and clones to obtain varieties resistant to the root-knot nematode, *Meloidogyne javanica*.

The evaluation of the commercial varieties and clones SP, RB and IAC is performed under field conditions, in locations highly infested, primarily by *M. javanica*.

The trials are arranged in randomized blocks with subdivided plots, which correspond to the application or non-application of the nematicides.

The criterion adopted for evaluation of the clones and varieties was developed by Dropkin and Nelson (5) and defines the possible host-parasite relationships. According to these interactions, the plants are classified as resistant, susceptible, tolerant and intolerant.

Recent studies (3, 9, 18 and 20) have enabled the classification of some clones SP and commercial varieties according to their conduct in relation to the nematode *Meloidogyne javanica*:

Tolerant: 'SP70-455,' 'SP70-592,' 'SP70-1203,' 'SP70-1604;'

Resistant: 'CB53-98,' 'Co740,' 'IAC48-65,' 'IAC52-150,' 'SP70-1143,' 'SP71-1578,' 'SP71-4156,' 'SP72-4790;'

Intolerant: 'CB40-13,' 'SP70-1072,' 'SP71-355,' 'SP71-1081,' 'SP71-5982,' 'SP71-6180;' and

Susceptible: 'CB41-76,' 'CB45-155,' 'CP51-22,' 'IAC51-205,' 'IAC58-400,' 'NA56-79,' 'SP70-1078,' 'SP70-1145,' 'SP70-1284,' 'SP70-1423,' 'SP70-3370,' 'SP71-1043,' 'SP71-1182,' 'SP71-2530,' 'SP71-3149,' 'SP715368,' 'SP71-5574,' 'SP71-5913,' 'SP71-6099,' 'SP71-6163,' 'SP71-6186,' 'SP71-6196,' 'SP71-6949,' 'SP71-6113,' 'SP72-1395.'

In studies of the response of 29 commercial clones and 13 varieties under field conditions of high *M. javanica* infestation, it was observed that there is some tendency for the parents to transmit the ability to resist root-knot development to their progeny (17).

Based mainly on these works, Copersucar has begun a project to develop varieties of sugar cane which are resistant to *M. javanica*, using controlled and direct inoculations.

The work consists briefly of controlled inoculation of the seedlings with populations of only one species of nematodes, and later visual evaluation of the root system.

In the evaluation of the root systems of the seedlings, marks were attributed according to the following criterion:

Mark	Infestation level
0	0% root system with root-knot
1	Between 0.1 and 10% root system with root-knot
2	Between 10.1 and 25% root system with root-knot
3	Between 25.1 and 70% root system with root-knot
4	Above 70% root system with root-knot.

Seedlings that receive marks $\geq$ 2 are eliminated.

The selected material is planted again and incorporated into the improvement program proposed by Copersucar, mainly with respect to the agro-industrial features and resistance to certain diseases.

Research in progress and future research guidelines

1. Evaluation of new varieties not only for resistance to *M. javanica* but also for the other nematodes important on sugar cane.

2. Evaluation of the varieties in different ecological regions.

3. Development of resistant varieties from controlled and directed breedings, for each species and race of Meloidogyne.

Cultural Control

Some cultural practices can be effective methods of control. However, because of the semi-permanent character of the sugar cane crop, most of them can't be used.

Crop rotation. If well planned, crop rotation can be quite effective in controlling a number of nematodes. In Puerto Rico, good results were obtained in the control of M. incognita on sugar cane by rotation with pineapple (1).

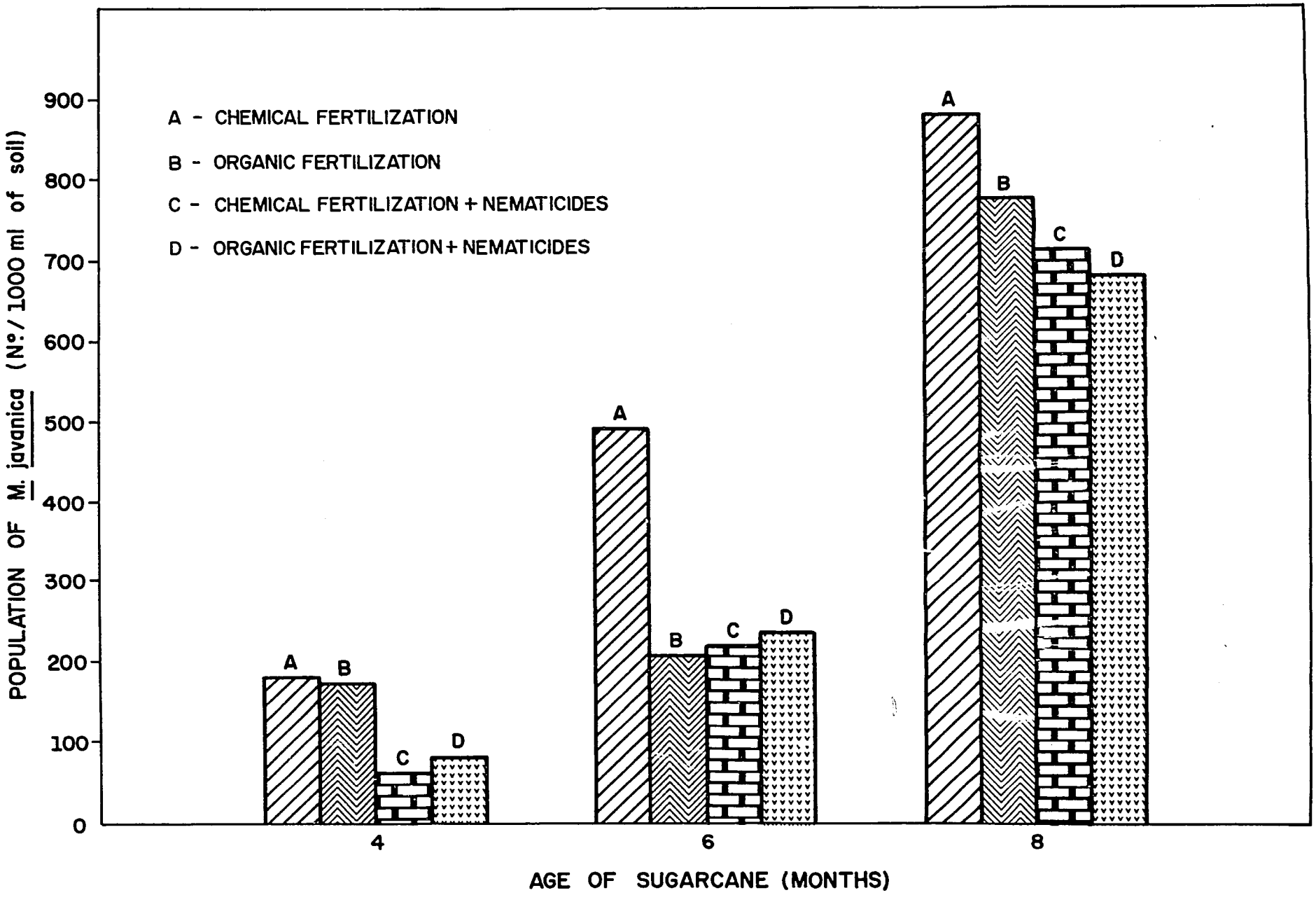
In Brazil, the cultivation of a leguminous plant between shoot destruction and planting of a new sugar cane field is becoming common (6). Several plants are used in this 'pseudo-rotation,' among them mucuna, soybean, 'lab-lab,' 'crotalaria,' bean, peanut, etc.

However, in areas where Meloidogyne nematodes occur, some of these leguminous plants can act as excellent hosts, increasing the population of these parasites (23). Therefore, the subsequent crop, sugar cane, in this case, might be damaged greatly because of the increase in nematode inoculum potential.

Organic matter. The addition of organic substances to the soil causes reduction in the population of some nematodes. Based on experimental work, several authors have reported that the organic matter added to the soil creates conditions which favor the multiplication of the natural enemies of nematodes, especially fungi (8). In addition, some products resulting from the decomposition of the organic substances, such as volatile fatty acids, may have a nematicidal effect.

In reference to the use of filter cake for controlling nematodes, some experiments performed in South Africa (4) showed the efficacy of this sugar manufacturing by-product when applied at 90 tons/ha. However, studies performed under Brazilian conditions (24) demonstrated only a slight control of the populations of M. javanica (Fig. 2); the results of yield increase can be attributed to the fertilization by this cake.

FIG. 2. POPULATION OF Meloidogyne javanica AFTER NEMATICIDE AND FERTILIZATION TREATMENTS



Use of Crotalaria spectabilis. Several authors have reported that infecting larvae of Meloidogyne penetrate into the roots of C. spectabilis, but that they do not survive. This plant acts, therefore, as a trap (8).

Experiments performed under our conditions (15), using leguminous plants from October to February, before planting the cane, did not show reduction in the nematode population. On the other hand, the cultivation of C. spectabilis led to a significant increase in Helicotylenchus sp. by serving as a host to this nematode.

Research in progress and future research guidelines

1. Reduction of nematicide dosage by using filter cake

2. Utilization of other organic matter sources for controlling nematodes

3. Utilization of anhydrous ammonia or aqua ammonia for controlling nematodes.

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A BRAZILIAN EFFORT TO DEVELOP SOYBEAN CULTIVARS RESISTANT TO ROOT-KNOT NEMATODES

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Plant-parasitic nematodes are important pests of soybean all over the world. They cause 5% of crop losses worldwide (20) and 10% in the United States (11). In Brazil, crop losses due to nematodes have not been estimated yet, but climatic conditions are favorable for most nematode species to develop and multiply. They have not been recognized as a real problem until recently. Presently, many research institutions in Brazil are involved in studying nematodes, specifically root-knot species.

DISTRIBUTION OF ROOT-KNOT NEMATODES IN SOYBEAN IN BRAZIL

According to the informations we have so far, root-knot species are by far the most important for soybeans in Brazil. Barker (3), in a consultant report on nematodes associated with soybean in Brazil, indicated that *Meloidogyne incognita* and *M. javanica* were the two most important species. Antonio and Dall'Agnol (unpublished) examined 24 samples of nematode-infected soybean roots collected from all over Brazil and detected the presence of *M. javanica* in 21 of the samples, *M. incognita* in 2 samples, and a mixed population of *M. javanica* and *M. incognita* in one sample.

Several authors have reported on the occurrence of root-knot nematodes in the state of Rio Grande do Sul (5,6,7,8,12). They collected samples of root-knot infected soybeans from 14 counties and found *M. javanica* and *M. incognica* in eight and six samples, respectively. *M. javanica* seems to be the root-knot species more commonly found in Brazilian soybeans. This distribution differs from worldwide findings which, according to Sasser as cited by Hadisoeganda (15), show that 52% of root-knot species found in world soils belong to the *M. incognita* species.

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A REVIEW OF BRAZILIAN LITERATURE ON RESISTANCE OF SOYBEANS TO ROOT-KNOT NEMATODES

The first published research relating to soybean resistance to root-knot nematodes in Brazil goes back to 1952 when Silva et al. at Campinas, State of São Paulo, tested the reaction of 21 soybean genotypes to an unknown population of Meloidogyne spp. (19). Later, this population was identified as M. inornata, a species closely related to M. incognita (17). Out of 21 genotypes tested, 'Palmeto,' 'Otootan,' 'La 41-1219' and 'N 45-3799' showed resistance to M. inornata. Miyasaka selected the breeding line 'N 47-3332,' out of 16 soybean genotypes, as resistant to Meloidogyne spp. (18). He did not identify the species.

Kiihl and Miyasaka (16) tested several soybean cultivars against M. javanica and indicated that 'IAC-2' and 'Santa Rosa' were the most resistant. Bonetti and Bescow, in Rio Grande do Sul, tested 56 soybean genotypes in a field naturally infested with M. javanica and found 'Forrest,' 'Semmes,' 'Pickett,' 'Bragg' and 'Bossier' as the most resistant varieties along with seven breeding lines (5).

Gomes et al. (12) tested 134 soybean genotypes against root-knot nematodes M. incognita and M. javanica. Genotypes showed more resistance to M. incognita than to M. javanica. Varieties 'Santa Rosa,' 'IAS-1,' 'Mack,' 'Pickett 71,' 'Bragg,' 'Industrial,' 'Tiaraju' and four breeding lines were considered moderately resistant to M. javanica; 'Hill,' 'Jackson,' 'Hampton,' 'IAS-4,' 'IAS-1,' 'Bragg,' 'Coker 4504,' 'IAS-2,' 'IAS-5,' 'Hardee,' 'Bienville,' 'IAS-3,' 'Hale-7,' 'Louisiana,' 'Paraná' and 42 breeding lines showed resistance to M. incognita. In 1976, Gomes et al. (13) tested 26 soybean genotypes for resistance to M. javanica and found that cv. 'Santa Rosa' was the most resistant, followed by 'Bragg,' 'IAS-1,' 'Tiaraju,' 'Mack,' 'Lee,' 'Semmes,' 'Bossier' and five breeding lines. Bescow and Vieira (4) tested the reaction of 60 soybean genotypes in a M. javanica-infested soil in the State of Rio Grande do Sul and observed that most genotypes had a low gall score, possibly due to uneven soil infestation. However, it was evident that 'IAS-1,' 'Semmes' and the breeding line 'CEP 7402' were resistant, particularly 'Semmes' and 'IAS-1.' These findings confirmed those of a previous study carried out in the same area (5).

Covolo (8) indicated that cvs. 'Bragg,' 'IAS-1,' and 'Prata' were the most resistant to M. javanica among 10 soybean cultivars evaluated in a greenhouse study. Based on egg mass indices, Antonio (1) selected cvs. 'Santa Rosa' and 'Bossier' as the most resistant to M. javanica out of 20 soybean genotypes tested in a greenhouse study in Piracicaba, São Paulo. Antonio and Dall'Agnol (2) tested 41 soybean cultivars recommended for planting in Brazil in 1980 against root-knot nematode M. arenaria and found cvs. 'Tropical,' 'Bragg,' 'São Luiz,' 'IAS-1,' 'Cobb' and 'Santa Rosa' as the most resistant, while cvs. 'Pérola,' 'UFV-1,' 'Planalto,' 'IAC-5,' 'Prata' and 'Viçoja' were the most susceptible. The gall scores were low because the amount of inoculum used was too low to separate the genotypes precisely according to their reaction to M. arenaria.

Tables 1, 2 and 3 show the reaction of the most common soybean cultivars grown in Brazil to the most important root-knot nematode species.

THE BRAZILIAN SOYBEAN BREEDING PROGRAM FOR ROOT-KNOT RESISTANCE

There are several research programs breeding soybeans for root-knot resistance in Brazil. The largest program is conducted by the National Soybean Research Center (NSRC) at Londrina (Latitude 23°23'S), state of Paraná, near to the center of the Brazilian soybean production area. At this research center more than 50 researchers (MSc or PhD) study soybeans full time, and nine of them are soybean breeders. One of those breeders is working exclusively to develop root-knot resistant varieties.

Breeding soybeans to develop resistant genotypes started in 1980 at the NSRC. The program began by testing the reaction to M. javanica and M. incognita of all Brazilian varieties and over 300 advanced breeding lines and by hybridizing the best varieties to known root-knot resistant genotypes ('Forrest,' 'Bragg,' 'BR-6,' 'Hill,' 'F 77-6790,' 'F 77-1790,' 'F 77-1797' and 'F 77-6903'). More than 800 F_1 seeds were produced from these crosses.

In 1981, hybridizations continued, but the sources of root-knot resistant genes were mainly the cv. 'Tropical' and eight breeding lines selected from the 1980 field evaluations because they were highly

TABLE 1. Reaction of Brazilian soybeans varieties to root-knot nematode *Meloidogyne incognita* according to evaluations made by several authors.

Varieties	Evaluations*			
	Dall'Agnol & Antonio (1980) Scale 0-5	Dall'Agnol & Antonio (1981) Scale 0-5	Gomes *et al.* (1975) Scale 0-4	Ferraz (1978) Scale 0-5
Andrews	3.7	3.1	-	-
Bienville	0.0	0.3	0.6	-
Bossier	4.2	3.6	2.8	-
BR-1	1.6	1.5	-	-
BR-2	1.6	0.6	-	-
BR-3	1.1	1.5	-	-
BR-4	1.9	2.0	-	-
BR-5	2.3	0.3	-	-
BR-6 (New Bragg)	0.3	0.0	-	-
Bragg	0.2	0.6	0.3	2.8
Campos Gerais	-	2.7	-	-
Cobb	0.1	0.5	-	-
Coker 136	0.8	0.8	-	4.5
Coker 318	-	1.0	-	-
Cristalina	1.9	0.4	-	-
Davis	2.3	2.4	1.7	-
Década	4.4	3.0	-	-
Doko	0.8	0.8	-	-
Dourados	-	0.3	-	-
Emgopa 301	-	1.4	-	-
Flórida	-	0.0	-	-
Forrest	-	0.0	-	2.7
Foscarin 31	-	0.4	-	-
FT-1	3.7	2.3	-	-
FT-2	1.6	0.8	-	-
Hampton	0.1	0.3	0.2	-
Hardee	1.6	-	0.6	-
Hill	-	-	0.0	-
Hood	-	2.3	1.6	-
IAC-2	4.0	2.7	-	4.2
IAC-3	0.7	1.1	-	-
IAC-4	4.1	3.2	-	-
IAC-5	1.1	0.9	-	-
IAC-6	2.1	0.7	-	-
IAC-7	1.3	0.9	-	-
IAC-8	0.0	0.6	-	-
IAC-9	-	0.7	-	-
IAS-1	0.0	0.0	0.3	-
IAS-2	0.3	0.0	0.5	-
IAS-3	0.8	0.5	0.7	-
IAS-4	0.2	-	0.2	-
IAS-5	0.8	0.0	0.6	-
Industrial	4.0	3.6	2.8	-
IPAGRO 20	-	1.1	-	-
Ivaí	1.3	1.3	-	-
Ivorá	2.7	1.1	1.4	-
Lancer	1.6	0.6	-	-
LC 72-749	-	0.5	-	-
Mineira	1.3	1.3	-	4.7
Missões	-	0.0	-	-
Numbaíra	-	0.4	-	-
OCEPAR 2-IAPÓ	-	0.5	-	-
Pampeira	-	0.9	2.0	-
Paraná	1.8	0.3	0.9	-
Paranagoiana	-	0.8	-	-
Pérola	1.9	1.0	1.7	-
Planalto	1.7	1.4	2.0	-
Prata	1.4	0.3	1.2	-
Santa Rosa	4.4	2.7	3.3	4.1
Sant'Ana	-	0.8	-	-
São Luiz	2.8	2.9	-	-
Semmes	-	1.1	-	-
Sulina	1.3	0.0	-	-
Tiarajú	-	2.9	-	-
Tropical	0.0	0.0	-	-
UFV-1	2.5	1.6	-	5.0
UFV-2	2.0	1.8	-	4.8
UFV-3	3.8	3.6	-	-
UFV-4	-	2.0	-	-
União	1.6	0.4	-	-
Viçoja	2.1	1.3	2.0	4.8
Vila Rica	1.5	1.0	-	-

*0 (no galls) to 4 or 5 (lot of galls) scale

TABLE 2. Reaction of Brazilian soybean varieties to root-knot nematode *Meloidogyne javanica* according to evaluations made by several authors.

Varieties	Evaluations*											
	Dall'Agnol & Antonio (1980) Scale 0-5	Dall'Agnol & Antonio (1981) Scale 0-5	Bonetti & Bescow (1975) Scale 1-4	Bescow & Vieira (1976) Scale 0-4	Bonetti & Vieira (1980) Scale 1-4	Bonetti & Tragnago (1981) Scale 1-4	Gomes *et al* (1975) Scale 0-4	Gomes *et al* (1976) Scale 0-4	Gomes *et al* (1977) Scale 0-4	Ferraz (1978) Scale 0-5	Covollo (1975) Scale 0-5	Antonio (1980) Scale 0-5
Andrews	1.8	2.1	-	-	-	-	-	-	-	-	-	2.1
Bienville	3.3	2.6	3.2	2.5	-	-	3.5	-	-	-	1.8	-
Bossier	2.6	1.3	1.2	1.4	-	1.7	2.2	2.0	1.2	-	-	2.0
BR-1	3.3	1.7	-	-	-	1.7	-	-	1.0	-	-	-
BR-2	3.4	1.6	-	-	-	4.0	-	-	-	-	-	-
BR-3	3.5	2.6	-	-	-	3.8	-	-	-	-	-	-
BR-4	3.8	2.5	-	-	2.3	4.0	-	-	-	-	-	-
BR-5	3.0	1.8	-	-	-	-	-	-	-	-	-	-
BR-6 (New Bragg)	1.4	0.6	-	-	-	-	-	-	-	-	-	-
Bragg	1.5	1.6	1.2	0.9	1.7	1.3	1.5	1.4	1.2	4.1	0.5	-
Campos Gerais	-	3.0	-	-	-	-	-	-	-	-	-	-
Cobb	3.1	2.0	1.8	3.0	1.7	3.7	-	-	-	4.9	-	-
Coker 136	3.3	1.4	-	-	-	-	-	-	1.9	4.9	-	-
Coker 318	-	2.7	-	-	-	-	-	-	-	-	-	-
Cristalina	4.0	1.5	-	-	-	-	-	-	-	-	-	-
Davis	3.5	2.8	3.8	-	2.5	3.7	3.9	3.1	-	-	-	-
Década	-	1.3	-	-	1.2	-	-	-	-	-	-	-
Doko	4.6	3.3	-	-	-	-	-	-	-	-	-	-
Dourados	-	3.3	-	-	-	-	-	-	-	-	-	-
Emgopa 301	-	1.3	-	-	-	-	-	-	-	-	-	-
Florida	-	2.7	-	-	-	-	-	-	-	-	-	-
Forrest	-	0.8	1.0	0.1	1.0	1.3	-	2.2	0.8	4.1	-	2.7
Foscarim 31	-	2.3	-	-	-	-	-	-	-	-	-	-
FT-1	0.8	2.2	-	-	-	-	-	-	-	-	-	-
FT-2	4.5	1.5	-	-	-	-	-	-	-	-	-	-
Hampton	2.5	-	1.2	-	-	-	3.7	-	-	-	-	-
Hardee	3.0	2.0	3.6	3.9	2.4	3.8	3.3	-	-	-	2.5	3.7
Hill	-	-	2.5	0.7	-	-	3.4	-	-	-	-	5.0
Hood	-	1.8	3.3	1.2	-	-	3.7	-	-	-	-	-
IAC-2	1.3	1.3	-	-	-	-	-	-	-	4.8	-	-
IAC-3	2.6	2.3	-	-	-	-	-	-	-	-	-	-
IAC-4	2.2	1.2	-	-	-	-	-	-	-	-	-	-
IAC-5	3.0	2.9	-	-	-	-	-	-	-	-	-	-
IAC-6	3.2	2.9	-	-	-	-	-	-	-	-	-	-
IAC-7	3.5	1.3	-	-	-	-	-	-	-	-	-	-
IAC-8	3.5	1.4	-	-	-	-	-	-	-	-	-	-
IAC-9	-	1.4	-	-	-	-	-	-	-	-	-	-
IAS-1	2.3	0.4	2.2	0.4	1.3	1.2	1.5	1.4	1.0	-	1.0	-
IAS-2	-	1.8	3.7	-	-	-	3.6	-	-	-	2.0	-
IAS-3	2.6	1.8	4.0	1.4	-	-	3.5	-	-	-	1.8	-
IAS-4	3.6	1.3	3.7	1.9	1.0	4.0	3.7	-	-	-	-	-
IAS-5	4.3	3.2	4.0	0.8	-	2.8	3.7	-	-	-	-	-
Industrial	2.6	1.3	1.5	1.7	-	-	1.8	2.3	-	-	-	-
IPAGRO 20	-	2.0	-	-	-	-	-	-	-	-	-	-
Ivaí	3.7	1.2	-	-	2.0	4.0	-	-	-	-	-	-
Ivorá	3.6	2.3	-	-	-	4.0	3.9	-	-	-	-	-
Lancer	2.9	2.8	-	-	-	-	-	-	-	-	-	-
LC 72-749	-	1-6	-	-	-	-	-	-	-	-	-	-
Mineira	4.7	3.3	4.0	3.3	-	3.8	-	-	-	4.8	-	3.1
Missões	-	2.7	-	-	-	4.0	-	-	-	-	-	-
Nambaíra	-	2.1	-	-	-	-	-	-	-	-	-	-
OCEPAR 2-IAPÓ	2.7	-	-	-	-	-	-	-	-	-	-	-
Pampeira	-	2.6	4.0	1.6	-	3.8	3.8	-	-	-	-	3.2
Paraná	3.0	2.3	4.0	1.2	1.2	3.5	3.7	2.4	-	-	-	-
Paranagoiana	-	1.8	-	-	-	-	-	-	-	-	-	-
Pérola	3.7	2.8	4.0	1.7	-	3.5	3.2	2.7	-	-	1.5	-
Planalto	3.0	2.5	4.0	1.4	-	4.0	3.8	-	-	-	1.5	-
Prata	1.9	2.1	4.0	0.1	-	3.8	3.5	-	-	-	1.0	-
Santa Rosa	2.0	1.4	3.5	0.9	-	2.7	1.3	0.7	0.6	4.8	2.0	1.2
Sant'Ana	-	1.4	-	-	-	-	-	-	-	-	-	-
São Luiz	3.0	1.6	-	-	-	-	-	-	-	-	-	-
Sonnes	-	1.9	1.2	1.0	-	1.5	-	2.0	-	-	-	3.9
Sulina	3.5	3.0	-	-	-	3.8	-	-	-	-	-	-
Tiaraju	-	1.2	-	-	-	-	1.9	1.4	0.6	-	-	-
Tropical	0.3	0.8	-	-	-	1.0	-	-	-	-	-	-
UFV-1	3.5	2.1	-	-	-	-	-	-	-	4.9	-	-
UFV-2	4.2	1.5	-	-	-	-	-	-	-	4.9	-	-
UFV-3	2.1	1.3	-	-	-	-	-	-	-	-	-	-
UFV-4	-	2.8	-	-	-	-	-	-	-	-	-	-
União	4.6	1.5	-	-	1.2	4.0	-	-	-	-	-	-
Viçoja	3.5	2.7	4.0	3.3	-	-	3.7	-	-	5.0	-	2.9
Vila Rica	4.1	2.1	-	-	-	-	-	-	-	-	-	-

* 0 (no galls) to 4 or 5 (lot of galls) scale

TABLE 3. Reaction of Brazilian soybean varieties to root-knot nematode *Meloidogyne arenaria*. Antonio and Dall' Agnol, 1982.

Varieties	Gall Score*	Nº. of eggs and juveniles
Tropical	0.00	379
Bragg	0.00	350
São Luiz	0.07	379
IAS-1	0.07	707
Cobb	0.14	1,407
Santa Rosa	0.21	243
FT-1	0.28	736
Industrial	0.35	443
UFV-3	0.35	557
IAC-4	0.35	650
Hampton	0.42	1,857
IAC-8	0.42	1,857
Sulina	0.42	3,271
Coker 136	0.50	2,711
IAC-2	0.50	379
IAC-4	0.58	3,525
Lancer	0.64	3,201
Bossier	0.71	864
IAC-3	0.78	1,564
Campos Gerais	0.80	4,317
Missões	0.92	2,621
BR-2	1.07	2,757
Paraná	1.08	2,308
IAS-5	1.14	1,729
Numbaíra	1.21	3,314
Ivorá	1.28	2,743
Dourados	1.28	3,307
BR-3	1.35	5,958
BR-5	1.35	4,231
BR-1	1.42	3,186
União	1.42	2,493
Ivaí	1.64	3,008
BR-4	1.78	4,429
UFV-2	1.85	1,393
Bienville	2.00	4,114
Cristalina	2.00	5,064
IAC-7	2.00	2,914
Pampeira	2.07	4,186
Davis	2.14	3,100
Hardee	2.28	4,393
Doko	2.42	4,329
Mineira	2.42	6,771
IAC-3	2.50	4,136
IAC-6	2.57	3,036
Vila Rica	2.78	5,164
Viçoja	2.92	6,592
Prata	3.21	6,093
IAC-5	3.28	11,479
Planalto	3.42	6,750
UFV-1	3.57	7,057
Pérola	3.78	7,071

* 0 (no galls) to 5 (lot of galls) scale

resistant to both M. javanica and M. incognita. Field evaluations also continued in 1981, and the number of entries increased from 394 to 1,200. Among these entries were all advanced breeding lines of the NSRC and genotypes from many other breeding programs throughout Brazil and genotypes from the germ plasm collection. From this evaluation we selected 32 breeding lines as highly resistant to both M. javanica and M. incognita to be used in the 1982 hybridizations. The genotypes selected for their resistance to root-knot nematodes (8 in 1980 and 32 in 1981) were included in our germ plasm collection and are available to soybean breeders as sources of resistance to root-knot nematodes.

Since the NSRC has a national reach, the hybridization program gives special attention to the maturity group of the parent material, in order to generate material adapted to all Brazilian latitudes (from 34° S to 5° N). Particular attention is also given to resistance to the frog eye leaf spot (Cercospora sojina Hara) and to bacterial pustule (Xanthomonas phaseoli var. sojense (Hedges) Star Burkolder). Resistance to the former disease is desired because of its potential to cause serious damage to soybeans in Brazil, and resistance to the latter disease is desired because of the simplicity of incorporating such resistance. F_1 plants are grown during winter months in greenhouses with controlled temperature, and the segregating populations, from there on, are planted in the field during the summer.

Presently (October 1982), our nematode breeding program has $30F_3$ bulks, 1,500 F_2 progenies and 2,000 F_1 seeds from the hybridizations made in 1980, 1981 and 1982, respectively. Evaluations of the material to check the reaction to root-knot nematodes will be done after one year of preliminary tests for yield (F_6 of F_7).

Despite nematode resistance being the main goal of this breeding program, it is needless to say that we consider yield to be more important than resistance to root-knot nematodes. A high-yielding genotype developed by this program will be released, despite being susceptible to nematodes. We hope this effort will lead to the development of high yielding, but root-knot resistant varieties.

RESUMO

Um Esforço Brasileiro Para O Desenvolvimento De Variedades De Soja Resistentes Aos Nematóides Das Galhas

Os nematóides são importantes pragas das plantas cultivadas. Estima-se que eles são responsáveis por uma redução de 5% dos alimentos produzidos no mundo. Levantamentos feitos pela Sociedade Norte Americana de Nematologistas calculou em 10% a redução da produção de soja daquele país pelo ataque dos nematóides. No Brasil, somente muito recentemente, eles tem despertado a atenção de agricultores e pesquisadores. Quanto eles reduzem a produção brasileira ainda não sabemos.

Meloidogyne javanica e M. incognita parecem ser destacadamente as duas espécies mais encontradas atacando soja no Brasil. O seu controle através de produtos químicos é economicamente inviável para uma cultura como a soja. Rotação e pousio são práticas eficientes mas de difícil aplicação. Uso de variedades resistentes surge como a mais eficiente, prática e econômica medida para controlar os nematóides da soja.

A pesquisa com resistência varietalem soja começou no Brasil em 1952 com Silva, Lordello e Miyasaka. Continuou com Miyasaka (18), Kiihl e Miyasaka (16), Bonetti e Bescow (5), Gomes e outros (12,14), Bescow e Vieira (4), Covolo (8), Antonio (1), Bonetti e Vieira (6), Dall'Agnol e Antonio (9,10) e Bonetti e Tragnago (7). Dessas pesquisas, resultaram as seguintes cultivares como moderada ou altamente resistentes a M. javanica e/ou M. incognita: 'Palmeto,' 'Forrest,' 'Semmes,' 'Pickett,' 'Bragg,' 'Santa Rosa,' 'Tiaraju,' 'Mack,' 'IAS-1,' 'Jackson,' 'Hill,' 'Hampton,' 'Cobb,' 'Tropical,' 'Década' e mais uma série de linhagens.

A partir de 1980, grande ênfase foi dada pelo Centro Nacional de Pesquisa de Soja (CNPSo) localizado em Londrina, estado do Paraná, ao desenvolvimento de cultivares resistentes aos nematóides formadores de galhas. Um intenso programa de hibridações, foi iniciado envolvendo conhecidos genótipos resistentes aos nematóides das galhas com cultivares adaptadas às diferentes condições ecológicas brasileiras. Mais de 30 combinações diferentes foram realizadas. Em 1981 o número de combinações foi ampliado para mais de 50 e em 1982 para mais de 100 combinações.

Embora esse programa tenha sido iniciado com o objetivo de conseguir variedades resistentes às principais espéceis de nematóides que atacam a cultura da soja no Brasil, produtividade é considerada mais importante que resistência aos nematóides. Por essa razão, seleção para nematóides somente será realizada após o primeiro teste de produtividade a que as linhagens serão submetidas nas gerações F_5 ou F_6.

A geração F_1 é conduzida durante o inverno em casa de vegetação e as demais gerações segregantes são avançadas pelo método de bulk, a campo, em Londrina, Paraná. Presentemente, o programa de nematóides conta com 30 bulks em F_3, 1.500 linhas em F_2 e aproximadamente 2.000 sementes F_1 provenientes dos cruzamentos feitos em 1980, 1981 e 1982, respectivamente.

Paralelamente aos trabalhos de hibridações e condução das populações segregantes, o programa de nematóides do CNPSo avalia anualmente a campo as variedades recomendadas no Brasil, as linhagens promissoras do CNPSo e dos demais programas de melhoramento interessados em conhecer a reação do seu material genético aos nematóides das galhas.

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MELOIDOGYNE SPP. CHEMICAL CONTROL ON VEGETABLES

Antônio Carlos Zem*

INTRODUCTION

Root knot (caused by Meloidogyne spp.) can be considered the most economically important nematode disease in Brazilian vegetables because these nematodes live like parasites on most vegetables and have a wide geographic distribution. Crops like lettuce, pumpkin, potato, eggplant, beet, onion, carrot, chayote, okra, parsley, tomato and cabbage, among others, are extremely susceptible to the attack of these nematodes, and the economic losses they promote are considerable (2, 5, 10, 11, 14). For this reason, farmers and researchers often have tried to control them through chemical treatment (nematicides).

This is a review of the references on the chemical control of root-knot nematodes on several vegetables, in light of available information in Brazil relative to this important area of nematode control. This information will be reviewed by crop.

POTATO

The potato plant (Solanum tuberosum L.) figures among the most susceptible to root-knot nematode attack. The following species often occur in association: Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949; M. javanica (Treub, 1885) Chitwood, 1949; and M. arenaria (Neal, 1889) Chitwood, 1949. These species cause much damage, especially in crops located in sandy soil and during the hot and rainy season (4). In some cases, 100% "popped" tubercles occur (16); this has caused the development of studies on nematicides by Boock (2) and Boock & Lordello (3) for root-knot nematode control. These authors observed that the fumigating nematicides dichloropropene and ethyl dibromide were efficient, and that dibromochloropropane was highly phytotoxic.

Recently Zem et al. have achieved yield increases and remarkable influence on the quality of tubercles, by using the nematicide

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carbofuran at 3 kg a.i./ha for controlling M. javanica on potatoes (16); they also have noticed that applications in the planting furrow or those equally divided between planting and moulding up were superior to application during moulding up.

CARROT

The losses promoted by the root-knot nematode (Meloidogyne spp.) on carrot (Daucus carota L.) are mainly qualitative, resulting in an increase of knots, deformity, digitation and cracks on roots, and consequent loss in value during commercialization of the harvested product.

Brancalion & Zem (5) observed that in Castro, Paraná, the losses caused by M. javanica on carrots varied from 16.6 to 20%.

In relation to chemical control of the root-knot nematode on carrot, Petenucci emphasized the efficacy of dibromochloropropane as well as the cost/benefit ratio involved in nematicide usage (13).

Ikuta et al. obtained significant yield increases and qualitative improvements by using the nematicides carbofuran and dibromochloropropane for control of M. javanica on carrot (9).

Brancalion & Zem developed two trials on chemical control of M. javanica (5). They observed that applications of the nematicides carbofuran and fensulfothion resulted in good control of M. javanica juveniles, and provided yield increases of up to 43%.

OKRA

The okra plant (Hibiscus esculentus L.), in spite of its relative strength, can be attacked by several pests and diseases, of which the root-knot nematode is one of the more serious.

In Brazil, heavy infestations of M. incognita and M. javanica have often been reported, causing innumerable knots on the okra roots, with sizes varying from 2 to 9 times the normal diameter, and sheltering many females, parasitic juveniles, and eggs. Because of the parasitism, there is intense cortex detaching, root system reduction and little development of the above ground portion of the plant, which sometimes leads to death even before the plants begin to produce.

The observation of the problem has stimulated some researchers to develop experiments with the purpose of controlling these parasites

chemically. Carvalho & Zica used fumigants for root-knot nematode control, observing a remarkable nematicidal effect of D.D. at 40 ml/m^2 (6). Almeida et al. reported the nematicidal effects of carbofuran and AC-64-475 (geophos) which caused a reduction in root infection, without causing significant differences in the height of plants (1).

Zem & Araújo observed that the use of aldicarb, dibromochloropropane, carbofuran and fensulfothion, at 0.2 g a.i./plant for control of M. incognita on okra, didn't provide significant statistical differences in plant height or numbers and weight of fruits (15). They emphasized that because of the short cycle of the crop (first harvests at 60 days), systemic nematicide use is not recommended, since the residue persistence is very likely. In the same area, it was observed that fallow practiced for 4 months in association with discing reduced the infestation of M. incognita to undetectable levels, thereby favoring guinea pepper and eggplant (susceptible plants) growth without infection (Zem, unpublished data).

TOMATO

The species M. incognita, M. javanica and M. arenaria cause damage to tomato plants in Brazil (11). Ponte et al. (14) observed that tomato plants attacked by M. incognita and M. javanica exhibited growth reduction (66.5%), as well as yield reduction, in relation to both weight (37.6%) and number of fruits (40.7%).

Tomato growers traditionally have used chemical fumigants, especially methyl bromide, in tomato seedbed preparation. At field level, there are several registered nematicides (aldicarb, carbofuran) in use, although results from experimentation are still scarce.

Peracchi (12) presented a review of parasitic nematodes on tomato plants with considerations about the control of these parasites when using nematicide fumigants. Dantas & Matta tested systemic insecticides for M. incognita, but no yield response was obtained (7).

Filgueira et al. evaluated the nematicides carbofuran at 2, 3 and 4 kg a.i./ha and fensulfothion at 1.6 kg a.i./ha on tomatoes, and observed that they were efficient and superior to Thimet at 2 kg a.i./ha with respect to the infection rate on roots (knots); their influence on yield, however, was minimal (8).

OTHER VEGETABLES

Several other vegetables also are damaged intensely by Meloidogyne spp., and although several nematicides have been employed in field experiments, published information obtained through experimentation is not available.

APPLICATION METHODS

Success in the use of a nematicide partially depends on the equipment available for correct and safe application. In Brazil, this aspect has not yet been developed.

Nematicide application in the planting furrow on potato has provided more satisfactory results than applications during moulding up (16). On carrot, due to the seeding modality, the application in the entire area followed by incorporation has been considered highly effective for preventing qualitative damage on roots (5)

Manual applications directly on the seeds or transplanted seedlings sometimes have promoted phytotoxicity and, in some cases, are not sufficient for protecting the whole area of root development, causing partially protected root systems.

FINAL CONSIDERATIONS

Although a relatively great amount of work has been published on the positive effects of nematicide application (reduction of infection, increase and improvement of yield quality), it is necessary to emphasize some factors, such as residues, application methods, economy, and period of control.

Residues

The chemicals to be used should be properly registered, and the recommended safety intervals should be compatible with the crop cycle and adopted cultural practices.

Application Methods

Nematicide applications at planting are, in general, superior to post-plant applications, in reference to their effects.

Economy

Only crops with high yields per hectare (for instance, potato, carrot and tomato) successfully bear the investment costs of nematicides, and present a good cost/benefit ratio for the farmer.

Period of Control

In the colder areas of the country, it has been observed by farmers and some researchers that root-knot nematode occurrence during the dry (cold) season is less intense than in the rainy (hot) season, so that under the former condition, nematicides can be avoided, or, if indispensable, can be applied at lower dosages.

Finally, in order to control the root-knot nematode, a widely spread pest in Brazil, cultural management seems to be the most viable solution because whereas chemical control and crop rotation are uneconomical, or technically impracticable, techniques such as fallow, organic matter utilization, resistant varieties and disinfestation of planting soil could be used successfully, as well as the integration of two or more of these practices. Such measures would provide the farmer with economic success, even in areas infested by root-knot nematodes.

RESUMO

Controle químico de *Meloidogyne* spp. em hortaliças

Os nematóides das galhas, *Meloidogyne* spp., são considerados no Brasil como os de maior importância econômica para o cultivo de hortaliças por parasitarem a maioria delas, por terem ampla distribuição geográfica e pelos danos econômicos causados, razão pela qual se tem tentado seu controle através de medidas químicas. Reuniu-se neste trabalho as informações disponíveis no Brasil sobre esta importante área de controle de nematóides. As culturas da batata e cenoura, por sofrerem danos diretos da meloidoginose no produto colhido e por apresentarem alto retorno financeiro, são as culturas mais estudadas do ponto de vista de controle químico, onde a aplicação de diversos nematicidas tem propiciado aumentos significativos de produção, bem como sensível melhora na qualidade do produto colhido. Também o tomateiro, por sofrer perdas consideráveis, quando parasitado por *Meloidogyne* spp. tem sido protegido por nematicidas tanto em sememteira como no campo.

Inúmeras outras hortaliças são prejudicadas pelos nematóides formaodres de galhas, porém o controle químico não tem sido frequente por razões econômicas ou por incompatibilidade com práticas culturais.

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OS NEMATOIDES DAS GALHAS, MELOIDOGYNE SPP., NO ESTADO DO MARANHÃO

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Introdução

Os nematóides das galhas, Meloidogyne spp., enquadram-se entre os mais nocivos inimigos das plantas cultivadas no Estado do Maranhão. As informações sobre a ocorrência e danos causados pelos nematóides das galhas são escassos, apesar de se reconhecer há muito tempo sua importância. Os estudos preliminares visaram exclusivamente conhecer o aspecto fitossanitário das culturas (4). A partir de 1982, as pesquisas foram reiniciadas objetivando não só o conhecimento das espécies ocorrentes, mas, sobretudo, o seu controle.

Importância Econômica

De ocorrência generalizada em todo o Estado, parasitando inúmeras espécies vegetais, os nematóides das galhas são responsáveis por danos severos sendo, em algumas áreas, particularmente a Ilha de São Luis, fatores limitantes à produção de hortaliças tais como: tomate, cenoura, repolho, couve e algumas fruteiras como o mamoeiro. Além de sua importância como patógenos, reduzindo a produção ou depreciando produtos, esses nematóides podem vir associados a fungos e bactérias, originando complexos etiológicos, normalmente de efeito sinérgico (2, 3, 6). Associação entre Meloidogyne spp. e Pseudomonas solanacearum, Fusarium spp. também são muito frequentes. Esse quadro tem sido responsável pelo abandono de culturas, face às significativas perdas causadas.

Em levantamentos efetuados em diferentes Regiões do Estado, três espécies de Meloidogyne foram assinaladas: M. incognita, M. javanica e M. arenaria (1, 7). Destas M. incognita destaca-se como a mais importante, devido a sua ampla distribuição geográfica bem como pelo maior número de hospedeiros.

Perdas elevadas foram constatadas recentemente por Silva (5) em jaborandi (Pilocarpus mycrophyllus), planta nativa de importância econômica na indústria farmaceutica.

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Pesquisas em Andamento

Procede-se um levantamento de hospedeiros de Meloidogyne spp. As populações obtidas estão sendo multiplicadas em tomateiro para posteriores estudos de identificação de espécies e raças de acordo com o método de Hospedeiros Diferenciais da Carolina do Norte e estudo da região perineal. Algumas espécies já foram determinadas. Os primeiros resultados são apresentados na Tabela 1.

Pesquisas Planejadas

1. identificação de espécies e raças de Meloidogyne spp. associadas à hortaliças na Ilha de São Luis;
2. resistência varietal de diferentes hortaliças às espécies de Meloidogyne;
3. controle de Meloidogyne spp. através da estação de cultura, incorporação de matéria orgânica e uso de Crotalaria spp.;
4. estudo da interação de Meloidogyne x Pseudomonas em tomateiro.

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Tabela 1. Hospedeiros de *Meloidogyne* spp. no Estado do Maranhão

Nome vulgar	Nome científico	*Meloidogyne* Mi	Mj	Ma
Alface	*Lactuca sativa*	X	-	-
Begonia	*Begonia* spp.	X	-	-
Beldroega	*Portulaca oleracea*	X	-	-
Beringela	*Solanum melongena*	X	-	-
Cenoura	*Daucus carota*	X	-	-
Couve	*Brassica oleracea* var. *acephala*	X	-	-
"Coentro Tapuio"	*Eryngium foetidum*	X	-	-
"Emilia"	*Emilia sonchifolia*	X	-	-
Espinafre africano	*Amaranthus* spp.	X	-	-
Espinafre indiano	*Celosia argentea*	X	-	-
Girassol	*Helianthus annuus*	-	X	-
Jaborandi	*Pilocarpus microphyllus*	-	-	X
Mamoeiro	*Carica papaya*	X	X	-
Maxixe	*Cucumis anguria*	X	-	-
"Pariparova"	*Heckeria umbelata*	X	-	-
Pepino	*Cucumis sativus*	X	-	-
Quiabeiro	*Albemoschus esculentus*	X	-	-
Repolho	*Brassica oleracea* var. *capitata*	X	-	-
Tomateiro	*Lycopersicon esculentum*	X	X	X

SUGAR CANE MELOIDOGYNOSIS IN BRAZIL

M. M. Aguillera*

Generalities

Studies on sugar cane nematology in Brazil are relatively recent. Only occasional papers reporting the occurrence of the most important genera on some cultivars were published until a short time ago. The first survey concerning this crop was carried out in 1974, demonstrating the genera which generally are found associated with sugar cane in the State of São Paulo (12). Studies on chemical control (7,8,9,13,15) and reaction of varieties (1,3,11,16,17) were conducted subsequently. Gradually, the importance of nematodes to this crop has been evidenced through the results of trials and records on the occurrence associated with damage and losses under field conditions (15). Interesting papers about populational fluctuations and distribution of some important genera, including Meloidogyne, have been published (4,6,10).

In order that the extent of losses due to nematodes in sugar cane production can be evaluated, an example of what occurs in the Center-South Region of Brazil will be given. In that region the most cultivated varieties, 'CB41-76' and 'NA56-79,' are susceptible to nematode complexes in which the species Meloidogyne javanica predominates. In such situations, losses of up to 27% have been observed in trials under field conditions (Table 1). A tolerant variety 'IAC52-150' cannot be cultivated over large areas, mainly because it is a heavy flowering variety. It is recommended that the area cultivated to this variety does not exceed 10% of the whole area. Two other varieties, 'IAC48-65' and 'IAC51-205,' which are tolerant to some nematode complexes, present the same type of problem.

According to some nematologists, the losses due to nematodes in Brazilian sugar cane production could be estimated around 20% (5).

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Table 1. Reduction in yields of commercial varieties due to nematode attack under field conditions. Comparisons between yields in nematicide-treated and non-treated plots. (Barra Grande Sugar Mill, São Paulo).

Varieties	Percent of reduction			
	Plant	1st ratoon	2nd ratoon	Average
'CB41-76'	42	21	12	26
'CB46-355'	21	08	14	13
'CB49-260'	34	07	01	15
'IAC48-65'	24	07	+4	09
'IAC51-205'	17	06	+8	06
'IAC52-150'	20	07	03	14
'NA56-79'	38	20	21	27

From: IAA/PLANALSUCAR

The problem resulting from nematode attack to sugar cane in Brazil has recently increased due to the expansion of cultivation into sandy and poor soils, where high nematode populations frequently have been found causing great losses. This expansion was due to the need to increase alcohol production.

Several coffee crops attacked by nematodes have been destroyed and replaced by sugar cane crops. These areas are heavily infested mainly by Meloidogyne incognita. Fortunately, sugar cane cropping in Brazil involves the planting of a relatively high number of varieties, which offer the possibility of selecting the most adequate for a particular situation. On the other hand, some of these varieties present agronomic or industrial restrictions. Furthermore, the reaction of a number of these varieties to nematodes is still unknown and only now being studied.

Sugar cane in Brazil is attacked by three species of the genus Meloidogyne: M. javanica, M. incognita and M. arenaria. The former seems to be the most widespread and causes the greatest losses under our conditions. Since the root symptoms caused by the root-knot nematodes are easily evidenced, their importance has been emphasized and all the research carried out referred to that genus. However, incidence of high levels of plant-parasitic nematodes belonging to other genera has frequently been reported in association with great damage. The genera most frequently found are Pratylenchus, Helicotylenchus, Trichodorus and Criconemoides. They form complexes with distinct levels. Other genera such as Tylenchorhynchus and Xiphinema are less common. Since symptoms caused by these parasites on the roots are less evident, their importance has been neglected. Thus, one may assume that somtimes damage attributed to Meloidogyne may actually be due to other genera of plant-parasitic nematodes or to a complex of organisms.

Since research on sugar cane nematode problems in Brasil is so recent, many aspects still remain to be studied. However, some alternatives aimed at decreasing the suppressing effects of nematodes to the crop are already available (1, 3).

Control

The planting of resistant varieties constitutes the most adequate and feasible method of nematode control to sugar cane cropping in Brazil. However, only a few varieties actually can be recommended for cultivation in areas with problems of high nematode populations. Each variety shows different agronomic and industrial characteristics as well as a specific reaction to diseases, pests and adverse environmental conditions. This trait may make planting under some ecological conditions unsuitable for some varieties. This situation demonstrates the difficulty of obtaining a variety which is resistant to nematodes and also presents other desired characteristics.

Institutions which develop breeding programs, such as Cooperativa Central dos Produtores de Açúcar e Álcool de São Paulo (COPERSUCAR) and Instituto do Açúcar e do Álcool - Programa Nacional de Melhoramento da Cana-de-Açúcar (IAA/PLANALSUCAR), have given great emphasis to tests concerning the reaction of sugar cane varieties, clones and seedlings to nematodes. As a result, data concerning the classification of the main commercial varieties and promising clones are already available (1, 3, 11, 16).

The recently released variety 'SP70-1143' has shown resistance to *M. javanica* (3). Due to this important aspect, it has been recommended to be grown in sandy soils, where the incidence of high levels of infestation is frequent.

Greenhouse tests have shown that another recently released variety 'RB735275' has a resistant reaction to *M. javanica* (unpublished data). It was observed that under the conditions of the tests mentioned only a few females reached maturity and few galls were formed. These data have been confirmed under field conditions through soil analysis, and excellent yields have been obtained under experimental conditions. Good performance in fields where high population levels of the genera *Helicotylenchus* and *Trichodorus* occur has also been observed. This reaction may constitute one reason for the good behavior of this variety in poor sandy soils.

The importance of testing clones and varieties in distinct ecological conditions where different complexes are present should be emphasized.

A few commercial varieties, besides the two mentioned above, also show resistance to nematodes and may be recommended for planting or for use as progenitors in breeding programs (1, 3, 11).

Varietal resistance to nematodes is an especially important aspect since sugar cane remains in the field for up to 6 years after planting.

Suitable soil management practices are another way to minimize losses caused by nematodes. These practices aim at improving physical, chemical and biological conditions of the soil.

Green manuring, rotation with nonhosts, filter cake and stillage applications, subsoiling and deep ploughing are practices that may be used in sugar cane cropping. Stress due to Ca and Mg deficiency should be corrected in order to improve the development of the root system toward deep soil layers. This practice would probably give the plants a chance of escaping heavy nematode attack, besides providing other benefits, such as a greater water uptake.

These practices besides improving the physical condition of the soil aim at increasing the organic matter level, a factor that directly and indirectly favors biological control of nematodes by soil microorganisms. Data obtained from a field survey carried out by IAA/PLANALSUCAR show incidence of parasite and predator fungi of nematodes in areas where Stizolobium aterrimum Piper & Tracy (Mucuna aterrima) is grown and incorporated into the soil (2). This crop has shown resistance to Meloidogyne incognita as another important characteristic (18). Chemical control presents several limitations, although it may be necessary in cases where there is a high infestation and the adoption of another method of control is impractical. It should be pointed out that benefit from treating the soil with current nematicides is obtained only when a susceptible variety is planted and all the factors that interfere with yields are perfectly under control. Healthiness of seed cane, especially concerning RSD (Ratoon Stunting Disease) incidence (14) is of particular importance. Also, it should be pointed out that nematicide application is not recommended for ratoons (14) as the increase in production is not beneficial (Table 1).

Suggestions for Future Studies

As nematode problems in sugar cane crops gradually expand, the adoption of control measures which make the cultivation economically feasible in areas with high infestation levels is essentially important.

Research institutions have given special attention to programs that refer to nematode studies, mainly those concerning control measures. These programs are:

1) varietal resistance evaluation of the reaction of Brazilian and foreign varieties, clones and seedlings against distinct nematode complexes and environmental conditions;

2) soil management practice studies on the effects of practices such as rotation, green manuring, filter cake and stillage applications and minimum tillage on nematode populations and sugar cane yields;

3) chemical control studies aiming at determining the efficiency of different chemicals, dosages and economic feasibility of nematicide applications.

Difficulties Encountered in Sugar cane Research

1) Areas planted to sugar cane in Brazil are very extensive and the variations in environmental conditions are also very great. Consequently, a large number of experiments are required.

2) Studies in pots are difficult to carry out due to several factors: intense rooting which makes the evaluation of number of galls difficult; variability in root formation (especially in cuttings); and also variability in plant height. Thus, a large number of replications are required.

3) In order to analyze the results adequately, it is essential to determine nematode population fluctuations.

4) Population studies are difficult to carry out due to problems concerning soil sampling in areas so extensive and due to differences in the efficiency of the nematode extraction methods available.

5) As already mentioned, sugar cane varieties may show different behavior in each cycle (Table 1). Thus, it is necessary to study their reactions for at least three consecutive cycles.

6) It is essential to control other factors that interfere with yields, such as seed healthiness, soil preparation, fertilization, etc., to evaluate the results correctly.

7) Seedling tests are useful for early elimination of susceptible ones; however, the difficulty of testing a large number of seedlings may render the results of these tests insignificant, in view of the very large number of seedlings produced and selected by breeding programs each year.

RESUMO

Meloidogynosis da cana-de-açúcar no Brasil

Pesquisas referentes a problemas causados por nematóides em cana-de-açúcar no Brasil são recentes. Entretanto, resultados experimentais já estão disponíveis, principalmente no que se refere a resistência varietal e controle químico. Outras medidas tais como prática de manejo de solo também estão em estudo, devendo-se ressaltar que maior ênfase tem sido dada as determinações de reações de variedades e clones.

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

Hedwig H. Triantaphyllou*

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

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

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

THE GENUS MELOIDOGYNE

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

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Table 1. Classification of Heteroderoidea

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

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

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

DIFFERENTIATING CHARACTERS OF SPECIES OF MELOIDOGYNE

Females (9)

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

Table 2. Species of *Meloidogyne*

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

Table 2 (continued)

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

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

Second-Stage Juveniles (6, 7)

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

Males (8)

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

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

J. N. Sasser*

Approximately 1,300 live populations of Meloidogyne species, forwarded to project headquarters from approximately 100 cooperators representing more than 70 developing nations, are being studied. To date, 914 have been identified and frequency of species encountered is as follows: M. incognita, 52%; M. javanica, 31%; M. hapla, 8%; M. arenaria, 7%; M. exigua, 1%; and others, M. graminicola, M. megatyla, M. microtyla, M. naasi, M. graminis and M. oryzae, 1%. Within the M. incognita complex are four host races. Race 1 comprises 72% of 472 populations studied; Race 2, 13%; Race 3, 13%; and Race 4, 2%. Within the species M. arenaria, there are two host races. Race 1 (16% of 70 populations) infects and reproduces on peanut, while Race 2 (84%) does not attack peanut. Research on root-knot nematodes in agricultural soils must hereafter take into consideration the existence of host races. Otherwise, it will be incomplete and of limited value. Previous reports on resistance to M. incognita and M. arenaria must be reviewed and the races involved identified.

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

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studies should make breeding cultivars for resistance to root-knot more attractive, since breeding lines can be tested against a small number of populations. Once a resistant cultivar has been developed, it can be marketed with assurance that results in the field will be satisfactory. Furthermore, a much larger, indeed a world-wide market, is open to producers of seed of resistant cultivars.

MORPHOLOGICAL CHARACTERS USEFUL IN THE IDENTIFICATION OF *MELOIDOGYNE* SPECIES

J. D. Eisenback*

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

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

An important goal of the International *Meloidogyne* Project has been to elucidate new and more reliable morphological characters that would make the identifications of species practical and more rapid in laboratories with limited equipment and personnel. Morphological characterization of the four most common species, *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*, has been emphasized. Because these nematodes are extremely small, the scanning electron microscope (SEM) has been utilized to examine critically second-stage juveniles, males, and females. The SEM gives a three-dimensional image with high resolution and large depth of focus of the external surface morphology. The value of the SEM is that it greatly clarifies morphological details that are often subsequently visible by light microscopy (LM). Because the SEM is not readily available to many investigators, only characters that can also be seen by LM are of practical value.

The external morphology of second-stage juveniles of the four most common *Meloidogyne* species were examined by SEM. Observations were made on head structures, lateral field, excretory pore, anal opening, and tail. Body morphology was of little taxonomic value. Head morphology--

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including expression of sensilla; shape of labial disc, medial lips, and lateral lips; and markings on the head region--was distinctly different among the species. Unfortunately, differences in the head morphology of second-stage juveniles were too small to be seen clearly by LM.

In the past, the morphology of the female has provided the most important characters in routine species identifications. Perineal patterns and head morphology of the four common species were examined by SEM. In addition, a technique was developed for the removal of the stylet from a female for SEM observation. New characters of perineal patterns among the species were not revealed by SEM. Differences in head morphology, however, were found. Head shape differed among the species in the expression of sensilla; shape of the labial disc, medial lips, and lateral lips; and markings on the head region. Unfortunately, the heads of females are difficult to prepare, orientate, and see clearly by LM. The most useful new character of females is stylet morphology. As elucidated by SEM, distinct differences exist among the species. Differences occur in the shape of the cone, shaft, and knobs and distance of the dorsal esophageal gland orifice to the base of the stylet. The morphological characters of the stylets of females first detected by SEM were seen subsequently by LM and are thus helpful in species identification. Difficulty in specimen preparation, however, reduces the usefulness of this character. In order for these differences to be seen clearly, the stylet must be level and in exact lateral position.

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

were readily visible by LM. Head shape and stylet morphology of males are thus recommended as useful and reliable characters in the identification of the four most common species of root-knot nematodes.

The head shape and stylet morphology of males are not, of course, the only characters that should be examined in the identification of root-knot species. As many different characters (morphology, host response, cytology, biochemistry, ecology) as possible should be used congruently in the final identification of a species. A correct identification is extremely important in the design of effective control programs. A more complete characterization of the four common species has been prepared recently and should allow more accurate identifications (1).

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CYTOGENETIC AND BIOCHEMICAL STUDIES AS AN AID TO IDENTIFICATION

A. C. Triantaphyllou*

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

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

M. arenaria. All populations of M. arenaria reproduce by mitotic parthenogenesis. Two chromosomal races are recognized in this species. Race A is the most common and includes triploid populations with 3n=50 to 56 chromosomes. Race B is the diploid race with 2n=34 to 37. The chromosomes of M. arenaria are similar in morphology and behavior to those of M. javanica. The two species differ only in chromosome number. Therefore, determination

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

M. hapla. This species is made up of populations belonging to two distinct cytogenetic races (A and B). Race A is the more common and includes populations that reproduce by facultative, meiotic parthenogenesis. Most of them have a haploid chromosome number of n=16 or 17; some have n=14 or 15. Race B populations reproduce exclusively by mitotic parthenogenesis. Some of them are diploid with 2n=30 to 31, but most are triploid with 3n=43 to 48 chromosomes.

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

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

ECOLOGICAL STUDIES -- PROGRESS TO DATE

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

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

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

Species Distribution

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

Temperature

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

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

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

Precipitation

In this survey, root-knot nematodes were collected from locations with total annual precipitation ranging from nearly zero to 5000 mm. Most populations were collected from areas with 1000 to 1500 mm annual precipitation. Less than 10% of the M. hapla and M. arenaria populations and only 17% of M. incognita populations came from areas with less than 500 mm annual precipitation. However, 42% of the M. javanica samples were received from such dry climates. These facts indicate that M. javanica is the best adapted of the four species for survival in dry climates.

Many regions of the world have distinct wet and dry seasons which can be classified by the number of "dry months" with precipitation less than 10 mm. About 80% of the M. hapla samples, 70% of the M. arenaria samples, and 48% of the M. incognita samples and 30% of the M. javanica samples came from regions with precipitation well distributed throughout the year, that is, with no dry months.

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

Soil pH

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

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

Soil Texture

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

Practical Applications of Ecology Program Results

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

The status of *M. arenaria* is not yet clear, but there are indications that it will be found mixed with *M. incognita* and *M. javanica* in regions where there is well-distributed rainfall. *M. hapla* is the most common cool climate species and will be found in regions where the average temperature for the coldest month of the year is less than 0°C; the other species will not be found in these regions. *M. hapla* will also thrive where the average annual temperature is about 12-15°C, but will be less common where it is higher. There is still some uncertainty as to the upper limit for *M. hapla*. It occurs sporadically in Florida where the average warm month temperature reaches about 27°C, but most infections can be traced back to strawberry plants brought in from northern states.

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

BIOLOGICAL CONTROL WITH THE FUNGUS *Paecilomyces lilacinus*

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

Parviz Jatala*

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

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

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

Laboratory, greenhouse and field experiments conducted in Peru confirmed that *P. lilacinus* effectively controls the root-knot nematode *Meloidogyne* species. The fungus penetrates the nematode eggs and destroys the embryo. It also attacks and grows inside developing females resulting in their death. So far, the fungus has been most effective for controlling *M. incognita*. However, trials are underway to determine if it also would aid in controlling other

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nematodes. P. lilacinus is not pathogenic to plants and can be readily cultured under laboratory conditions.

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

Isolation Establishment of the Fungal Culture

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

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

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

3. Repeat step No. 2.

4. Place 2 or 3 drops of the solution from the third dilution tube on a plate containing potato dextrose agar medium. Spread the liquid with a sterilized loop on the medium and store the plates at room temperature.

5. Step 4 can be repeated using dilution tube number 2 or further dilutions can be made to obtain individual colonies.

6. Fungal colonies will appear in two days and within 7-10 days the surface of medium will be covered by fungal hyphae. Sporulation takes place within 48 hours. P. lilacinus grows very flat with no aerial mycelium, and the colonies are light violet or lilac in color. The fungus can be maintained on PDA by periodic transfer without it loosing its effectivity to control Meloidogyne species.

Preparation for Field Inoculation

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

Procedure:

1. Soak rice grains in water for 12 hours. After this period dry the seeds with paper towel or cloth, place them in an Erlenmyer flask and sterilize in an autoclave for 50 minutes.

2. Place several milliliters of sterilized water in the plates containing 10- to 14-day-old fungal colonies. Gently mix well with a sterilized needle or loop to make a spore suspension. (Care should be taken not to break the agar medium.)

3. Collect the spore suspension from several plates in a sterilized bottle and inoculate the sterilized rice grains with several ml of this suspension. Allow the fungus to grow on rice grains at room temperature. Shake the flask every day to promote uniform growth of the fungus.

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

5. Fourteen days after inoculation, there should be sufficient fungal growth for field application.

Field Inoculation and Experiment

1. Prepare a uniformly *Meloidogyne*-infested field for planting.

2. If possible, use potatoes as the experimental crop. If not, use a crop that *Meloidogyne* species infect and which produces readily visible egg masses. It is advisable to avoid a crop that exhibits big galls with not many visible egg masses.

3. Conduct a randomized block design experiment using at least 5 replications per treatment. Each treatment should consist of at least 5 rows.

4. Treatments should consist of non-treated, fungus-treated and, if possible, nematicide-treated plots with a 1-meter space between plots.

5. If sufficient field space is not available for the experiment described above, use the above 3 treatments with at least 10 rows of 20 meters per row in each treatment.

6. Apply approximately 1.5 kg of fungus-infected rice grains per 40 square meter-plots at planting. Spread the inoculum evenly 10-15 cm deep in the soil and cover well before planting.

7. If possible, in nematicide-treated plots, recommended rates of granular preparations such as Temik, Furadan or Nemacur should be used at planting.

8. Care should be taken so that the run-off water from the irrigation does not enter one plot from another. Avoid re-using the tools used in the fungus-treated plots in other plots. First use the tools in other plots, then in the fungus-treated plot.

9. Upon harvest, examine and rate the roots for nematode infection using a galling index of 1-5 (1 = no root galling and/or nematode reproduction to 5 = very severe root galling index and/or a very high nematode reproduction).

10. If a randomized block design experiment with 5 or more replications is used, evaluate each plant root of the center 3 rows of each plot. In case of the 10 rows of 20 meters per row treatment, use the center 8 rows and randomly evaluate at least 20 plants per row.

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

1 (no tuber infection per plant) to 5 (100% tuber infection per plant).

12. Random root samples should be taken to the laboratory for staining.

13. Stain a 10-gm composite root sample per row with acid fuchsin in lactophenol and clear in lactophenol for 24 hours prior to examination.

14. Extract 20-50 egg masses per sample. Crush 5 egg masses on a microscope slide using a coverglass. Examine under a compound scope for fungal infection. Data should be recorded on the number of fungus-infected egg masses and the percentage of infected eggs per egg mass.

15. Yield should also be recorded. If the experimental crop is potato or another root of tuber crops, yield of infected and non-infected tubers or roots per plot should be recorded. For yield per hectare to be calculated accurately, it is advisable that the yield of a definite number of plants per plot be recorded.

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

Comments

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

CONCLUSIONS OF GROUP 1: BREEDING FOR RESISTANCE

Chairman: Amélio Dall'Agnol

Root-Knot Resistance

Right at the beginning of the meeting we realized that there were so many points that needed to be discussed and straightened out that we decided we needed a special meeting of the members of the group to discuss for two or three days all the polemic points related mainly to methodology and terminology. The following is a summary of the points discussed.

1. Methodology
   a) Use of the 0-5 scale for galls and egg masses;
   b) Establishment of a 0-5 scale for number of eggs and juveniles;
   c) Change of evaluation criteria according to the crop;
   d) Change of inoculation level with the crop;
   e) Methods of inoculation vs. level of inoculum vs. size of the pots;
   f) Specification of conditions (temperature) in which the experiment was conducted;
   g) Specification of the race or races with which we work.
2. Terminology (resistant, mod. resistant, mod. susceptible, susceptible, tolerant)
   a) Do these terms mean the same thing for everybody, or
   b) Is it better to use only the score and give the scale?
3. Exchange of experiences and germ plasm within the group.
4. Need to get everybody acquainted with breeding techniques and other problems related to plant breeding. Need for training.
5. Provision by IMP of all project publications related to our subject and other helpful papers to which we might not have access.
6. Development by IMP of a list of all germ plasm existing in the world for all crops with which we work and a directory of the researchers working on this matter. The list should be updated every year.
7. Provision of equipment by IMP: screens, pipets.
8. For the next meeting, each member of the resistance group should present an outline of his breeding program to be discussed in the group and give suggestions.

CONCLUSIONS OF GROUP 2:
EVALUATION OF CROPPING SYSTEMS IN REGION III - BRAZIL

Chairman: Silamar Ferraz

Evaluation of Cropping Systems Research for Region III

1. Crop rotation

Several researchers are working in this area. The main approach concerns the use of antagonistic plants like *Stizolobium aterrimum* ("*Mucuna aterrima*"), *Crotalaria spectabilis*, *C. juncea* and others. These plant species have been tested mainly against *Meloidogyne javanica* and *M. incognita*. However, there is also a need to test these plants for resistance to each important race of *M. incognita*. These races have been studied lately in different regions of the country.

Germ plasm of different economic crops (bean, sugarcane, soybean, coffee, sunflower, carrot, tomato and others) and forage crops have been tested for resistance to *M. javanica* and *M. incognita*. Here again, resistance to specific races was not evaluated.

2. Use of organic amendments

In the sugar industry, residues and by-products have been tested against nematodes. Cow manure has been compared with chicken manure as to its effects on *Meloidogyne* spp. in coffee plants. Research on castor bean cake and a cassava derivate called "manipueira" (liquid residue from the cassava flour industry) is also underway.

3. Fallow, flooding, planting time, etc.

Research in these areas has not been emphasized.

4. Biological control

Bacillus penentrans has been found in certain areas in Brazil; however, this organism and others have not been tested here yet.

5. Chemical control

As far as nematode control is concerned, this has been the main area of research in Brazil. Studies on the economics of chemical control of nematodes on sugarcane under field conditions have shown very good results. However, the findings on other crops generally have been inconsistent. There is a need for a better look at nematicide residues and the economic aspects of their application.

Recommendations for Future Work

-Identification of the *M. incognita* races

-Evaluation of resistance of cultivars to species and races

-Studies on crop sequences for each different region

-Necessity for economic analyses in the experiments on nematode control

Participants

Silamar Ferraz

Vicente Paulo Campos

Regina Carneiro

João Maria Charchar

Rosa Maria Farias Asmus

CONCLUSIONS OF GROUP 3: TECHNOLOGY TRANSFER

Chairman: Antônio Carlos Zem

TECHNOLOGY TRANSFER

Needs

1. Training Program

a) More opportunities for specialized training programs for Brazilian cooperators in the United States and/or foreign countries with subsequent transfer of results and information to untrained personnel in Brazil.

b) More frequent presence of IMP specialists in Brazil participating in short-term practical training programs.

2. Basic Material to Support Research and Teaching Activities

a) For identification purposes: slide sets, illustrated descriptions, high-quality photographs, preparations for microscopy

b) Annual publications as well as papers or abstracts about root-knot nematodes from all over the world

c) Facilities for cooperators to obtain materials not available or hardly found in Brazil such as phloxine, micropipets, very specialized bibliograhies, etc.

3. International directory of IMP cooperators with names, addresses and specialization.

Participants

Ailton Rocha Monteiro

Antonio Carlos Zem

Luiz Carlos C. B. Ferraz

Wilson T. T. Novaretti

Jean Kleber Mattos

CONFERENCE PHOTOGRAPHS

Front row: Regina Carneiro, Liana Maria Teixeira, C. S. Huang, unidentified, Sérgio Cury, Antonio C. Zem, Ailton R. Monteiro, J. P. Pimentel, unidentified, J. M. Charchar.

Second row: Rui Carneiro, Helenita Antonio, Renata C. V. Tenente, Luiz C. B. Ferraz, Rosa Mª Farias, Wilson R. Novaretti, Rubens Lordello.

Third row: Gilson S. Silva, Jose J. Ponte, Marcelo A. Targa, A. C. Triantaphyllou, J. D. Eisenback, S. P. Huang.

Fourth row: Silamar Ferraz, Vicente Campos, unidentified, Romero M. de Moura.

Last row: Parviz Jatala, Antonio Filex.

(1) Silamar Ferraz, (2) Juvenil Cares, (3) J. N. Sasser,
(4) Rubens Lordello, (5) Ailton R. Monteiro

(1) C. S. Huang, (2) Parviz Jatala, (3) Otília B. Leal,
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