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INTERNATIONAL MELOIDOGYNE PROJECT

Contract No. AID/ta-c-1234

PROCEEDINGS OF THE RESEARCH PLANNING CONFERENCE

ON

ROOT-KNOT NEMATODES, *MELOIDOGYNE* SPP.

JUNE 7–11, 1976

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
PMB 5320
IBADAN, NIGERIA

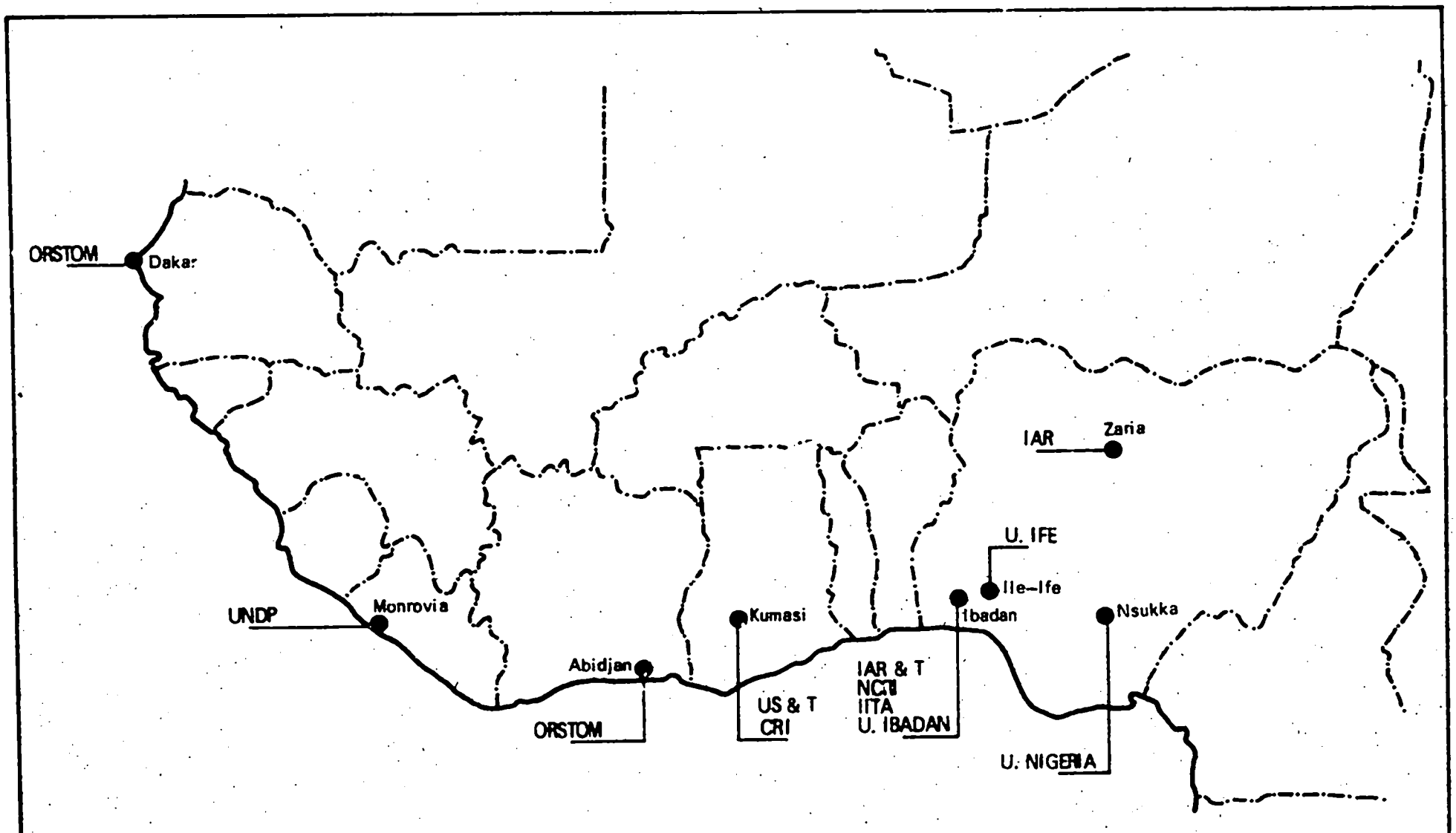

Fig. 17 INTERNATIONAL *MELOIDOGYNE* PROJECT REGION IV PARTICIPATING INSTITUTIONS

INTERNATIONAL MELOIDOGYNE PROJECT

IMP

Contract No. AID/ta-c-1234

PROCEEDINGS OF THE RESEARCH PLANNING CONFERENCE

ON

ROOT-KNOT NEMATODES, *MELOIDOGYNE* SPP.

JUNE 7—11, 1976

NOTE: These proceedings represent Phase III of the International *Meloidogyne* project (IMP), entitled "Research on Integrated Crop Protection Systems with Emphasis on the Root-Knot Nematodes (*Meloidogyne* spp.) affecting Economic Food Crops in Developing Nations." This project has been funded by the United States Agency for International Development and is being implemented through a contract (AID/ta-c-1234) with North Carolina State University. The conference was hosted by Crop Protection, Farming Systems Program, International Institute of Tropical Agriculture.

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Fig. 2. Scientists participating in the research planning conference of the International *Meloidogyne* Projet (IMP), International Institute of Tropical Agriculture, Ibadan, Nigeria, June 7 - 11, 1976.

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PREFACE

The West African regional research planning conference on root-knot nematodes, Meloidogyne spp., was held June 7 - 11, 1976 at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria in cooperation with North Carolina State University (NCSU), Raleigh, N. C. This conference represents the third phase of an international cooperative effort involving scientists from some 60 developing nations of the tropics. Six regional laboratories, located around the world in tropical climates, coordinate and assist the scientists from cooperating nations in their area. This West African regional research planning conference follows on the worldwide planning conference for regional coordinators held January 12 - 16, 1976 at NCSU*. The conference was to review the basic aspects of root-knot nematodes in each of the regions involved and develop programs and procedures for the six coordinating laboratories.

The West African countries were represented by nematologists and scientists from universities, specialized laboratories and institutes (Fig. 2). Each representative reviewed root-knot nematode history, on-going research and needs in his particular area. Several consultants from the United States and IITA contributed toa review of the basic aspects of the genus Meloidogyne and the soils, crops and climate of the region (Figs. 3 & 4).

In-depth discussions were held concerning the overall program goals and objectives and how best to achieve them. The reports, technical discussions and demonstrations have greatly helped in assessing the present situation with regional reference to what is known about the genus Meloidogyne and in defining research priorities and their local feasibility.

Warm thanks are extended to all who participated as their contributions helped summarize the most essential information concerning this very important group of plant pathogens. This foundation of information will serve as a basis for formulating further research leading to control of root-knot nematode pests in developing nations and therefore to increased and efficient food production and the betterment of the general welfare of their peoples.

*For additional information see: Proceedings of the Research Planning Conference on Root-Knot Nematodes, Meloidogyne spp., 1976. Plant Pathology Department, NCSU, Raleigh, N. C. 27607.

Fig. 3. University of California consultant and environment-nematology expert, Dr. S. D. Van Gundy, addresses the research conference on the role of the environment in nematological research.

Fig. 4. IITA maize breeder and training specialist, Michael N. Harrison, discusses maize cultivation under tropical conditions with the research conference participants.

II. OVERVIEW OF THE PROJECT - PRINCIPAL GOALS AND OBJECTIVES AND IMPLEMENTATION SCHEDULE

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 six 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 six proposed regions of study (Central America, South America, Brazil, West Africa, East Africa and Southeast Asia).

WHY WAS ROOT-KNOT SELECTED:

The root-knot nematodes (*Meloidogyne* spp.) were selected because of their overall importance throughout the world as limiting factors in food production. Their world-wide distribution, extensive host ranges and involvement with fungi, bacteria and viruses in disease complexes, rank them high on the list of disease agents affecting the world's food supply. Collectively, the various species of root-knot nematodes attack nearly every crop that is grown including both annuals and perennials. Not only are crop yields greatly affected, but quality is also reduced, especially for root crops such as potato, yams, yuca and peanuts.

PROJECT IMPLEMENTATION SCHEDULE

PHASE I: Organization of the "Research Center" at North Carolina State University, Raleigh, N.C., and establishment of Regional Laboratories (Fig. 1).

The team of principal researchers, cooperators, and consultants and their respective locations is as follows:

A. North Carolina State University, Raleigh, N. C.

Dr. J. N. Sasser, Nematologist, Department of Plant Pathology, Principal Investigator
Dr. A. C. Triantaphyllou, Nematologist-Geneticist, Dept. of Genetics, Cooperator.
Dr. Hedwig Hirschmann Triantaphyllou, Nematologist-Taxonomist, Dept. of Plant Pathology, Cooperator.
Dr. James G. Baldwin, Nematologist-Morphologist, Dept. of Plant Pathology.
Dr. James L. Starr, Nematologist-Physiologist, Dept. of Plant Pathology.
Dr. L. A. Nelson, Statistician, Dept. of Experimental Statistics, Consultant.

B. Regional Investigators:

Central America, Mexico and the Caribbean (Region I)
Dr. Rodrigo Tarte
Universidade de Panama
Facultad de Agronomia
Panama, R. de Panama

Brazil (Region III) not funded by project
Dr. Romero Marinao de Moura
Universidade Federal Rural de Pernambuco
Escola Superior de Agricultura
Dois Irmaos, Recife, Pernambuco
Brazil

East Africa (Region V)
Dr. Benjamin W. Ngundo
East Africa Agriculture & Forestry Res. Org.
P. O. Box 30148
Nairobi, Kenya

South America (Region II)
Dr. Rodolfo Barriga
Department of Plant Pathology
ICA - Tibaitata
Apartado Aereo 151123
Bogota, Colombia

West Africa (Region IV)
Dr. Fields E. Caveness
International Institute of Tropical Agriculture
Oyo Road, P.M.B. 5320
Ibadan, Nigeria

Southeast Asia (Region VI)
Dr. Cesar P. Madamba
Nematologist
Department of Zoology
University of the Philippines
College, Laguna
Philippines

PHASE II: Conference at Raleigh

The regional investigators have been invited to spend this week with us for the purpose of discussing the overall goals and objectives of the international Meloidogyne project. Their reports concerning root-knot nematode research in their regions will be of much help in our deliberations. Also attending the conference, in addition to local faculty participating in the project, are six consultants who have been asked to review certain basic aspects of the genus. We feel certain that from the discussions to follow, much will be gained in helping us to decide on research priorities and emphasis.

PHASE III: Regional Research Planning Conferences

Following this one-week conference in Raleigh, a regional research conference will be held in each of the six regions. Participants from the various countries will first give a summary of the state of knowledge concerning the root-knot nematodes in their country. Each country will then outline research they can do in keeping with the objectives and goals of the international project. Special consideration will be given to research

methodology relating to the genus Meloidogyne including collecting and maintaining inoculum, inoculation techniques, species identification, methods of evaluating for resistance, and interpretation of research results.

PROPOSED SCHEDULE FOR REGIONAL PLANNING CONFERENCES

Locations	Dates
Southeast Asia	February 16-20, 1976
South America	March 22-26, 1976
Central America	April 26-30, 1976
West Africa	June 7-11, 1976
East Africa	To be determined
Brazil	July 26-30, 1976

PHASE IV:

Research will begin within each region upon the completion of the planning conference in Raleigh and the regional research conference in the 6 regions. Specific activities will include:

1) Collection of nematode populations.
2) Identification of species and/or variants in the field collections.
3) Differential host tests to detect pathogenic variation.
4) Host susceptibility and/or resistance studies of major food crops in the region.
5) Utilization of crop response information in the development and implementation of effective rotation schemes for control of root-knot nematodes in each region.
6) Collection of information on environmental factors which may influence development of new pathogenic races and/or species.
7) Identification and utilization of resistant germ plasm.

Research at North Carolina State University on the genus Meloidogyne is ongoing, but will be expanded and intensified. Specific activities will include:

1) Detailed morphological and taxonomic studies, including descriptions of new species. Emphasis will be to find new and more reliable characters to support species identification and to distinguish between new pathotypes of the nematode.
2) Differential hosts tests of populations from the United States and areas not covered by the 6 regions to detect pathogenic variation.
3) A detailed study of the variants encountered.
4) Cytogenetic studies involving comparisons of populations with regard to chromosome numbers, mode of reproduction, sexuality, and the genetic basis of their ability to reproduce on resistant crops.
5) Biochemical investigations of general protein patterns and specific enzyme systems.

SUMMARY:

These cooperative research efforts involving a network of scientists, and institutions representing major geographical regions of the developing world, should enable us to better understand the biological behavior of one of the world's major crop pests. Such behavior is influenced not only by the genetic and biochemical makeup of the organism, but by pressures imposed by various environmental influences. The more we know about the nematode and these environmental influences on disease development, the more likely we will be able to provide conditions favorable to the host plant and less favorable or unfavorable to the nematode (Fig. 5). The thrust of this research proposal is to provide this information.

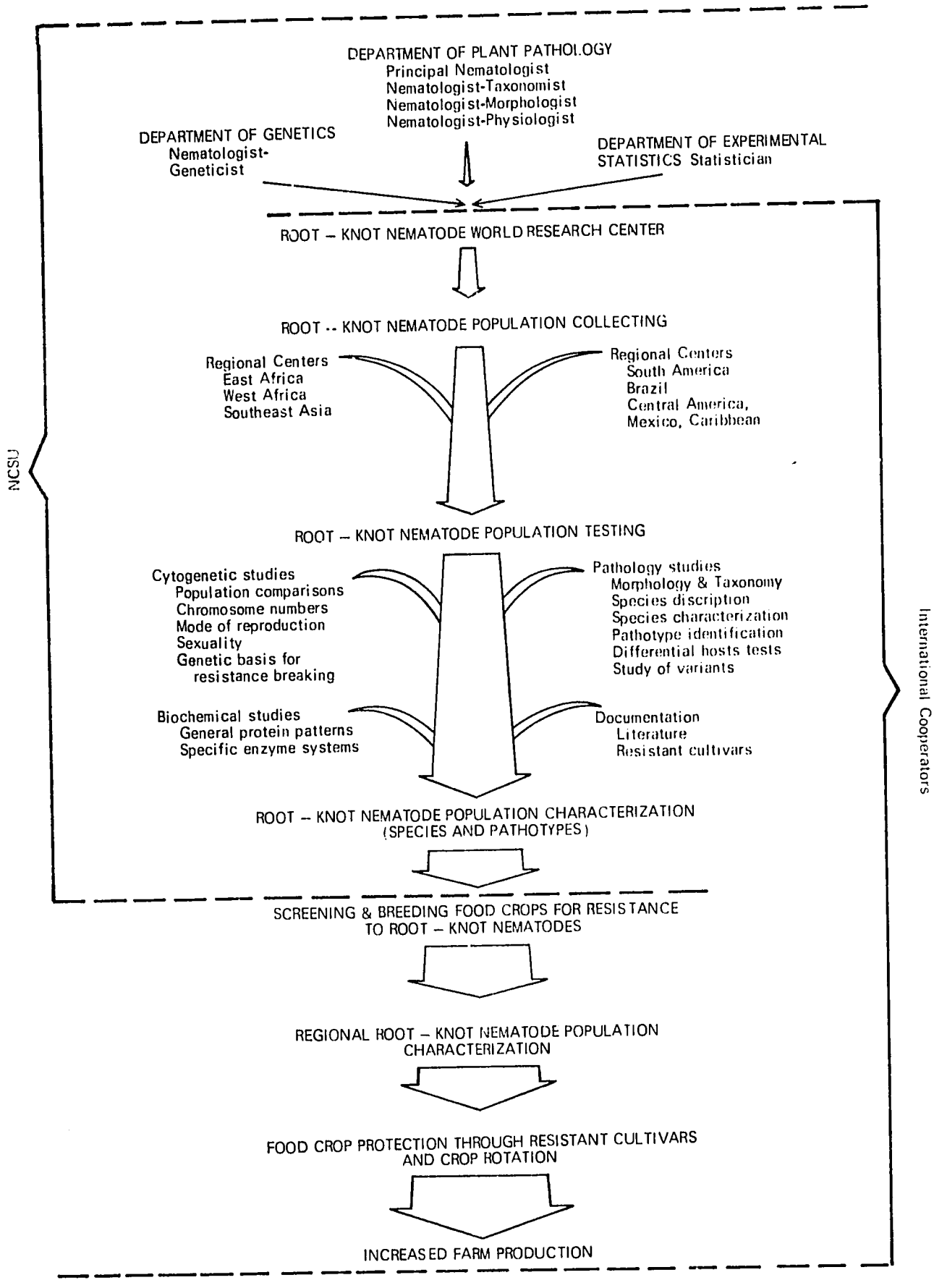

Fig. 5. Schematic representation of ongoing *Meloidogyne* research and program cooperators.

RESEARCH ON MELOIDOGYNE AT THE INSTITUTE OF AGRIC. RESEARCH AND TRAINING, UNIV. OF IFE, MOOR PLANTATION, IBADAN

A. O. Ogunfowora

Root-knot nematodes, Meloidogyne spp., are the most destructive group of nematodes known at present in Nigeria. The disease caused by this group of nematodes is characterized by numerous swellings or galls on the roots of host plants. Three species namely Meloidogyne arenaria, M. javanica and M. incognita have been found attacking crops in Nigeria (1). All three species of root-knot nematode are widely distributed in Nigeria and have been recovered from virgin forest soil (1). Wilson (6) listed 108 plants and Caveness (1) 116 plants from Nigeria as being susceptible to root-knot nematode attack. Root-knot nematodes are favoured by light, warm soils with adequate moisture for plant growth.

It has not been possible to be so precise about the annual losses caused by root-knot nematode in Nigeria, but judging by its wide distribution, extensive host range and involvement with fungi, bacteria and viruses in disease complexes, the toll must be running into millions of Naira.

There has been, therefore, an increasing awareness of the importance of root-knot nematode and its control in Nigeria. This paper reports the research work on Meloidogyne at I.A.R. & T.

OBSERVATIONS AND EXPERIMENTS

Damage to Cowpea: During 1975 late cropping season at Ibadan, cowpea (Ife brown) crops were seen to be infested in patches by root-knot nematodes, mainly Meloidogyne incognita and as all other factors influencing growth appeared to be the same, the opportunity was taken to compare the yield of cowpea which grew in the nematode free and nematode infested areas at maturity.

Method: Plants in the patches showing symptoms of attack by root-knot nematode were examined to confirm the presence of the root-knot nematode. Similarly, the apparently healthy plants a few metres from the infected patches were also examined to confirm the absence of the root-knot nematode. From the field three paired sites were marked and when the crop was mature in December the bean plants within one square metre area were collected. For each sample, counts were made on the number of plants and pods. Yield of the grains was also determined.

Results: The difference in appearance of plants at the time of harvest in healthy and infested areas was marked. Roots of plants from infested area showed medium to very heavy galling, but no galls were observed on plants from nematode free areas. Mean cowpea grain yield loss was 59.1%.

Resistant Plants

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.

Screening tomato cultivars

Method: Soil infected with root-knot nematodes, *Meloidogyne* spp. were collected from two sites on Moor-Plantation, Ibadan. Examination of the perineal pattern of 100 adult females from each location showed that soil from site 1 contained mainly *M. incognita* while soil from site 2 contained mixed populations of *M. arenaria*, *M. javanica* and *M. incognita*. Estimates of initial root-knot nematode population of the two soils were 400 and 365 larvae/100 ml of soil for soils 1 and 2 respectively.

Four-week-old seedlings of each of the 27 tomato cultivars raised in steam sterilized soil and of uniform sizes, were transplanted into 5-litre plastic pots, filled with thoroughly mixed soil from the two sites. One tomato seedling was transplanted into each pot. The experimental design was a randomized block with four replications. The pots were spaced 1 metre x 1/3 metre in the open field. The plants were grown for six weeks before they were carefully removed from the pots. The root system was washed and scored for the degree of galling according to the method described by Daulton and Nusbaum (3). The root-knot nematode index used contained six categories: 0 = immune, no galls; 1 = resistant, trace of galling; 2 = moderately resistant, light galling; 3 = moderately susceptible, moderate galling; 4 = highly susceptible, heavy galling; 5 = very highly susceptible, very heavy galling. In each of the cultivars root weight was taken. The number of adult females/5g of root was determined by the dilution method after roots were comminuted in a blender for 25 seconds. Root segments were removed by pouring the resulting suspension through a 1-mm sieve. Aliquots were counted at 15x. Females were also squashed to determine whether eggs had been produced.

Results: None of the tomato CVS was immune to the root-knot nematodes. In terms of degree of galling and production of females, Ibadan local and

Harvester were the most susceptible, Nemared was moderately susceptible while three cultivars namely Rossol, Nematex and Enterprizer showed slight resistance. Ronita was the most resistant in terms of degree of galling and production of females. All other cultivars including Campbell 135, Ife 1, Marzanino, New Yorker and Pusa Early Dwarf were highly susceptible to root-knot nematodes. Heavily galled roots weighed more than the less galled roots. Mature egg-laying females were present on all cultivars.

Effect of different population levels on yield of tomato

Most information in the relationship between nematode population density and crop loss is based on yield comparisons between nematode-infested plots and those in which the nematode has been eliminated or greatly reduced in number by soil fumigation. The inherent disadvantages of this method are many: usually only one population density is considered, the size of the initial population varies from plot to plot and chemical soil treatment itself may cause yield increase regardless of nematode kill (4).

Method: In pot experiments carried out in the open on Moor-Plantation, seven tomato cultivars were grown in 5-litre plastic pots infested with 0, 741, 2222, 6666 and 20,000 larvae of *M. incognita* per litre of soil. There were six replicates of each population level for each of the tomato cultivars. Plants were spaced 1/3 metre apart in 6 rows (=6 replicates) spaced 1 metre apart in the open. Five days after transplanting the seedlings into the pots, single superphosphate and 15-15-15 fertilizers were applied to each plant at the rate of 500kg/ha and 200kg/ha respectively. When the first fruits were formed and when the first fruits ripened 15-15-15 fertilizer was applied at the rate of 120kg/ha to each plant. Foliage disease was controlled with Dithane M-45 and insect pests of fruits with Vetox 85.

Six weeks after transplanting the seedlings into the pots, soil samples were taken to determine population level at mid-season. Immediately after the final harvest and three weeks later similar soil samples were taken to determine final nematode populations. Data on marketable fruit yield and root galling were also taken. An economic loss threshold of 10% of the marketable fruit yield was derived from the knowledge of the market value of tomato (5) and the cost of nematode control (2).

This threshold represents a percentage of the total value of the crop equivalent to the cost of nematode control.

Results: Statistical analysis of yield data showed that there were significant differences between yields obtained from different nematode populations. There were also significant differences between the yields

of different varieties. The interaction between varieties and populations was not significant. At a nematode population of 20,000, marketable yields in all the varieties were inversely correlated with nematode populations with a maximum decrease of 89, 86, 84, 77, 74, 73 and 58% for Ife 1, Ibadan local, Pusa Farly Dwarf, Marzanino, Ronita, New Yorker and Rossol respectively. Yorker contained higher nematode populations at harvest than at planting at 741 and 2222 nematode population densities. Ife 1, Marzamino and Pusa Early Dwarf also contained higher nematode population at harvest than at planting at 741 population density. Rossol and Ronita maintained about the same population level at harvest as at planting at 741 population density. At other pre-plant population densities, populations at harvest under Rossol and Ronita were very much lower than at planting. At initial population densities of 6666 and 20,000 nematodes, all varieties, except New Yorker at 6666 initial nematode population contained lower nematode populations at harvest than at planting.

Final populations in the soil three weeks after final harvest were considerably more than final populations in the soil immediately after final harvest. As the initial nematode population increased, susceptibility, in terms of root-galling increased except for Rossol at 6666 and Ronita at 20,000 nematode densities.

Pre-plant populations likely to cause economic loss (10% yield loss) in Rossol lies between 2222 and 6666 nematodes whereas in other six varieties it is about 741 nematodes per litre of soil.

Root-knot nematode control by chemicals

Method: Different rates of five nematicides were applied three weeks before seeding the nursery beds to compare their relative efficacy on the control of root-knot nematode on tomato seedlings. The nematicides and their application rates were as follows: Basamid at 125, 250 and 500kg/ha; DD at 140, 281 and 421 l/ha; Nemagon 20 granules at 42, 84 and 126kg/ha; Nemagon 75 EC at 7.3, 14.6 and 22 l/ha and Vapam at 140, 281 and 421 l/ha. Water soluble nematicides, Nemagon 75 EC and Vapam, were mixed with water and applied as a drench using a watering can. DD was applied along trenches 15cm deep and spaced 30cm apart. Granular nematicides, Basamid and Nemagon 20, were broadcast uniformly on the soil surface and thoroughly mixed with the top 15cm of soil with a hand hoe. The soil surface was sealed off by tapping it with the back of a shovel. Control plots were only turned, so that all plots were treated alike as far as possible. There were three randomized replicates of each nematicide rate and of untreated control plots. The plot size was one metre square. Ife 1 tomato seeds were spaced approximately 1cm apart in the drill. There were six drilled rows spaced 15cm. apart in each plot. After germination, the

seedlings were thinned to one per 2.5cm of drill leaving about 25-30 seedlings per row. Thirty-two days after sowing, samples were taken from the four middle rows in each plot. Every other fourth or fifth plant was sampled in each row, making a total of 5 plants per row. Thus a total of 20 plants were carefully dug from each plot and scored for height of plant, number of galls/root, root weight and shoot weight.

Results: Basamid at 500kg/ha stunted the plants. There was no evidence of fumigant toxicity from the other treatments. Number of galls for all the treatments were less than in the control except for Basamid at 125kg/ha. There were no significant differences in root weight for all the treatments. Shoot weight for all the treatments were better than control except for Basamid at 500kg/ha.

Research Projects in Progress:

1. Chemical control of root-knot of tomato for fruits

2. Determination of resistance or susceptibility of economic crop plants and economic weed plants to root-knot nematodes *Meloidogyne* spp.

3. Cropping sequences for the control of root-knot of tomato.

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RESEARCH WORK ON ROOT KNOT NEMATODES AT THE NATIONAL CEREALS RESEARCH INSTITUTE, IBADAN

T. Olowe

The National Cereals Research Institute, formerly known as the Federal Department of Agricultural Research, has recently been given sole national research responsibility of working on maize, rice, sugarcane and grain legumes throughout the Federation of Nigeria. Thus, nematology research work is now concentrated on these crops and research work on root-knot nematodes, Meloidogyne spp., is part of the general research programme aimed at identifying and quantifying nematode problems limiting production of cowpea, soybean, sugarcane, rice and maize crops and also seeking short term and long term economic control measures. The long time control measures include looking for resistant crops or varieties as cultural means of control. Work on grain legumes, especially cowpea, where root-knot nematodes pose great problems has just begun in the Institute and the work going on at present includes survey work on nematode diseases, occurrence and distribution and also screening trial of cowpea varieties/lines for resistance to root-knot nematodes.

SURVEY

Survey of cowpea growing areas in Imo (Enugu, Umudike), Anambra (Owerri, Onitsha) and River (Port Harcourt) States of Nigeria conducted in early season in 1974 showed that there were four species of root-knot nematodes, M. incognita, M. arenaria, M. javanica and Meloidogyne sp. associated with cowpea out of which Meloidogyne incognita was of wider distribution than others. Similarly, a survey conducted at the sugarcane plantation in Bacita in 1969 also revealed the presence of Meloidogyne incognita in both sandy and clayish soil under sugarcane though more on sandy soil. Not only were the root-knot nematodes found in association with cowpea or sugarcane, they also occurred under maize as the survey undertaken in 1975 to sixty-five maize growing sites scattered in seven different states - Oyo, Ondo, Ogun, Bendel, Anambra, Imo and Plateau states of Nigeria (Table 1) showed the occurrence and distribution of Meloidogyne spp. in 51% of the sites. The varieties in each site included four of the following: Farz 1, 6, 7, 22, 24, 26, 27 together with local variety specific for each site making five varieties in each site. However, the varieties Farz 26 & 27 appeared to habour more of Meloidogyne nematode than the other varieties regardless of the site location.

TABLE 1.
DISTRIBUTION OF MELOIDOGYNE SPP. UNDER MAIZE IN NIGERIA

Oyo State	Alakia, (Ibadan), Ajegunle, Asipa (Ife), Iyagani (Ife), Toro (Ife), Iloko (Ilesha), Ife township, Olu o i (Iwo), Onikoko (Iwo), Oniyo Ikoyi
Ondo State	Ado-Ekiti, Aiyetoro Iloro Ekiti, Igbara Ekiti, Okemesi Ekiti, Oye Ekiti, Iju (Akure), Okonileowo Ijero Ondo.
Ogun State	Fatedo (Egbado), Jagun-Ijebuode, Ikenne, Ilisan Remo, Imosan.
Bendel State	Abavo, Alifikede, Ekakpamure Utujereni, Akverhauwe, Otovwodo Ugheli, Umunede.
Kwara State	Ala, Gbeleko-Kabba, Ogosun-oja.
Anambra State	Ozalla, Umukabia
Imo State	Ajata, Lodu (Umuahia).

OUTLOOK

It is intended to extend the survey of Meloidogyne spp. in cowpea growing areas to almost all the nineteen states of Nigeria with a view to find out the types and extent of distribution and also to identify resistance breaking biotypes if any.

SCREENING OF COWPEA VARIETIES/LINES FOR RESISTANCE TO M. INCOGNITA

Forty-six cowpea varieties/lines in five replicates each and set out in an open air in a completely randomized design were screened for resistance to M. incognita using 4,000 second stage juveniles obtained by dilution method, as an inoculum density. This nematode was propagated from a single egg mass on tomato. The cowpea varieties/lines were contained in a five-litre plastic bucket filled with a mixture of sterilized soil and sand in ratio 1:1. At two to three full leaf stage, the buckets were inoculated with 4,000 second stage juveniles of M. incognita at 2.5cm soil depth and the cowpea seedlings transplanted at the same time. The plants were left till the pod ripening before

harvesting for root knot scoring and juvenile nematode count per 1 gram root subsample. The proportion of the root galled was scored and used as an index for resistance assessment. The scorings are:

1 = Immune, no galling;

2 = Highly resistant, 1 - 5% of the root galled;

3 = Resistant, 6 - 25% of the root galled;

4 = Moderately resistant, 26 - 50% of the root galled;

5 = Susceptible, 51 - 75% of the root galled;

6 = Highly susceptible, 76 - 100% of the root galled.

Using this index, one variety was found to be immune; 12 highly resistant; 12 resistant; 4 moderately resistant; 7 susceptible and 10 highly susceptible.

OUTLOOK

(1) It is intended to re-examine the resistant varieties using higher inoculum density level of second stage juveniles of M. incognita obtained by subjecting three different resistant varieties to five levels of inoculum densities ranging from 2,500 - 60,000 to obtain percent of root galling of more than 50%. (2) It is also being proposed to carry out the resistance screen trial in two phases for quick results. (3) The first phase will be carried out in the field for mass screening. For this purpose, a hell of M. incognita, which happens to be the only Meloidogyne sp. present in our A8 irrigation field is being built up by a monocropping of tomato. The second phase will be carried out in the screenhouse. The promising resistant varieties from the field will be re-examined in the screenhouse. (4) The selected resistant varieties will be further subjected to different isolates of M. incognita obtained from different ecological zones in Nigeria. (5) Attempts will also be made to test the selected resistant varieties in different ecological zones where the nematode M. incognita is known to exist in an endemic level.

1976/77 GRAIN LEGUME (COWPEA, SOYBEAN) NEMATOLOGY INCLUDING ROOT-KNOT NEMATODES RESEARCH PROGRAM

(1) Survey for occurrence and distribution of nematode diseases and plant parasitic nematodes, including root-knot nematodes, affecting cowpea and soybean.

Materials and Methods

(a) Field sampling of cowpea and soybean soil, root and top in cowpea and soybean growing areas in different ecological zones in Nigeria.

(b) Laboratory processing of samples for identification of:

(i) Seed borne plant parasitic nematodes

(ii) Root nematodes

(iii) Stem nematodes

(iv) Soil ectoparasites.

Location: Cowpea and soybean growing areas in Nigeria
Phasing: Continuous

(2) Investigation of the nature and extent of damage of nematodes affecting cowpea and soybean.

Materials and Methods: Greenhouse/laboratory studies:

(a) Establishment and maintenance of monocultures of pathogenic nematodes

(b) Pathogenicity studies with different inoculum levels and the effect on grain yield

(c) Determination of nematode population build up in cowpea and soybean soil and root and the disease severity with different cowpea and soybean growth phase.

Location: Moor Plantation, Ibadan.
Phasing: Continuous.

(3) Screening of cowpea varieties/lines for resistance to pathogenic nematodes.

Materials and Methods: Field and Greenhouse studies: (a) Field trials for natural infestation for mass screening. (b) Greenhouse inoculation of promising resistant varieties from the field. Resistance assessed by root disease index and/or multiplication rate of nematodes.
Location: Moor Plantation, Ibadan.
Phasing: Continuous.

(4) Host range/status of various food and cover crops, grasses and weeds to pathogenic nematodes of cowpea.

Materials and Methods: Greenhouse studies. Host status evaluated by multiplication rate of nematodes.

Location: Moor Plantation, Ibadan.

Phasing: Continuous.

(5) Comparative effectiveness of various nematicides in controlling pathogenic cowpea nematodes.

Materials and Methods: Greenhouse and field trials. Nematicide efficacy evaluated by the nematode population build up, disease expression and grain yield.

Location: Moor Plantation, Ibadan.

Phasing: Continuous.

MELOIDOGYNE RESEARCH AT THE UNIVERSITY OF IBADAN

R. A. Odihirin

Root-knot on cowpeas

A survey of root-knot nematodes infecting cowpea (New Era) in gardens at the University of Ibadan revealed the presence of Meloidogyne incognita, M. arenaria, M. javanica and Meloidogyne spp.

The perineal pattern of M. incognita, in particular, varied considerably. The M. arenaria found was the winged type. M. hapla is not usually found in the tropics except at high altitudes. The unidentified species resembled the perineal pattern of M. hapla but differs from it by lack of punctation in the dorsal area.

Since cowpea is a very important source of protein in the diet of Nigerians, attempts that are made to breed for resistance should put the following facts into consideration:

(a) Cowpea cultivars used by our farmers at present are all very susceptible to root-knot nematodes.

(b) One cultivar may be susceptible to four or more different species of root-knot.

(c) M. incognita which appears to be the most common species in Ibadan area has several biotypes or pathotypes. The same may be true of other root-knot species.

Root-knot on yam tubers

Until recently, it was generally believed that Scutellonema bradys was the only important nematode parasite of yam tubers in Nigeria, hence it was popularly called "the yam nematode". An extensive survey has revealed that root-knot species are equally important causes of yam decay in several areas of Nigeria. M. incognita was identified from decaying yams in Cross River State and Bendel State. M. javanica is common in yam tubers at Ibadan. Both white yam (Dioscorea rotundata) and water yam (D. alata) are heavily parasitized. Root-knot infected yams have also been collected from a farm at Kaduna.

Farm to farm dissemination through propagative organs

This is a natural corollary from the existence of root-knot nematodes in tubers and other crop propagative organs like bulbs, corms and rhizomes. Yam setts infected with root-knot nematodes are used in raising a new crop. Banana suckers, complete with corms and roots are carried far away for raising new banana fields along with embedded egg masses of root-knot. The list of crops raised from tubers, bulbs, corms and rhizomes in tropical countries is a long one.

Root-knot on grasses

This is worthy of special mention because galling or knotting is the quickest symptom for recognition of root-knot infestation in plants. Several grasses in Nigeria habour root-knot nematodes without any signs of galling. In such cases, the visible egg masses could be mistaken for those of Rotylenchulus reniformis. Examples of such grasses are Axonopus campressus and Mariscus umbellatus. Grasses are used for mulching.

Dry season survival of root-knot

Apart from hibernation in tubers, bulbs, corms and rhizomes, root-knot nematodes multiply in the roots of perennial and persistent weeds in tropical climates during the dry season. A three-month survey revealed root-knot presence in weeds belonging to 20 plant families. As many as 1,000 eggs were recovered from the roots of some individual plants. These eggs supply inoculum to the next crop. The largest numbers of eggs were found in weeds belonging to the families Portulacaceae, Euphorbiaceae, Amaranthaceae, and Compositae.

Observations on locations of egg masses of root-knot female in different host plants

The same root-knot nematode that produces an egg mass outside the root of the host plant may produce an egg mass that is completely embedded inside the tissue of another host. For example, M. incognita egg mass is outside the roots in tomato and cowpea, but inside the roots of Indian Spinach, carrot and yam tubers. Such a situation helps them to survive better in the hot and dry tropics pending the arrival of rains.

Screening for resistance to root-knot nematodes

Just about every crop and every weed sampled has been found with one species of root-knot or the other.

There are, however, some promising candidates with natural immunity or tolerance. Groundnuts, maize, sugarcane and cassava are relatively free of economic root-knot damage. Among weeds, Eupatorium and Tridax seem to be free from root-knot. Further screening continues. A cultivar of a fodder crop Cynodon dactylon, 'IB-8', bred by Professor Chedda has been shown to be resistant to M. incognita both in greenhouse and field trials.

Root-knot control problems that are peculiar to the tropics

Effective control measures against root-knot and other nematode problems in the tropics will be futile if cognisance of the peculiarities of tropical climates is not taken into account. A few of these which we have encountered from field experience are listed below:-

(i) Multiplication of root-knot nematode is going on all the year round because of suitable temperature. The only limiting factor is water in the dry areas of Nigeria, but this is again eliminated by man-made irrigation.

(ii) Tropical rains cause greater splashing and soil transfer through torrents than gentle temperate rainfall.

(iii) Tropical ecosystems have a greater diversity of plants (weeds) per hectare than temperate zones. As a result, there is a greater diversity of nematode species per hectare in tropical farms. This makes control measures more difficult to arrange.

(iv) Nematicides applied as fumigants evaporate faster in the tropical sun or can be washed off by rain the following day depending on the season.

DISCUSSION

The points raised above show that the problems facing Tropical Nematologists are enormous. Correct identification of root-knot nematode is one of them, finding an effective control measure is another. Screening for naturally immune varieties and breeding for new resistant cultivars should be on the priority list of control measures in view of the practical difficulties posed against chemical fumigation by the tropical climate. Granular nematicides stand a better chance than volatile fumigants.

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

F. E. Caveness

DISTRIBUTION

Three species of the root-knot nematode are found in Nigeria. Meloidogyne arenaria has been found most frequently in the west occurring as 48.2% of the specimens identified. M. incognita (=M. incognita acrita) was next being identified as 38.1% of the species and M. javanica being identified as 13.7%. In a plant-parasitic nematode survey in Nigeria (2, 3, 4) Meloidogyne spp. juveniles were found in soil samples from the three regions: West, 100 (3%) of 3,280 samples; East, 44 (2.9%) of 1,511 samples and North, 29 (1.3%) of 2,218 samples (Fig. 6).

Working in the north of Nigeria Wilson (9) reported the presence of Meloidogyne spp. on 108 host plants. M. javanica was the most common species being found on 68.5% of the plants. M. incognita was found on 49.1%, M. arenaria on 2.8%, with 7.4% not identified. Wilson cites locations of Meloidogyne spp. infestation as Zaria, Daura, Jos, Kano, Jema'a, Ilorin, Yandev and Kabba but does not distinguish nematode or plant species.

As part of the survey and also in line with other work a portion of the soil samples from the Western Region were returned to Ibadan and potted using tomato as an indicator plant. Adult Meloidogyne spp. females were recovered from 48% of the samples handled by this method. Distance, weight of samples and transport available did not lend itself to using this method for the other regions. The known geographic range of identified adult Meloidogyne spp. is therefore biased toward the Western Region (Figs. 7, 8, 9). (Included are updated Meloidogyne spp. locations supplied by J. J. Smit, W. S. Bos, R. O. Ogbuji and J.O. Amosu; personal communications).

ENVIRONMENTAL FACTORS

Using the distribution data available some associations of gross environmental factors that might influence this geographic range can be considered. Although each of the factors is considered independently of the other factors, that each is a part of the total environment and acknowledged as such. Human population density, rainfall, temperature and elevation are environmental factors that govern the distribution, density and survival of host plants.

Human population density in a predominately rural country with its dependence on the cultivation of food crops suggests an influencing factor. The distribution of Meloidogyne spp. given in Figure 10 shows the presence of the nematode in heavily populated as well as lightly populated areas. In other locations the reverse can be shown. Human activity alone does not seem to be a dominant factor.

Meloidogyne spp. distribution in relation to mean annual rainfall is given in Figure 11. It should be noted that a longer calendar distribution is correlated with higher amounts of rainfall and might be an overriding factor.

The annual mean maximum and minimum temperatures presented in Figures 12 and 13 are unlikely to be a limiting or even influencing factors of much consequence in Meloidogyne spp. distribution in the mild climate of Nigeria. The mean extreme temperatures in bare cultivated soils would be greater at the 5-cm depth but moderated at greater depths.

Being a predominately agricultural as well as a timber exporting nation the natural vegetation of Nigeria has often be replaced, frequently, by farms with a variety of crops. Timber cut areas generally have not been allowed to regenerate forests as growers with a shifting-cultivation-farming system keep the land in secondary bush regrowth. Since about 75% of the samples were collected from cultivated crops, the nematode distributions may not reflect the influence of the natural vegetation and the dispersion of Meloidogyne spp. has undoubtedly been greatly aided by man (Fig. 14).

HOST RANGE

The number of host plants recorded in Nigeria now exceeds 140 species of cultivated and uncultivated plants (2, 3, 4, 7, 9). Included as host plants are many important foods from vegetables and field crops.

LIFE HISTORY

The nematodes M. incognita, M. arenaria and M. javanica were grown in shadehouse benchbeds. For each species five cowpea plants were lifted each day for a period of 35 days. Soil temperature in the benchbeds was 28 ± 2 C. The roots were preserved and stained by boiling in lactophenol containing acid Fuchsin for three minutes. The cowpea roots were destained and stored in clear lactophenol until examined.

Vermiform infective juveniles of M. incognita were found in the roots the second day after planting. Vermiform juveniles were not seen in cowpea

roots for M. arenaria and M. javanica until the sixth day after planting. Fusiform juveniles were found on the seventh and eighth days for the three Meloidogyne spp. Rapid saccate growth commenced on the 11th day. Fully saccate females with matrix (before egg laying) were found on the 19th and 20th days. The first eggs were laid on the 21st day for M. incognita and M. javanica and on the 23rd day for M. arenaria. The development for the three species of root-knot nematode in western Nigeria is essentially the same as those reported in the literature for like conditions.

SCREENING PLANT GERMPLASM FOR ROOT-KNOT NEMATODE RESISTANCE

The controlled temperature facility in the screenhouse is used in screening plant germplasm at a standard soil temperature of 27 ± 1 C. Seeds are planted singly in 12-cm plastic pots in pasteurized river sand. Five thousand root-knot nematode eggs are added to each pot at planting for cowpea and at emergence for lima bean. The seed and nematode eggs are covered with 2 cm of dry sand. The residual moisture is adequate for germination and emergence. Each line is planted once then replanted in replicates of five if further testing is warranted. After five weeks plants are lifted, rinsed in water and indexed for development of nematode root galls. The root-knot nematode index used contains five categories: 1 = immune, no galls; 2 = resistant, very light and small galling; 3 = moderately resistant, lightly galled; 4 = susceptible, abundant galling; 5 = highly susceptible, very heavily galled. For each individual plant the number of eggs is determined by the dilution method after the roots are comminuted for 30 seconds in a blender. Root segments are removed by pouring the communition through a 0.5 mm sieve. The results of a cowpea trial are summarized in Table 1.

TABLE 1

The root-knot nematode index and the mean number of eggs per plant on 241 lines of Vigna unguiculata screened for resistance/susceptibility to Meloidogyne incognita during 1974

	Root-knot nematode index				
	Immune	Resistant	Moderately resistant	Susceptible	Highly susceptible
	1	2	3	4	5
No. lines	0	4	52	117	68
Mean no eggs/plant	-	229	2,529	14,769	37,977

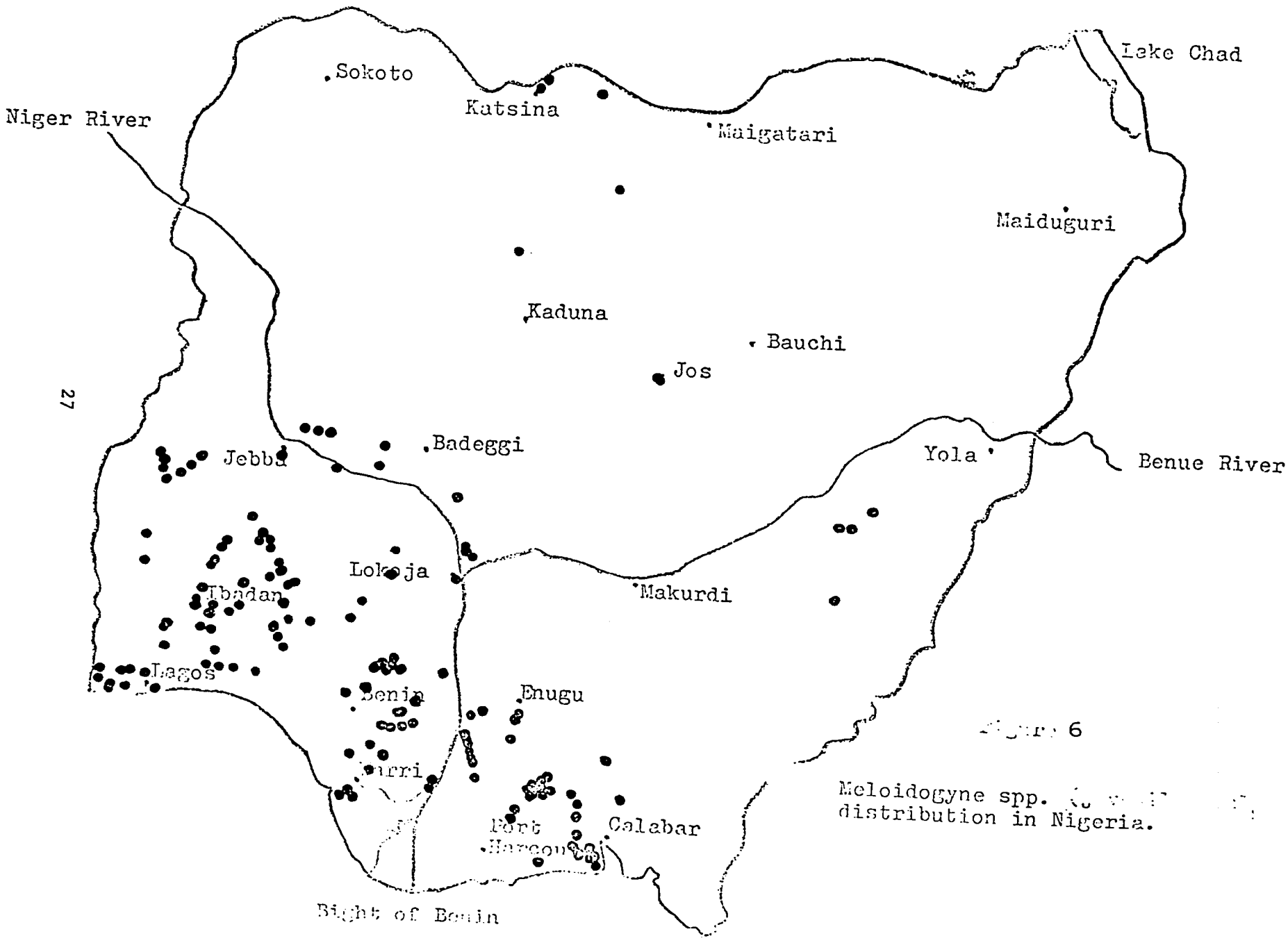

Figure 6

Meloidogyne spp. distribution in Nigeria.

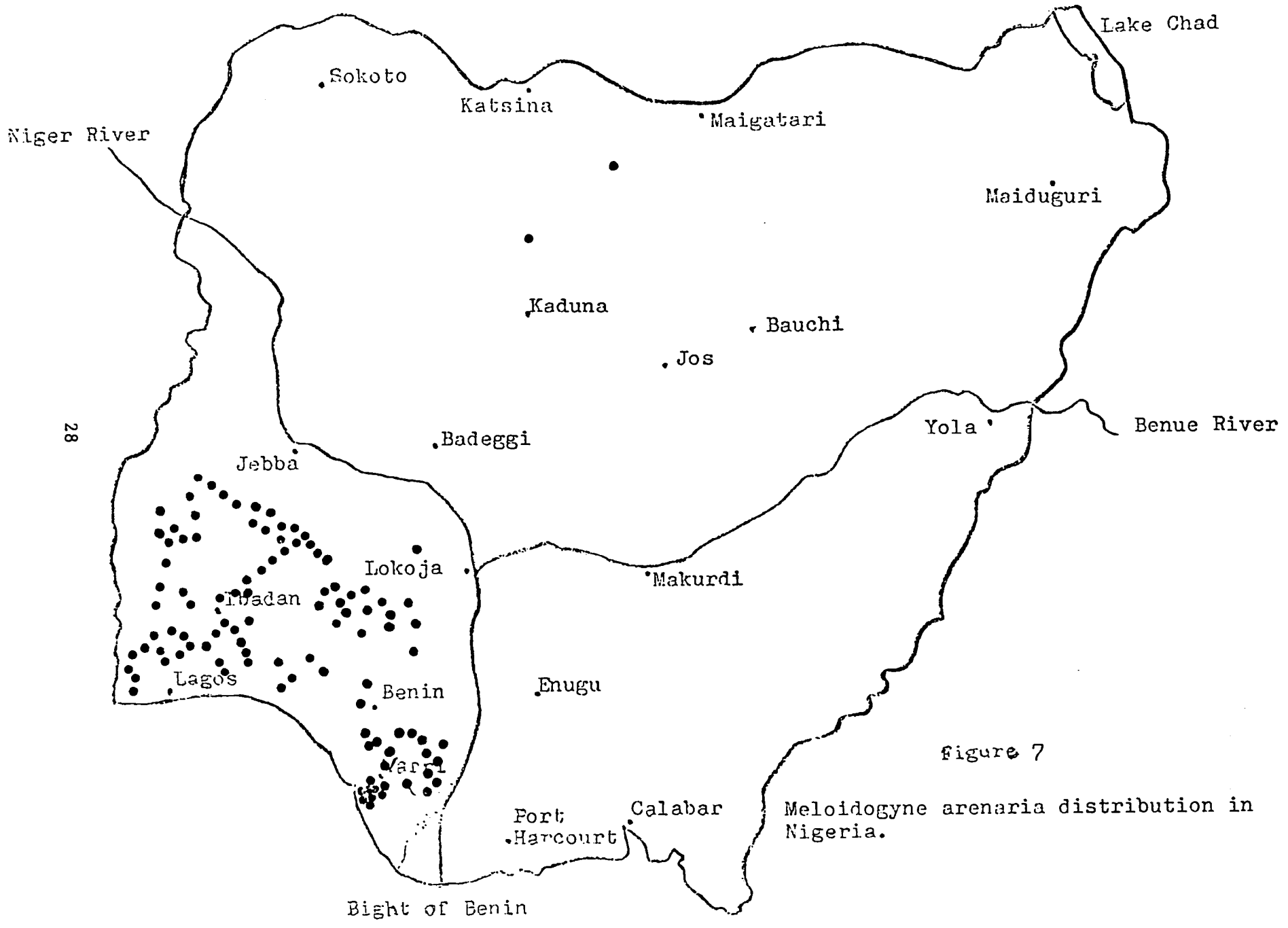

Figure 7

Meloidogyne arenaria distribution in Nigeria.

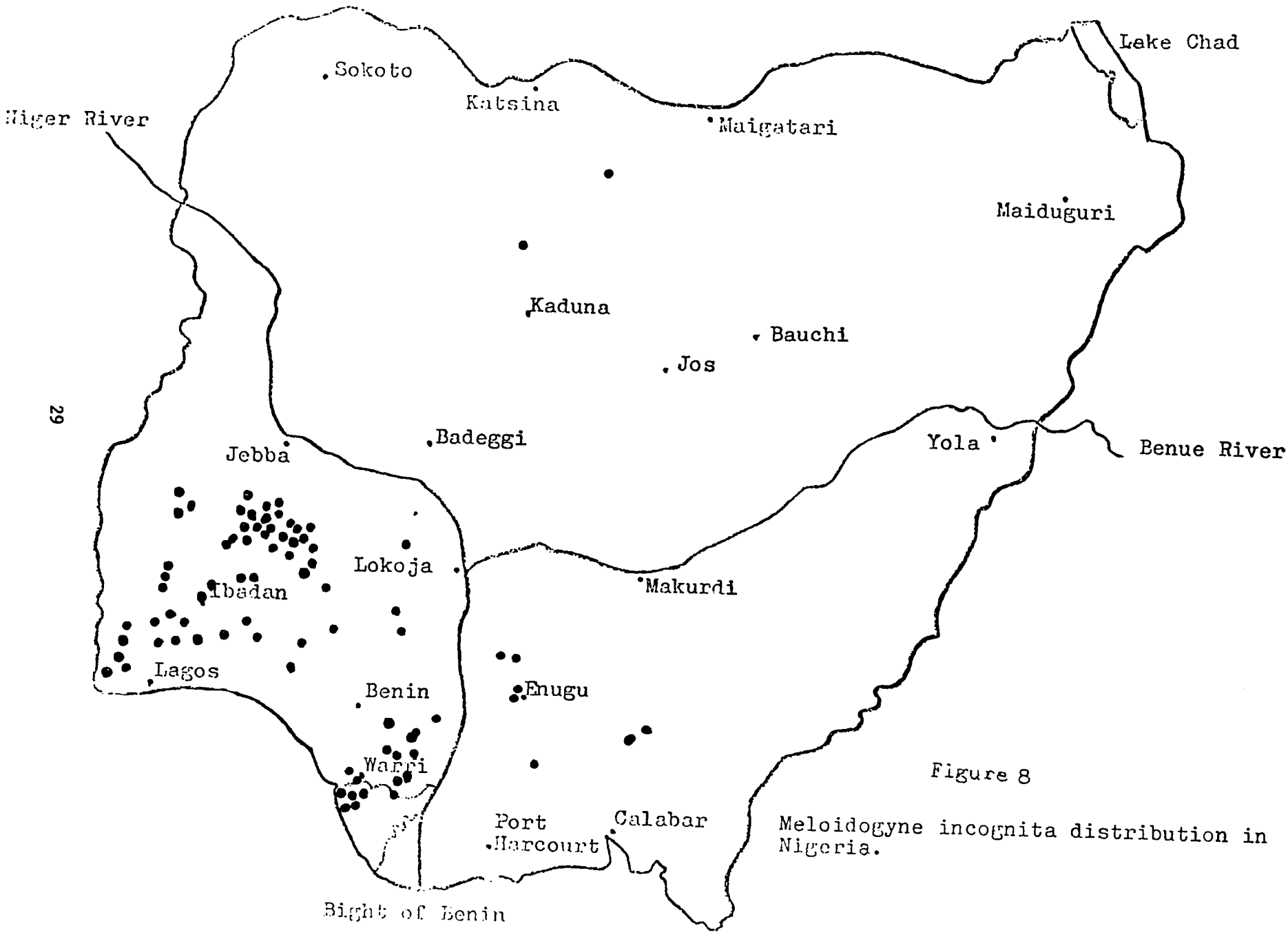

Figure 8

Meloidogyne incognita distribution in Nigeria.

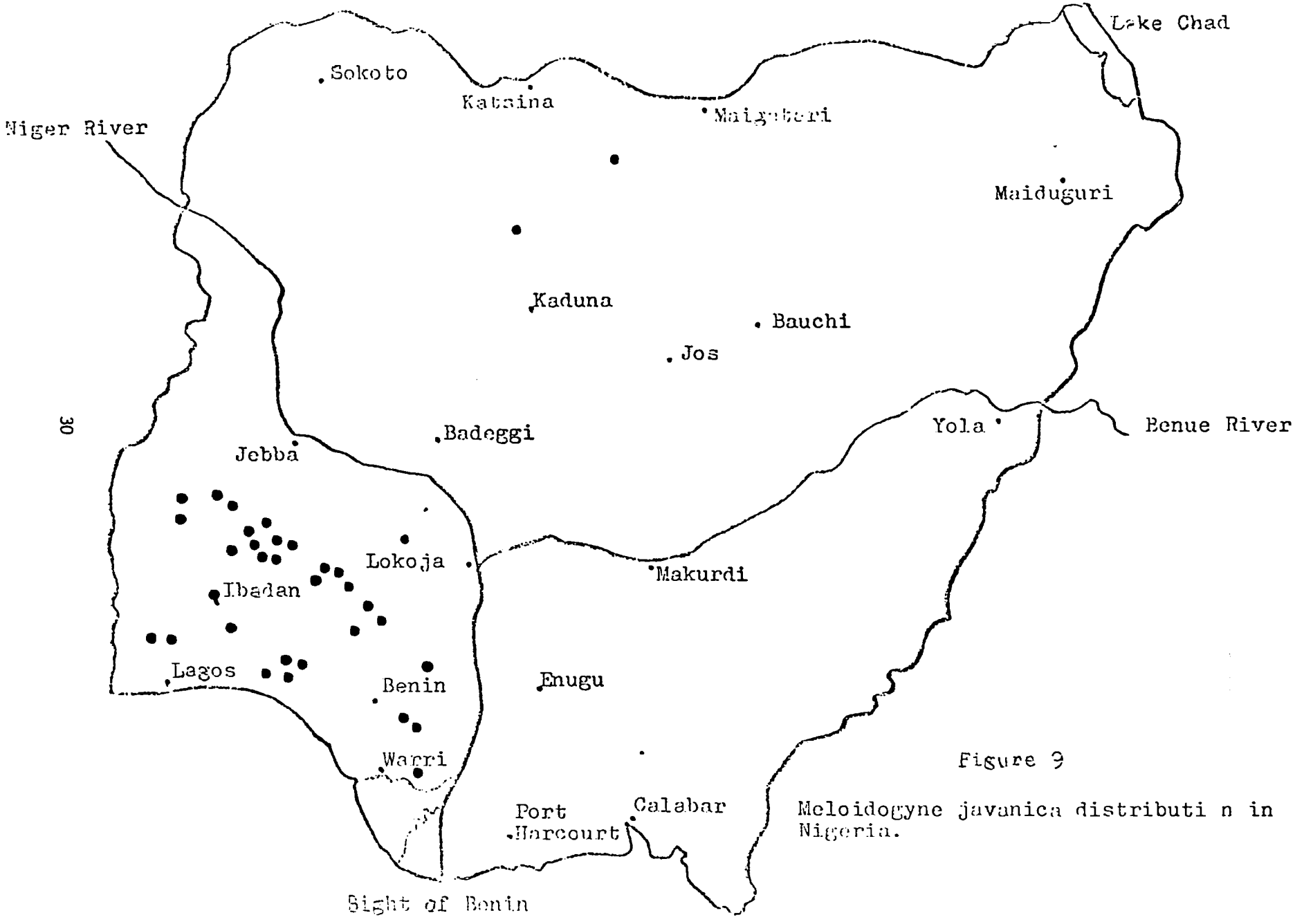

Figure 9

Meloidogyne javanica distributi n in Nigeria.

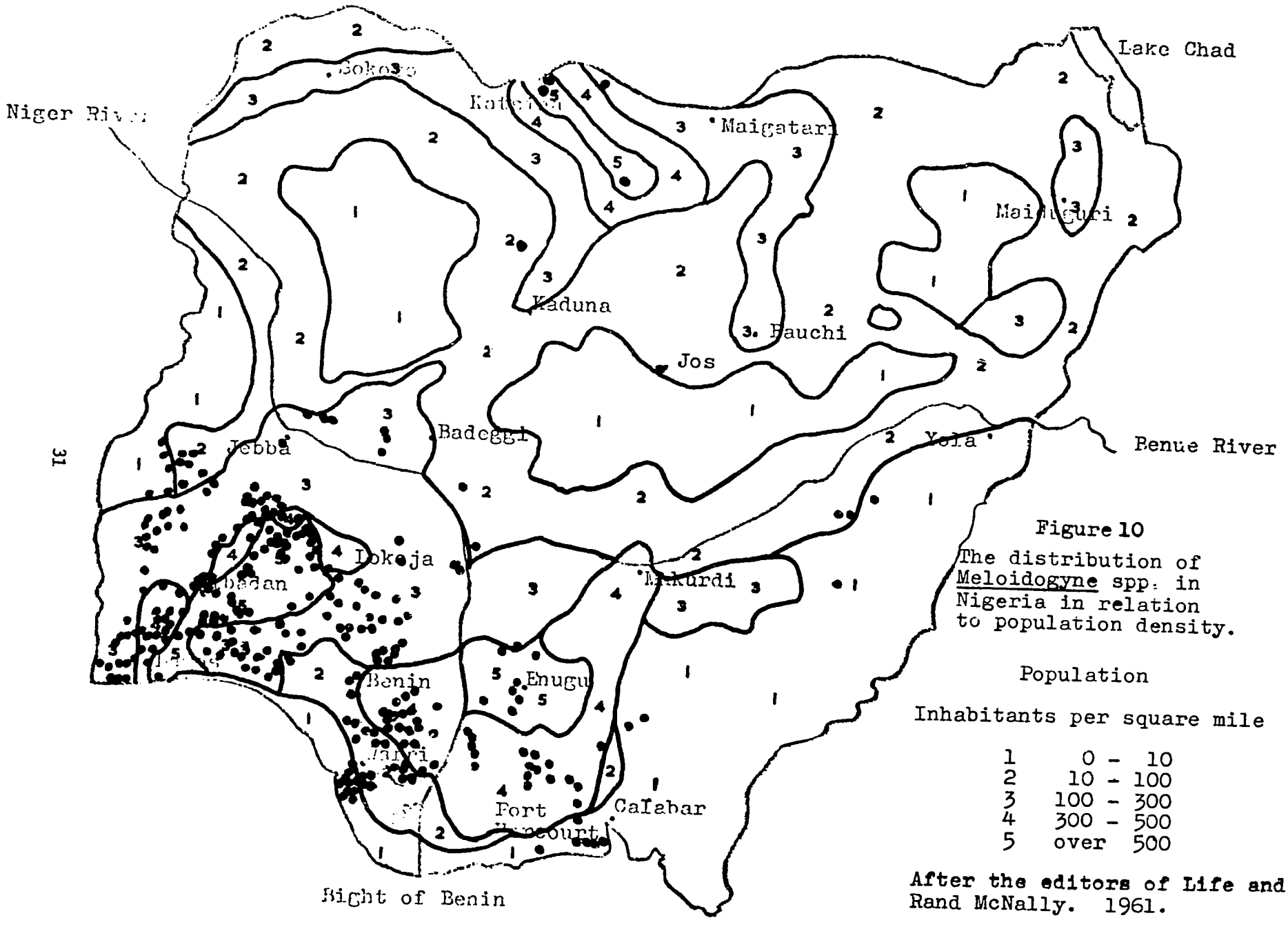

Figure 10

The distribution of Meloidogyne spp. in Nigeria in relation to population density.

Population

Inhabitants per square mile

1	0 - 10
2	10 - 100
3	100 - 300
4	300 - 500
5	over 500

After the editors of Life and Rand McNally. 1961.

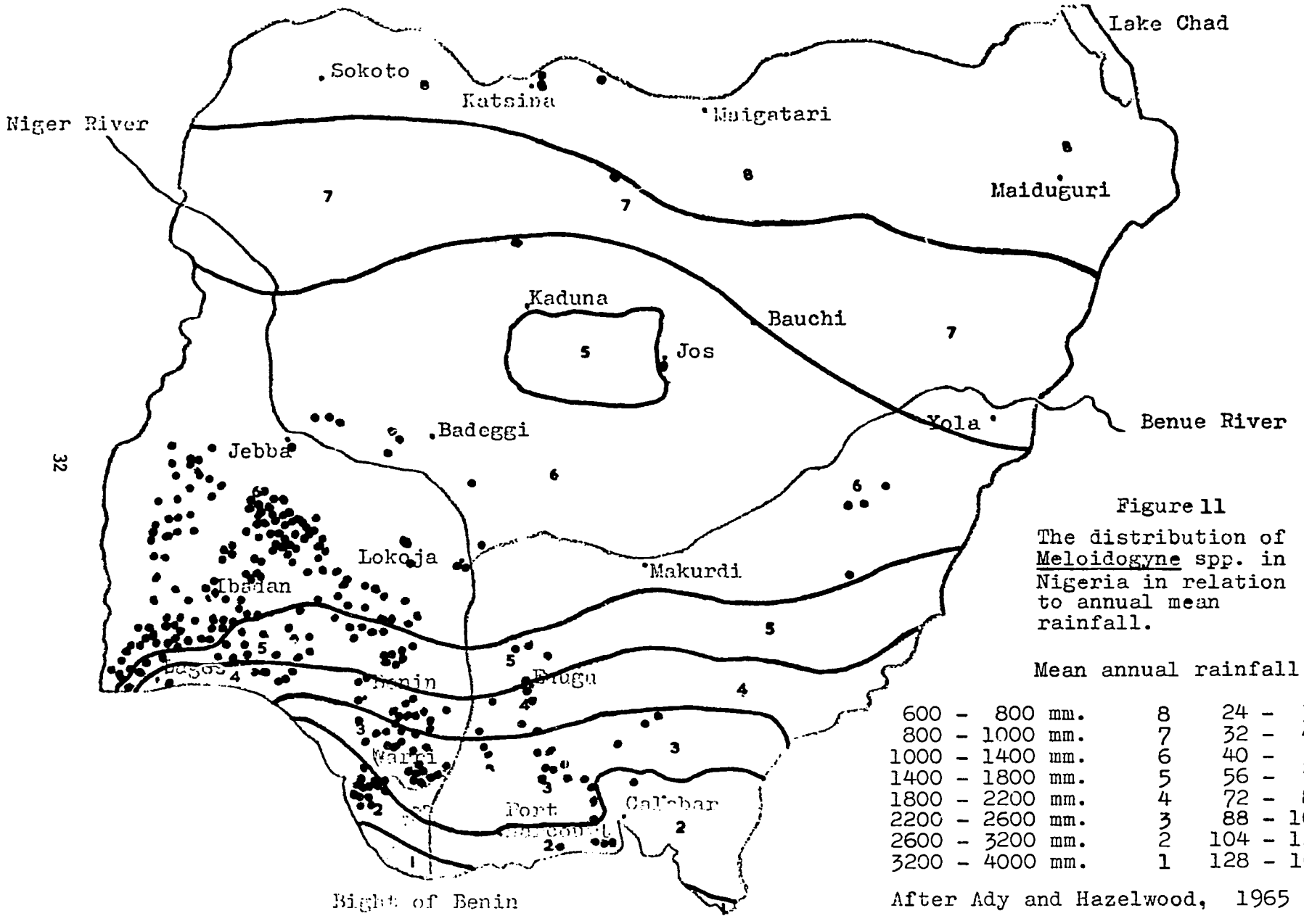

Figure 11

The distribution of *Meloidogyne* spp. in Nigeria in relation to annual mean rainfall.

Mean annual rainfall

600 - 800 mm.	8	24 - 32 in.
800 - 1000 mm.	7	32 - 40 in.
1000 - 1400 mm.	6	40 - 56 in.
1400 - 1800 mm.	5	56 - 72 in.
1800 - 2200 mm.	4	72 - 88 in.
2200 - 2600 mm.	3	88 - 104 in.
2600 - 3200 mm.	2	104 - 128 in.
3200 - 4000 mm.	1	128 - 160 in.

After Ady and Hazelwood, 1965

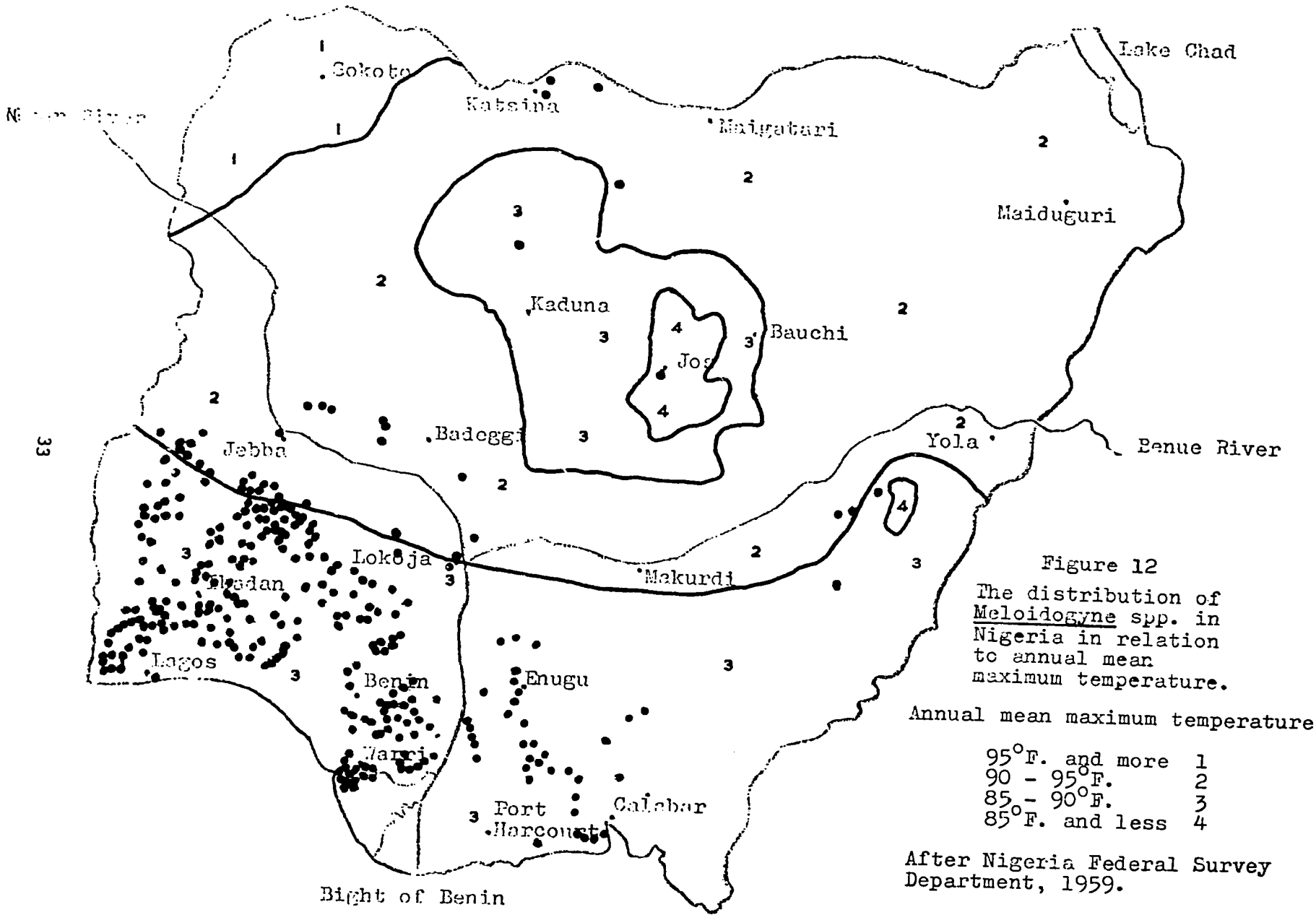

Figure 12

The distribution of Meloidogyne spp. in Nigeria in relation to annual mean maximum temperature.

Annual mean maximum temperature

95°F. and more	1
90 - 95°F.	2
85 - 90°F.	3
85°F. and less	4

After Nigeria Federal Survey Department, 1959.

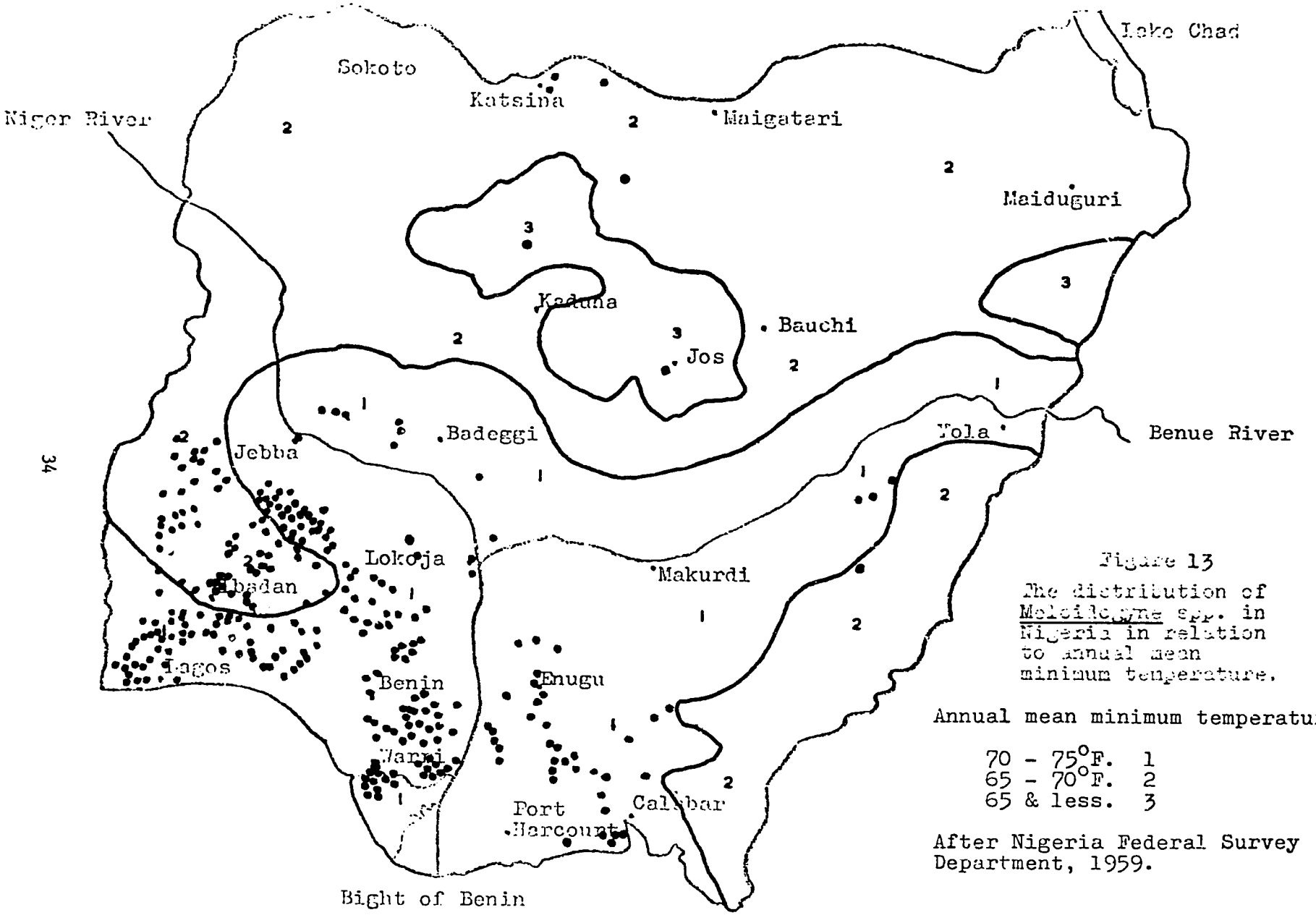

Figure 13

The distribution of *Meloidogyne* spp. in Nigeria in relation to annual mean minimum temperature.

Annual mean minimum temperature

70 - 75°F.	1
65 - 70°F.	2
65 & less.	3

After Nigeria Federal Survey Department, 1959.

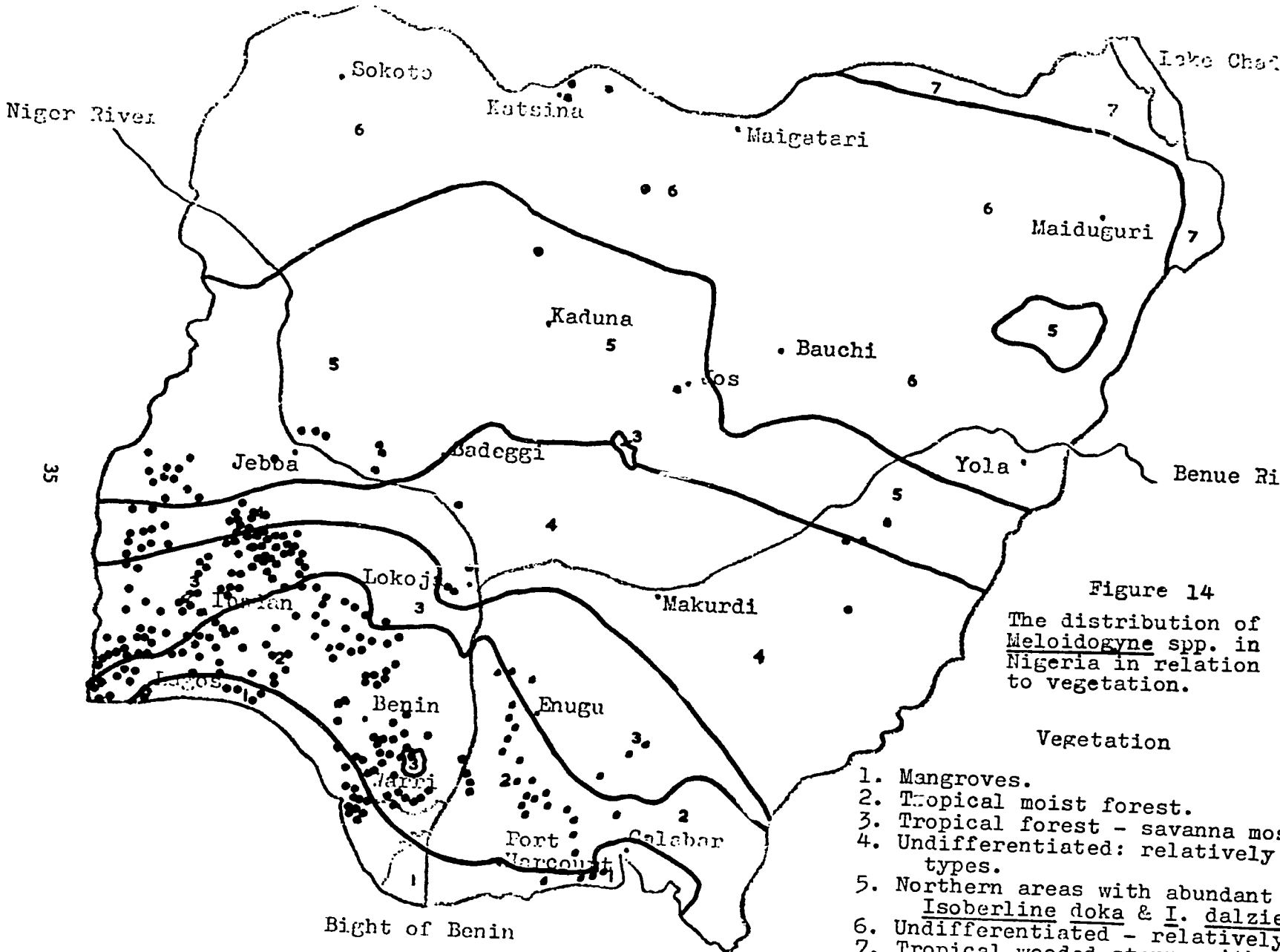

Figure 14

The distribution of *Meloidogyne* spp. in Nigeria in relation to vegetation.

Vegetation

1. Mangroves.
2. Tropical moist forest.
3. Tropical forest - savanna mosaic.
4. Undifferentiated: relatively moist types.
5. Northern areas with abundant *Isoberline doka* & *I. dalzielii*.
6. Undifferentiated - relatively dry
7. Tropical wooded steppe with abundant Acacia and Cammiphora.

After Ady and Hazelwood. 1965.

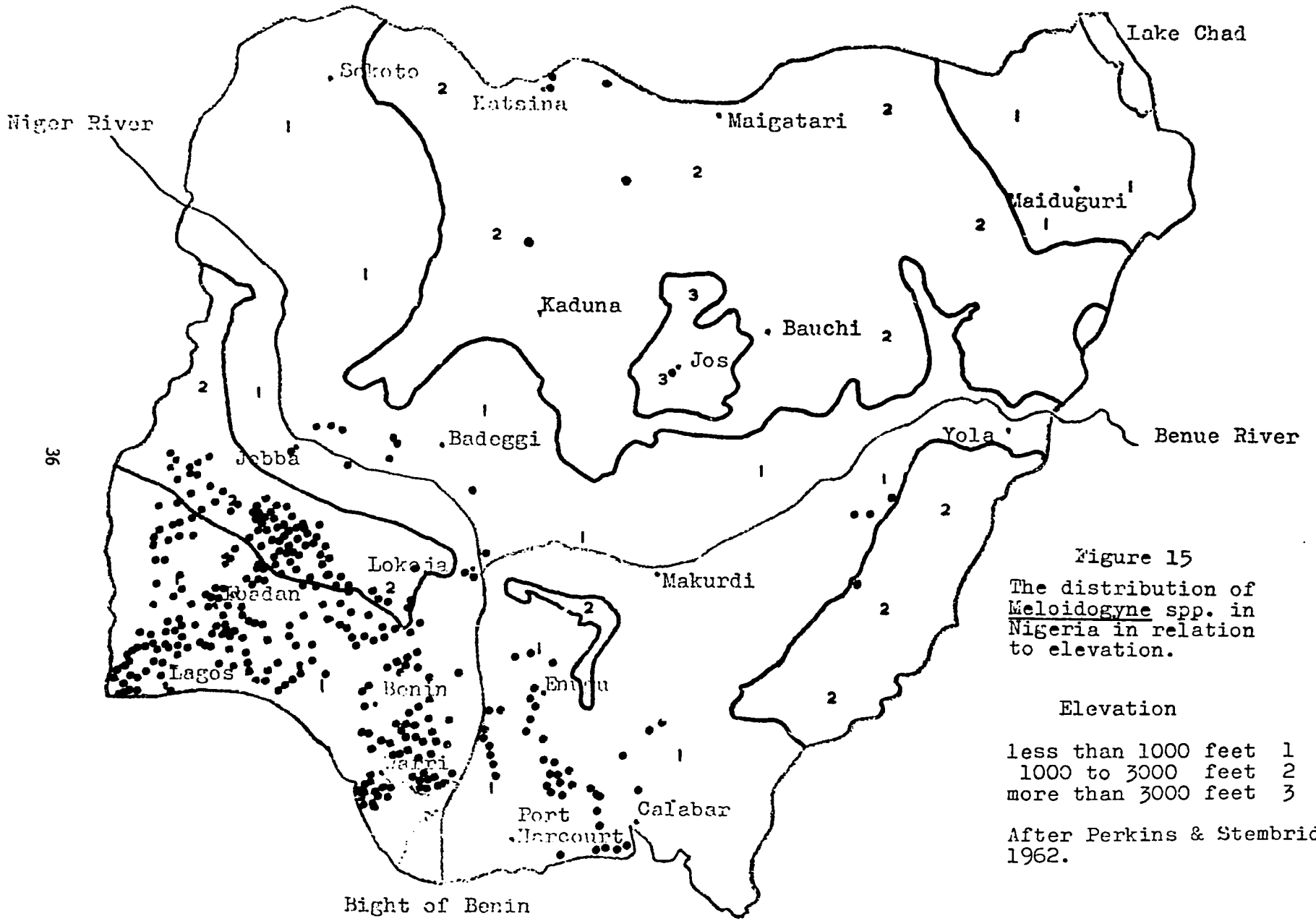

Figure 15

The distribution of *Meloidogyne* spp. in Nigeria in relation to elevation.

Elevation

less than 1000 feet	1
1000 to 3000 feet	2
more than 3000 feet	3

After Perkins & Stembridge 1962.

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REPORT OF MELOIDOGYNE RESEARCH AT UNIVERSITY OF IFE, ILE-IFE

J. O. Amosu

Meloidogyne research at the Department of Plant Science, University of Ife is concentrated on integrated control of root-knot nematode on grain legumes and vegetable crops and on the interaction of Meloidogyne spp. with certain soil borne diseases.

INTEGRATED CONTROL OF ROOT-KNOT NEMATODE ON GRAIN LEGUMES AND VEGETABLE CROPS

OBJECTIVES

(1) To develop in cooperation with plant breeders resistant cultivars of selected vegetable crops and grain legumes to root-knot nematode.

(2) To determine the host-parasite relationship and mechanism of resistance in some selected vegetable crops.

(3) To evaluate various management practices and cropping system for ability to suppress root-knot nematode populations and attain maximum yield production from susceptible vegetable and grain legumes crops.

Resistance to Root-knot Nematodes

Several cowpea (Vigna unguiculata spp unguiculata and tomato (Lycopersicon esculentum) cultivars and lines had been screened for resistance/susceptibility to the root-knot nematode M. incognita. Thirty-six cowpea cultivars and lines showed a high degree of resistance to M. incognita. The roots of a Mississippi Silver were free of infection in screenhouse and field tests. Mak 1/1 and Victor K798 were free of infection in wet season tests and were slightly galled in dry season tests (2).

Thirty-five cultivars and lines of tomato were tested for resistance to root-knot nematode in the screenhouse. The tomato cultivars Atkinson, Nematex, Rossol, VEN8 and Ife 1 (Improved Line 76) were resistant to the

root-knot nematode while Ronita, Puunui and Nemared showed some level of tolerance (3).

Evaluation of advanced generation of tomato lines into which root-knot nematode resistant genes have been incorporated continues.

Host-parasite Relationship and Mechanism of Resistance

Study has been conducted to determine the inheritance pattern for resistance to root-knot nematode in cowpea. The data supported the hypothesis that a single dominant factor governs resistance to populations of *M. incognita* (1).

Studies are in progress to determine optimum inoculum levels for screening tomato and cowpea seedlings for resistance to root-knot nematode resistance and also nature and mechanism of resistance in cowpea and tomato.

Management Practices

Experiments are in progress to study the influence of cropping sequence on root-knot nematode population development. The treatments were selected on basis of the different crop cultures in the different ecological zones in Western parts of Nigeria. Recently, at the University of Ife, an experiment on cropping systems involving various agricultural disciplines was intiated. The study is to investigate the feasibility of four different double cropping systems (Maize-maize; maize-cowpea; rice-rice and rice-cowpea) under no tillage (chemical weed control and hand tillage) and conventional cultivation. The root-knot nematode population dynamics is being monitored under the cropping system.

ROOT-KNOT NEMATODE INTERACTION WITH OTHER SOIL BORNE ORGANISMS

OBJECTIVES

(1) To determine the effect of root-knot nematode-fungi interaction on the host and disease development.

(2) To determine the effect of nematode-nematode interaction on population of nematode.

(3) To determine effect of nematode interaction on the host.

Experiments on interaction of root-knot nematode, M. incognita and Helicotylenchus pseudorobustus singly and in various combinations as regards time of inoculation on cowpea (cvs. Mak 1/1 and Ife Brown) and tomato (cvs Rossol and Ife 1) were conducted. H. pseudorobustus alone caused 16% reduction in the top growth of Ife Brown. It also reduced the pathogenic effect of M. incognita on Ife Brown when both were in combination. M. incognita alone caused 34% reduction in the top growth of Ife Brown.

H. pseudorobustus was also found to be pathogenic on tomato cvs Rossol and Ife 1. Also H. pseudorobustus appeared to repress the pathogenicity of M. incognita on Ife 1 when both were in combination. Plans are in progress to study interaction of root-knot nematode and Rhizoctonia solani on cowpea and tomato and also interaction of root-knot nematode and Fusarium oxysporum f. tracheiphilum on cowpea.

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ROOT KNOT IN NORTHERN NIGERIA

J. J. Smit & W. S. Bos

The earliest records on the importance of root knot in northern Nigeria are by W.R. Wilson (1962). He found Meloidogyne incognita (both 'acrita' and 'incognita'), M. javanica and M. arenaria*. He also mentioned many host plants, including new weed hosts. Wilson made some soil sterilisation trials with DD and Nemagon, in tomato and carrot fields. He recommended the use of Nemagon 20% granular, at 200 - 240 lbs/acre, or 4 oz/5 square yards, 2 weeks prior to planting. Since the, no other records of M. arenaria have been made from this region.

From 1959 - 1965 an extensive survey was made of the Nigerian nematode fauna, by F.E. Caveness. He sampled mainly in southern and Eastern Nigeria, and no records for the northern parts are given in his reports. In 1972 J.J. Bridge made a survey of the nematode fauna of irrigated crops in northern Nigeria. He found predominantly M. javanica, but also M. incognita. Root-knot was found in about 50% of all fields sampled.

One year later, in 1973, a nematology unit was set up in Samaru. Its first objective was a survey of all plant parasitic nematodes in northern Nigeria with emphasis on irrigated crops. Nematology is now taught as an integrated part of the agricultural courses at both BSc. and MSc. level. The importance of root knot nematodes is specifically stressed. A few research projects on root knot have been undertaken, which will be given in more detail.

1: Trials with crop rotation on irrigated lands

The objective of these trials is to determine the effect of various crops that are important in the region on the nematode populations present, and to see how long it would take before root knot nematodes would establish themselves in these fields (in the beginning there was no root knot found). In one of these fields, at Dadawa, a new, large irrigation project, root knot was found this year for the first time, two years after

* identifications by A. G. Whitehead.

starting the trial. (M. incognita and M. javanica were found in other fields of this project).

2: On the Jos Plateau, a soil sterilisation trial was laid out using DD at 300 and 600 l/ha. Tomatoes and potatoes were the crops grown, both susceptible to root knot attack. The tomatoes suffered heavily from fungi, but in the potatoes the results were encouraging. The general appearance of the tubers had much improved in both treatments as compared with the control, and especially in the 600 l/ha treatment the yields were higher, by about 50%.

Everywhere on the traditionally irrigated lands ('fadamas') farmers wish to grow as many crops of tomatoes as possible, since they form a profitable crop, and even low yields still make good money. The inclination of the average farmer to practise crop rotation is low. Root knot nematodes are found in almost every fadama field so they constitute a real problem. Recently a huge tomato seed multiplication scheme has been started by the Nigerian Government. Over 300 kg of seed have been purchased, most of which is to be multiplied in the North. If indeed this scheme succeeds in an enormous increase of the land under tomatoes, it seems obvious that root knot will become an even more important and constant danger.

Onions and wheat have often been mentioned as capable of reducing root knot populations. To check this some tests were made, including six varieties of wheat, and three local onion selections. The effect of three root knot resistant tomato varieties was also tested: Rossol, Ronita and Roma VFN. Only at high population levels were wheat and onions shown to reduce the root knot population level, at low and moderate levels (200 larvae / 100 ml soil) there was at least maintenance of the level, often an increase. Strangely enough the tomato variety Ronita appeared to be a good host, almost as good as the control plant Roma VF. The reason is sought in the fact that Ronita has been propagated in Samaru since 1970, without importation of any new seed.

The new, large scale irrigation projects that are being developed in the North, will no doubt all become heavily infested with root knot unless certain precautions are taken. Many crops that are grown on these lands are capable of sustaining root knot populations. The best method to control these nematodes seems to be the introduction and development of resistant varieties. This alone however is not enough, there remains a role for the extension services to educate the people concerned. We have the example of a large tomato paste factory and farm, where 80% of all tomatoes that were grown were a resistant variety 'Rossol', but where in the field

resistant and susceptible varieties were 'interplanted', and also the farm was just big enough for the large factory so that there was no room for rotation.

THE STATUS OF ROOT KNOT NEMATODES IN THE EASTERN STATES OF NIGERIA

R. O. Ogbuji

Although several plant parasitic nematodes are available for study in the eastern areas of Nigeria, it is the root-knot nematodes that engage the greater attention yet. This is so because of our assumption that root-knot nematodes are the public enemy number one and must more sophisticated partners in crime with other plant pathogens. They are distributed in the four eastern states of Nigeria - Anambra, Cross River, Imo and the Rivers States. Their host range is long. Commercial root crop farmers, fruit and vegetable growers, are now facing their most serious problems for the future.

The effects of the root-knot nematodes upon host crops depend upon a number of factors but can be summarized as follows:

(a) dwarfed or stunted plants of no economic value;

(b) reduced yields because of the low level of nutritional input; and

(c) reduced returns because the pests inhabit and contaminate marketable products.

So, we have here a loss, actual or potential amounting to millions of Naira and certain to continue every year thereafter. Physical factors are suitable for rapid build-up of root-knot nematode populations: temperature and moisture are adequate; soil texture is somewhere between clay and sand. It is quite probable we have indigenous soil infestations. The species most common is Meloidogyne incognita; in few cases M. arenaria has been found. These pests show unique adaptations for survival and distribution.

Basic survey studies on the damage caused by the root-knot nematodes indicate that the problem is most acute in places like the University farms, farms in agricultural stations, demonstration farms in schools and colleges (high schools), and in farm settlements. As one moves from these 'modern methods' agricultural centres to the peasant farms in and around the villages, the status of root-knot nematodes (in terms of damage to crops) diminishes. Still one has to reach those peasant farms located right in the

in the bush far away from the villages. It could mean winding one's way through foot paths, three to four kilometres from village centres. In those farm's one could find that most crops there are relatively free from root-knot damage, or just slightly infected.

What I am trying to say here is that in the eastern areas of Nigeria, cultural practices in traditional agriculture appear to disfavour or discourage rapid root-knot nematode build-up, in contrast to what obtains in locations where 'modern agriculture' is practised.

For those who are unfamiliar with traditional agriculture in the eastern areas of Nigeria, I will attempt to describe in a nutshell what are involved:

(1) Cultural practice in traditional agriculture allows for bush clearing by manual labour early in the dry season; tree branches are cut down. When the cleared area has become dry, it is set on fire and burned out in roaring flames. The heat generated in this process is enough to physically eliminate soil pathogens including root-knot nematodes.

(2) Another feature in the traditional farming system is the fact that distant farms are not cropped every year. Shifting cultivation is the rule. When a piece of land is cropped in one year, it is left under fallow for upward of four years before it is cropped again. During this rest period the character of the vegetation changes from one type to another. These changes, ecological in nature, are probably detrimental to nematode welfare in terms of its finding suitable and permanent hosts to subsist on. Ultimately, the land is going to be cleared again and burned prior to planting crops. Our local farmers know that shifting cultivation is done to avoid over-cropping of one piece of land. It is not practised consciously as a method to control soil pathogens.

(3) One more feature in traditional agriculture is the interplanting of crops and intercropping. A farmer's interest is to harvest different crops grown on the same piece of land. Interplanting of crops is an immitation of what obtains in nature. A natural vegetation comprises plants of different taxonomic descriptions.

For the past three years, I have been visiting what we usually refer to as 'back-yard farms' belonging to village farmers in our rural areas;

I have examined several plant roots from each farm. Any one farm is usually planted up with different crops. For example, on the same piece of land, okra and corn and tomato and cassava and telfairia, etc. could be grown in that random fashion. Yields from all these crops are reasonably good. Nematode damage to the usually susceptible crops like tomato, okra etc is minimal. But in nearby schools, colleges and other commercial farms, these same susceptible varieties are so severely infected that plants are dwarfed and yields reduced - in spite of adequate husbandary.

I have tried to point out that root-knot nematode problems are more acute in certain institutions of learning or research involved in agriculture. These problems will intensify as more and more people abandon the old agriculture to the intensive, modern farming methods. Problems, sometimes, arise with change. I assume that modern day agriculture often dictates repeated plantings of susceptible crops on an infested soil. This kind of modern crop production method could increase rapidly the population level of pests already established. Additional expansion of agricultural production to new lands will result in further establishment of root-knot nematodes as major pathogens. They are spread into new areas through infected planting materials. So, I am looking forward to increased root-knot nematode activity in this country.

All our governments are emphasizing the need to grow more food; that increased production is required to meet increased demands. The annual losses caused by root-knot nematodes could be an important factor in deciding the difference between success in the national objective and failure. Where then do these nematodes and the control measures fit in the future? Soil fumigation is a technical procedure involving several factors insure effective control. Most of our farmers are ill equipped to take to this.

Resistant varieties, therefore, provide the ideal means for nonchemical control of nematodes. Our research emphasis will shift towards an ecological approach. Probably, the traditional farmers by their planting system are following this approach already. Their main problem is being less selective in planting materials used. To aid their efforts, I would interest myself more on screening tests of our local crops against root-knot nematodes. A sound breeding programme of our crops could produce stable and effective resistance to most root-knot nematode problems.

Finally, I like to think that interplanting crops as done by our local farmers may have been helping in checking rapid build-up of root-knot nematodes in their farms. Accepting and adapting this system in modern agriculture may prove a down-to-earth method of controlling root-knot nematodes.

ROOT KNOT NEMATODES IN GHANA

O.B. Hemeng and B.S. Hemeng

Root-knot nematodes attack many crops of economic importance in Ghana. These include yams, tobacco, kenaf and jute. Field and green house studies have shown marked variation in susceptibility within varieties of a particular crop except groundnut varieties which have all proved resistant.

Among 14 yam varieties screened only var. 'Dendenkuli' showed slight resistant while the rest were susceptible.

Tobacco varieties 'Mandole', 'Brown leaf', 'KY 160', 'KY 171', 'DF 300' and 'NC 95' were slightly resistant. The remaining varieties 'KY 151', 'KY 170' and 'Dark Heavy Western' were susceptible.

Out of twenty varieties of fibre crops (kenaf, jute and roselle) studied only roselle var. 'Thai 17' was resistant.

Although nematicides like D-D, Nemagon and Vapam provided effective control of root-knot nematodes attacking tomatoes, mulching with dead vegetative matter provided better yield increase than the nematicides.

Occurrence of Root-knot nematodes in Ghana was first reported in 1953 by Edwards (4) who found a high infestation in a tomato field near Accra where total crop failure was attributed to these nematodes. Further investigations revealed that many plants were attacked including *Lactuca sativa*, *Brassica oleracea* var. *capitata*, *B. pekinensis*, *B. rutabaga*, *B. rapa*, *Cucumis sativus* and *Manihot esculenta*. Other crops were *Phaseolus multiflorus* and *Solanum melongena* var. *ovigerum*. The rest were *Capsicum annum* and *Daucus carota*. It was also stated that the life cycle of the nematode took 30 days to complete on turnip, swede and cabbage.

The results of subsequent work showed 14 new hosts which had not been previously known (5). It was reported that root-knot nematodes had been long established in the country because the hosts included common indigenous weeds. The report added that *M. esculenta*, *Hibiscus sabdariffa* and *C. annum* showed less galling than the introduced crops.

Studies on the resistance showed that galls failed to develop on the roots of some plant in the presence of the nematodes (5). The list of resistant hosts included Arachis hypogaea, Crotolaria retusa, C. spectabilis, Gossypium hirsutum, G. barbadense, Oryza sativa, Trifolium resupinatum, Centrosema pubescens, Medicago sativa and American white variety of Zea mays.

Peacock (7,8,9,10) found that tomato was the most susceptible host to Meloidogyne incognita acrita followed by cowpea, tobacco, soya bean and maize. Among other crops Peacock's report confirmed the resistance of A. hypogeae to root-knot nematodes.

It was estimated that 10 to 12 generations might occur in a year, because the life cycle was completed on the roots of tomato and cowpea in 28 days at 26 - 31°C.

In the sixties attempts were made to grow potatoes in selected areas of the country where conditions appeared to be favourable for the crop. At Mampong in the Ashanti Region, there was severe root-knot nematode attack on the potato tubers and the yield loss was estimated to be 33% (3).

Addoh (2) reported that among the 141 plant species examined, 15 were very susceptible, 59 susceptible, 52 slightly susceptible, and 15 moderately resistant. The list showed that very susceptible hosts previously unknown included okro, yam and kenaf. The susceptible hosts were pigeon pea, cotton, lettuce, cabbage and cauliflower. Some of the slightly susceptible hosts were oil palm, onion, and sugarcane. The moderately resistant hosts included banana and resistant hosts were jute and rice. A. hypogeae was again found to be resistant.

The species of Meloidogyne were M. incognita, M. arenaria and M. javanica.

CONTROL MEASURES

Chemical control of root-knot nematodes was started in the late fifties (7,8,9,10). The results of field experiments showed that top dressing with ammonium sulphate, muriate of potash, superphosphate, calcium cynamide and urea did not have any marked effect on the infection. Application of D-D, EDB and tetrachlorobutadiene significantly controlled the nematodes. EDB and tetrachlorobutadiene produced persistent effect while D-D was effective only for short period in the life of the tomato plant. The influence of these chemicals on the yield was not mentioned.

It was also found in pot experiment that desiccation adversely affected the larvae and egg masses of the nematodes in the absence of the host. Excessive moisture could not be tolerated by the egg masses. The effect of these extreme conditions was minimum in the presence of the host plant. It was concluded by field experiments that turning over the soil twice per week for 30 days during the dry season remarkably reduced the soil population.

Addoh and Amanquah (1) reported that results of field trials conducted at Kwadaso near Kumasi showed that Temik effectively controlled root-knot nematodes on kenaf but there was no corresponding increase in the yield.

Attempts were made in 1975 to compare the effect of nematicides and cultural practices on the infection of M. incognita and growth of tomato plants (6). The chemical treatments were D-D at 54.71/ha, Nemagon at 18.7kg/ha and Vapam at 90.9 l/ha. The cultural practices were trash burning after ploughing, mulching after ploughing and trash burning, and ploughing without burning (control). The results of the experiment in the major cropping season showed general low infection of root-knot nematodes yet there were significant differences in plant growth and yield. D-D reduced the infection by 75% while Nemagon and Vapam reduced the infection by about 50%. During the minor season, a period of good tomato crop, there were significant differences in plant growth, yield and nematode infection but the differences in infection between the nematicides were not significant.

Mulching in the two seasons' experiments produced the highest yield although the infection was also higher than any of the other treatments. All the treatments improved yield except Vapam which suppressed yield.

Varying dosages of Nemagon were applied in the field for the control of root-knot nematodes of kenaf (Hibiscus cannabinus L.) in 1975. The rates were 58.2kg, 174.7kg, 291.2kg, 465.9kg per hectare. Untreated plots served as control.

Though the infection was low, all the dosages markedly reduced it. The highest reduction in infection, 67%, occurred when the dosage 353kg per hectare was applied, and there was a corresponding yield increase of 38.4%.

Since 1974 preliminary investigations have been carried out at Kwadaso near Kumasi to screen varieties of Groundnut, Yam, Tobacco and Fibre crops for resistance to M. incognita. The experiments were carried out in soil cultures of M. incognita in the green house and in

the field. The infection assessments were done at least 30 days after planting. The infection rating ranged from 0 (immune) to 5 (very susceptible). All the 49 varieties of groundnut tested in the green house were immune.

Fourteen varieties of yam were tested in potted soil in 1975. Var. 'Dendenkuli' was slightly resistant. Vars. 'Dendenpuka', 'Afun', Water yam (red), 'Tem' and 'Kplongo' were very susceptible. The susceptible varieties were 'Nananto', 'Nkanfo' and Water yam (white). Vars. 'Liliya', 'Nyamasu' and 'Asubayere' were moderately susceptible.

Varieties of tobacco tested in the field were ten. Varieties 'KY 151', 'KY 170' and 'Dark Heavy western' were susceptible, var. 'Black mammoth' was moderately susceptible. Vars. Mandole, Brown Leaf, 'KY 160; 'KY 171' and 'NC 95' were slightly resistant.

Out of the twenty varieties of fibre crops tested in the field only Roselle 'Thai 17' was immune. All the 13 varieties of kenaf were susceptible except var. 'H-GT.3-BT5(2)' which was very susceptible.

Four varieties of Jute were moderately susceptible and two were susceptible.

DISCUSSION

Evidence so far collected show that root-knot nematodes are ubiquitous in Ghana and they attack many crops of economic importance. There is a varied range of host susceptibility.

In the past, vegetables were considered to be the hosts which were mostly damaged. Recent investigations, however, suggest that other crops like yam and kenaf, are also seriously damaged therefore, further work should be done to elucidate host susceptibility and the nature of resistance found in some crops, especially groundnut varieties, most of which appear to be resistant.

The scarcity of information on the biology of root-knot nematodes in Ghana suggests that this aspect of the problem has been neglected and should be given due attention. Factors like temperature, moisture and humidity are variable between the southern and northern parts of the country. Studies on these factors in relation to the development of the nematodes will elucidate the behaviour of the nematodes throughout the year.

The application of chemicals is at the moment, the only measure for controlling these nematodes in the country, but the high cost discourages the farmers from using them. Therefore, emphasis must be placed on the studies of cultural practices, such as burning, mulching, fallowing and the use of resistant crops to determine their influence on root-knot nematodes. The findings will facilitate provision of specific recommendations for adoption by the farmers.

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MELOIDOGYNE RESEARCH AT THE DEPARTMENT OF CROP PRODUCTION, UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

B. M. S. Hemeng

The Nematology Section of the Department of Crop Production, Faculty of Agriculture, University of Science and Technology was established by Ir. Casper Netscher in 1960, continued by R. Mulder 1963 to 1966, then by Dr. Kankam, Plant Pathologist, 1967 and by P. G. Addo in 1968. The only record on research on Meloidogyne spp. was by Addo (1) which was the completion of work started at the Crops Research Institute.

In 1970 Dr. J. C. Gupta initiated research on 1) Screening nine tomato cultivars for resistance against Meloidogyne species. He found seven of the nine cultivars were highly susceptible to Meloidogyne attack and the cultivars Ronita and Harvester comparatively resistant. No further details of the work could be found. 2) Studies on the nematode complex of cocoa and found M. incognita to be one of the nematodes attacking cocoa. 3) Gupta found Meloidogyne spp. among the chief nematodes attacking banana, others being Helicotylenchus spp. and Pratylenchus spp. 4) Screening of local germ plasm of garden eggs for nematode resistance. No details on this work survive. 5) In 1974 Gupta supervised a student project on "Studies on the effectiveness of various nematicides in the control of plant-parasitic nematodes including Meloidogyne spp. under tropical conditions." The nematicides tested were Telone, Nemagon, Ditrapez, Furadan and Vapam. Telone at the rate of 24 ml/m^2 (ai) was found to be the best nematicide followed by Furadan, Vapam was found to be the least effective nematicide.

In October, 1975 I took the seat of nematology lectureship. Research into the root-knot nematode problems of the Department of Horticulture has been initiated with the aim of working out a rotation system for the forest zone of Ghana. Later the work will be initiated in the other regions of the country using non-susceptible cash crops with susceptible crops.

Work done since March 1976, the beginning of the rainy season, is as follows:

A survey of the weedy land for root-knot nematode infection of weeds was undertaken with the following being found infected:

Engeron floribundus, Portulaca quadrifida, Amaranthus viridis, Tridax procumbens, Vernonia cinerea, Celosia trigyna, C. argentea and Ageratum conyzoides. The infected roots were boiled in lactophenol-acid fuscin and the female nematodes dissected from the roots. They are awaiting identification. Soil samples were taken and examined for other forms of plant-parasitic nematodes. Improvised Whitehead and Hemming sets were constructed and tested for efficiency in extracting plant-parasitic nematodes. There were three types, two were constructed by me and the third was in use at the Department as a modified Baermann funnel. The metal basket and the dissecting dish adaptations collected the highest numbers of all kinds of nematodes and Meloidogyne juveniles at 22°C than the other set at 22 or 25°C.

Among the nonhost or resistant plants listed by Addo (1) the following are cash crops: rice, cotton, groundnuts, banana, cocoa, Urena lobata and Stylosanthes gracilis. I propose to use some of the immune or resistant crops to work out a rotation scheme for the main agricultural regions in Ghana for the control of the root-knot nematode. I also intend to screen the 16 local legumes for resistance against Meloidogyne spp.

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REPORT ON THE ROOT KNOT NEMATODE SITUATION IN LIBERIA

A. A. van Nieuwenhuyzen

Of course root-knot nematodes exist in Liberia too. So far the major damage observed is in horticultural crops. For instance, almost all of the locally grown lettuce for sale in the supermarkets shows serious infestation of these nematodes.

The picture we are giving you on the root-knot nematodes situation in Liberia is far from complete. In general Crop Protection in Liberia is still in a rather initial stage. For several years plant pathologists have been working at the Firestone Rubber Plantations at Harbel, but their working field was restricted to rubber culture. In 1971 a plant pathologist joined the FAO/UNDP Project at the College of Agriculture and Forestry at the University of Liberia and in 1975 the first Liberian plant pathologist took up his work at the Ministry of Agriculture. Several persons will be sent for further studies in plant pathology in due course and we hope that within a few years enough workers in the various fields of crop protection will be available to cope with the many pests and disease problems existing in Liberia.

Techniques.

For nematology work we are using the following techniques at the moment:

Extraction of nematodes from plant material.

This is done by the blender-cotton wool filter method (7). The infested roots are washed thoroughly and cut into pieces of about 1-cm length. After mixing, a sample of 10g is placed with 100 ml water in a domestic blender. After blending for five seconds, the suspension is poured over a cotton wool filter into a sieve. This sieve is placed in an extraction dish with water touching the sieve. After two days, the sieve with the filter is removed and the suspension is analysed.

Extraction of nematodes from the soil.

For this work we use a modification of Seinhorst's Erlenmeyer method (5). The sample is mixed thoroughly and a subsample of 500ml is

placed in a beaker with tap water. After stirring this suspension is poured over a domestic sieve to remove coarse material. A one liter bottle (A) is filled with the suspension and a plastic funnel is attached to it. Flask A is placed on top of flask B which is filled with tap water. After 10 minutes flask B is placed on top of flask C, also filled with tap water. The soil particles will settle in flask C, whereas most nematodes will be in flask A and B. After three minutes the contents of flasks A and B are poured over a bank of seven sieves with a pore size diameter of 50 micron. The catch of these sieves is washed into a plastic pan. This suspension is poured onto a double cotton-wool filter in a 175 micron pore size sieve. Sieve and filter are placed in an extraction dish containing 90ml tap water. The next day the sieve is removed and the suspension is ready for analysing.

Preparing semi-permanent mounts.

For mounting nematodes we follow a method described by Goodey (1). The nematodes are collected in a small drop of water on a watch glass; FA4-1 heated to 90°C is added. The nematodes are transferred to a fixation dish with FA4-10, a coverslip put on top, and left overnight. Then the nematodes are removed in a drop of warm, vaporizing lactophenol with 0.01% cotton blue and allowed to cool. After which the nematodes are mounted in a small drop of lactophenol.

Preparation of perineal patterns for the determination of <u>Meloidogyne</u> species from roots.

After the roots are thoroughly washed, the swollen females are carefully removed from the root galls with a dissecting needle under a dissecting microscope. The females are pierced carefully at the cervical and are cut open. As much body content as possible is removed by pressing the body in water on a slide. The remaining tissues are kept in cold lactophenol with 0.03% cotton blue for a period of 24 hours at room temperature. The stained tissues are transferred to a very small drop of lactophenol on a perspex slide and the posterior end is cut off with a scalpel. Inner tissues is removed carefully with a needle and the ends are trimmed carefully so that the main piece is about 5-10 times the perineal pattern. The perineal patterns are transferred to a drop of lactophenol cotton blue 0.03% on a glass slide. About 10 patterns are mounted together with three pieces of glass-fibre in lactophenol with 0.03% cotton blue.

Observations.

Up till now we have observed root-knot nematodes on the following host plants:

Cabbage	(Brassica oleracea Var. capitata)	M. incognita acrita
Cowpea	(Vigna sinensus)	M. javanica
Eggplant	(Solanum melongena)	M. spp.
Lettuce	(Lactuca sativa)	M. incognita acrita
Okra	(Hibiscus esculentus)	M. incognita acrita
Onion	(Allium cepa)	M. incognita acrita
Tobacco	(Nicotinia tabacum)	M. spp.
Tomato	(Lycopersicon esculentum)	M. javanica

Please note that these are only the findings from three locations. We are convinced that an intensive survey will result in more Meloidogyne species and many more host plants.

Control.

Several nematocides are imported into Liberia but they are used only incidentally. Liquid nematicides are difficult to apply which results in the fact that mainly Mocap (granular) and Basamid (powder) are used. However the main restriction is the high cost of these chemicals for the farmers. Resistant varieties are not being grown purposeful yet.

Conclusion.

Little is known as yet concerning the root-knot nematode, Meloidogyne spp. situation in Liberia. During a few investigations so far only two species have been found. However a more intensive program will most probably show more species and a wider host range.

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ROOT KNOT PROBLEMS IN IVORY COAST

G. Merny

A preliminary list of nematodes associated with plants in West Africa was published in 1960 by LUC and de GUIRAN. They identified Meloidogyne spp. associated with 115 plants belonging to 38 families from the Ivory Coast. Since then, only a few additional hosts have been added to this list.

The species of Meloidogyne existing in Ivory Coast are very polyphagous and their host range covers a large number of different plants which includes almost every kind of cultivated food and fiber crop.

SPECIES OF PARASITES

From 1962 to 1970, NETSCHER studied the taxonomy of the Meloidogyne found in the Ivory Coast. He collected a large number of strains all over the country and studied their morphological characters, especially perineal patterns and size of the larvae. He recognized the presence of three species:

M. incognita
M. javanica
M. arenaria

Some of his observations of morphological characters appeared to be conflicting with those in other parts of the world.

In 1970, all the collections were removed to Dakar where the fundamental work on root-knot nematodes is now concentrated.

HOSTS

Meloidogyne can be found parasitizing every kind of crop although their economic importance is not fully understood. There are many Meloidogyne spp. commonly associated with wild plants as seen in LUC and de GUIRAN's list but we will consider only those of cultivated crops.

COVER CROPS - Most of them belong to the leguminosae family and most of them are commonly very susceptible to Meloidogyne. In

Ivory Coast, the following species have proved to be hosts.

Cajanus cajan, Calopogonium mucunoides, Canavalia ensiformis, C. gladiata, Centrosema plumieri, C. pubescens and Pueraria phaseoloides.

The use of cover crops can be a factor of maintaining high populations of Meloidogyne in a field for succeeding crops. The above species must be used with care in crop rotations.

FOOD CROPS

Meloidogyne has been observed in the roots of "bread tree" (Artocarpus incisa) near Abidjan but this big tree seems to be very tolerant and the importance of this crop in Africa appears relatively low.

Soybean (Glycine soja) is frequently and highly parasitized and Meloidogyne may be a problem if commercial production increases in the Ivory Coast.

Lowland rice is generally not attacked. However, root-knot nematodes are frequently found in upland rice fields. In one case, recently, high populations of parasites have been observed on rice roots, in one field, in the Central Region. It seemed restricted to a small area but an extensive survey will be started in 1977.

Maize is rarely attacked by Meloidogyne spp.

TUBER CROPS

The three main African tuber crops have been observed in Ivory Coast, to be hosts of Meloidogyne spp.

Sweet potato (Ipomoea batatas) is attacked in the south of the country, little is known about its economic importance.

Cassava (Manihot esculenta) is sometimes attacked but root-knot nematodes are minor parasites of this crop, for which the main parasite is Pratylenchus brachyurus

The same has been observed for yam (Dioscorea esculenta). It is known that Meloidogyne spp. attack yam tubers and may cause severe losses but this has almost never been observed in the Ivory Coast where

another parasite, Scutellonema bradys, is prevalent in yam tubers.

FRUIT CROPS

Pineapple (Ananas sativus) when grown in cleared land is severely attacked by Meloidogyne spp. but, as the season progresses, Pratylenchus brachyurus becomes the dominant species and is the most important parasite of pineapple in the Ivory Coast. Almost all the commercial production of pineapple is fumigated with DBCP at planting time and, again, about 4 months after planting.

Banana: Root-knot nematodes are very frequently observed in banana roots but their multiplication is limited by the development of Radopholus similis which is the dominant parasite of banana in the Ivory Coast. Almost all the banana plantations are treated with DBCP or phenamiphos.

Papaw (Carica papaya) is in general highly parasitized though it appears rather tolerant. The common practice of growing papaw trees among vegetable gardens is very bad because it provides a continuing source of high populations of root-knot nematodes to attack the vegetable crops.

FIBER CROPS

Although cotton (Gossypium spp.) is commonly attacked by root-knot nematodes in America and in some African countries, like Central African Republic, where the presence of Meloidogyne is related to the severity of Fusarium wilt, the occurence of root-knot nematodes on cotton plants is occasional in the Ivory Coast.

On the other hand, roselle (Hibiscus sabdariffa) is heavily infected and this appears to be a limiting factor for the development of this crop in the north of the country.

COMMERCIAL CROPS

Although Meloidogyne spp. have been observed in the roots of tea, coffee (var. robusta) and cocoa, they are only minor problems in the production of these crops.

Tobacco is commonly infected and the yield losses, though not precisely known, are obviously important in many cases.

Sugarcane is known to be a host of Meloidogyne spp. all over the

world. Little is known about nematodes associated with sugarcane in Ivory Coast but, in Upper-Volta, about 200 kilometers to the north of the main sugarcane area of Ivory Coast and in similar ecological conditions, root-knot nematodes are commonly observed in sugarcane fields where they seem to cause yield losses.

The absence of root knot on groundnut (Arachis hypogaea), commonly infected in America, is worth being noted and is one of the inconsistances with species identification.

VEGETABLE CROPS

Root-knot nematode is a major problem in all vegetable growing areas.

Tomato, lettuce, melon, carrot and bean (Phaseolus vulgaris) are the most severely damaged of the garden vegetables.

Two local vegetables, bitter tomato (Solanum incanum) and okra (Hibiscus esculentus) are often highly infested and the yield must be reduced by this infection.

Cabbage seems to be relatively resistant and, when infected, tolerant with no effect on yield.

In the Ivory Coast, infection of onion and leek is rare.

CONTROL

RESISTANT VARIETIES - Few resistant varieties have been developped in vegetable crops. One resistant variety of tomato, "Ronita", has been tested and proved to be effective against the strains of Meloidogyne present in two vegetable growing areas: North and Center. Unfortunately, this variety has not all the qualities required for the commercial market and its use will be limited. Continuous use of the resistant varieties without crop rotation soon leads to the development of pathotypes of the nematode which will overcome the plant resistance.

CROP ROTATION

In the areas where vegetables alone are grown, a crop rotation system, effective against root-knot nematodes is difficult to maintain since the only resistant plants are onion, leek and to a lesser extent, cabbage and

one can not avoid growing susceptible plants one after the other in the same soil.

In large areas where commercial tomato production for canning is planned, the recommended rotation will be one year tomato and two years rice. The Meloidogyne populations will be limited so that commercial production will be extended for a number of years.

CHEMICAL CONTROL

During the last two years trials have been made in vegetable crops, especially on tomato, melon and carrot which included a fumigant, DBCP, and two non-fumigant nematicides, Carbofuran and phenamiphos.

On tomato, a preplant treatment with DBCP (60 l/ha) has greatly reduced the infection of the roots. A scale between 0 (no root knot) and 5 (roots completely knotted and dead) was rated for each root system. The average was 1.3 for the treated plants as compared to 3.8 for the control. However, the difference in yield was not significant and, in fact, very low. A second trial with DBCP gave the same results. It was concluded that DBCP had a phytotoxic effect on tomato. A trial with DD will be done.

On melon, a trial was made, in 1975, using DBCP at the rate of 60 l/ha applied as a preplant treatment. The application of the product at three different times were compared:

a - the day of sowing
b - 5 days before sowing
c - 10 days before sowing

The average quotations for Meloidogyne infection were:

a: 1.3 b: 1.7 c: 0.56

the difference between c and a and c and b being significant.

The yields, in tons/ha were:

a: 7 b: 10.5 c: 11.5

The difference between b and c is not significant.

Thus, between a and b, there is no difference in the infection but a difference in the yield. Between b and c there is a difference in the

infection but no difference in the yield.

It can be concluded that all three treatments were effective against Meloidogyne but treatments a and b were more or less phytotoxic.

Controls could not be included in the statistical analysis because the infestation was very high, almost all the plants died and no melon could be harvested.

Nonfumigant nematicides were tried on tomato without success but, in a trial in progress, carbofuran gives promising results on carrot.

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

C. Netscher & D. P. Taylor

The Nematology Laboratory of O.R.S.T.O.M. (Office de la Recherche Scientifique at Technique Outre - Mer) was created by M. Luc in Abidjan, Ivory Coast, in 1955. As a result of a survey of Senegal made by C. Netscher in 1964, ORSTOM decided to create another nematology laboratory in Dakar, Senegal, primarily to study nematodes of semi-arid areas. This laboratory was inaugurated in June 1970, and at the present time there is a staff of seven nematologists of whom six are engaged in research concerning the genus Meloidogyne.

A major activity of the Nematology Section of ORSTOM has been to conduct surveys in different African countries to define the most urgent problems in agriculture caused by plant-parasitic nematodes. These surveys established that Meloidogyne spp. were abundant in Madagascar, Ivory Coast, Canary Islands, Congo, Central African Republic, Senegal, Mauritania and the Gambia. A recent survey has demonstrated that Meloidogyne is also frequently encountered in the Cape Verde Islands.

Concerning the distribution of species of Meloidogyne in West Africa, the following picture is provided (identification based on perineal patterns): M. incognita and M. javanica are common in the Congo, Central African Republic, Ivory Coast, Senegal, Mauritania, and the Gambia; whereas M. arenaria is less frequently found. In many cases populations were composed of two species, and often such mixed populations contained individuals showing characters intermediate between the species present.

Since Chitwood reestablished the genus Meloidogyne in 1949 the possibility was created to determine the host ranges of the different species, on the basis of which a crop rotations could be envisaged in soils where the identity of the root-knot nematode was known. However, the occurrence in the field of mixed populations and the presence of individuals possessing intermediate characters necessitated a more profound study of the subject. Therefore, more than sixty single-egg mass populations were established to study their morphology and karyology in order to obtain a better comprehension of intraspecific variation and specific differentiation within the genus.

In addition to the difficulties caused by the great variability of

perineal patterns, information obtained from Senegalese isolates suggested great physiological variability. Therefore, host range studies, including plant species used by Sasser (2) to differentiate between species of Meloidogyne as well as resistant tomato varieties, were made with the single egg-mass cultures maintained in the laboratory. To avoid contamination between different isolates, they were aseptically reared on tomato root cultures. Unfortunately for this study, all these monoxenic cultures were accidentally destroyed before all measurements and tests were completed. At the present time a less ambitious program has been started in which 14 single-egg-mass cultures will be compared. Nevertheless, a number of measurements of juveniles from different isolates was made. These showed that contrary to the findings of Whitehead (4) it was not possible to distinguish between M. javanica and M. incognita on the basis of juvenile length because a clear overlapping of this character existed. When comparing lengths of juveniles produced by sister females (derived from the same eggmass) of a M. javanica culture, using Whitehead's criterion, it was shown that certain females belonged to M. incognita whereas others belonged to M. javanica. This result was rather astonishing, because in the related genus Heterodera it had been shown that, using the same techniques, stabilization of the variability of juvenile length was observed after four generations of inbreeding. Inbred lines of this amphimictic species were obtained by having females fertilized by their brothers during four successive generations.

Great differences exist between the reaction of different Meloidogyne populations towards the same crop because of interspecific variation and intraspecific variation. For example, only three of six isolates from Florida of M. arenaria, the "peanut root-knot nematode," were parasitic on peanut; and resistance-breaking biotypes ("B-races") of M. incognita and M. javanica have been described on resistant tomato by Riggs & Winstead (1) and by several other workers since.

Because of the great practical importance of this subject experiments were carried out in Senegal involving plants having potential use in crop rotations in vegetable production. Although results in general agreed with those of Sasser, a number of exceptions must be mentioned: M. arenaria from Senegal has consistantly failed to reproduce on peanut; strawberry originally not attacked in a field infested with M. javanica became heavily infected after this crop had been grown continuously for 12 months. Furthermore, resistance-breaking biotypes of both M. incognita and M. javanica were developed on resistant tomato.

Detailed studies were undertaken to better understand the mechanism of resistance or susceptibility to species of Meloidogyne in several plants including peanut, millet, Hibiscus sabdariffa and resistant tomato.

Peanuts are readily penetrated by juveniles of all isolates of Meloidogyne tested, including those containing M. arenaria. The juveniles provoke a hypersensative reaction within the root which results in the death of the nematodes. Plants that are heavily invaded are severely damaged by the extensive root necrosis. Population studies have shown that Meloidogyne populations decrease more rapidly in the presence of peanut than when no plants are present. Heavily infested fields are virtually cleaned of root-knot nematodes by a crop of peanuts, and a susceptible crop grown after peanut performs much better than when grown after a susceptible crop.

Although millet reduced populations of Meloidogyne in the field, it was found to be a host even though development rate and rate of reproduction were low.

Hibiscus sabdariffa, reported to be resistant to Meloidogyne, was classified as a poor host supporting limited reproduction of both M. incognita and M. javanica. Histological examination of the basal portion of the stem of H. sabdariffa grown in Meloidogyne - infested soil revealed stem galling, synctial development, and the presence of mature females and egg masses of both species.

The reactions of more than 70 isolates of Meloidogyne on resistant tomato were studied. B-races were selected from 10 of these populations by repeated reinoculation of juveniles recovered from the resistant varieties. One isolate each of M. incognita and M. javanica were capable of attacking resistant tomato immediately although no selection pressure had been exerted by resistant tomatoes. The remaining populations either did not attack the resistant varieties at all or occasionally produced one or two galls each containing a female with an egg mass. Subsequent inoculation of resistant tomato with juveniles derived from these egg masses produced no increase in pathogenicity. In two of the ten isolates from which B-races could be developed, indications were obtained that pathogenicity increased with each generation. B-races could be obtained from certain single egg mass cultures.

Two tomato varieties containing different genes for resistance

(Small Fry with gene L Mi R_1 and Nematex with gene L Mi R_2 (3) were tested against several Meloidogyne isolates. A B-race capable of attacking both varieties was observed in one isolate each of M. incognita and M. javanica. In addition, a wild population of M. incognita was found that was capable of attacking Small Fry but not Nematex indicating that even within B-races physiologic variation exists. A systematic search for biological races capable of attacking the different known resistant genes in tomato is in progress.

The variability in behavior towards resistant tomato shown by certain single egg mass cultures as well as in variability in juvenile length previously mentioned, suggests that in parthenogenetic species of Meloidogyne mechanisms, yet unknown, exist that assure sufficient variability to enable the organisms to adapt to changing environmental conditions.

In order to study the relationships between species and the physiological variations (biotypes) within species, an enzymatological and serological research product was initiated using the Meloidogyne material available at Dakar. Research was initiated, techniques developed and tested, but the untimely death of the researcher forced the abandonment of this work.

Survival of Meloidogyne under the semi-arid conditions of Senegal has been studied since 1972. Climatically there is a four-month long wet period followed by a dry season of eight months. Before dependable results could be obtained, an accurate method of recovering the maximum numbers of Meloidogyne had to be developed. All extraction methods had been tested and were unsatisfactory because in Senegal egg masses with adhering sand particles were associated with the large sand particle fraction of the soil. A method combining elutriation and mist extraction techniques was developed to recover active juveniles, individuals present as eggs in egg masses and loose eggs. Using this technique Meloidogyne population dynamics were followed during the dry season in fields containing, or not containing, roots from a previous crop infected with Meloidogyne. Population counts taken at regular intervals during the dry season indicate that nematodes disappear rapidly in the 0-20 cm horizon; however, in the 20-40 cm horizon a few Meloidogyne survive a dry season. Evidence indicates that eggs within egg masses are responsible for survival of Meloidogyne in the dry season; juveniles do not survive dry conditions for a long time. Egg masses associated with roots did not possess greater resistance to drying than those found free in the soil.

Field observations suggested that movement of root-knot nematodes was greater than generally believed. Therefore, a program was started in early 1973 in which attraction of Meloidogyne juveniles to plants was studied. Initial results have shown that soil in which plants of resistant or susceptible tomato or peanut had been grown actively attracted Meloidogyne juveniles. In vitro studies showed that Meloidogyne juveniles were attracted to nutrient agar on which tomato roots had been grown aseptically.

Horizontal and vertical movement (migrations?) of M. javanica juveniles was studied in the presence or absence of a susceptible variety of tomato (Roma). Nematodes were placed at different distances from the roots which were isolated by a screen with openings of 35 um that permitted passage of nematodes. Results showed that M. javanica juveniles placed 75 cm vertically and 50 cm horizontally from the roots were capable of penetration in large numbers and that migration was greater in the presence of plants. Juveniles of M. javanica were shown to have a great capacity of movement, with 20% capable of moving vertically 50 cm in three days. In addition, movement towards roots did not appear to be greater in rhizosphere soil than in sterile soil. A susceptible variety of tomato (Roma) exerted a greater attraction than a resistant variety (Rossol).

More recently a program has been initiated to investigate physiclogical aspects of penetration of root-knot nematodes. At the present time techniquesare being developed to measure food reserves (proteins, glucosides and lipids) of Meloidogyne juveniles.

To test the validity of some of these findings some field experiments have been made in Senegal. One example, it was shown that under field conditions resistant tomato varieties yielded 30% more than comparative susceptible varieties when grown in moderately infested soil and that yields of resistant varieties equal those of susceptible varieties grown in fumigated soil.

Comparing development of Meloidogyne in a resistant and susceptible tomato variety growing in parallel rows in an infested field it was shown that under natural conditions all infection sites of susceptible plants were galled and contained giant cells, no necrosis was observed. In the resistant varieties galling and giant cell formation were rare; necrosis occurred at a high percentage of infection sites. Fewer juveniles penetrated in the resistant variety and very few exhibited development. Several B-races were isolated from the resistant varieties.

In Savaigne (northern Senegal) soils of fields of a tomato cannery

were found to be infested with Meloidogyne down to a depth of 1.5 m. Treatments with DD at a depth of 30 cm and with a double dosage (one at 30 and one at 60 cm) did not show any difference in infestation of tomatoes subsequently grown. Both treatments protected one crop fairly well. An equally good result was obtained either by maintaining a clean fallow for three months during the rainy season or by growing a crop of peanut.

A crop rotation trial at Camberene showed that a crop of peanut or strawberry grown in heavily infested land prior to tomato greatly increased the yield potential, as compared with a previous crop of tomato. Incidence of Fusarium was delayed for 20 days in plots where Meloidogyne populations had decreased due to the effect of previous crops.

Results obtained in the field so far are too fragmentary to draw general conclusions, but it may be anticipated that when a continued effort is made to test results obtained in the laboratory in field trials, a pattern of integrated control of root-knot nematode in annual crops may be developed. However, it should be emphasized that the variability of Meloidogyne isolates necessitates that rotation should be developed and tested locally. From our observations so far it has become clear that much emphasis should be placed on prevention rather than curative measures.

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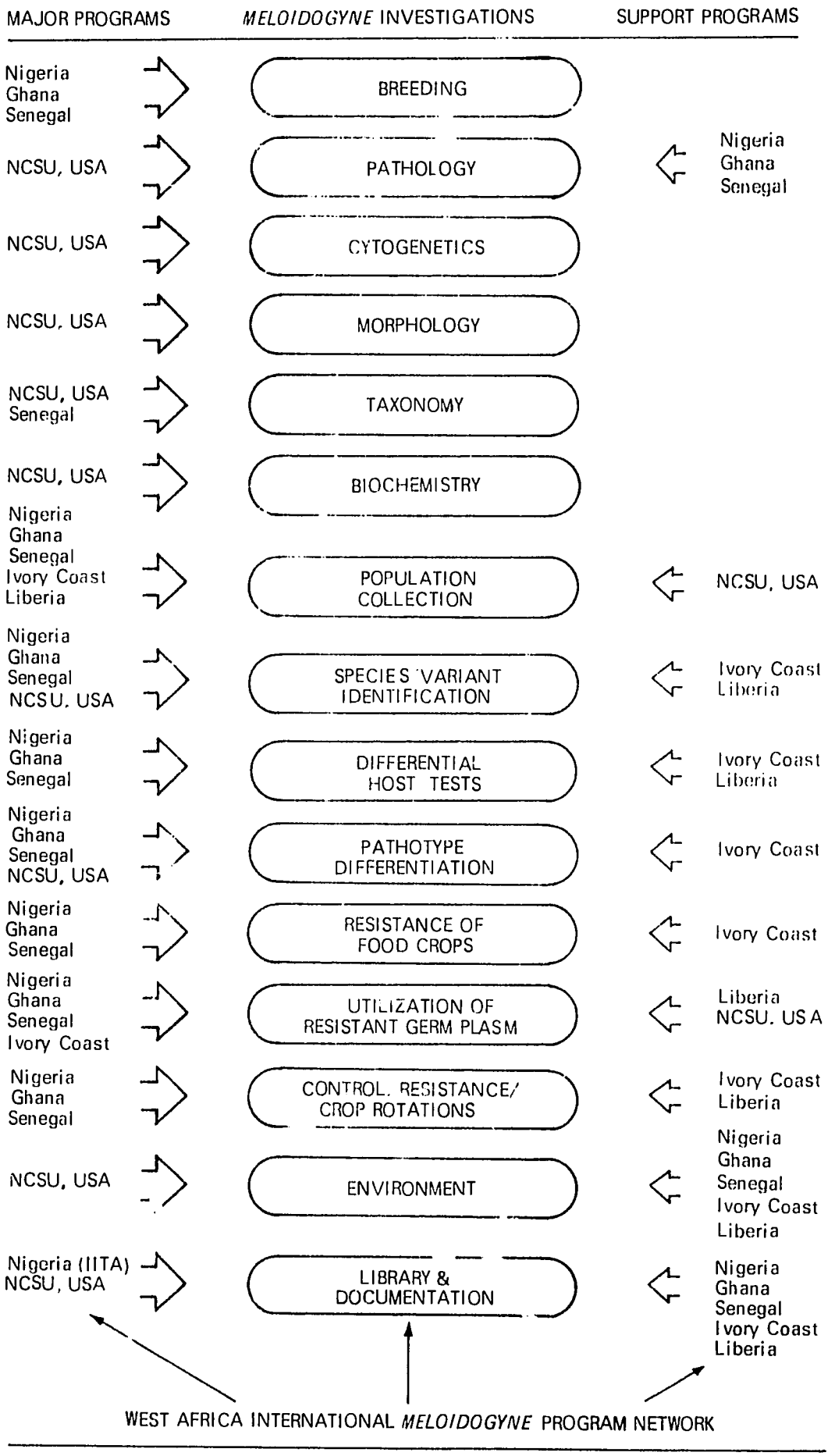

Fig. 16. The IMP cooperative network.

IV. WEST AFRICA RESEARCH PROPOSALS AND AREAS OF COOPERATION

Phase IV of the International Meloidogyne Project is the initiation of research activities apropos to the individuals and situations at the several centers of research. As brought out in the group discussions the goals and objectives of IMP wholly or in part were often congruous with the on-going research programs of the several institutes and universities. Therefore, the merging of the IMP input with the local research programs has the possibility of providing a synergism which will accelerate developments in meeting the ultimate goals of better and greater food production. The research proposals in the areas of specific activities that can be undertaken are as follows (Figs. 16, 17):

Collection of root-knot nematode populations

1. The collection and rearing of nematode populations is a common activity that all participants agreed could contribute. These multiple collections will assure a broad specturm of Meloidogyne species, biotypes and pathotypes will be sent to the IMP Research Center at NCSU. ORSTOM will also be able to collect in Upper Volta and Mali.

Identification of species and/or variants in the field collections of root-knot nematodes

2. The requirements for this activity are more exacting than can be handled by some institutions or it is more feasible to supply field populations of the nematode to a central research center for identification research. In Nigeria the identification research can be undertaken at the Nematology Section, IAR; Plant Science Department, University of Ife; IAR & T, Moor Plantation; NCRI, Moor Plantation; and Farming Systems Program, IITA. ORSTOM, Ivory Coast is to study in detail a Meloidogyne population infecting rice. ORSTOM, Senegal; Nematology Department, Crops Research Institute, Kumasi; Department of Nematology, US&T, Kumasi; and UNDP/Liberia (to a lesser extent) can participate in this activity.

3. Differential host tests to detect pathogenic variation

This research activity can be undertaken by the research centers listed in Two above.

4. Host susceptibility and/or resistance studies of major food crops in the region or nation

Root-knot nematode resistance sources can be sought in one or more major food crops at all centers in Nigeria, Ghana and Senegal.

5. Utilization of crop response information in the development and implementation of effective rotation schemes for control of root-knot nematode

Nonhost crop cultivars detected can be included in rotation schemes utilizing resistance/susceptibility information against the West African root-knot nematode biotypes and all centers in Nigeria, Ghana and Senegal.

6. Collection of information on environmental factors which may influence development of new pathogenic races and/or species

All centers will cooperate in collecting and defining root-knot nematodes from diverse habitats and geographical regions providing information on cropping history, soil type, moisture distribution, temperature, weed hosts and agricultural systems.

7. Identification and utilization of resistant germ plasm

Identified plant resistance to root-knot nematode populations will be made available to plant breeders in national and international food crop improvement programs by all IMP cooperators.

8. Library and documentation center

As part of its mandate the IITA has a well developed library and documentation center operating internationally. All IMP participants were briefed on the library's use and function and its willingness and capability to coordinate nematological literature receiving and respond to requests. All cooperators agreed to contribute to the library's further development and usefulness.

V. Methods, Techniques and Differential Host Tests for Meloidogyne species.

I. Collecting Root-knot Nematode Populations

Field populations are initiated by collecting soil samples from a Meloidogyne infested field or collecting 30 egg masses from infected plants from different sections of the field. Root-knot susceptible tomatoes (3-week-old) are transplanted into the infested soil or are inoculated with the egg masses for increasing the population for the host test.

II. Culturing of Nematode Populations

Root-knot nematodes are easily maintained and propagated on a

susceptible tomato, Lycopersicon esculentum Mill., cultivar such as Rutgers. Populations usually need to be subcultured approximately every 2 to 3 months by inoculating new tomatoes with 15 egg masses each. Usually three plants for each population will suffice. Plastic-coated wire screen splash guards around each pot will help to reduce contamination. Pots should not be crowded on the bench. Tomato plants do best with abundant sunlight, daily watering and biweekly fertilizing with a water soluble complete fertilizer.

III. Preparation of Inoculum

A. Materials required:

1. Clorox (5.25% NaOCl) or similar strength commercial sodium hypochlorite solution

2. 200-mesh and 500-mesh 3-inch Tyler sieves, standard height and stainless steel.
   (Manufacturer)
   W. S. Tyler, Inc.
   Screening Division
   Mentor, Ohio U.S.A. 44060
   Approximate cost: 500-mesh, $35.00; 200-mesh, $21.00

3. 500 ml jar or similar container with large orifice and tight seal.

B. Reference:

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

C. Procedure:

1. Wash soil from galled roots of a plant harvested a minimum of 45 days after inoculation. If older plants are used, make sure roots are not in an advanced stage of deterioration. Eggs from roots of an older plant will be less uniform in development than if a younger plant is used.

2. Excise roots and wash well. Cleaner the root system, the easier it will be to collect the eggs by the sieving process. If root system is large, process only half at a time.

3. Prepare a 10% Clorox solution (0.525% sodium hypochlorite) by adding 20 ml of Clorox to 180 ml of tap water.

4. Place washed roots in jar, add 200 ml of the NaOCl solution and seal top. Vigorously shake jar manually for 4 minutes. Do not expose the eggs to the NaOCl solution any longer than 4 minutes.

5. After shaking, quickly pass the NaOCl solution through two sieves, a 200-mesh sieve nested in a 500-mesh sieve. Once original NaOCl solution has been sieved, fill jar containing the roots with water and set it aside. After the NaOCl solution has passed through the sieves, remove the 200-mesh sieve and hold the 500-mesh sieve (containing eggs) under a slow stream of cold tap water to remove residual NaOCl. Rinse eggs from 500-mesh sieve into a 2-liter flask.

6. Rinse the roots at least twice with water to remove additional eggs and collect eggs by sieving as described. If you intend to collect eggs of two Meloidogyne species, sterilize all equipment in very hot water between collections.

7. For determining the concentration of eggs per milliliter, remove three 1-ml samples, count the eggs, and use the average to represent the number of eggs per milliliter. Representative 1-ml samples are obtained best by blowing air through the pipette into the egg suspension for a few seconds prior to removing sample. Finally, adjusting the volume of water to make 1000 per ml will simplify the dispensing of eggs.

IV. Differential Host Test

Seedlings of tomato (Rutgers), tobacco (NC95), pepper (California Wonder), corn (Minn A401), peanuts (Florrunner), watermelon (Charleston Gray), cotton (Delta Pine 16), strawberry (Albritton), sweet potato (Allgold - round leaf base and Puerto Rico - pointed leaf base) should be transplanted into 4" pots with 5 replications. Two additional replicates of tomato should be included for use in determining when the test should be terminated. Also one or two noninoculated tomatoes planted in the sterilized soil will serve to check for any possible soil contamination with root-knot nematodes. Sterilized sandy loam soil mixed 1:1 with quartz sand (35 mesh) makes an excellent soil medium for the nematodes and plants. A soil mixture of this type is good for most nematode studies.

After determining the number of eggs per ml (see above), plants can be inoculated. Plants are to be inoculated at the time of

transplanting with 10,000 eggs/pot. Eggs are added to a depression in the soil at the time of transplanting. Eggs can be dispensed easily and accurately by using a calibrated pipetter (10 ml volume) attached to a 2-liter flask. Fisher Scientific Company, 690 Miami Circle, N. E., Atlanta, Ga. 30324, sells a pipetter (Cat #13-683-10C). Another source is SMI, 1399 64th St., Emeryville, Calif. 94608, Cat #5060 (10 ml head) and #5065 (special 2-liter flask). Since the flask is tilted back to fill pipet head to designated volume, eggs are easily kept in suspension. Eggs are dispensed when flask is tilted forward.

V. Termination of Test and Rating of Root System

Since temperature will have an effect on the development of the root-knot nematode, the duration of the test will vary slightly depending on the temperature at which test was conducted. Ratings for gall number and egg mass number should be made 50 days after inoculation if grown within a temperature range of 24° to 30°C. If temperature is below this, the duration of the experiment should be lengthened to 55 days and if temperature is above, the experiment should be shortened to 45 days. Additional replicates of tomato, which could be sacrificed should be included. These could be examined to determine if time and temperature conditions have allowed maturation of the egg masses (light brown color). Root systems with a very light infection may be stained by incubating roots in an aqueous solution of Phloxine B (.15 gm/liter tap water) for 15 minutes to emphasize egg masses.

The egg mass and gall ratings should be made according to the following scale.

0=0, 1= 1-2, 2= 3-10, 3= 11-30, 4= 31-100, and 5= greater than 100 galls or egg masses.

In an effort to obtain more quantitative data on egg number which will indicate the degree of nematode reproduction, the procedure used to obtain egg inoculum can also serve to collect eggs for determining the number of eggs per plant. For collecting eggs for this purpose, a 1.05% or higher concentration of NaCCl should be used since these concentrations free more eggs than the 0.525% solution. Root weights can also be determined.

Since field populations are used in these experiments, it is possible that a mixture of Meloidogyne species may have been collected. If a mixed population was used it will be evident after

conducting the host range study. Usually all of the plants will be infected. If this happens, egg masses must be collected from the appropriate hosts and put on tomato to build up population for retesting on the differential hosts.

VI. Usual response of plant species to attack by the more common *Meloidogyne* spp.

Meloidogyne species	Differential Hosts[1]									
	Tobacco	Cotton	Pepper	Water-melon	Peanut	Corn	Straw-berry	S. Potato All Gold	S. Potato P. Rico	Tomato
M. incognita	-	±[2]	+	+	-	+	-	+	±	+
M. javanica	+	-	-	+	-	+	-	+	-	+
M. hapla	+	-	+	-	+	-	+	+	+	+
M. arenaria	+	-	+	+	±	+	-	±	-	+
M. exigua	-	-	+	+	-	-	-	-	-	-

[1] Plant varieties include: Tobacco, N.C.95; Cotton, DeltaPine 16; Pepper, California Wonder; Watermelon, CharlestonGrey; Peanut, Florunner; Corn, Minn.A401; Strawberry, Allbritton; SweetPotato, All Gold and PuertoRico; Tomato, Rutgers.

[2] Some populations attack the differential hosts while others do not.

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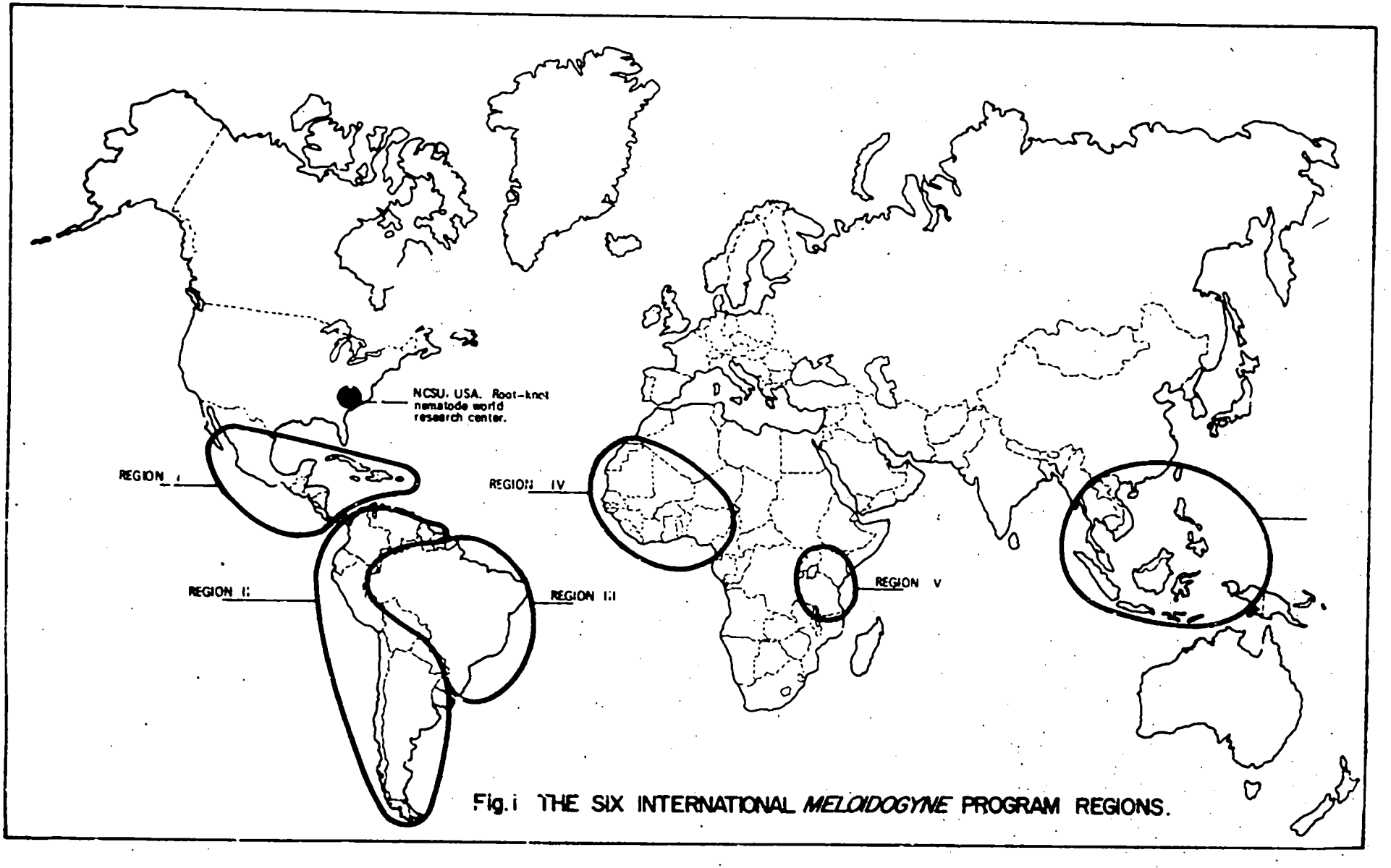

Fig.i THE SIX INTERNATIONAL *MELOIDOGYNE* PROGRAM REGIONS.