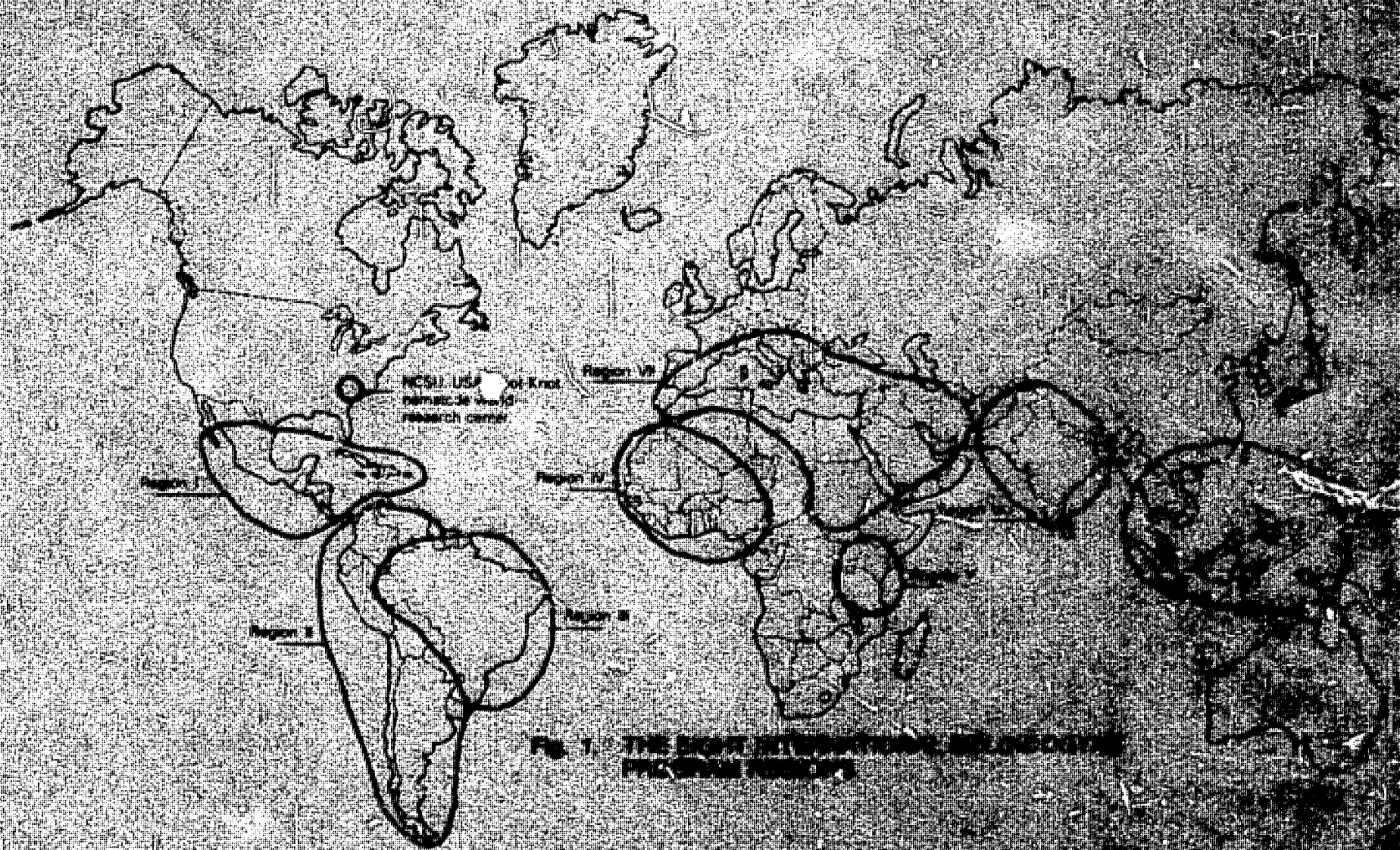

Fig. 1. THE EIGHT INTERNATIONAL BIOLOGICAL PROGRAM REGIONS

PN AAQ 216

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IAN = 34901

INTERNATIONAL MELOIDOGYNE PROJECT

IMP

Contract No. AID/ta-c-1234

Proceedings of the Second Research Planning Conference on Root-knot Nematodes, Meloidogyne spp.

February 20 – 24, 1978
Abidjan, Ivory Coast

International Institute of Tropical Agriculture
Oyo Road, PMB 5320
Ibadan, Nigeria

Fig. 2. Scientists participating in the research planning conference of the International *Meloidogyne* Project (IMP) at Abidjan, Ivory Coast.

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PREFACE

This second West African regional research planning conference on root-knot nematodes was held February 20-24, 1978 in Abidjan, Ivory Coast under the auspices of the Ministre de la Recherche Scientifique and Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) cooperating with North Carolina State University, Raleigh, N. C. and the International Institute of Tropical Agriculture, Ibadan, Nigeria. The conference represents the advanced phase of an international cooperative effort of some 65 developing nations. The IMP program with its eight regional laboratories, located around the world in tropical and subtropical climates coordinate and assist the regional scientists from the cooperating countries (Fig. 1). Global planning and support is provided by the IMP World Center at the Department of Plant Pathology, North Carolina State University, Raleigh.

The researchers gathered at this conference to report on studies made, evaluate overall progress, discuss common constraints and develop and realign the program for accelerated advancement toward the principal goals of increased food crop production, improved crop protection capabilities for developing nations and advancement of the knowledge of these important parasites of food crops.

Scientists from the participating West African countries are associated with nematology research units at universities, specialized laboratories and institute of agricultural research (Fig. 7). Each scientist reported on problems and progress on root-knot nematodes and associated food crops for his or her particular area. The principal scientist and support researchers from the world center contributed findings and achievements from the global scene (Figs. 2, 3).

Thanks are due to all conference participants as it is through their continuous and enthusiastic efforts that significant knowledge is being accumulated on local and regional root-knot nematode research. This essential information builds on the foundation laid at earlier planning conferences at the world center and in the seven regions. The continued accumulation of this information through research will further efforts for the control of root-knot nematode pests in developing nations and to increased and efficient food production and the betterment of the general welfare of their peoples.

Warm thanks are extended to our Ivory Coast hosts, Monsieur le Ministre de la Recherche Scientifique Jean Guede Dorougnon and the Directors of ORSTOM for Ivory Coast and Adiopodoume for their warm reception and friendly hospitality.

The local organizing committee headed by Renaud Fortuner deserves the appreciation of all participants for the efforts that made for a successful conference and a pleasurable visit. Renaud Fortuner is also thanked for providing the French summaries.

F. E. Caveness

Fig. 3. ORSTOM specialists briefing IMP conference participants on laboratory facilities and microplot techniques.

A RESTATEMENT OF THE PROJECT, PRINCIPAL GOALS AND OBJECTIVES.

J. N. SASSER

One of the major obstacles to the production of adequate supplies of food in developing nations is the damage caused by plant-parasitic nematodes, especially the "root-knot group", Meloidogyne spp. The most effective management practice for control of these pests, especially for developing nations, is through the use of certain cultural practices, including crop rotation, the use of available resistant crop cultivars, and development of other resistant cultivars. Crop rotation sequences capable of reducing soil populations of the root-knot nematode below the economic injury threshold can be developed. It will be necessary, however, to test the resistance and/or susceptibility of the economic crop plants grown in the regions covered by this project to the nematode species present. Furthermore, to develop resistant crop cultivars, it will be necessary to discover sources of resistant germ plasm and to determine the extent of pathogenic variation in the nematode. With this knowledge, effective crop rotation programs can be designed and resistant or tolerant cultivars developed on a regional basis. This proposal is to initiate research on the root-knot nematodes at a U.S. university and to link the research with international and national research institutions for the purpose of gaining information on the biology of these pests that will enable developing countries to cope with crop diseases caused by this group of nematodes.

PRINCIPAL GOALS

1. To increase production of economic food crops in developing nations.

2. To upgrade crop protection capabilities of developing nations.

3. To advance knowledge about one of the world's most important group of plant-parasitic nematodes.

OBJECTIVES

1. To determine the species and biotypes of the root-knot nematodes present within each of the geographical regions.

2. To determine the susceptibility and/or resistance of the currently grown basic food crops in each of the regions to the root-knot nematodes which are present.

3. To establish a bank of information on cultivars which display resistance to any or all of the species of root-knot nematodes which have been identified in the several regions of study (Central America, South America, Brazil, West Africa, Mediterranean and East Africa and Southeast Asia) (Fig. 1).

MELOIDOGYNE ON UPLAND RICE IN IVORY COAST

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A general survey of soil parasitic nematodes on upland rice was made in Ivory Coast in 1977. About 300 samples were taken from fields in every rice growing area in the country. The nematodes were extracted from soil and roots by the methods of Seinhorst (elutriator and mistifier), and counted at generic level under a dissection microscope. The determination of the identity of the different species is still in process, but general conclusions on the geographical repartition of the genera can already be drawn. Only the repartition of Meloidogyne will be discussed here.

Individuals belonging to this genus were found in many samples. Actually it is second in numbers only to Helicotylenchus. The map shows its distribution in Ivory Coast. In a particular sample, either no Meloidogyne was found - this is indicated on the map by a zero- or some were present, in the soil - indicated by a 'S' and/or in the roots - indicated by a 'R' - The larger the letter, the greater the population (Fig. 4).

It is evident from this map that the populations of Meloidogyne are not equally distributed in the country. They are more frequent and abundant in a long and narrow area in the south part of Ivory Coast. In the West and North-West regions, Meloidogyne does occur but the populations are smaller and scattered. In the North-East regions, the rainfall - less than 1200 mm - is unable to support upland rice cultivation.

The cause of this particular distribution is not yet known but it may be due to different ecological conditions: vegetation, rainfall, soil or other causes such as cultural practices. The area where Meloidogyne is abundant is a forest region, but the West is also a forest region, with a mean annual rainfall of 1400-1600 mm, but in the West, similar mean rainfall can be found. However, in the South, the rainfall is distributed during two rain seasons, whereas there is only one in the West. The distribution of Meloidogyne does not seem to be related to the nature of the soil: in the area where this nematode is abundant are present the three main types of soil which exist in Ivory Coast (granite, schiste and basalt).

The cultivation practices differ slightly. In the South, the upland rice is grown first, just after clearing the forest, whereas in the North there is a first crop of yam before the rice, but it is not known if this is significant. In every village are used different local rice cultivars

but that cannot be the explanation of the difference in the distribution of Meloidogyne: migrant people from the North have recently introduced in the South their knowledge of upland rice culture together with their traditional cultivars.

Whatever may be its cause, this particular distribution of Meloidogyne may have a very practical aspect. Upland rice is often part of a rotation including vegetables: tomatoes at the SODEFEL (Societe pur le Developpement des Fruits et Legumes) in the North, winged bean at the 'Foundation Nestle' in the South. In the North, tomato was found to be no or very slightly infested by the root-knot nematode. In the South, the winged bean was very heavily dammaged. Is this because different species of Meloidogyne attack preferentially either rice or vegetables, or because of particular ecological requirements of the rice Meloidogyne? The identity of the rice Meloidogyne is not yet known and may be different of the M. incognita - M. javanica - M. arenaria complex parasitic on vegetables. It is contemplated to start detailed studies on the taxonomy and the physiological and ecological requirements of the rice Meloidogyne to try and explain its repartition in Ivory Coast and clear its relations with and the danger it may offer to the vegetable cultures of this country.

SUMMARY

In the Cote d'Ivoire Meloidogyne species occur more frequently in the southern part of the country. Ecological factors, cultivation practices and the movement of peoples are being considered in the distribution study. In upland rice and vegetable rotations, tomato is lightly attacked in the north while in the south the winged bean is severely damaged.

RÉSUMÉ

Meloidogyne sur riz de plateau en Cote d'Ivoire

En Cote d'Ivoire les especes de Meloidogyne sont presentes de façon plus fréquente dans la partie méridionale du pays. L'influence des facteurs écologiques, des méthodes de culture et des migrations des cultivateurs sur leur répartition est etudiée. Dans des rotations culturales incluant riz de plateau et plantes maraichères, la Tomate est peu attaquée dans la région nord tandis que le Haricot ailé est gravement atteint dans la région sud.

MORPHOLOGICAL AND PHYSIOLOGICAL VARIABILITY OF SPECIES OF *MELOIDOGYNE* IN WEST AFRICA AND IMPLICATIONS FOR THEIR CONTROL[a]

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The extreme morphological and physiological variability of certain root-knot nematodes (*Meloidogyne* spp.) and its implication on the development of control methods of these parasites, based upon crop rotations and the use of resistant varieties of otherwise susceptible crops are discussed.

In a review of the systematics of the genus *Meloidogyne* reestablished in 1949 by Chitwood to replace the polyphagous species *Heterodera marioni* Cornu, 1887, the variability of the so-called perineal pattern of the females, the most important character to distinguish species within the genus, is emphasized.

The results of the cytological investigations of Triantaphyllou (2,3,4,5,6) are briefly discussed. It has been shown that most species studied are characterized by a parthenogenetic mode of reproduction. Two types of non-amphimictic reproduction have been observed: mitotic and meiotic parthenogenesis. *Meloidogyne incognita*, *M. javanica* and *M. arenaria* are characterized by mitotic parthenogenesis.

An analysis of the number of publications appearing between 1949 and 1976, dealing with identified species of *Meloidogyne* has revealed that 93% of the articles concern Chitwood's species of 1949, and that 76% refer to *M. incognita*, *M. javanica* and *M. arenaria*.

Faunistic studies in West Africa have shown that the most frequently encountered root-knot nematodes belong to the species *M. incognita*, *M. javanica* and *M. arenaria*. Identification of West African populations are complicated by the occurrence of mixtures of species, the great morphological variability and the existance of populations possessing rather large proportions of individuals exhibiting characters intermediate between species.

Certain morphometric characters of perineal patterns (width of vulva and distance between phasmids) were measured in a number of clones of *Meloidogyne* populations. These observations have demonstrated that although these characters are stable within clones, they cannot distinguish *M. javanica* from *M. incognita*.

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[a]Summary reprinted from Mededelingen Landboushogeschool, Wageningen, Nederland. 78-3 (1978).

The distance of the excretory pore of females from the anterior end, expressed in stylet lengths might possibly be an aid to distinguish M. incognita from M. arenaria and M. javanica.

The author is reluctant to describe populations characterized by unusual perineal patterns as new species and suggests inclusion of host-plant and cytological data in the description of new species.

Data presented indicate that length of juveniles could not be used to distinguish among M. incognita, M. javanica and M. arenaria.

Observations of juveniles from a population of M. incognita acrita have demonstrated that the inflation of the rectum is not an absolute criterium to distinguish M. incognita and M. acrita. A critical evaluation of the data of Terenteva (1) concerning the height of the lip region of males of M. incognita and M. incognita acrita makes the author reject the statement that this character might be useful to distinguish between these two taxa.

The author concludes that up till now, no infallible methods have been found to identify naturally occurring populations of Meloidogyne in West Africa.

After the splitting of the polyphagous Heterodera marioni into a number of species of Meloidogyne it became possible to assemble host lists for each species. In principal this information should provide a basis for crop rotation recommendations, intended to reduce root-knot nematode infestation, provided that the Meloidogyne populations could be identified to the species level. Comparison of the host ranges of M. incognita, M. javanica and M. arenaria emphasized that these species have a great number of host plants in common, many of which are important crops. Only a few species could be used as differential plants to distinguish among these three species.

Published data and original results presented show that when many populations of the same species of Meloidogyne are studied, resistance/susceptibility of a given plant species cannot be predicted with confidence. Certain populations are able to parasitize a given plant and others are not.

The same phenomenon is observed with resistant varieties of otherwise susceptible crops. When several populations of the same species of Meloidogyne are tested against such a variety, those populations capable of parasitizing the resistant varieties are often called 'B races'. Studies concerning development of 'B races' on resistant tomatoes in Senegal have shown that some populations of Meloidogyne are able to parasitize resistant varieties strongly and immediately, others are able to form 'B races' after a selection has taken place; the majority however, are not capable of parasitizing resistant tomatoes.

Indications have been obtained that a gene for gene relation exists between nematode populations and resistant tomato varieties and a code indicating nematode and resistant variety genotype is proposed.

It is assumed that most plant species are attacked by Meloidogyne populations; the reaction of the plant attacked towards the specific Meloidogyne population concerned, determines if a successful parasitic relation develops.

It is proposed to consider as a group the tropical polyphagous species of Meloidogyne, which are characterized by a certain degree of polyploidy and a mitotic parthenogenetic mode of reproduction. This group should comprise M. incognita, M. javanica, M. arenaria, populations intermediate between these species, possibly undescribed species and certain described species for which information on mode of reproduction and physiological characters (host-range) is lacking.

On the basis of an actual field trial in Senegal, it is shown that recommendations for crop sequences or rotations should be based on testing different crops and varieties against naturally occurring populations of root-knot nematodes. Incorrect choice of crops may be made if rotations are based upon Meloidogyne identifications only. It is recommended that different populations in an area be tested on cash, food, and cover crops and resistant varieties.

Selection of resistant varieties should be based on reactions to as many different populations of Meloidogyne as possible. Using such a technique 'B races' may be detected, and in addition much material not possessing root-knot resistance in the area where the varieties are developed, may be found to have resistance against other populations elsewhere.

In order to obtain the maximum value of non-hosts and resistant varieties, it is recommended to use these plants as a preventive measure rather than as a cure. Therefore, their use should be recommended in slightly infested or Meloidogyne-free soils.

The author has observed in fact, that non-hosts planted in heavily infested soil may be badly damaged because of a necrotic reaction to invading juveniles. In extreme cases this may give rise to dead patches in the field and a resultant increase of weed growth, accompanied by an increase of Meloidogyne on susceptible weeds. Thus, usefulness of the non-host can be nullified. Moreover the risk of selecting 'B races' is much higher in heavily infested land than in non- or slightly infested fields.

Thus it is recommended to use non-hosts and resistant varieties as preventive treatments within an integrated control including the various chemical and physical treatments available.

Summary

Morphological and physiological variability was studied in Meloidogyne species. Data presented indicated that body length of juveniles could not be used to distinguish among M. incognita, M. javanica and M. arenaria. Observations on juveniles rejects the inflated rectum and on males the height of the lip region as useful characters in species identification. On the basis of actual field trials, it is shown that recommendations for crop sequences should be on crop tests against naturally occurring field populations of the nematode. The use of nonhosts and resistant varieties is recommended as a preventive measure within an integrated control program including the various chemical and physical treatments available.

Résumé

Variabilité morphologique et physiologique des espèces de Meloidogyne en Afrique de l'Ouest et implications pour les méthodes de lutte.

La variabilité morphologique et physiologique est étudiée chez des espèces de Meloidogyne. Les résultats présentés indiquent que la longueur du corps des juvéniles ne peut pas être utilisée pour séparer M. incognita, M. javanica et M. arenaria. Les observations montrent que les caractères rectum gonflé chez les juvéniles et hauteur de la région labiale chez les mâles ne peuvent être considérés comme utiles pour l'identification des espèces. A la suite d'essais effectués au champ en vraie grandeur, it est montré que les recommandations de séquences de cultures doivent être basées sur des tests de plantes envers les populations de nématodes présentes naturellement dans le champ. L'utilisation de plantes non-hôtes et de variétés resistantes est recommandée comme traitement préventif à l'intérieur d'un programme de lutte intégrée comprenant les diverses méthodes chimiques et physiques disponibles.

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MELOIDOGYNE RESEARCH AT O.R.S.T.O.M., DAKAR

D.P. Taylor & C. Netscher

The following summary contains research results, published and unpublished, obtained by various O.R.S.T.O.M. nematologists located at Dakar, Senegal, since the last regional conference in Ibadan, Nigeria, 7-11 June, 1976.

Comparison of biochemical composition of 2nd-stage juveniles of M. javanica with those of Heterodera oryzae. It has been shown that these two organisms differ greatly in their chemical composition especially in regard to percentage of total lipids and cabohydrates present. H. oryzae contains 24.4% and 13.9%, respectively. M. javanica contains 40.4% and 6.9%. Protein content was about the same, i.e. 40.9% (See: G. Reversat, 1977. Cah. ORSTOM, Ser. Biol. 11(3) (1976), 225-234).

Hydroponic culture of Meloidogyne. A technique was described to increase and maintain cultures of Meloidogyne using aerated hydroponic cultures. Plants are placed in a small quantity of soil and juveniles added. In the case of tomato a 5-day exposure period is maintained before the roots are washed and the plants in 1/4 strength Hoagland's solution. Containers with plants may be placed in a constant temperature bath. Aeration is supplied with an "aquarium" pump. Light should be excluded from the container to prevent algal growth. Caution must be taken that the host-parasite relations be known because certain plants have only external egg masses and no reinfection occurs; in others, reinfection occurs readily. (G. Reversat, unpublished).

Detecting light Meloidogyne infestations. Three techniques to detect light Meloidogyne infestations were compared in the field. A combination elutriation-mist chamber technique gave the lowest figure (47% sites were infested). Taking two dm^3 of soil and placing it in pots into which were planted susceptible tomato improved detection (64% of the same site were infested). However, the most accurate technique involved planting a susceptible tomato plant in each site (96% of the sites were infested). It was suggested that this improved detection results from the migration of juveniles from a large hemisphere of soil under the influence of a susceptible plant. In other words, the volume of soil "sampled" is much larger. This was confirmed by inoculation experiments in Meloidogyne-free microplots. A large number of juveniles were able to penetrate tomato roots when introduced 40 cm vertically or horizontally from the susceptible plant. (Prot & Netscher, Nematologica In press).

Meloidogyne in the Cape Verdian Republic. A survey of nematodes associated with crops in Cape Verde was made under the terms of an agreement between the government of that nation and the French Ministry of Cooperation. Meloidogyne was found on all four islands investigated. It was associated with potato, cassava, bean, cajanus, sweet potato, tomato, cabbage, onion, lettuce, sweet and hot pepper, banana, papaya, avocado, sugar cane and tobacco. It was not observed on coffee. The most severe nematode problem appears to be Meloidogyne on cassava. (G. Germani, unpublished data).

Natural occurring hosts of Meloidogyne. A survey has been initiated to determine what perennial hosts of Meloidogyne occur in the Sahelian region of Senegal that can serve as loci of infestation for Meloidogyne when certain of these areas are brought into intensive cultivation under irrigation. To date, the most interesting observation made is that baobab, Adansonia digitata, supports large populations of Meloidogyne under natural conditions. An example was given of infestation of experimental plots by roots of infected baobab. The plants were 13 meters distant from the tree. This project may be extended to the entire Sahelian region (Taylor, Netscher & Germani, Plant Dis. Reptr., in press).

Nonhosts and resistant clones of susceptible crops. No strains of Meloidogyne have been found in Senegal that attack groundnut successfully. Its status as a nonhost remains (Netscher, per. comm.).

Highly resistant clones of sweet potato, derived from IITA seeds, have been observed. Seedlings were very heterogeneous for many characters. A few resistant clones have been increased for further testing. Some have been found to have excellent agronomic characters and are being studied for possible use in rotations to control Meloidogyne. Resistance of local sweet potato cultivars has been found and other cultivars are under study. Other investigators within IMP are encouraged to investigate this plant. (Taylor & Netscher, unpublished data).

Attraction of juveniles of Meloidogyne to plant roots. This study, preliminary results of which were reported in 1976, has been continued but have not yet reached the point of being applicable to field control of Meloidogyne. Several recent results were presented, among which the following are considered the most important.

Four additional populations of Meloidogyne were tested for their ability to migrate considerable distances vertically to infect susceptible plants. All populations had this ability, and thus it appears to be a common ability within populations found in this area. In other experiments it was demonstrated that juveniles of Meloidogyne, when placed in a moisture gradient, will migrate to the region of highest moisture content. However, when a salt gradient is superimposed on a moisture gradient, the reverse is found. That is, the juveniles will migrate to that part of a salt gradient with the lowest salt concentration even though it is also the region with the lowest moisture percentage. This suggested that repulsion by salts is stronger than attraction to higher moisture contents. These studies are being continued. (See J. -C. Prot, 1978 a, b, c, and d).

Summary

In Senegal, it has been shown that Meloidogyne javanica and Heterodera oryzae differ greatly in their chemical composition. A technique was described to increase and maintain cultures of Meloidogyne species using an aerated hydroponic culture. The use of tomato indicator plants in the field is recommended as superior to other methods of detecting Meloidogyne infestations.

A survey in the Cape Verdian Republic showed Meloidogyne species to be present on all four islands on numerous crops, but not on coffee. Meloidogyne appeared to be most severe on cassava.

Studies on the migration of Meloidogyne juveniles showed that all populations had the ability to move at least 40 cm vertically or horizontally to reach a host plant. Other studies showed that juveniles will migrate to the region of highest moisture content but to the region of lowest concentration in a salt gradient.

Résumé

Recherches sur les Meloidogyne à l'ORSTOM, à Dakar

Au Sénégal, il a été montré que Meloidogyne javanica et Heterodera oryzae présentent de grandes différences dans leur composition chimique. Une technique a été décrite pour développer et maintenir des élevages d'espèces de Meloidogyne sur culture hydroponique aérée. L'utilisation de plants de tomate comme indicateurs au champ est recommandée car meilleure que les autres méthodes d'estimation de l'infestation par Meloidogyne.

Une mission de prospection dans la République du Cap-Vert a révélé que des espèces de Meloidogyne étaient présentes dans les quatre îles sur de nombreuses cultures, mais pas sur caféier. Meloidogyne semble être le plus dangereux sur manioc.

Des études sur la migration de juvéniles de Meloidogyne ont montré que toutes les populations étaient capables de se déplacer d'au moins 40 cm verticalement ou horizontalement pour atteindre une plante hôte. D'autres études ont prouvé que les juvéniles migreront vers la zone ayant la plus forte humidité mais qu'ils migreront vers la région la moins concentrée dans un gradient de sel.

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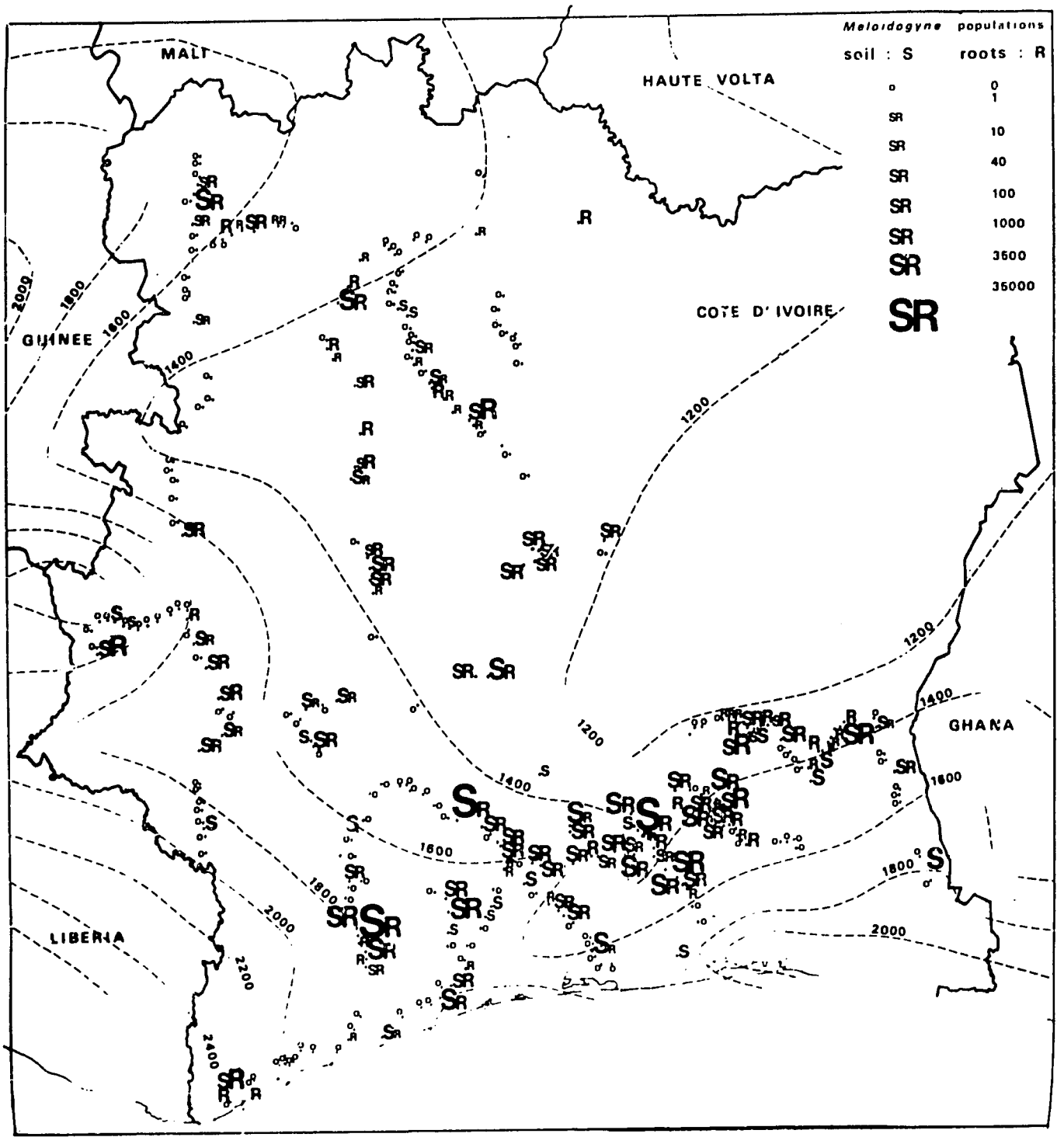

Fig. 4. Repartition of Meloidogyne species in Ivory Coast.
Distribution of Meloidogyne species in Ivory Coast.

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THE INTERNATIONAL MELOIDOGYNE PROJECT

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At the Research Planning Conference on Root-Knot Nematodes, *Meloidogyne* spp. (1) the following program was adopted for this research unit: 1) to participate in the world collection of *Meloidogyne* spp. by taking populations from both cultivated and uncultivated lands in the Northern, the Upper, the Volta, the Greater Accra, the Eastern and the Central Regions of Ghana, 2) to identify the populations using perineal patterns and the differential host tests (2), 3) to gather environmental data for the world project on such factors as temperature, rainfall, soils and others and submit them to the world center at North Carolina State University, Raleigh, 4) to undertake studies on the resistance and susceptibility of major food crops of the region, with the emphasis on vegetables and 5) to utilize the crop response data on resistance to implement effective rotation schemes for control of root-knot nematodes in the main ecological zones of Ghana.

Root-knot populations were taken by collecting whole root systems of infested crops and soil of the rhizosphere. Only four crops could be sampled in any one field as this meant plant destruction. The farmers usually had to be compensated for crop damage. Samples were serially numbered and composite soil samples were made for individual fields. Egg masses were picked from washed roots from each location and placed in labeled vials containing 1% NaCl solution for shipment to the world center.

Populations were collected and identified from the following locations: Kwadaso, Sunyani Junction, cabbage, *M. incognita* and *M. javanica* mix; U.S.T. Horticulture Section, tomato, *M. incognita*; Kwadaso, wild tomato, *M. incognita*; Kwadaso Agricultural Station, cauliflower, *M. arenaria*; Ayigya, eggplant, *M. incognita* and *M. javanica* mix; Accra, Chinese cabbage, *M. incognita* and *M. javanica* mix; U.S.T. Entomology Fields, Okro, *M. incognita*; U.S.T. Pathology Fields, cowpea, *M. incognita*; Nyankpala, tomato, *M. incognita* and Tamale, eggplant, *M. incognita*. Each population was maintained on tomato cv Asesewa. The differential host tests were made following established procedures (2).

Vegetables, such as pepper and tomato, are grown in Ghana throughout the year and it appears that these two crops are highly susceptible to all the populations. Watermelon is grown mainly in the Western and Southern regions and this crop is also highly susceptible to all the populations.

Peanut appears to be resistant to all the populations tested. This crop is grown mainly in the Northern, Upper and Brong Ahafor regions which have light sandy soils.

Tobacco NC-95, which is known to be resistant to root-knot nematodes, was highly susceptible to populations 1,2,3 and 5, all from the Ashanti region, but resistant to populations 4 and 7 from a different area of the Ashanti region. Tobacco was moderately resistant to populations 6 from Accra region and 8 from U.S.T. Tobacco was also highly susceptible to populations 9 and 10 from the Northern region. The crop tobacco is grown mainly in the Ashanti and Brong Ahafo regions and it appears that NC-95 is not resistant to most of the populations for the regions where tobacco is grown.

Corn is also widely grown and is susceptible to populations 2, 8, 9 and 10 from the north and is moderately susceptible to populations 1, 3, 4, 5, 6 and 7.

Cotton is highly susceptible to population 10 from the Northern region which is the main cotton growing area and susceptible to populations 2, 4, and 7 from the Ashanti region. Cotton is resistant to populations 3, 6 and 8 and moderately resistant to populations 1, 5 and 9.

The results show that with the exception of pepper, watermelon and tomato, which were highly susceptible to all the populations, and peanut, which was completely resistant to all the populations, the other crops responded differently to attack by populations from the same regions, though miles apart, have the same soil type, same rainfall records and the same temperature range.

Summary

In Ghana, Meloidogyne incognita, M. javanica and M. arenaria have been found infecting numerous vegetables in all areas. Groundnut did not become infected when tested against the Meloidogyne collections. Tobacco NC-95 was susceptible to populations from the Ashanti and Brong Ahafo regions. Pepper, watermelon and tomato were susceptible to all populations while maize and cotton showed a mixed response.

Résumé

L'International Meloidogyne Project

Au Ghana, Meloidogyne incognita, M. javanica et M. arenaria infestant de nombreuses cultures légumières ont été observes dans toutes les régions. L'Arachide n'est pas attaquée par les souches de Meloidogyne testées. Le Tabac (NC-95) est sensible envers les populations des régions Ashanti et Brong Ahafo. Poivrier, Pasteque et Tomate sont sensibles à toutes les populations tandis que Maïs et Cotonnier ont des réactions mitigées.

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PROGRESS REPORT ON THE INTERNATIONAL MELOIDOGYNE PROJECT

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The program for cooperation as outlined at the Research Planning Conference on Root-Knot Nematodes, *Meloidogyne* spp. (1) was 1) a field survey to determine the *Meloidogyne* species in Ghana, 2) contribute root-knot nematode populations and soil samples to the world center at North Carolina State University, Raleigh for further study, 3) identify populations using the perineal patterns and differential hosts tests, 4) screening of local crops and cultivars for resistance or susceptibility to the root-knot nematode populations and 5) the gathering of ecological data on soil type, rainfall, temperature and cropping sequences.

Field survey. Soil and root samples were collected mainly from the rain forest zone using recommended procedures (1). Ten soil samples and nematode populations as egg masses in 1% saline solution were forwarded to the world center. Location, soil type, host plant and root-knot nematode species identification were as follows: Kumasi, Dystric Nitosol, papaya, *M. incognita* and *M. arenaria*; Kwadaso, Dystric Rhegosol, pepper, *M. incognita* and *M. arenaria*; Tema, Dystric Rhegosol, tomato, *M. incognita*, and *M. arenaria*, Sunyani, Systric Nitosol, eggplant, *M. incognita*, Ejura, Ferric Acrisol, tomato, not identified; Dwenase, Dystric Gleysol, cauliflower, *M. incognita*; Sefwi Wiawso, Dystric Gleysol, okro, *M. incognita*; Kwadaso, Dystric Nitosol, cowpea, *M. incognita* and *M. arenaria*; Goaso, Eutric Nitosol, okro, *M. arenaria* and Patasi, Dystric Gleysol, eggplant, *M. incognita* and *M. javanica*. Of the species identified, *M. incognita* formed 67%, *M. arenaria* 17% and *M. javanica* 11%. *M. incognita* was the dominant species in all localities with the exception of Goaso. *M. incognita* occurred alone or in combination with *M. arenaria* or *M. javanica*. The three species nor *M. arenaria* or *M. javanica* were found together.

Host range studies. Test plants were grown individually in plastic pots in six replications. Twenty-five egg masses of *M. incognita* were inoculated to each pot. Infection assessment was carried out on three replicates 40 and 80 days after inoculation respectively. Tomato seedlings as test plants were grown in the soil for another infection assessment 30 days after transplanting. This was considered necessary because preliminary experiments showed that some crops sustained the population of *M. incognita* without the usual gall formation on the roots. Gall formation became apparent within 40 days in the roots of cocoa, sunflower, okro and tomato. In plantain, banana, cocoyam, cassava, coffee and sweet potato galls took more than 40 days to develop. The tomato test crop showed that oil palm, sweet orange, pineapple, groundnut and cowpea cv 1190 failed to support *M. incognita* population tested (Table 1).

Ecological data. Rainfall figures were compiled but data on air temperature which were not readily available were omitted. Information on cropping sequences was lacking because the local farmers did not keep records on farm practices and the actual owners of the farms were not available to be interviewed.

The field survey has shown that in general more than one species of *Meloidogyne* attack food crops. The differential host tests revealed the presence of mixed populations in some farmers' fields.

Summary

Meloidogyne populations were mainly taken in the forest zone of Ghana. *M. incognita* (67%) was found most frequently, then *M. arenaria* (17%) and *M. javanica* (11%). Oil palm, sweet orange, pineapple, groundnut and cowpea cv 1190 did not support the *M. incognita* population tested. Mixed populations of *Meloidogyne* were often found in farmer fields.

Résumé

Etat d'avancement de l'International *Meloidogyne* Project

Les populations de *Meloidogyne* furent principalement prelevees dans la zone forestière du Ghana. *M. incognita* (67%) était plus frequent que *M. arenaria* (17%) et *M. javanica* (11%). Les populations de *Meloidogyne* testées n'ont pas survécu sur Palmier à huile, Oranger, Ananas, Arachide et Vigna cv 1190. Des populations constituees d'un mélange d'espèces de *Meloidogyne* sont souvent observées dans les champs des paysans.

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Table 1. Root-knot nematode index of *Meloidogyne incognita* on selected test plants in a host range study.

Crop	Variety	Root-knot index[a] 40 days	Root-knot index[a] 80 days	Root-knot index Tomato test plant
Plantain	local	0	3	4
Citrus	sweet	0	1	0
Oil palm	hybrid	0	0	0
Banana	Gros Michel	0	4	3
Sugarcane		0	0	3
Pineapple	sugar loaf	0	0	0
Coffee	robusta	0	1	2
Cocoa	hybrid	2	2	3
Cocoyam	local	0	3	5
Sweet potato	local	0	2	1
Cassava	Ankra	0	4	5
Groundnut	Kumawu	0	0	0
Maize	La Posta W	0	0	5
Sorghum	Mankerewa	0	0	3
Millet	Manga	0	0	3
Sunflower	Sputnik	3	4	5
Okro	local	3	5	5
Tomato	local	5	5	4
Cowpea	TVu 1190	0	0	0
Cowpea	TVu 1977	0	0	3

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

SOME WEED HOSTS OF A POPULATION OF *MELOIDOGYNE INCOGNITA* IN NIGERIA

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The last report I gave was titled "The status of root-knot nematodes in the eastern states of Nigeria" (4). In it I said, among other things, that the root-knot nematodes are our public enemy number one, because they attack a vast number of crops. I was talking essentially of cultivated crops. It was also stated that the root-knot nematodes show unique adaptations for survival and distribution. One such adaptation is their ability to switch to some weeds and reproduce on them when cultivated crops have been harvested. My definition of a weed is a plant man does not want to grow and he would get rid of it in a given situation. A plant man wants to grow is his crop.

Weeds represent a contained population. They are usually in the field before the crop is planted. Some of the weeds are perennial, deep-rooted and characterized by high levels of persistence. Weeds that harbour and increase populations of root-knot nematodes constitute additional hazards for future crops (1,3).

An area (0.1 ha) of the university farm was naturally infested with *M. incognita*. The land had previously been cropped to two seasons of *Lycopersicon esculentum* cv Roma VF. Studies have demonstrated that the nematode is able to reproduce on 39 Nigerian weeds (Table 2).

Weeds are pests by themselves. They compete for essential environmental factors with cultivated crops. They introduce unpalatable or toxic components to the harvested crop (2). Weed pests harbour and increase populations of other pests, i.e., root-knot nematodes. A suitable cultural practice to control root-knot nematodes would take into account the role of weeds. I have in mind one cultural practice. This is the practice of bare fallow. By bare fallow I mean the practice of keeping the land free of all vegetation for varying periods. There are objections to the practice of bare fallow: 1) the operations necessary to maintain land completely free of weeds are difficult and expensive and cannot be readily accepted by the average Nigerian farmer, 2) the southern areas of Nigeria are in the high rainfall belt and fallow is a poor conservation practice and is likely to impair the physical structure of the soil, 3) fallow land does not contribute to farmer income.

That many Nigerian weeds meet the nutritional requirements of the root-knot nematode is an unpleasant development which renders some cultural techniques still less effective.

Summary

In the eastern part of Nigeria weed hosts of Meloidogyne incognita were studied. Thirty-nine weed species were found to be host plants for the nematode.

Résumé

Quelques adventices hôtes d'une population de Meloidogyne incognita au Nigeria

Les adventices hôtes d'espèces de Meloidogyne incognita furent etudiees dans la partie orientale du Nigeria. Il est apparu que trente neuf espèces d'adventices sont hôtes des nématodes.

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Table 2. Weeds found to be hosts to *Meloidogyne incognita*.

Amaranthaceae

Achyranthes aspera L.
Achyranthes indica L.
Alternanthera repens (L.) Link, Enum. Pl. Berol.
Alternanthera sessilis (L.) R. Br. ex. Roth.
Amaranthus dubius L.
Celosia argentea L.
Pupalia lappacea (L.) Juss

Rubiaceae

Borreria Laevis G.F.W. Mey.
Borreria verticillata (L.) G. F. W. Mey.
Oldenlandia affinis (Roem & Schult.) DC.
Oldenlandia corymbosa L.

Cyperaceae

Cyperus diffusus Vahl

Commelinaceae

Commelina erecta ssp. erecta L.

Capparidaceae

Glynandropsis gynandria (L.) Big.

Oxalidaceae

Biophytum sensitivum (Lam.) Oken

Compositae

Ageratum conzoides L.
Chrysanthellum americanum (L.) Vatke.
Emilia sonchifolia (L.) DC.
Vernonia cinerea (L.) Less.

Portulacaceae

Portulaca oleracea L.
Portulaca quadrifida Hook.
Talinum triangulare (Jacq.) Willd.

Table 2. Continued.

Euphorbiaceae

Croton lobatus L.

Leguminosae

Calopogonium mucunoides Desu.
Chamaecrysta aeschynomena Millsp.
Desmodium ramosissimum G. Don.
Desmodium triflorum (L.) DC.
Sesbania exaltata Scop.
Vigna gracilis (Guill. & Perr.) Hook. f.
Zornia glochidiata Reichb ex. DC.

Labiatae

Solenostemon monostachyus (P. Beauv.) Briq.

Solanaceae

Physalis angulata L.

Loganiaceae

Spigelia anthelmia L.

Papaveraceae

Argemone mexicana L.

Gentianaceae

Canscora decussata (Roxb.) Roem & Schult.

Verbenaceae

Stachytarpheta jamaicensis Vahl.

Convolvulaceae

Ipomea congesta R. Br.
Ipomea involucrata P. Beauv.

Crassulaceae

Bryophyllum pinnatum (Lam.) Oken.

FURTHER STUDIES ON CONTROL OF ROOT-KNOT NEMATODES, *MELOIDOGYNE SPP.*

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Ideally, the most economical and effective method of controlling nematodes is the use of nematode resistant plant varieties. At present, largely because of limited research in this area, few nematode resistant varieties of plants are available to the farmers. Also, the use of crop rotation to reduce crop losses is without question the most effective and mostly widely used land management practice. As at present no acceptable crop rotation including crops known to suppress root-knot nematode population has been devised so as to permit economic production of susceptible crops like tomato (*Lycopersicon esculentum*).

Most tomato cultivars are known to be susceptible to root-knot nematodes (1,2,6,8,9). Caveness and Wilson (3) showed that root-knot nematodes on *Celosia argentea* can be effectively controlled, with significant yield increases by soil fumigation with D-D mixture (1,3, - dichloropropene and 1,2 - dichloropropane).

Root-knot nematodes are common and very damaging to susceptible tomato cultivars in southwestern Nigeria (8). There has, therefore, been an increasing awareness of the importance of root-knot nematodes and their control in Nigeria. The present study, therefore, further attempts (i) to identify sources of resistance to root-knot nematodes in soybean which might be useful in formulating crop rotation programs, (ii) to determine the best cropping sequences for the control of root-knot nematodes on tomato and (iii) to assess the efficiency of three nematicides - D-D, Nemagon 20 and Nemagon 75 EC - in controlling root-knot nematodes for fresh tomato fruit production.

GENERAL MATERIALS AND METHODS

Fields or field soil heavily infested with a mixture of root-knot nematodes, *Meloidogyne arenaria*, *M. javanica* and *M. incognita* were used except where otherwise stated.

RESULTS

(a) Screening soybean cultivars.

Two seeds of each soybean cultivar (*Glycine max*) were sown into 5-litre plastic pots filled with soil infested with *Meloidogyne incognita* (300 larvae/100 cm^3 soil). After germination, plants were thinned to one

per pot in three replicates each. After ten weeks the plants were carefully lifted, the roots rinsed in water and scored for degree of galling according to the method of Daulton and Nusbaum (4).

None of the 24 cultivars of soybean tested was immune to M. incognita. Hardee was highly resistant while Hampton was resistant. Six cultuvars were moderately susceptible while others were susceptible or highly susceptible (Table 3).

(b) Crop rotation

For three growing seasons, beginning from late season in 1975, a series of cropping sequence were initiated on root-knot nematode infested experimental plots at Ikenne in the forest zone and Ilora in the derived savannah area of Nigeria. Crops used included groundnut (Arachis hypogaea) or rice (Oryza sativa), maize (Zea mays) tomato, Stylozanthes (Stylozanthes gracilis) in addition to bush fallow. At Ilora, rice was replaced with groundnut.

At the beginning of the fourth season (early cropping season in 1977), all field plots were planted to tomato cv. Ife No. 1. At maturity yields of fresh tomato fruits were taken to show the effect of various cropping sequences.

Common weeds found in the fields included Imperata cylindrica (spear grass), Rottboellia exultata (corngrass), Pennisetum spp., Eupatorium odoratum (siam weed), Aspila spp., Euphobia spp., Amaranthus spp., Celosia trigyna, Tridax procumbens, Corchorus capsuloria and Indigofera dandroides.

Yields of fresh tomato fruits resulting from the cropping sequences are shown in Table 4. Growing nonhost or resistant crops such as maize, rice, groundnut and stylozanthes prior to growing tomato often greatly increased yields of tomato. Continuous stylozanthes appears to be detrimental at Ikenne where excessive vegetative growth of tomato plants was observed.

(c) Chemical control

This trial was carried out at Ilora and Ikenne on fields heavily infested with root-knot nematodes. Three different rates of each nematicide and a control were compared as shown in Table 3. Each treatment was replicated four times. All nematicides were applied three weeks before transplanting the test crop, Ife No. 1 tomato cultivar, into the fields. Plants were fertilized with complete fertilizer and sprayed weekly against insect and fungus attack. At maturity fruit yields were recorded. At Ikenne plants were also rated for root galling on the scale 0-5 after final harvest of fresh fruits.

D-D gave the best control of root-knot nematodes (Table 5). However, yields of fresh fruits of tomato were not significantly different between the treated and the untreated control. At Ikenne mean gall index for the

control plots was significantly higher than all the other treatments, but there were no significant differences in mean gall index between the fumigant treatments.

DISCUSSION

Observation on the resistance of soybean to M. incognita showed that Hardee was highly resistant while Hampton was resistant. Only the resistance indicated in Hardee approaches immunity. Therefore, the discovery of greater resistance to M. incognita among soybean cultivars awaits only the testing of a larger number of cultivars as they become available.

Some treatment effects, though not significant, were observed in the yield of indicator tomato crop at the end of sequential cropping. Inclusion of rice, maize, groundnut and stylozanthes often led to increases in yields of tomato crop. Peakcock (7) has also shown that the inclusion of groundnut, an immune crop, in a crop rotation was highly effective in controlling root-knot nematodes. Tests also substantiated farmers' observations that satisfactory yield of tomato can be obtained following bush fallow. The detrimental effect on tomato yield of continuous stylozanthes cultivation observed at Ikenne might be due to high nitrogen accumulation in the soil.

Chemical control of root-know nematodes in the field did not significantly increase tomato yields. However D-D effectively controlled root-knot nematodes on Celosia argentea with significant yield increases (3). Nemagon 75 EC, which requires mixing with large quantity of water before application, as a field treatment for tomatoes appears doubtful. This nematicide will therefore be most useful in the nursery beds rather than for field application. Lear and Thomason (5) have made two similar observations on Vapam.

Summary

In Western Nigeria, none of the 24 cultivars of soybean tested was immune to Meloidogyne incognita. Hardee was highly resistant while Hampton was resistant. Other cultivars were susceptible or highly susceptible. The growing of resistant or nonhost crops or the use of a nematicide greatly increased yields of tomato cv. Ife No. 1.

Résumé

Au Nigeria occidental, aucun des 24 cultivars de soja testés ne s'est montré immun à Meloidogyne incognita. Hardee est hautement résistant, Hampton est resistant. Les autres cultivars sont sesibles ou fortement sensibles. La culture de plantes non-hotes ou résistantes ou l'emploi d'un nématicide a considérablement augmenté les rendements de tomate cv. Ife N° 1.

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Table 3. Relative susceptibility of soybean to root-knot nematode, *Meloidogyne incognita*

Soybean Cultivar	Root-knot Index[a]	Resistance rating[b]
Amasy	2.0	MS
Bienville	2.7	S
Bossier	3.0	S
CES 407	2.3	MS
CES 486	3.3	S
Chippenwa 64	3.3	S
Chunghsing No. 1	2.0	MS
Clark 63	2.3	MS
CNS	2.0	MS
Hale	4.0	HS
Hampton	1.0	R
Hardee	0.1	HR
Hawkeye	4.0	HS
Hood	4.0	HS
Improved Pelican	3.3	S
Jupiter	3.3	S
Kent	4.3	HS
Local Check 1	3.7	S
Local Check 2	4.0	HS
Ranoke	4.3	HS
Semmes	3.0	S
Shelby	3.7	S
Pickett	2.0	MS
280 - 3	2.7	S

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

[b]Resistance rating: HR = highly resistant, R = resistant, MS = Moderately susceptible, S = Susceptible, HS = Highly susceptible, VHS = Very Highly Susceptible.

Table 4. Ceopping sequence and resulting tomato yields

Test No.	1975 Late Season	1976 Early Season	1976 Late Season	1977 Early Season Yield (Ife No. 1 tomato cultivar) tons/ha.	
				ILORA	IKENNE
1	Maize	G'nut/rice[a]	Maize	10.98	6.20
2	Tomato	G'nut/rice	Maize	5.69	7.13
3	Tomato	Maize	Maize	8.13	6.94
4	Maize	G'nut/rice	Bush fallow	6.09	4.47
5	Maize	G'nut/rice	Tomato	9.20	6.18
6	Maize	Tomato	Stylo	7.53	5.09
7	Stylo	Stylo	Stylo	9.97	4.01
8	Bush fallow	Bush fallow	Bush fallow	8.71	5.20
9	Cowpea	Bush fallow	Bush fallow	7.78	4.88
10	Tomato	Tomato	Tomato	6.88	5.18

[a]Groundnut at Ilora, rice at Ikenne

Table 5. Effect of soil fumigation on root-knot control and fresh fruit production of tomato cv. Ife No. 1

Treatment	Rate/ha		ILORA[a]		IKENNE[a]	
		Yield/plot (kg)	Estimated Yield (t/ha)	Yield/plot (kg)	Estimated Yield (t/ha)	Mean gall Index[b]
D-D	205.4 litres	4.87	8.1	9.10	15.2	2.1b
	308.1 "	-	-	7.28	12.1	1.7b
	410.8 "	4.02	6.7	8.28	13.8	1.1b
Nemagon 20	51.2 kg	2.87	4.8	8.25	13.8	3.0b
	76.8 "	3.02	5.0	7.14	11.9	2.8b
	102.4 "	2.69	4.5	7.12	11.9	2.1b
Nemagon 75 E-C	17.7 litres	3.72	6.2	6.46	10.8	2.5b
	26.6 "	3.05	5.1	9.78	16.3	2.0b
	35.5 "	2.28	3.8	9.04	15.1	1.2b
Control	-	3.49	5.8	8.39	14.0	4.2a
Mean	-	0.564	-	0.957	-	0.779

[a]Plot size = 1 x 6 metres, [b]Gall index 0 - 5. (Means with the same letter do not differ significantly at P = 0.05 according to Duncan's multiple range test).

ROOT-KNOT NEMATODES IN THE NIGERIAN SAVANNA ZONES WITH SPECIAL REFERENCE TO ROOT-KNOT PROBLEMS OF IRRIGATED CROPS IN THE KANO RIVER PROJECT AT KADAWA.[a]

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In those areas of Nigeria where the soil thoroughly dries each year during the dry season, root-knot nematodes do not pose a serious threat to field crops grown solely during the rainy season. These nematodes cannot survive extreme desiccation and most of the field crops are immune or bad hosts. Under irrigation during the dry season, many crops are grown that are very good hosts of root-knot nematodes and they multiply rapidly. As a consequence, these nematodes may cause serious damage in a field within a short time once they have been introduced.

Traditional 'Shadoof' - irrigation along the rivers has been practised for a very long time and root-knot nematodes can be found wherever this type of irrigation is seen. Probably these nematodes have been present in these sites for centuries although records do not exist.

More recently, upland areas have been brought under irrigation in both small and large irrigation projects. The largest project so far being the Kano River Project, with a pilot farm at Kadawa, about 50 km south of Kano. In this project eventually 25,000 ha will be brought under irrigation. The first land at Kadawa was developed about ten years ago and already root-knot nematodes are among the major pests, causing considerable damage to the crops. In this paper a summary of root-knot nematode investigations in the Nigerian Savanna Zones, an assessment of the present situation and possible ways to reduce the damage will be discussed.

Previous investigations

The different situation that, with regard to pests and diseases, arises under irrigation, was recognised by Keay (4). She stated, "The establishment of irrigated areas brings about an entirely new situation with regard to pests and diseases. A situation in which much of the control exercised by the natural environment is no longer functional. In planning it is better to recognize this new situation from the beginning than to wait until crop failures force its recognition." She also wrote, "Unless rotations are carefully planned, and strictly followed, there may be rapid multiplication of destructive soil organisms." Her warnings have proven particularly true for root-knot nematodes *Meloidogyne* species.

[a]Adapted from Bos, W.S. 1978. Root-knot nematodes in the Nigerian savanna zone. Samaru Misc. Paper 79, IAR. Samaru.

Wilson (7) was the first to make a survey in the Nigerian savanna regions. Two species, M. javanica and M. incognita, were found widespread with M. javanica being the more common species. A third species, M. arenaria, was found at a few locations. Wilson gave an extensive list of food crops and weeds attacked and reported yields of tomato reduced by 75% in fields near Samaru.

In a survey of several irrigated sites Bridge (1) confirmed the widespread distribution of the two principal root knot species in the savanna regions. Bridge was of the opinion that in heavily infested crops of tomato, garden egg, cucumber and cowpea, about 40% of the crop was lost, and even more in the case of melons. The need to consider root-knot nematode problems on lands under irrigation was also stressed.

A survey in the southern portion of Nigeria listed additional food crops that were susceptible to Nigerian root-knot nematode populations (2).

Current investigations

Current investigations have shown most traditionally irrigated land to be infested, mainly with M. javanica. The degree of infestation varies greatly. Low areas that become inundated or marshy during the wet season have the least numbers of nematodes. During the wet season however much of this land is abandoned or grown to poor hosts or nonsusceptible crops such as sorghum, millet, maize, rice or groundnuts. Vegetables, especially tomatoes, are cash crops and their repeated growing has led to high levels of infestation and low yields.

Hot peppers, parsnips, celery, green gram and local spinach (Amaranthus spp.) have now also been found highly susceptible to M. incognita and/or M. javanica. To date, root-knot nematodes have not been found to attack groundnut, rice, cotton, sorghum, millet or maize. However, Wilson (7) mentioned a light infestation of sorghum by M. javanica and Caveness (2 and personal communication) found maize and upland rice infected with M. incognita in the southern areas. At the Kadawa irrigation project comparatively low densities of root-knot nematodes severely reduced the growth of melons. Peppers growing in heavily infested seedbeds were examined for M. incognita attack. Gall development on the several varieties ranged from many galls with egg masses to few without egg masses (Table 6). In small scale experiments at Samaru, Omiyi (5) found that onions and wheat had light galling on the roots but yield reductions could not be demonstrated. Growing these crops maintained low soil population levels of the root-knot nematodes.

The Kano River Project

At present about 1,000 ha of the planned 25,000 ha are under irrigation. The main irrigated crops are wheat, tomatoes, maize, melons and vegetables including French beans, garden eggs, bell peppers and cabbage. In the wet season, maize, millet, cotton, rice and groundnut are grown.

A long term rotation was started in 1973 to investigate the build-up of nematode populations under the various crops grown. The first sign of root-knot nematode was in the dry season crop of 1975 and it was found that root-knot nematode was present on the farm in many places. BUD-Holland, a commercial firm, started growing vegetables for export in November 1976, especially French beans, melons, lettuce, garden egg and tomato. Most of the older fields had a high incidence of nematode and crop damage on more recently developed fields was evident. The large-scale vegetable growing considerably increased the area under highly susceptible crops which has accentuated the root-knot nematode problem. Large parts of the French bean crop yellowed and dried and yields were severely reduced. Yields averaged three to four t/ha while eight to fourteen t/ha were being harvested on nematode-free land in Senegal (BUD personal communication). In some melon fields, irrigation was stopped as the plants ceased to grow. The nursery beds were badly infested and La Bonita tomato seedlings were not suitable for transplanting at seven weeks. The seedbeds of peppers, lettuce and garden eggs were also heavily infected. The nursery area had been in use since 1973 and infected seedlings had spread root-knot nematodes to many fields.

The root-knot resistant tomato, Roma VEN, showed light gall development at seven weeks when grown in the seedbeds. Mature females with egg masses were found. It is suggested that a resistance breaking strain of the nematode is present as the high soil temperatures which might inactivate the resistant gene should not occur in the moist soils during the dry season. This fact would complicate future crop production and rotations. The breaking of root-knot nematode resistance in tomatoes has been reported from other West African countries (6).

Control measures for the Kadawa scheme

Control measures should be employed to (1) prevent further spread of nematodes to noninfested fields and (2) reduce crop damage in fields aready infested.

Preventive measures against the spread of nematodes would include sanitation in the form of clean farm implements, restricting the movement of livestock and ensuring that only nematode-free transplants are used. Weed hosts of the nematodes along the banks of irrigation canals need to be controlled. Irrigation water should not be recycled.

In infested fields that nematode numbers need to be reduced to levels below the threshold of economic damage. This would involve the implementation of suitable crop rotation regimes using nonhost or poor host crops such as cotton, groundnuts, sorghum, millet, maize and to a lesser extent wheat, onions and hot peppers. The judicious use of resistant and susceptible crop varieties should prevent the development of resistant breaking strains of the nematode. Resistant varieties have been developed for tomatoes, peppers, French beans, cowpeas, soyabeans and sweet potatoes. Resistant varieties are reported to be capable of reducing nematode numbers by trapping root-knot nematode juveniles (6).

Strict sanitation in the form of weed control and the control of volunteer plants from previous susceptible crops is vital to nematode population containment. Weed control would need to cover broadleaf plants and grasses. Wilson (7) mentioned Cynodon dactylon as a host of M. incognita and in the present study Setaria pallidefusca was found to be highly infested with M. javanica at another site. The examination of weeds along one irrigation canal showed 10 of the 15 plant species sampled to be infected by root-knot nematodes and five of these were heavily infected. Several other weed species were determined to be host plants for root-knot nematodes at other Kadawa locations (Table 7). Nematode species identifications have shown M. incognita to be more common than M. javanica at Kadawa, but both are widespread.

In the growing of high value food crops susceptible to root-knot nematode the use of chemicals as an integrated part of the control program should prove feasible.

Control measures on small farms

Small plot size and limited financial reserves pose a special situation for small scale farmers. A suitable rotation scheme might not be adaptable to the small plot in a practical or economic sense. Seeds of resistant plant varieties generally are not available nor the knowledge for their best use. In addition, the small scale farmer is most likely unaware of any need for nematode control practices.

Summary

In the north of Nigeria most of the traditionally irrigated farms along river banks are infested, mainly with Meloidogyne javanica. The growing of vegetable cash crops results in high levels of infestation and low yields. Meloidogyne species have not been found to attack groundnut, rice, cotton, sorghum, millet or maize. Meloidogyne species have become a limiting factor in the production of vegetables in the Kadawa irrigation project.

Résumé

Dans le nord du Nigeria, la plupart des fermes soumises à l'irrigation traditionnelle le long des rives de la rivière sont infestées, principalement par Meloidogyne javanica. La culture de plantes maraichères destinees a la vente proveque de hauts niveaux d'infestation et de faibles rendements. Les espèces de Meloidogyne ne semblent pas attaquer Arachide, Riz, Cotonnier, Sorgho, Mil ni Maïs. Les espèces de Meloidogyne sont devenues un facteur limitant dans la production legumière du projet d'irrigation de la Kadawa.

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Table 6: *Meloidogyne incognita* root-knot galling on seedling pepper (*Capsicum frutescens grossum*) in seedbeds at the Kano River Project, Kadawa

Variety	Root-knot galling[a]
Anaheim	many galls with mature females
Ataryu (ex Samaru)	very few galls, some containing mature females
Caloro	few females and egg masses
Dantsiga	very few females and egg masses
Hungarian Yellow wax	many small galls with large egg masses
Hunkoyi variety	some small galls with several egg masses
L. 2096	few galls, small, no egg masses seen
L. 2155	few mature females and egg masses
L. 2190	several small galls with egg masses
L. 2191	several small galls with few egg masses
L. 3874 5BE	very few small galls without egg masses
L. 5962-2	very few small galls without egg masses
Mercury	many small galls with egg masses
Mild California	many small galls, few egg masses
Red Cherry	galling severe, many egg masses
Sararho	few rather large galls, several egg masses
Yolo Wonder	few single galls (less than one per plant), containing mature females and egg masses

[a]n = 50 females.

Table 7. Crops and weeds found infected by root-knot nematodes, *Meloidogyne* spp., at the Kano River Irrigation Project at Kadawa

Plant name[a]	Root-knot index[b]	Root-knot nematode frequency per plant[c]		
		Meloidogyne javanica	*Meloidogyne incognita*	*Meloidogyne arenaria*[d]
Acalypha brachystachia	1	2	1	
	1		4	
	1	2	5	
	1	3	2	
Acanthospermium hispidum	1		1	
	1	1	2	
Amaranthus spinosus	1		5	
	2	7	3	
Amaranthus viridis	1		9	
	2/3		10	
			8	
Aspilia africana	3		unidentified	
Aspilia helianthoides prieuriana	2		4	
Capsicum frutescens	3		12	
	3			
Celosia trigyna	3	8		
Ceratotheca sesamoides	3		10	
Celome monophylla	3		8	3?
Croton lobatus	1	1	5	
Cyperus esculentus	2	4	5	1?
Cyperus rotundus	2	1	9	
Cyperus sp.	1		unidentified	

Table 7 Continued

Dactyloctenium aegyptium	1	3	2	
Eclipta prostrata	1	9	1?	
Eragrostis sp.	2	10	1	
Gnaphalium luteo-album	1		5	
Gynandropsis gynandra	1		unidentified	
Hibiscus sp. 1	3		9	
Hibiscus sp. 2	1			2
Hibiscus esculentus	2		1	
Leucas martinicensis	1	5	5	
	4		10	
	1		4	
Lycopersicon esculentum	1 - 4 (several plants)	M. javanica and M. incognita mixed		
Paspalium orbiculare	1	6	2	
	1	2	3	
	1	3	7	
Phaseolus vulgaris	2	7	1	2?
	4	2	8	
	1	1	9	
	3	10		
	3		10	
	4	8	3	
	4	4	5	
	4		7	1?
	4	10	1	1?
	3		8	1?
	4	1	9	
	4	1?	4	
Portulaca oleracea	3	7	4	
	3		8	
	3	2	1	
Schwenckia americana	3		unidentified	
Sesbania sesban	3	7	2	
	3		10	
	3	1	9	
	3	4	8	

Table 7 Continued

Sida rhombifolia	1		1	
Solanum nigrum	1		10	
	2	5	5	
	3	3	5	
	3		10	1
	1		3	
	2	5	1	
	1		4	
	4		1	3?
Triticum aestivum	1		unidentified	
Vigna unguiculata	4		2	

[a]Weeds identified by Mr. D.O. Magaji of the Soil Survey Section, IAR, Samaru.

[b]Root-knot index: 1 = light galling, 4 = very severe galling.

[c]Where more than one plant per species was sampled, the recordings for each plant have been given separately to show the uneven distribution of the root-knot species.

[d]Most females identified as Meloidogyne arenaria by perineal pattern examination were not very typical for this species.

ROOT-KNOT NEMATODE RESEARCH AT THE INSTITUTE FOR AGRICULTURAL RESEARCH, AHMADU BELLO UNIVERSITY

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Root-knot nematode research at the Institute for Agricultural Research is now an integral part of the programme for horticultural crops such as tomatoes and vegetables. The two Institute nematologists will thus allot more time to the IMP Meloidogyne project. Within the Institute, two postgraduate students have research projects concerned with Meloidogyne spp. and are supported in part by IMP. An advanced student, Mr. P.I. Omiyi, is now in the United Kingdom to submit his Ph.D. thesis on a Meloidogyne research project for the completion of his training.

Progress to date. Specific activities of the IMP research cooperators and the research students they supervise include: 1) identification of Meloidogyne species and variants from regional collections, 2) food crop susceptibility and/or resistance studies on tomatoes and vegetable crops, 3) evaluation studies to develop and implement effective crop rotation schemes were initiated, 4) the influence of manure and susceptible weeds on field populations of Meloidogyne were investigated and 5) information on the development of a new Meloidogyne pathogenic race affecting resistance in tomato and its field distribution was obtained.

The implementation of the Meloidogyne differential host tests was held in abeyance pending release of plant material by the Nigerian Quarantine Service.

Materials and methods. Procedures are essentially the same as previously described (1). Extraction, inoculation and collecting equipment were received from IMP and utilized in the local project. Shadehouse and greenhouse facilities have been considerably improved so that culturing of root-knot nematode populations can now be extended, especially under dry season conditions when low relative humidity combined with low night temperatures make successful growing of host plants difficult.

Results. Studies of the original Wilson collection (5) containing 93 slides with about 10 perineal patterns each from root-knot populations found in and around Zaria were made by F.E. Caveness and J.J. Smit. Apparently this collection is not complete as Wilson recorded root-knot incidence on an additional 33 plant species. Part of the original slide collection may have been lost. Some of Wilson's identifications were in error, but many others were correctly made. The new identifications of the slides re-examined together with the galling incidences reported by Wilson are given in Table 8.

A postgraduate student, Mr. A.A. Idowu, collected root-knot populations from various locations and crops and recorded available data on the sample sites. Perineal pattern observations were made for each population under the supervision of Ir. Smit and Bos (Table 9). Sampling sites in nothern Nigeria are shown in Figure 5.

Bos (3) reported on the root-knot nematodes found in the Nigerian savanna zones. New information on root-knot nematode incidence on food crops and weed species at the Kano River Project, Kadawa is presented.

It is noteworthy that only three Meloidogyne species, M. javanica, M acrita and M. incognita were recorded regularly in pure or mixed populations from northern Nigeria. M. arenaria is only rarely found. The predominant species is M. javanica, which is almost exclusively found at higher elevations on the Jos Plateau. However, many variants and atypical perineal patterns were found for all species. The populations in which they were found are to be studied in greater detail. Samples of collected populations will be sent to the world center for the IMP at North Carolina State University, Raleigh. Culturing of these populations on appropriate host plants will also be pursued at the Institute.

Summary

Meloidogyne research at the Institute is now an integral part of the program for horticultural crops. Research projects cover identification of Meloidogyne species, food crop resistance studies, development of effective crop rotation schemes, the influence of soil amendments and Meloidogyne pathogenicity studies on production tomatoes.

M. javanica, M. acrita, M. incognita and M. arenaria are found in the north of Nigeria. M. javanica is the most common species and M. arenaria the most rare.

Résumé

Etudes sur les nématodes galligènes à l'Institut de Recherches Agronomiques Université Ahmadu Bello

L'étude de Meloidogyne à l'Institut est maintenant partie intégrale du programme pour les cultures horticoles. Les projets de recherche comprennent l'identification des espèces de Meloidogyne, des études de résistances des plantes alimentaires, l'établissement de séquences de rotations culturales efficaces, l'influence des amendements du sol et des études de pathogenie de Meloidogyne sur les tomates industrielles.

M. javanica, M. acrita. M. incognita et M. arenaria sont observés au nord du Nigeria. M. javanica est l'espèce la plus commune et M. arenaria la plus rare.

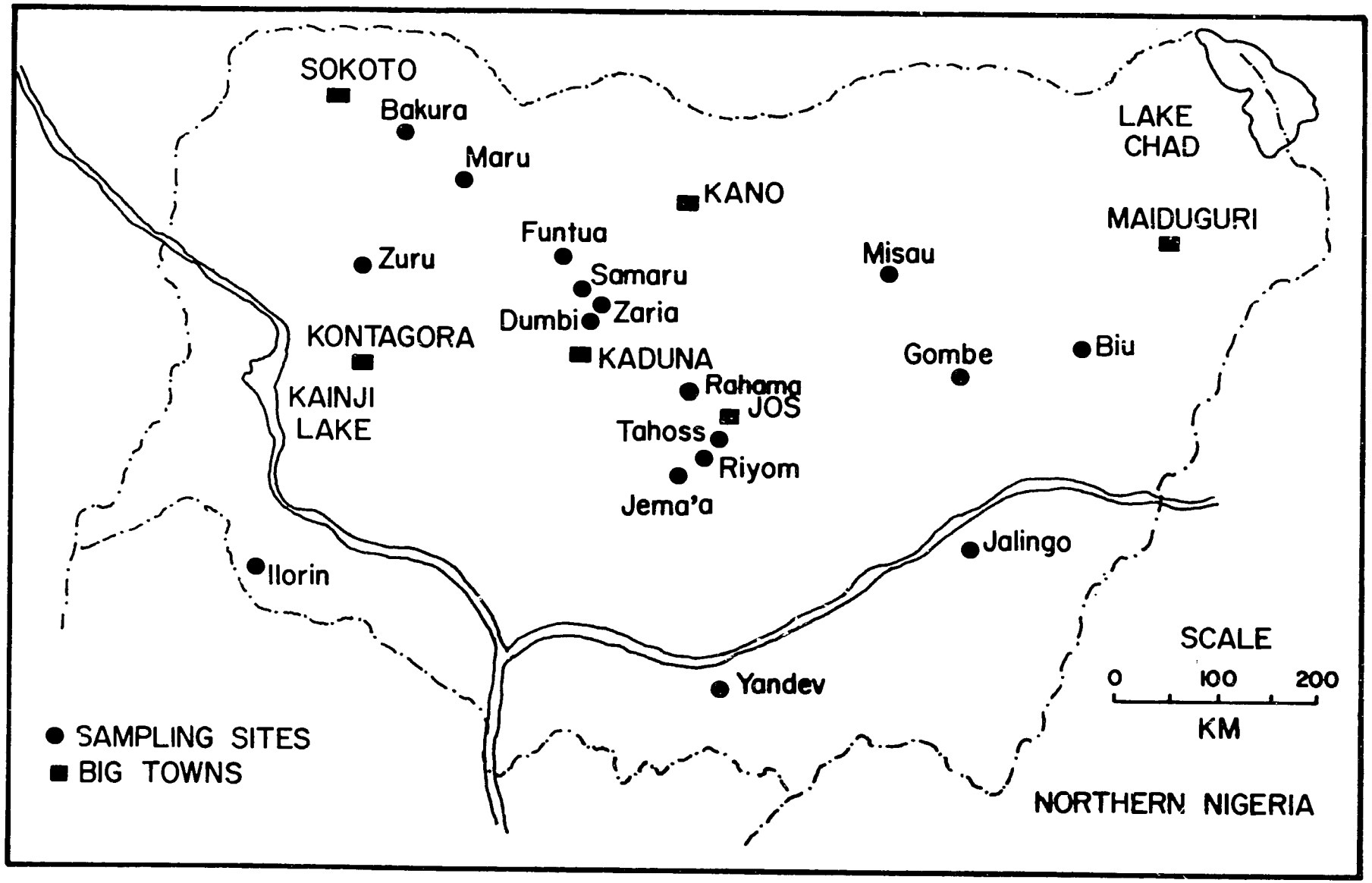

Fig. 5. Sample sites for root-knot nematode populations in northern Nigeria.

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Table 8. Root-knot nematode distribution and host plant association in the northern region of Nigeria. Modified after re-examination of the Wilson collection (5).

Host plant name	Root-knot index[a]	Species[b]	M-j[c]	M-i[d]	M-a[e]	M-ar[f]	Slide No. & location[g]
Acalypha segetalis	3		x			x	37S
Achyrospermum africanum	2		x				78Je
Ageratum conyzoides	4 ?		X		x		57Z
" "	4 ?				x		66Z
Allium cepa onion	3			x	x		20S
Allium porrum leek	4		x?				4S
Alysicarpus glumaceus	2		x				35S
Alysicarpus sp.	4		x				25S
Amaranthus caudatus African spinach	4 ?		x?		x		59Z
" "	4 ?		x		x		62Z
Amaranthus spinosus	2		x+atyp		x		49Z
Amaranthus sp.	2			x			47S
Ananas comosus pineapple	2				x		77Je
Anthirrhinum majus snapdragon	4		x				88S
Apium graveolens celery	2		x		x		12S

Aspilia sp.	2		x			92Je
Basella alba Indian spinach	4				x	10S
Beta vulgaris v. rubra beetroot	2		x			7S
Beta vulgaris v. cicla spinach beet	?		x		x	14S
Borreria ruelliae	2		x			26S
Brassica oleracea v. botrytis cauliflower	4 ?		x			39S
" "	4 ?		x			65Je
Brassica oleracea v. capitata cabbage	3				x	1S
Brasscia oleracea v. gemmifera Brussels sprouts	4	x				11S
Brassica rapa turnip	3				x	22S
Capsicum annuum sweet pepper	3		x			43Z
Carica papaya pawpaw	4		x	x?		45 ?
Celosia argentea potherb	4			x+at	x+atyp	48Z
Celosia cristata cockscomb	4			x	x	16S
Celosia plumosa	4		x			3 ?
Cephalostigma perroteti	4		x+2var.			81Je
Chrysanthellum americanum	3		x		x	90Je
Citrullus vulgaris watermelon	4		x			42S
" "	?		x			70Je
Clerodendron ugandense	3		x			41S
Colocasia esculenta taro (eddo)	2 ?		x			44S
Corchorus olitorius	3		x			64Z
Crassocephalium sp.	2		x	x ?		84Je

Crassocephalium rubens	2			x	91Je
Crassula pinnatum	3		x	x	40S
Cucumis sativus cucumber	4	xatyp			13S
Daucus carota carrot	4 ?	x+var			2S
" "	4 ?	x+var			86S
Desmodium adscandens	3	x			54S
Dioscorea sp. yam	4		x		85Ya
Dissotis irvingiana	2	x+var			80Je
Ethulia conyzoides	2	x			28S
Glycine max soybean	3 ?	x			15S
"	3 ?		x		73Je
Hibiscus cannabinus kenaf	4 ?	x	x		67Z
"	4 ?	x			76Je
Hibiscus esculentus okra	4	x	x		60Z
Hibiscus Rosa-sinensis Rose-of-China	3	x			34S
Hibiscus sp. wild	2	x		x	78Je
Indigofera congolensis indigo	2	xatyp			72Je
Indigofera sp.	3	x			31S
Lactuca sativa Lettuce	4 ?	x			83Je
"	4 ?			x	8S
Laggera alata	2	x+var			71Je
Lepidium sativum garden cress	4	x			53S
Melanthera elliptica	4	x			32S
Melothera maderaspatana	4	x			29S
Musa sp. banana	3	x	x		24S

Nicotiana tabacum tobacco	3		x			75Je
Nicotiana sp. wild tobacco	4				x	74Je
Petroselinum sativum parsley	4		x ?	x	x	5S
Petunia sp.	2		x+var			18S
Phaseolus lunatus Lima bean	4	x	x			69R
Phaseolus vulgaris French bean	3			x+var		87S
Physalis peruviana cape gooseberry	3		x			17S
Pisum sativum pea	2				x	51S
Portulaca sp.	3			x	x	33S
Psophocarpus tetragonolobus winged bean	3		x			61S
Raphanus sativus radish	3		x			56S
Sesbania sesban	4		x			30S
Solanum incanum African eggplant	3 ?		x+var			58S
" "	3 ?		x			46?
" "	3 ?	x		x		82?
Solanum Melongena esculentum eggplant	4		x ?			6S
Solanum tuberosum Irish potato	4 ?				x	19Je
" "	4 ?		x			21S
Spinacea oleracea spinach	2		x+var			9S
Talinum triangulare waterleaf	4				x	63Z
Tephorosia vogelii	4	x				68Je
Veronia perroteti	3		x			33S
Vigna unguiculata	4		x+var			89Zu

Voandzeia subterranea Bambara nut	3	x	x	93I1
Zinnia sp.	4	x		50S

[a]Root-knot index: 1 = nil, 4 = heavy galling.

[b]*Meloidogyne* sp.

[c]*Meloidogyne javanica*.

[d]*Meloidogyne incognita*.

[e]*Meloidogyne acrita*.

[f]*Meloidogyne arenaria*.

[g]Il = Ilorin

J = Jalingo

Je = Je'ma'a

R = Ramma (= Rahama ?)

S = Samaru

Ya = Yandev

Z = Zaria

Zu = Zuru (Kontagora)

Table 9. Root-knot nematode populations identified by perineal patterns with crop and location in nothern Nigeria.

Location	Host plant	Root-knot index	Species[b]	M-j[c]	M-i[d]	M-a[e]
Dumbi Dutse (Zaria, Kaduna Rd)						
1	peppers	4.5			x	x ?
2	tomato	4.5		x	x+var	
3	okra	3.5		x	x+var	
4	Vernonia pauciflora	4.0		x		
Riyom (Jos Plateau)						
5	okra	3.0		x		
6	spinach	2.0		x		
7	eggplant	4.0		x		
Ta Hoss (Jos Plateau)						
8	tomato	3.5		x+var		
9	Senecio clarencearus	3.0		x		
Bakura (near Sokoto)						
10	tomato	2.0		x		
11	okra	1.0	x			
Funtua (Zaria-Sokoto road)						
12	tomato	5.0		x		
13	peppers	3.5			x	
Maru (Funtua-Bakura road)						
14	peppers	3.0			x	
Misau (Kano-Maiduguri road)						
15	okra	1.0		x	xxx	
Gombe (Jos-Biu road)						
16	okra	4.5		x		
Samaru						
17	eggplant	5.0		x		
18	tomato	5.0		x		

19	Portulaca oleracea	4.5		xxx	x
20	Leucas martinensis	4.5			x
21	Ageratum conyzoides	4.0		x+var	xxx
22	eggplant	4.0	x	x	xxx
23	pepper	?		x	x
Hunkuyi (Near Zaria, Kano road)					
24	tomato	5.0		xatyp	xatyp

[a]Root-knot index: 1 = no galling, 5 = maximum galling.

[b]*Meloidogyne* sp.

[c]*Meloidogyne javanica*

[d]*Meloidogyne incognita*

[e]*Meloidogyne acrita*.

INTERNATIONAL MELOIDOGYNE PROJECT

PROGRESS REPORT

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Efforts on international Meloidogyne project have been concentrated on cowpea Vigna unguiculata (L) walp. It may also be possible to include rice, sugarcane and maize in the near future as the National Cereals Research Institute (NCRI) also has national responsibility for these corps.

Collection, Identification and Host Differentiation of Root-Knot Nematode Field Populations.

Field Collection. Collections of rootknot nematode were made in cowpea growing areas in both forest and savannah zones in Nigeria. Depending on the extent of the farm, 25 to 50 cowpea plants were systematically sampled in a zigzag fashion across the field. The degree of severity of infestation was rated by counting the number of galled infested plants and expressing it as a percentage of the total plants sampled.

Incidence of root-knot nematode infestation was more severe on Government farms (5 - 100%), where improved sole cowpea cultivars were grown, than in Local farms (0 - 15%), where local cultivars in mixed cropping were grown (Table 10). The low incidence of cowpea infestation in local farms may be due to the shifting cultivation, mixed cropping, age-long practice of bush burning during each season or the local cowpea cultivar grown which may not encourage the build up of the nematode. However, among the improved cultivar, ACC 64298, consistently showed mild infestation of root-knot nematode (Table 10).

Identification. Morphological identifications were made on the basis of perineal patterns from 20 - 25 root-knot nematode adult females per population. Three root-knot nematode species, M. incognita, M. javanica and M. arenaria were encountered during the survey in that order of abundance but M. incognita was more prevalent in the forest zone while M. javanica in the savannah zone.

Host Differentiation. The host differentiation of the root-knot nematode could not be carried out because the host crops were still under quarantine.

Outlook. The survey will be extended to cover wider cowpea growing areas and soyabeans, sugarcane, rice and maize may be included in the future. The different root-knot nematode populations collected in field will be cultured on tomato awaiting release of the standard host crops for host differentiation of the nematodes.

Host susceptibility and/or Resistance Studies of Cowpea Cultivar and Major Food Crops.

Determination of Optimum Inoculum Level. Studies were initiated first with M. incognita being the most prevalent and devastating. The nematode culture was propagated from a single egg mass. A susceptible cowpea cultivar, ACC 73001, as revealed from survey studies (Table 10) was inoculated at planting under screenhouse conditions with eight different inoculum levels of M. incognita eggs (extracted with 10% Chlorox for 4 minutes) ranging from 200 to 80,000 eggs per 5-litre pot filled with 6kg of pasteurised soil in ten replicates each. The experiment was left for 77 days before rating for grain yield and dead plants.

The results showed that grain yield loss (0 - 94%) and percentage dead plant (0 - 80%) increased with increase in inoculum level (Table 11) with substantial grain loss (68 - 94%) occurring as from inoculum level of 4,000 (68%) to 80,000 (94%). However, the optimum inoculum level, i.e., a level where a substantial grain loss (68%) occurred but no incidence of dead plants, appeared between 4,000 and 10,000 egg inoculum level.

Outlook. The inoculum level between 4,000 to 10,000 eggs will be employed in pathogenic studies with M. incognita. This also agrees with the IMP recommendation.

Development of Quick Mass Screening Technique. In an attempt to develop a quick technique for mass screening using root galling symptoms as a criterion for assessing resistance, susceptible cowpea cultivar (ACC 73001) in five-litre pots filled with 6kg of pasteurised soil were inoculated with 5,000 M. incognita eggs at planting under screenhouse conditions. Observations were made on the degree of galling, incidence of mature females and eggs weekly for 10 weeks. The inoculated plants for each weekly observation was replicated ten times in a randomised complete block design.

Results (Table 12) showed that as early as between 7 - 14 days, small galls covering about 65% of the total root system developed on the roots even though a generation cycle has not been completed (no appearance of eggs or mature females). The first generation cycle was completed between 21 - 28 days as reflected by appearance of eggs and mature females, but there was little change in the degree of galling. The size and degree of galling started increasing as from day 35 and reaching a large size, covering about 88% of

the total root system. This increase in degree of galling might be occasioned by the completion of the second generation cycle between day 56 and 73 with consequential tertiary invasion of second-stage larvae of second generation adult female.

It does seem that the appearance of galling within 14 days after inoculation covering more than 25% of the total root system under screenhouse conditions might be adopted in eliminating susceptible cultivar in a mass screening. However, this will have to await further studies.

Outlook. More susceptible cultivars and resistant ones will be similarly evaluated before generalising on the use of incidence of galls within two weeks on susceptible cowpea cultivars as criterion in mass resistance evaluation.

Screening of Cowpea Cultivars for Resistance to M. incognita. Seventy-three cowpea cultivars in pasteurised sandy soil of five replicates each were inoculated with 10,000 eggs of M. incognita under screenhouse conditions in 1976 and 1977. The experiment was terminated at the end of 60 days to allow for two generation of cycles of the nematode.

The results are shown on Table 13. Three cowpea cultivars ACC 64298, 71012 and 72001 having percentage of total root system with galls of less than 10% were rated as being resistant while another three cultivars with percentage of total system galled ranging from 11 - 25% were rated as being moderately resistant. The remaining 67 cultivars with percentage of total root system with galls of more than 25% were considered susceptible. The cultivar ACC 64298 consistently showed resistance in both the 1976 and 1977 trials.

Outlook. More cultivars will be included in the mass screening. The promising resistant cultivars will be further evaluated against different field populations of M. incognita and other root-knot nematode species. The mechanism of resistance will be investigated in the promising resistant cultivars. Ecological zonal field evaluations will also be made on the promising cultivars. The resistant cultivar ACC 64298 will be distributed to other cooperators for global assessment.

Evaluation of Resistant Cowpea ACC 64298 to Four Races of M. incognita and M. javanica and M. arenaria. The resistance of cultivar 64298 (Table 10, 13) was further evaluated for resistance to other root-knot nematode species and also to four races of M. incognita under (mean 32°C; Range 23-42°C) greenhouse conditions at North Carolina State University, Raleigh, USA. The four races of M. incognita used were differentiated by their pathogenic reactions on pepper, cotton and tobacco. Four known susceptible cultivars (ACC 68029, 70002, 70014 and 76007) were included in the trials for comparison with the resistant cultivar ACC 64298. Inoculation with 10,000 eggs of each nematode was carried out at transplanting of two-week-old cowpea

seedlings using 7.5cm clay pots containing methylbromide-sterilized loamy and sandy soil mixture (ratio 1.2). Each treatment was replicated four times in a randomised block design. Sixty days after planting, the cultivars were rated for root galling and egg mass production. Except for M. javanica and M. incognita Race 2, the evaluated resistant cultivar 64298 showed low incidence of galling and egg masses (the number being less than or about 10, covering less than or about 10% of the total root system) to the root knot nematodes tested including M. arenaria (Table 14). The four known susceptible cultivars showed heavy galling and egg mass production to all the root-knot species or races tested.

Host Susceptibility and/or Resistance of Food Crops to Meloidogyne incognita. Fifteen cereals, 12 leguminous and 11 vegetables crops in 5-litre pots of pasteurised sandy soil were inoculated with 10,000 eggs of M. incognita at about two-week old seedlings. Each crop was replicated five times. Sixty days after inoculation, the roots were rated for galling and the host status determined on the basis of degree of root galling: non-host = small galls covering about 10% of the total root system; fair host = small gallings covering between 11 - 25% of the total root system and good host = galling covering more than 25% of the total root system and excellent host = dead plants.

The results (Table 15) indicated that the evaluated cereals were generally poor hosts. In contrast, the evaluated leguminous (Table 16) or vegetable (Table 17) crops were good hosts except for groundnut, and Ewedu cultivar Angbadu of pepper var Rodo which showed poor host status.

Summary

In the forest zone of Nigeria, Meloidogyne species were found to be more common on Government farms (5-100%) growing sole crop improved cowpeas than on small farms (0-15%) growing local cowpea cultivars in a mixed cropping system. M. incognita was the more common in the forest zone while M. javanica was the more common in the savanna zone. M. arenaria was the least common in either zone. Three cowpea cultivars showed resistance against M. incognita in pot tests. Cowpea ACC 64298 was resistant to M. incognita, races 1, 3, 4 and M. arenaria but susceptible to M. incognita, race 2, and M. javanica.

Resume

Dans la zone forestière du Nigeria, on observe que les espèces de Meloidogyne sont plus communes sur les fermes gouvernementales cultivant exclusivement des Vigna améliores (5 - 100 % d'infestation) que sur les petites fermes utilisant des cultivars de Vigna locaux dans un système de cultures associées. M. incognita est le plus commun dans la zone forestière tandis que M. javanica est le plus commun dans la zone de savane. M. arenaria est le plus rare dans l'une et l'autre zone. Trois cultivars de Vigna ont montré une certaine résistance envers M. incognita lors de tests en pot. Le Vigna ACC 64298 est résistant a M. incognita races 1, 3, 4, et à M. arenaria mais il est sensible à M. incognita race 2 et à M. javanica.

Table 10. Incidence of root-knot nematode galls in cowpea growing areas in Nigeria. June - November, 1976.

Areas	Cultivars	Cropping systems	Galled cowpea stands %
Local farms			
Forest zone (11)[a]	Local	Mixed-cowpea cassava/maize okro/pepper	0 - 10
Savannah zone (7)	Local	Sole-cowpea cowpea/groundnut	5 - 15
Government farms			
Forest zone (5)	ACC 64298	Sole-cowpea	5 - 15
Forest zone (10)	ACC 73001	Sole-cowpea	20 - 100
Savannah zone (5)	ACC 73001	Sole-cowpea	25 - 100

[a]Parenthesis indicate the number of sites surveyed.

Table 11. Effect of different inoculum level of *Meloidogyne incognita* on susceptibility and grain yield of cowpea cultivar ACC 73001. August - November, 1976. Ibadan.

Inoculum level		Dead stands %	Mean grain yield reduction over the uninoculated %
per pot	per kg Soil		
80,000	13,300	80	94
40,000	6,600	70	89
20,000	3,300	60	80
10,000	1,666	40	79
4,000	666	0	68
1,000	166	0	21
800	133	0	26
200	33	0	5
0	0	0	0

Table 12. Incidence of root galling, eggs and mature females in cowpea cultivar ACC 73001 inoculated with *Meloidogyne incognita*. Ibadan, 1976.

Day after inoculation	Size of gall	Mean of total root system with galls %	Root eggs	Mature adults
7	0	0	0	0
14 - 21	Small	65 - 70	0	0
28 - 35	Small	71 - 73	+	+
42 - 56	Medium	84 - 88	+	+
63	Large	88	++	++
70	Large and deteriorating	88	±	±
Uninoculated	0	0	0	0

Table 13. Susceptibility of cowpea cultivars to *Meloidogyne incognita*. March - June, 1976, Ibadan.

Cowpea cultivar	Size of gall	Mean Rating of the total root system with galls %	Resistance/Susceptibility rating
3(ACC 64298, 71012, 72001)	Small	1 - 10	Resistant
3(ACC 64006, 72011, 74001)	Small	11 - 25	Moderate
20	Small	26 - 50	Susceptible
47	Moderate-Large	51 - 100	Highly Susceptible

Table 14. Performance of resistant (ACC 64298) and susceptible cowpea cultivars to *Meloidogyne arenaria*, *Meloidogyne javanica* and four races of *Meloidogyne incognita*. Sept. - Nov., 1977. Raleigh, North Carolina.

Rootknot Nematode sp./race		RATING RANGE			
	Size of gall[a]	Root system with galls rating %	Root system with eggs masses rating %	No. of galls rating	No. of egg masses rating
Meloidogyne incognita					
Race 1	None-Small[b] (Moderate-Large)[c]	0 - 10 (51 - 100)	0 - 10 (51 - 100)	0-10 (31-100)	0 - 10 (31 - 100)
2	Large[b] (Small-Large)[c]	76 - 100 (51 - 100)	51 - 100 (51 - 100)	31-100 (31-100)	31 - 100 (31 - 100)
3	None-Small[b] (Small-Large)[c]	0 - 10 (26 - 100)	0 - 10 (26 - 100)	0-10 (11-100)	0 - 10 (11 - 100)
4	None-Small[b] (Small-Large)[c]	0 - 10 (10 - 100)	0 - 10 (10 - 100)	0-30 (11-100)	0 - 30 (11 - 100)
Meloidogyne arenaria	Small[b] (Small-Large)[c]	1 - 25 (26 - 100)	1 - 25 (26 - 100)	3-30 (11-100)	3 - 30 (11 - 100)
Meloidogyne javanica	Moderate-Large[b] (Small-Large)[c]	51 - 100 (51 - 100)	51 - 100 (51 - 100)	31-100 (31-100)	31 - 100 (31 - 100)

[a]Parenthesis indicate the values for four (ACC 68029, 70002, 70014 & 76001) evaluated susceptible cultivars.

[b]The evaluated resistant Cowpea cultivar ACC 64298 showed resistant to *M. incognita* Race 1, 3, 4 and *M. arenaria* but susceptible to *M. incognita* Race 2 and *M. javanica*.

[c]All the four susceptible cowpea cultivars evaluated were susceptible regardless of the *Meloidogyne* race, species or the resistance parameter used.

Table 15. Host status of cereal crops to *Meloidogyne incognita*, 60 days after inoculation with 10,000 eggs. Screenhouse trial, Moor Plantation, Ibadan. May 4 - July 3, 1977.

Scientific name	Common Name	Cultivar	Size of gall rating[a]	Root system galled[b] %	Host status rating
Pennisetum sp	Pearl millet	Brown colour	1.0	1.0	Non host
Pennisetum sp	Pearl millet	Dark brown colour	1.2	1.2	Poor
Zea mays	Maize	FARZ 23	1.8	1.2	"
Zea mays	Maize	Minna 401	1.8	1.8	"
Oryza sativa	Rice	FARO 25	1.8	1.8	"
Zea mays	Maize	FARZ 17	2.0	2.0	"
Zea mays	Maize	FARZ 27	2.0	2.0	"
Oryza sativa	Rice	FARO 11	2.0	2.0	"
Oryza sativa	Rice	FARO 19	1.0	2.0	"
Oryza sativa	Rice	OS 6	2.0	2.0	"
Oryza sativa	Rice	TOS 78	2.0	2.0	"
Oryza sativa	Rice	TOS 42	2.0	2.0	"
Sorghum bicolour	Guinea corn	Bauchi	2.0	2.0	"
Sorghum bicolour	Guinea corn	HP 3 Kano	2.0	2.0	"
Sorghum bicolour	Guinea corn	12610 C	2.0	2.0	"
Sorghum bicolour	Guinea corn	HP 8 Kano	2.0	2.0	"
Sorghum bicolour	Guinea corn	RZ 1	2.0	2.0	"

[a]1 = None; 2 = Small; 3 = Moderate; 4 = Large; 5 = Dead plant

[b]1 = None; 2 = 1 - 10; 3 = 11 - 25; 4 = 26 - 50; 5 = 51 - 75; 6 = 76 - 100; 7 = Dead plant.

Table 16. Host status of leguminous crops to *Meloidogyne incognita*, 60 days after inoculation with 10,000 eggs. Screenhouse trial, Moor Plantation, Ibadan. May 4 - July 3, 1977.

Scientific Name	Common name	Cultivar	Size of gall rating[a]	Root system galled[b] %	Host status rating
Arachis hypogaea	Groundnut (Peanut)	Upe 651	1.0	1.0	None host
Voandzeia subterranea	Bambara groundnut	64504	2.0	2.0	Poor
Canavalia ensiformis	Sword bean	27	2.0	2.0	"
Pachyrhizu angulatus	Yam bean	TP 7	1.8	2.6	Fair
Phaseolus lunatus	Lima bean	TP 7	2.0	3.0	"
Cajanus cajan	Pigeon pea	8129	2.3	2.8	"
Phaseclus lunatus	Lima bean	TP 6	2.5	3.5	Very good
Glycine max	Soybean	Bossier	2.8	3.5	Very good
Vigna unguiculata	Cowpea	Ife Brown	3.3	4.8	Very good
Pachyrhizus angulatus	Yam bean	TP 6	3.5	5.3	Very good
Sphenostylis stenocarpa	African yam bean	TP 7	4.0	6.0	Very good
Pachyrhizus angulatus	Yam bean	281	4.3	6.3	Very good

[a]1 = None; 2 = Small; 3 = Moderate; 4 = Large; 5 = Dead plant.

[b]1 = None; 2 = 1 - 10; 3 = 11 - 25; 4 = 26 - 50; 5 = 51 - 75; 6 = 76 - 100; 7 = Dead plant.

Table 17. Host status of vegetable crops to *Meloidogyne incognita* 60 days after inoculation with 10,000 eggs. Screenhouse trial, Moor Plantation, Ibadan. May 4 - July 3, 1977.

Scientific Name	Common Name	Cultivar	Size of gall rating[a]	Root system galled[b] %	Host status rating
Corchorus olitorus	Ewedu	Angbadu	1.4	1.6	Poor
Capsicum sp	Pepper	Rodo	2.0	2.0	Poor
Caspsicum sp	Pepper	Tatase	2.0	2.5	Fair
Lactuca sativa	Lettuce		2.8	5.3	Very good
Corchorus olitorus	Ewedu	Yaya	2.5	3.0	Very good
Lycopersicon esculentum	Tomato	Roma VFN	3.0	3.3	Very good
Lycopersicon esculentum	Tomato	Ife 1	3.0	4.5	Very good
Lycopersicon esculentum	Tomato	Rutgers	3.8	5.3	Very good
Celosia argentea	Soko	TLY-8	4.0	5.5	Very good
Citrullus vulgaris	Watermelon	Charleston grey	4.0	6.0	Very good
Hibiscus esculentus	Okra		5.0	7.0	Excellent

[a]1 = None; 2 = Small; 3 = Moderate; 4 = Large; 5 = Dead plant.

b1 = None; 2 = 1 - 10; 3 = 11 - 25; 4 = 26 - 50; 5 = 51 - 75; 6 = 76 - 100; 7 = Dead plant.

ROOT-KNOT NEMATODES ON SELECTED FOOD CROPS IN NIGERIA

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Root-knot nematodes, Meloidogyne app., were first reported for Nigeria by the Ministry of Agriculture in the 1959/1960 annual report (5), however, A. L. Taylor in 1958 identified M. incognita, M. acrita, M. arenaria and M. javanica from cowpea (Vigna unguiculata (L.) Walp.) roots submitted to the U.S. Department of Agriculture (26). Over the next few years, Wilson and Caveness reported on the distribution and host range of root-knot nematodes in Nigeria (10,11,12,13,14,15,28,29). Studies on the life histories of M. acrita, M. arenaria and M. javanica showed them to be essentially the same life histories as for other warm climate reports in the literature (12,15).

The root-knot nematodes are more common in the southern rain forest region of the country and are also found in many home and market gardens in the northern region where irrigation keeps soils moist throughout the nine month dry season. Root-knot nematode has quickly become a limiting factor in food crop production in large-scale irrigation projects in the north of Nigeria (7,19,25).

Root-knot nematodes are the most serious nematode pests of numerous food crops in the tropics. The objectives of the International Institute of Tropical Agriculture (IITA) nematology subprogram in complementary accord with the International Meloidogyne Project are to increase and stabilize crop yields using minimum farmer input requirements such as nematode resistant crop cultivars, nematode population suppressing crop rotations, including live mulches and intercropping and modifying agronomic practices. The identification and development of resistant cultivars would have the triple advantages of increasing and stabilizing yields, being available to growers at no extra cost as development is generally done by government or other institutions and mitigating nematode attack on the following crop. Therefore, nematode resistant food crop cultivars in combination with improved cropping sequences and soil management could greatly contribute toward achieving optimum economic and long-term land use for growers within traditional farming systems as well as in more sophisticated and technical farming systems.

Cowpeas in Nigeria are attacked by all root-knot nematode species known to the area and in all regions where the nematodes have been reported and cowpeas are grown (5,7,10,11,12,13,14,15,20,21,22,23,26,28,29). M. incognita and M. javanica appear as the more common species. Grain yields of cowpea have been reduced by an average of 59% in one study in southern Nigeria (22). Cowpea screening programs for nematode resistance at the University of Ife and IITA have identified cowpea lines resistant to M. incognita (4,5,15,24). Amosu (4,5) identified Mississippi Silver as highly resistant to M. incognita in greenhouse and field tests.

A cowpea line with good resistance to M. incognita race 2, (27), multiple disease resistance and tolerance to several insect pests has been released as an improved cowpea line termed VITA-3 (24). Several additional cowpea lines have been identified with moderate resistance to M. incognita (4,5,15).

Lima bean (Phaseolus lunatus (L.)) is an important food in selected areas of West Africa. The IITA has included lima bean in its grain legume improvement program owing to its potential as a high yielding food crop. Some cultivation constraints are encountered with yellow mosaic disease, some insect pests and a general susceptibility to root-knot nematodes. In screening the IITA lima bean collection to M. incognita race 2, 10 lines showed moderate resistance while all the other 277 lines were susceptible or highly susceptible (16).

Cassava seed (Manihot esculenta Crantz) from IITA yield trials was bulked and greenhouse pot tested to determine the degree of genetic variability in seed being produced at IITA in relation to susceptibility or resistance and damange due to root-knot nematode attack (17). All cassava seedlings were shown to be susceptible to M. incognita, race 2, attack in the susceptibility trial. The root-knot index for root gall development showed all 190 plants to be highly susceptible with a mean root-knot index of 4.64 (5 = maximum galling).

In the seedling damage test (see Table 18 for inoculation rates) the plants receiving ½ and 1 thousand eggs per plant increased seedling height by a mean of 2 and 10% respectively, compared to the control plants (Fig.6). Root-knot nematode gall development increased mean root weight by 19, 31, 28% for the ½, 1 and 2 thousand eggs inoculation levels, respectively, over the control plants. Storage root weight was reduced at all levels of inoculum used. In all treatments, the greatest reductions were root weight 44%, seedling height 52% and storage root weight 87%.

Yams (Dioscorea spp.) are an important and preferred food in Nigeria. The yam nematode (Scutellonema bradys) and the root-knot nematodes are important field and post-harvest pests of yam tubers reducing market value and being involved in a tuber decay complex (1,2,3,8,9,20).

The IITA root and tuber improvement program's breeder made available two-month-old seedlings of D. dumetorum (Kunth) Pax, D. praehensillis Benth. and D. rotundata Poir. for testing for damage and resistance/susceptibility to M. incognita race 2 (18).

D. dumetorum was highly resistant to M. incognita attack. Two plants showed light ineffections on the roots and eggs were recovered from one plant only. No gall development was seen on the tubers (Table 19).

D. praehensilis, in general, was highly susceptible in both roots and tubers to attack by M. incognita. Some individual plants were rated resistant or moderately resistant. Two plants (of a total of 48) had no

galls on the roots or tubers nor were root-knot nematode eggs recovered. Mean root weight tended to increase with higher inoculum levels. Mean tuber weight was not significantly different from the control (Table 20).

Two breeding families of D. rotundata were highly susceptible in both roots and tubers. Some individual plants were rated resistant or moderately resistant and 11 plants (of a total of 96) had no gall development on roots or tubers nor were root-knot nematode eggs recovered. There was a mean increase in root and tuber weight over the noninoculated control treatments (Table 21).

Summary

In Nigeria, cowpeas are attacked by all Meloidogyne species present. Resistant cowpea lines have been identified at IITA and the University of Ife. In screening lima bean germ plasm, ten lines showed moderate resistance only. Cassava seedlings from a bulked source were all highly susceptible to nematode attack. In a Meloidogyne test on yam, Dioscorea dumetorum was highly resistant to M. incognita, race 2. D. praehensilis and D. rotundata were highly susceptible to infection in roots and tubers.

Résumé

Les nématodes galligenes de cultures alimentaires sélectionnées au Nigeria.

Au Nigeria, les Vigna sont attaqués par toutes les espèces de Meloidogyne présentes. Des lignées de Vigna résistantes ont été identifiées a l'IITA et a l'Université de Ife. Lors du criblage des ressources génétiques pour le haricot de Lima, dix lignées n'ont montré qu'une résistance modérée. Des maniocs, obtenus d'un mélange de plantules étaient tous fortement sensibles à l'attaque du nématode. Au cours d'un test de Meloidogyne sur igname, Dioscorea dumetorum a été hautement résistant à M. incognita, race 2. D. praehensilis et D. rotundata ont été fortement sensibles à l'infection dans les racines et les tubercules.

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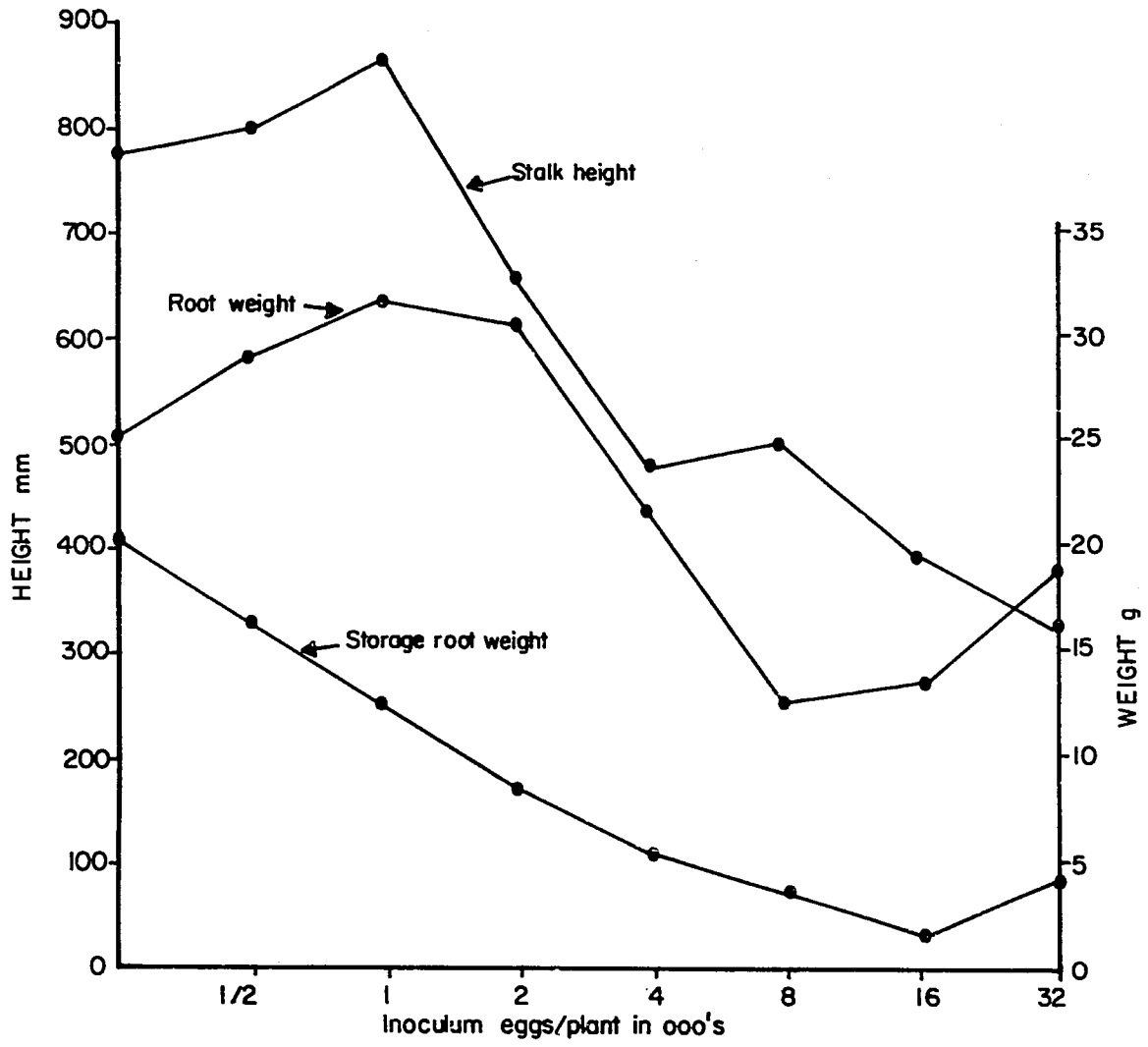

Fig. 6. The effect of the root-knot nematode, Meloidogyne incognita, race 2, on seedling cassava, Manihot esculenta.

Table 18. Cassava seedling, Manihot esculenta, attack by the root-knot nematode, Meloidogyne incognita race 2, in a 155 day greenhouse trial[a]

Inoculum Eggs/plant	Root-knot index[b]	Mean number eggs/plant
0	1.00	0
500	3.94	4,181
1,000	4.58	19,617
2,000	4.64	25,258
4,000	4.56	28,450
8,000	4.64	16,969
16,000	4.55	16,983
32,000	4.28	32,750

[a]Means of ten replicates of one plant each in a 12-cm pot.
[b]Root-knot index: 1 - no galling, 5 - maximum galling.

Table 19. Dioscorea dumetorum seedling attack by the root-knot nematode, Meloidogyne incognita, race 2, in a 131 day greenhouse trial.

	Root Wt g	Tuber Wt g	R-K index roots[c]	R-K index tubers[c]	Egg count
Grand mean[a]	2.6	21.8	1.09	1.00	1
Control[b]	2.9	19.8	1.00	1.00	0

[a]Means of 48 replications.
[b]Means of six replications.
[c]Root-knot index: 1 - no galling, 5 - maximum galling.

Table 20. *Dioscorea praehensilis* seedling attack by the root-knot nematode, *Meloidogyne incognita*, in a 131 day greenhouse trial.

	Root Wt g	Tuber Wt g	R-K index roots[c]	R-K index tubers[c]	Egg count
Grand mean[a]	1.1	19.3	2.87	3.85	4
Control[b]	0.6	20.2	1.00	1.00	0

[a]Means of 48 replications.
[b]Means of six replications.
[c]Root-knot index: 1 - no galling, 5 - maximum galling.

Table 21. *Dioscorea rotundata* seedling attack by the root-knot nematode, *Meloidogyne incognita*, race 2, in a 131 day greenhouse trial.

	Root Wt g	Tuber Wt g	R-K index roots[c]	R-K index tubers[c]	Egg count
Grand mean[a]	3.5	30.3	2.95	2.72	692
Control[b]	2.8	25.7	1.00	1.00	0

[a]Means of 96 replications
[b]Means of 12 replications.
[c]Root-knot index: 1 - no galling, 5 - maximum galling.

A PROGRESS REPORT OF RESEARCH COMPLETED AT THE RESEARCH CENTRE OF THE INTERNATIONAL MELOIDOGYNE PROJECT

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Research on several aspects of the biology, behavior, and biochemistry of *Meloidogyne* spp. is being carried out at North Carolina State University in connection with the international *Meloidogyne* project. This report will cover only a portion of the work; namely, the frequency of occurence of the major *Meloidogyne* species, pathogenic variation within these species, results of cytogenetic studies on many of the populations sent to the Research Centre, and results from some of the biological studies.

Identification of and Pathogenic Variation Within Field Populations

Five hundred and seven field populations have been sent to Raleigh by the local country cooperators. Of these populations, 399 have been studied for pathogenic variation and species identification. *M. incognita* and *M. javanica* together make up nearly 80% of these populations, followed by *M. hapla* and *M. arenaria* (Table 22). Other species (*M. exigua*, *M. microtyla*, *M. graminicola*, *M. graminis* and *M. naasi*) are only rarely encountered. Data on the distribution and frequency of these species is biased by the location and type of crops sampled; the majority of the samples being from vegetable and field crops in tropical regions. Species such as *M. hapla* and *M. naasi* would be expected to be found in higher frequecies in the temperate climates. Other species such as *M. brevicuada* and *M. mali* have very limited host ranges (tea and *Malus* spp., respectively) and would not expect to be found unless these crops were sampled. For these reasons, those species with wide host ranges and tropical to subtropical habitats would be expected to predominate. Nevertheless, it is noteworthy that *M. incognita* and *M. javanica* are the most frequently encountered species.

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

A major portion of the work on the Meloidogyne populations sent to Raleigh has involved the study of pathogenic variation with each species. This involves tests on the ability of each population to infect and reproduce on a standardized set of differential hosts. Previous studies have demonstrated that populations of M. incognita, M. javanica, M. hapla and M. arenaria respond to the host differentials in a characteristic or "usual" way (Table 23) (2). Deviations from the "usual" host responses therefore, are an indication of pathogenic variation. The results of these studies are not intended to be used in developing crop rotation systems because of the limited number of host differentials used. Nor can it be inferred that the results of the studies completely characterize the pathogenic variation within a species. The limited number of host differentials used in these studies are only intended to give some indication of the pathogenic variation that exists among populations of Meloidogyne species from widely separated geographic regions of the world.

Based on the ability to parasitize cotton (cv 'DeltaPine' 16') and tobacco (cv 'NC 95'), four host races of Meloidogyne incognita have been identified (Table 24). Based on the ability to parasitize peanut (cv 'Florrunner'), two host races of M. arenaria have been identified. There are no morphological differences among the host races of M. incognita or M. arenaria. The host races of these species are apparently worldwide in distribution, and for M. incognita do not appear to have developed through selection pressures. With M. arenaria, some selection pressure may be involved in the development of the two host races; Race 1, which attacks peanuts, has generally been found in regions where peanuts are frequently cultivated. Race 2 of M. arenaria, which does not attack peanuts, is generally from regions where peanuts are not grown. No host races have been detected among the different populations of M. javanica and M. hapla.

Approximately 200 of the populations received have been examined cytogenetically (Table 25). These studies have revealed that more than one chromosomal form can be detected in the different populations of M. incognita, M. hapla, and M. arenaria. All populations of M. javanica examined to date have a single chromosome form with a somatic chromosome number of 43 to 48. Cytological information, including chromosome numbers, morphology, and behavior, can assist identification of most common species especially when identification of a population on a morphological or host specificity characteristic is not possible or is doubtful. A feature of great value for species identification is the peculiar behavior of the prophase chromosomes during maturation of the oocytes of M. incognita. It involves a characteristic clumping of the prometaphase chromosomes which prolongs considerably the duration of this stage. This feature easily differentiates M. incognita from all other species of Meloidogyne studied thus far.

Biochemical studies

The biochemical studies have concentrated on the study of nematode produced enzymes that may play a role in the host-parasite relations of Meloidogyne species. An attempt is being made to characterize these enzymes in order that any role they might have in the parasitic mechanism can be assessed. Because of the difficulty in collection of a sufficient amount of nematodes to work with, a "micro" polyacrylamide gel electrophoresis system has been developed (3). Using the "micro" system the isozyme composition of different enzyme systems can be evaluated using small samples.

Peroxidase activity in M. incognita females was first reported by Hussey and Sasser (1). The present work (4) confirms this initial report of two peroxidase isozymes detectible in M. incognita females; two isozymes with identical electrophoretic mobilities have been found also in M. arenaria, M. hapla, and M. javanica females which were reared on tomato. However, no significant peroxidase activity could be detected in extracts of eggs or preparasitic larvae of any of these species. Electrophoretic analysis of extracts from M. hapla and M. incognita adult males also failed to reveal any peroxidase activity (Table 26).

When plants other than tomato were used to culture the nematodes, it was found that the peroxidase isozyme profile of the females changed with the host. Females of M. hapla, M. javanica, and M. incognita had a single peroxidase isozyme when cultured on bean or eggplant as compared with two isozymes when cultured on tomato. The electrophoretic mobility of each peroxidase isozyme was different for each host. When the nematodes were cultured on tobacco, no peroxidase activity was detectible following anionic electrophoresis. Activity was detected in total activity assays. In another series it was found that the peroxidase isozymes from nematodes reared on tomato were electrophoretically identical to some of the peroxidase isozymes from tomato root tissues. The host root tissues include nongalled roots, Meloidogyne root-galls, and isolated syncytial complexes.

These data show that i) only adult females of Meloidogyne spp., which have fed on the host, have significant levels of peroxidase activity; ii) the host has significant influence on the peroxidase isozyme profiles of Meloidogyne spp. females; and iii) tomato roots have the same peroxidase isozymes as detected in females reared on tomato. Collectively, these observations suggest that the peroxidase activity associated with Meloidogyne spp. females is not of nematode origin. Rather, it appears to be of host origin and was ingested by the nematode during feeding.

Another enzyme system that is currently being investigated is the glycosidase system. Both B-glucosidase and B-galactosidase activities have been reported for second stage larvea of Heterodera rostochiensis (5). The present work involves characterization of different glycosidase

activities in M. javanica and M. incognita (preparasitic larvae and females) and H. glycines females.

Extracts of M. javanica and M. incognita females and larvae are able to release the p-nitrophenol aglycone from B-glucosides, B-galactosides, and B-fucosides. Generally, the B-galactosidase activity is greater than the B-glucosidase or B-fucosidase activities. Immature, white H. glycines females also contain B-glucosidase and B-galactosidase activities; B-fucosidase activity has not been tested. With H. glycines, however, the B-glucosidase activity is higher than the B-glactosidase activity (Table 27). Work is currently in progress to determine the isozyme composition of each of these enzyme systems.

Based on the present information, no conclusions can be drawn as to the significance of glycosidase activity in the host-parasite relations of these nematodes.

Summary

In identification studies of the world collection, Meloidogyne incognita was the most common (55.6%), followed by M. javanica (24.3%), M. hapla (6.5%) and M. arenaria (4.5%). Population mixtures of M. incognita and M. javanica occurred with the highest frequency. Based on host differential tests four races of M. incognita and two races of M. arenaria have been identified. No races have been identified for M. javanica and M. hapla.

Cytogenetic studies have found a clumping characteristic of the prometaphase chromosomes which differentiates M. incognita from other species. In the biochemical studies a 'micro' polyacrylamide gel electrophoresis system has been developed. Observations suggest that peroxidase activity associated with females is not of nematode origin. Glycosidase activity in the host-parasite relationship is being investigated.

Résumé

Etat d'avancement des études effectuees au centre de recherche de l'International Meloidogyne Project

Lors des études pur l'identification de la collection mondiale, Meloidogyne incognita s'est révélé le plus commun (55,6%), suivi de M. javanica (24,3%), M. hapla (6,5%) et M. arenaria (4,5%). Des melanges de Des mélanges de populations de M. incognita et M. javanica se produisent avec la plus haute frequence. A la suite de tests de plantes-hôtes différentielles, quatre races de M. incognita et deux races de M. arenaria ont été identifiees. Aucune race n'a été decouverte pour M. javanica et M. hapla.

Les études cytogénétiques ont montré un regroupement caractéristique des chromosomes à la prométaphase qui différencie M. incognita des autres espèces. Lors des études biochimiques, un système d'électrophorese sur 'micro' gel de polyacrilamide a été mis au point. Les observations suggèrent que l'activité peroxydase associée aux femelles ne provient pas des nématodes. L'activité glycosidase dans les relations hôte-parasite est en cours d'examen.

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Table 22. *Meloidogyne* species identified from field population sent to the IMP Research Centre (Raleigh, NC) by local country cooperators

Species	% of 399 Populations studied
M. incognita	55.6
M. javanica	24.3
M. hapla	6.5
M. arenaria	4.5
Unknown	7.0
Others[a]	2.1

[a]Includes populations of *M. exigua*, *M. microtyla*, *M. graminicola*, *M. graminis* and *M. naasi*.

Table 23. Usual response of host differentials to attack by the common *Meloidogyne* species.

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

[a]Plant varieties include: Tobacco, NC95; cotton, DeltaPine 16; pepper, California Wonder; watermelon, Charleston Grey; peanut, Florrunner; tomato, Rutgers.

Table 24. Host races of *Meloidogyne incognita*

Race	Host Reaction		% of 222 Populations Studied
	Tobacco	Cotton	
1	-	-	62.6
2	+	-	22.0
3	-	+	10.0
4	+	+	5.4

Table 25. Major chromosomal forms detected in different populations of *Meloidogyne incognita*, *M. javanica*, *M. hapla* and *M. arenaria*.

Species	Number of Populations Studied	Chromosome Number
M. incognita	91	2N = 40-45
	5	2N = 32-36
M. javanica	63	2N = 43-48
M. hapla	3	N = 15
	7	N = 16
	11	N = 17
	2	2N = 45
	2	2N = 48
M. arenaria	2	2N = 36
	13	2N = 50-54

Table 26. Peroxidase activity in different developmental stages of *Meloidogyne arenaria*, *M. hapla*, *M. javanica*, and *M. incognita*.

Species	Stage of Development	Peroxidase Specific Activity[a]	No. of Peroxidase Isozymes Detected
M. arenaria	adult females	1.43	2
	eggs	0.007	0
	preparasitic L_2	0.004	0
M. hapla	adult females	1.08	2
	eggs	0.02	0
	adult males	-	0
M. javanica	adult females	1.44	2
	eggs	0.014	0
M. incognita	adult females	1.54	2
	preparasitic L_2	0.024	0
	adult males	-	0

[a]Specific activity is the change in absorbance at 460 nm per min per mg protein using H_2O_2 and o-dianisidine as cosubstrates.

Table 27. B-glycosidase activities in *Meloidogyne javanica*, *M. incognita* and *Heterodera glycines*.

	uM p-nitrophenal released/min/mg protein from		
	B-glucoside	B-galactoside	B-fucoside
M. javanica			
females	1.10	9.20	1.05
preparasitic L_2	1.25	5.75	1.10
M. incognita			
females	2.66	5.04	3.49
preparasitic L_2	4.77	8.27	3.38
H. glycines			
females	13.50	4.15	-

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[a]Names of weeds not given. See Tables 2, 7, 8 and page 32.

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[a]Names of weeds not given. See Tables 2,7,8 and page 32.

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