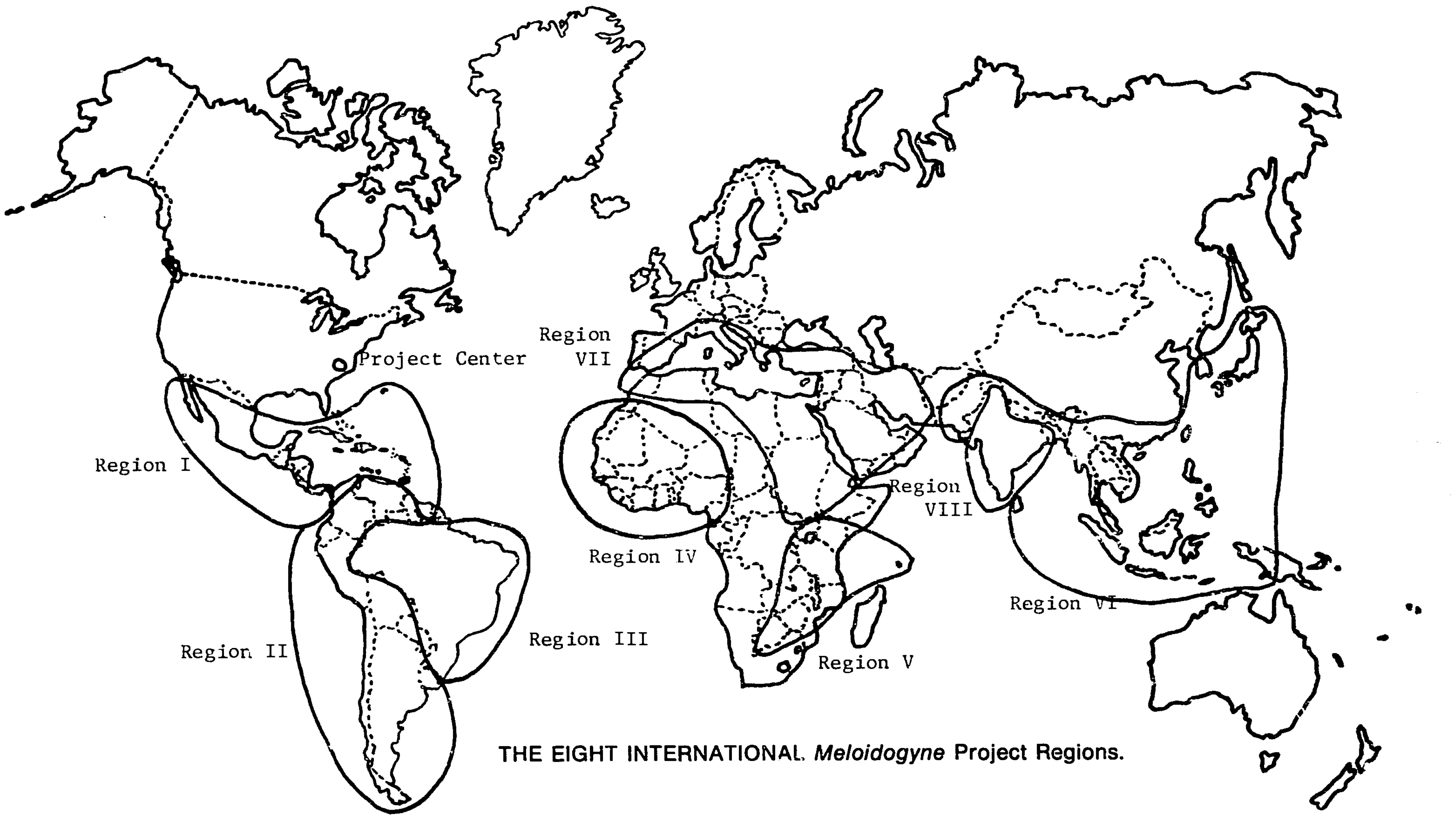

THE EIGHT INTERNATIONAL *Meloidogyne* Project Regions.

INTERNATIONAL MELOIDOGYNE PROJECT

Contract No. AID/ta-c-1234

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

REGION IV		&	**REGION V**	
Benin	Ivory Coast		Malawi	Uganda
Ghana	Nigeria		Tanzania	Zimbabwe

November 16-20, 1981
Ibadan, Nigeria

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

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

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Printed by North Carolina State University Graphics. 1982.

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PREFACE

The Third Regional Conference on Root-knot Nematode Research for West Africa, held November 16-20, 1981, in Ibadan, Nigeria, is a cooperative effort of the International Institute of Tropical Agriculture (IITA) in Ibadan and the International Meloidogyne Project (IMP) headquartered at North Carolina State University, Raleigh, N.C., U.S.A. The participating scientists have affiliation with nematology research units at universities, agricultural experiment stations, and research institutes in IMP Regions IV & V (Fig. 1, inside front cover). As with earlier conferences, the aim of this gathering is the exchange of new research findings on root-knot nematodes. The Project's efforts now focus primarily on screening and breeding for resistance, cropping systems research, and technology transfer. Continued research in these areas promises to promote increased crop yields in developing countries through more efficient and economical control of root-knot nematodes.

Gratitude and appreciation are extended to all conference participants for their dedicated efforts through which significant information on root-knot nematodes is being compiled. First-time conference participants from Malawi, Tanzania, Uganda, and Zimbabwe are particularly welcomed. Special thanks are extended to Bernadette Bakare, IITA Conference Coordinator, for her time in arranging the details of this conference and for her invaluable assistance to the participants. The work of Benson K. Fadare, IITA photographer, also deserves recognition. All efforts to make this conference successful and the visit enjoyable are heartily appreciated.

Finally, we wish to thank Mrs. Catherine Carter, Research Assistant, for editing and arranging the proceedings and Miss Mildred Oldham, Secretary, for typing the master copy.

WELCOME ADDRESS
THIRD REGIONAL CONFERENCE OF
THE INTERNATIONAL *MELOIDOGYNE* PROJECT
NOVEMBER 16-20, 1981

Dr. Bede N. Okigbo
IITA, Ibadan, Nigeria

The Principal Investigator, collaborators in the International *Meloidogyne* Project (IMP), participants and honored guests! I take this opportunity to welcome you to IITA on behalf of Dr. E. H. Hartmans, our Director General, who regrets his inability to be here to welcome you personally. In welcoming you to IITA, I would like to remind you that our task in this Institute is that of problem-oriented teamwork aimed at the improvement of major crops of the humid and subhumid tropics (viz. maize, rice, cowpea, soybean, yam, cassava, sweet potato and cocoyam) and the development of appropriate technologies for more efficient farming systems that constitute economically and ecologically viable alternatives for sustained yields to replace the somewhat increasingly outmoded **intermittent** bush fallow "land rotation" systems. High priority in our work is given to both quantitative and qualitative improvement of the important food crops grown on small farms on which over 90% of the food crops are produced and also to large scale production systems in tropical Africa and elsewhere in the humid and subhumid tropics. Our research and training activities and our cooperative programs are aimed at complementing and assisting national programs to develop capabilities to produce enough food to meet the demands of rapid population growth, urbanization and rising incomes. In subSaharan Africa, serious balance of payments problems have resulted from escalating food and petroleum import bills.

In our present concern for increased food production, root-knot nematodes constitute one of the major constraints directly responsible for substantial quantitative and qualitative losses in crop yields especially in such important crops as cowpeas and yams. In addition to direct losses of sometimes above 20%, nematodes interact with the host plants mechanically, physiologically and chemically to predispose them to further damage by fungi and bacteria.

I understand that this Project was launched in 1975:

1) To determine the species and biotypes of the root-knot nematodes present within each of the eight IMP geographic 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, and
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 regions studied.

Bearing in mind that although nematode infestation and damage is several centuries old, nematology itself as a discipline and societies associated with it are only about three to four decades old even in the developed countries, and the IMP is of incalculable value to developing countries in Africa. This is because it engenders collaboration between the relatively fewer younger scientists in Africa and the larger number of relatively more experienced scientists in the developed countries such as the United States. Apart from African scientists benefiting from the experiences of the more experienced nematologists, they are given some financial support for research which in many developing countries is often limited and/or erratic. Moreover, nematology is not often given the same priority that may be given to entomology and other areas of plant protection where damage or losses associated with them are usually more dramatic.

The nematologist at IITA gives effective support to the crop improvement programs in the screening for disease resistance and establishing the status of host/parasite relationships for the food crops of concern to IITA. Valuable service is also rendered to our Farming Systems Program in monitoring and evaluation of nematode population dynamics under various soil management practices and cropping patterns in terms of crop combinations and sequences. Since our farming systems research activities are directed more toward the development of permanent and intensive production systems than toward prevailing traditional systems, the importance of nematology input in dealing with the expected likely increases in nematode incidence must be given due consideration in the foreseable future. I am also gratified to learn that the Project has been able to determine the species of root-knot nematodes that are most widely distributed in West Africa, the relative importance of the various species and the occurrence of races of root-knot nematodes within these species. In addition, the identification of crops resistant or highly susceptible to these nematodes is important in the designing of rotations and development of integrated nematode management programs which, we hope, hold much promise as a strategy for dealing with the small farmer's production problems. We at IITA are also happy to be associated with the IMP, with Dr. Caveness as the Regional Coordinator, especially since it involves international and national institutions with which we have collaborated or are collaborating in various other activities in research and training. On behalf of these West African institutions and IITA, I wish to express our thanks to USAID, North Carolina State University, and collaborators from outside Africa, for their contributions towards making this Project successful.

I hope that while the conference lasts, participants will take full advantage of facilities placed at their disposal even though some of them may not be working as well as expected. Our staff of the Conference Center, International House and scientists in various programs will cooperate in assisting you in different ways in making your stay worthwhile as need be.

Again, I take this opportunity to welcome you all once more to IITA. I hereby declare this conference open, and wish you successful deliberations and free exchange of information and ideas.

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THE ROLE OF AID IN INTERNATIONAL AGRICULTURAL RESEARCH

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Introduction

Before I discuss the agricultural research programs of the United States Agency for International Development (AID), I would like to discuss in general terms why I believe agricultural research and development programs are vitally needed by all countries, and particularly in developing countries with large and rapidly expanding populations.

A recent report commissioned during the administration of former U.S. President Jimmy Carter, entitled "Global 2000" gives us some insight into population trends and agriculture production needs in the year 2000 as compared to 1975 (Table 1). The data contained in Table 1 are projections and thus not precise. However, they are considered to be well-informed estimates of general population trends that will be encountered by the year 2000.

Table 1
Population Projections for World, Major Regions

Area	1975	2000	% Increase by 2000	Average Annual Increase %
	--in millions--			
World	4090	6351	55	1.8
More developed regions	1131	1323	17	0.6
Less developed regions	2959	5023	70	2.1
Major Regions				
Africa	399	814	104	2.9
Asia/Oceania	2274	3630	60	1.9
Latin America	325	637	96	2.7
North America/Western Europe Australia/New Zealand/Japan	708	809	14	0.5

The developing countries of Africa, Asia and Latin America will have far greater demands placed on their agricultural production capabilities because of rapidly expanding populations than will the developed countries of North America, Western Europe, Australia, Japan and New Zealand where the population growth is not nearly as rapid. Not only will many countries of Africa, particularly Sub-Saharan Africa, Asia and Latin America need to dramatically increase their food production capabilities, but also they will need to produce this food on not very much more land. Land under cultivation is projected to increase only 4 percent by 2000, primarily because most good agricultural land is already in use. Accordingly in 1970, the food from one hectare of land supported 2.7 people, but by 2000, that same hectare must produce sufficient food to support 4.0 people. This projection represents a necessary increase of 32% in food production.

These projections present a tremendous challenge and opportunity to those of us involved in plant protection research. Estimates indicate that plant pests reduce production of basic food crops worldwide 20 to 40 percent annually. Dr. Sasser and his cooperators in the International *Meloidogyne* Project (IMP) have estimated that root-knot nematodes alone, and in combination with other pests and diseases, cause a 10 to 20 percent loss annually among a broad range of crops, particularly in the tropics and sub-tropics. If we as plant protectionists can significantly reduce losses due to plant pests, we can make a major contribution to stabilizing and ultimately increasing world food supplies.

Thus, the need to increase agricultural productivity through research and development is vitally important to future generations and is why AID and many other bi-lateral and international organizations are heavily involved in improving agriculture research capabilities in developing countries. In fact, the U.S. Government in creating AID in 1961 provided a method to establish partnerships with developing countries designed to increase the production of crops and the generation of rural income.

AID Agriculture Research Programs

Organizationally, AID is divided into a number of Offices and Bureaus located in Washington, D.C. Four Regional Bureaus (Africa, Asia, Latin America and the Caribbean, and Near East) coordinate the work of nearly 60 AID Missions located around the world. The Bureau for Science and Technology, also located in Washington, D.C., is a Bureau organized to supply technical input into the major interests of the Regional Bureaus and their associated Missions. Consequently, Regional Bureaus and the Bureau for Science and Technology work to assure that agriculture and other development projects reflect Mission and host country needs. The Bureau for Science and Technology maintains a permanent technical staff.

However, the Bureau's principal sources of technical expertise for agricultural projects are U.S. Land-Grant and 1890 Universities and Institutions. AID agriculture research activities are sponsored through:

1) The International Agriculture Research Centers (IARCs), principal donors in the Consultative Group on International Agriculture Research (CGIAR),

2) Collaborative Research Support Programs (CRSPs) with U.S. colleges and universities working in cooperation with developing country institutions,

3) Other projects and contracts with U.S. Institutions, and

4) Individual Mission/Host Country projects.

The CGIAR-IARC research and training activities deal with crops and livestock that represent three-quarters of the food consumed in developing countries. Table 2 lists the CGIAR-IARCs and their major research areas.

Table 2
International Agriculture Research Centers (IARCs) of the
Consultative Group on International Agriculture Research (CGIAR)

IARC Names/Locations	Principal Research Programs
International Center for Tropical Agriculture (CIAT) Cali, Colombia	Cassava, field bean, rice, tropical pastures
International Center for Maize and Wheat Improvement (CIMMYT) Mexico D.F., Mexico	Maize, wheat
International Potato Center (CIP) Lima, Peru	Potatoes
International Board for Plant Genetic Resources (IBPGR) Rome, Italy	Collection, evaluation, utilization of genetic resources of important species
International Center for Agriculture Research in the Dry Areas (ICARDA) Beirut, Lebanon	Farming systems, cereals, food legumes (broad bean , lentil, chickpea), forage crops
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Hyderabad, India	Chickpea, pigeonpea, pearl millet, sorghum, groundnut farming systems
International Livestock Center for Africa (ILCA) Addis Ababa, Ethiopia	Livestock production systems
International Laboratory for Research on Animal Diseases (ILRAD) Nairobi, Kenya	Trypanosomiasis, Theileriosis

Table 2 (continued)

IARC Names/Locations	Principal Research Programs
International Rice Research Institute (IRRI) Los Banos, Philippines	Rice
International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria	Farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), food legumes (cowpeas, lima beans, soybeans)
West Africa Rice Development Association (WARDA) Monrovia, Liberia	Rice
International Service for National Agricultural Research (ISNAR) The Hague, Netherlands	Provides assistance to developing countries to plan and manage research effectively
International Food Policy Research Institute (IFPRI) Washington, D.C., USA	Provide analysis of world food problems and actions to increase food supplies

AID also assists in the financial support of other non-CGIAR/IARCs, including the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, the International Fertilizer Development Center (IFDC) in Alabama, U.S.A., and the International Soybean Program (INTSOY) in Illinois, U.S.A.

The CRSPs are a mechanism set up under Title XII of the amended Foreign Assistance Act which provides ". . .support for long-term collaborative university research (in the developing countries to the maximum extent possible) on food production, distribution, storage, marketing and consumption." Four CRSPs have been established at this time. The subject matter areas and the Management Entities of these CRSPs are: Small Ruminants, University of California-Davis; Sorghum/Millet, University of Nebraska; Beans and Cowpeas, Michigan State University; Soil Management, North Carolina State University.

Other research projects with U.S. institutions provide a linkage through Regional Bureaus and Missions to furnish technical assistance, training and research capabilities in developing countries. Examples of the subject matter covered by some of these research projects are: irrigation water use, biological nitrogen fixation, control of vertebrate pests, tissue culture, seed industry development, food grain storage and marketing, and pest management. Projects in pest management include weed control, control of barley diseases, pest management and related environmental protection, postharvest food losses, and the subject of this workshop--root-knot nematodes.

The Regional Bureaus and worldwide associated Missions place major emphasis on agricultural improvement efforts in developing countries and, consequently, fund a large number of projects in agricultural research and development. It would be impractical to enumerate all these projects here since they number in the hundreds. However, some of the new or planned projects that may be of interest because of their pest management aspects to the participants at this conference are:

1) Africa:
   a. Regional Food Crop Protection Project,
   b. Integrated Pest Management,
2) Central America coffee rust control project,
3) Jordan Valley Agriculture Services Project, with a major pest management control component,
4) ASEAN Plant Quarantine Training Project, headquartered in Kuala Lumpur, Malaysia, to serve all ASEAN countries, and
5) Indonesia Comprehensive Pest Management Project.

Summary

Projections indicate populations will double in Africa and Latin America between 1975 and 2000. In Asia and Oceania, the most populous region of the world, a 60 percent increase is anticipated during this time. Most countries in these regions will have to greatly improve their agriculture production capabilities to meet only the minimal nutritional needs of their people by the year 2000. Consequently, AID and other bi-lateral and international assistance organizations have placed major emphasis on improving food production capabilities of developing countries through agriculture research and development activities. The substantial reduction of losses due to plant pests would substantially contribute to this goal.

AID's Bureau for Science and Technology works closely with the Regional Bureaus in Washington, D.C., who in turn work with AID Missions worldwide, to develop agricultural research projects relevant to the needs of host countries. Through this working partnership, agricultural research projects that will have a long-range impact on increasing the food production capabilities of the developing world are implemented.

RATIONALE FOR THE INTERNATIONAL <u>MELOIDOGYNE</u> PROJECT--
PRINCIPAL GOALS, OBJECTIVES, AND IMPLEMENTATION

J. N. Sasser, Principal Investigator,
International <u>Meloidogyne</u> Project Headquarters
Raleigh, N.C.

The Problem

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* species. Their world-wide distribution, extensive host ranges and involvement with fungi, bacteria and viruses in disease complexes cause them to rank high on the list of disease agents affecting the world's food supply. Collectively, the various species of root-knot nematode attack nearly every crop that is grown. Not only are yields greatly affected, but quality is also reduced, especially for root crops such as potato, yam and peanut.

Principal Goals

1) Increase production of economic food crops in developing nations.

2) Upgrade crop protection capabilities of developing nations.

3) Advance knowledge about one of the world's most important groups of plant-parasitic nematodes.

Specific Objectives

1) Identify species and biotypes of root-knot nematodes present within each of the eight geographical regions.

2) Determine susceptibility and/or resistance of food crops in each region to the root-knot nematodes present, and identify sources of resistant germ plasm.

3) Evaluate crop response information for the development and implementation of effective rotation schemes for control of root-knot nematodes in each region.

4) Study variability within species and populations with reference to host reaction, morphology, cytogenetics, and biochemistry, as a basis for species identification and understanding pathogenic behavior and phylogenetic relationships.

5) Evaluate various factors of the environment (past cropping history, soil type, moisture, temperature, weed hosts, and type of agriculture) with reference to distribution and survival.

6) Use the information obtained from these cooperative international studies to develop, on a regional basis, effective integrated crop protection systems for the control of root-knot nematodes.

Approach

Variations in root-knot nematode biology lead to differences in pathogenic behavior from one region of the world to another. As a result, concerted efforts on the part of scientists from various regions of the world are required if information vital for the control of these pests is to be obtained. A network of about 60 countries from eight, broad geographical regions, plus a research unit in Raleigh, N.C., U.S.A., is now cooperating on the problem. Through this network approach, it is possible to develop integrated crop protection systems based on control methods uniquely effective in each region.

The world-wide effort has the double effect of not only increasing knowledge on the biology of root-knot nematodes, but also facilitating greater communication among world scientists working on the problem. Important, additional benefits of the IMP include improvement of nematode research capabilities in many developing countries and enhancement of the nematode research efforts at the various cooperating international agricultural centers. Research in each of the regions is concentrated on collection of nematode species, screening plants for resistance, recording ecological data, evaluation of nematicides, etc. The project center in Raleigh is responsible for much research on identification, morphology, taxonomy, biochemistry and cytology.

REPORT ON THE RESEARCH WORK CARRIED OUT IN UGANDA AS PART OF THE INTERNATIONAL MELOIDOGYNE PROJECT

N. D. Bafokuzara
Kawanda Research Station
Kampala, Uganda

IMPORTANCE OF ROOT-KNOT NEMATODES IN UGANDA

To talk about crop damage by plant-parasitic nematodes to a layman in Uganda is virtually to talk about damage by root-knot nematodes (*Meloidogyne* spp.). Apparently, these nematodes, until recently, have been of major concern to crop protection agents and farmers.

In 1922, Small reported that *Heterodera radicicola* (sic.) was causing root galls on *Antirrhinum* (2). Trought carried out field trials to control *Meloidogyne* spp. on tobacco at Bulindi in Bunyoro District, N.W. of Kampala (3). Later, Whitehead and co-workers also made reference to and emphasized damge to many crops, due to root-knot nematodes. These nematodes have also been recorded on tea at Salama Tea Estate, S.E. of Kampala (1). Most damage by these nematodes on tea has been observed on tea seedlings in nurseries at Gayaza tea plantation (N.E. of Kampala) at Kyamara Tea Estate in Toro District, and at Bukuya Tea Estate in Mubende District (Patel, D.M. and Bafokuzara, N.D. 1968, unpublished). These nematodes are also serious pests on many vegetables (Bafokuzara in press) and have been found interacting with *Fusarium* wilt of cotton (2).

Reports in the literature indicate that *M. javanica* is the commonest species present. However, in eastern and central Uganda, *M. incognita* and *M. incognita acrita* are equally common (2).

Many crops are attacked by these pests.

Tobacco. Root-knot nematodes attack the crop in virtually all the districts where it is grown. Control measures recommended include use of new land where tobacco has not been grown for 6 years, use of clean water for watering in seedbeds, seed bed fumigation, and brush burning.

Tea. Damage has been observed in seedbeds. Control of these pests may be achieved through rotation of sites or seedbed fumigation.

Soybean. Data from spot surveys indicate that damage is substantial. However, no proper investigations have been carried out, hence no control recommendation has been suggested.

Pineapple. Meloidogyne spp., Rotylenchulus reniformis, Pratylenchus brachyurus and many other nematodes do occur on pineapple. Investigations are underway to find suitable measures for control of these pests.

Cotton. Damage has been reported, but no serious work has yet been started.

Vegetables. Damage by Meloidogyne is conspicuous on many vegetables including lettuce, cucumber, tomato, carrot and eggplant. Development of a rotation for nematode control is underway.

Pulse Crops. Damage by Meloidogyne has been observed on pulses, Musa spp. and several others. No serious work has been undertaken.

RESEARCH PROGRAMS UNDERWAY

Collection and Identification of Meloidogyne spp.

This program is part of a major project started in 1979 to identify the nematode fauna of Uganda. About 8 to 10 samples of infested plants representing the major crops and weeds growing in any one area and an equal number of soil samples, each about 1 kg, are taken per 40 to 50 sq. miles (104 to 130 sq. km). The samples are transferred to Kawanda and put in 20-cm earthenware pots. Identification of the species of Meloidogyne present on tomato cv. Moneymaker is based on morphological characters of the perineal patterns and on the reaction of host differentials.

Since May 1981, samples have been collected from eastern, central, and southwestern Uganda. The identified Meloidogyne spp. are ultimately used in host-parasite relationship studies.

Rotation Cropping

The aim of this program is to study the effect of growing five vegetable cultivars in sequence on populations of plant-parasitic nematodes. To identify nematodes that occur on onion, bean, lettuce, cowpea, and potato, we investigate factors that influence their fluctuations and design control measures.

The experiment has been situated at Kawanda Research Station. Data on soil type and structure, cropping history of the experimental site, and initial populations of nematodes have been taken. Initial populations of Meloidogyne spp. are estimated by taking soil samples from all plots in the field before planting. These nematodes are transferred into pots in the greenhouse and raised on Moneymaker tomato indicator plants. After

5 to 6 weeks of growth in the greenhouse, these plants were uprooted and the root-knot indices estimated. The same procedure is repeated at the start of each season to estimate the residual populations. During each season, changes in nematode numbers are estimated by taking soil samples from each plot at intervals of three weeks, beginning 3 weeks after planting. Populations of root-knot nematodes are recorded each season by taking root-knot indices of test plants at the end of each season.

RESULTS: NEW EXPERIMENT: DATA RECORDING, UNDERWAY

Pathogenicity, Histopathology and Control of Meloidogyne Javanica on Six Vegetable Cultivars

The objective of this effort is: 1) to determine if there are differences in the ability of larvae of M. javanica to penetrate and develop in roots of six vegetable cultivars; 2) to investigate the effect of nematode penetration and feeding on the integrity of host cells with a view toward identification of sources of resistance in each of the vegetables; and 3) to investigate the potential or effect of some management practices and use of soil amendments, such as mature crop residues, farm yard manure and grass straw on control of this nematode.

Seedlings of Amaranthus spinach Amaranthus hybridus subsp. incurvatus, cabbage Brassica oleracea L.V. capitata, bitterberries Solanum gilo, tomato Lycopersicon esculentum, African spiderherb Gynandropsis gynandra, and bean Phaseolus vulgaris will be inoculated with second-stage larvae of Meloidogyne javanica. Observations on nematode penetration and development will be made by uprooting plants at suitable intervals, staining them, and determining numbers and stage of development.

For histopathological tests, another batch of seedlings of each of the test plants will be exposed to infection by larvae of Meloidogyne javanica and will be subsequently processed for histological sectioning.

Control studies will concentrate on the following areas:

1. Use of biological control agents: Elephant grass Pennisetum purpureum Schum, Rhodes grass Chloris gayana Kunth, and Guinea grass Panicum maximum Jacq. are grasses popularly used in leys in Uganda. These are to be screened for resistance against Meloidogyne javanica with a view toward using them in rotation with susceptible vegetables.

2. Use of farm yard manure: Soil, artificially infested with M. javanica, will be mixed with F.Y.M. and then planted to indicator plants.

3. Use of mature crop residues: The effect of threshings of soybeans or beans and banana peelings on populations of *M. javanica* is to be tested. Soil will be infested with this nematode species, and then planted to some indicator plants for assessment of the level of infestation of the field.

HIGHLIGHTS OF RESEARCH COMPLETED AS A COOPERATOR

Not much has been completed so far. Most of the work has just been started. It is expected that with the improving conditions of work in my country, the next 6 to 12 months will see important developments or progress in our participation in the IMP.

OUTLINE OF FUTURE RESEARCH PLANS

1. Collection of *Meloidogyne* populations from different ecological zones and agroecosystems in the country
   a) for building into a local collection for identification and
   b) for obtaining material for sending to North Carolina State University.
2. Identification of species of *Meloidogyne*
   a) by perineal patterns
   b) by the North Carolina Differential Host Test.
3. Screening tests: Different vegetable cultivars will be tested for resistance to the most common species of *Meloidogyne*. Similar tests are to be carried out on suitable crop cultivars.
4. Evaluation of yield losses caused by the most widespread species of *Meloidogyne*
5. Investigations on control of *Meloidogyne* spp. by/through use of
   a) crop residues
   b) farm yard manure
   c) crop rotation
   d) nematicides
6. Breeding tomato and tobacco varieties that are resistant to *Meloidogyne* damage

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MELOIDOGYNE SPECIES IN ZIMBABWE
SUSCEPTIBLE CROPS OTHER THAN TOBACCO, TAXONOMY AND RESISTANT CROPS

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Crops Affected

Although the nematode population in the soils of Zimbabwe is varied, root-knot nematodes are far-and-away the most common and the most important in their effect on the growth of many crops. *Meloidogyne javanica* is the common root-knot nematode in Zimbabwe and has been considered by G. C. Martin to be indigenous, since populations are found in virgin forest (3). Also identified by G. C. Martin in the country were the three species *M. incognita* var. *acrita*, *M. hapla* and *M. arenaria* (3). These species Martin did not consider to be indigenous. They have a wide but restricted distribution, being found chiefly in home and market gardens and in commercial nurseries. Their presence in farm lands can usually be traced to the use of vegetative planting material such as potatoes, or to a position where flood water invades the land, such as on the banks of a river.

Tobacco (*Nicotiana tabacum*) is the most important crop which is affected by root-knot nematode in Zimbabwe. Though tobacco is not a food crop, the tobacco industry employs a large number of people and is a major earner of foreign currency for Zimbabwe, being the second highest value export at the present time.

The fact that soybeans (*Glycine max*) are highly susceptible to root-knot nematode may be a limiting factor in the growth of this crop. Soybeans are widely grown in Zimbabwe. Another widely grown oilseed crop, groundnut (*Arachis hypogea*) has not been found to be susceptible to root-knot nematode in Zimbabwe.

Maize (*Zea mays*) is not a host of *M. javanica* in the practical sense of the word, although large numbers of juveniles may enter a young root system under poor growing conditions, such as excess moisture. Very few, if any, of these juveniles progress to maturity and since maize is a prolific root grower, the plant very rapidly grows away from the infection under normal growing conditions.

Cotton (Gossypium hirsutum), grown both for the oil content of its seed and for the lint, is not susceptible to M. javanica, although juveniles are known to enter the roots and slight galling has been recorded (2). The number of known field infections of M. incognita increases every season, but still remains relatively low. Some dozen areas are known in northeastern Zimbabwe where cotton is extensively grown, and it has also been found in the Beit Bridge area in the extreme southern part of the country. The spread of M. incognita in recent years is probably as a result of increasing use of irrigation by the commercial farmers.

Root-knot nematode is a major problem in market gardens and commercial nurseries, but because these enterprises grow high value crops on a relatively small area, the cost of fumigation is well within the economic scope of such enterprises. This is not true of the peasant farmers who grow vegetables for sale and may lose yield through root-knot nematode infection.

Potatoes (Solanum tuberosum) are susceptible to all the species of root-knot nematode found in Zimbabwe, and summer crops may be heavily infected. Seed producers who have to produce within maximum infection levels (AA - 0.2%, A - 1.0%) use grass rotations as for tobacco, but fumigation is not a common practice. M. hapla has not been found to show the normal warty symptoms on potatoes and infection with this species is difficult to see in the field. It has, however, been found on potatoes in the Inyanga district on a supposedly AA crop.

Meloidogyne infections have also been found in Zimbabwe on coffee, sugar cane, deciduous fruit grown on peach rootstock, some pasture grasses, and many of the pasture legumes. However, up to the present time, none of these infections have been of great importance to the economy of the country as a whole. Many of these findings were by G. C. Martin during his time in Zimbabwe and have been taken from annual reports and notes made by him as well as from his host list (4).

Identity of Meloidogyne Populations in Zimbabwe

Four species of root-knot nematode were identified in Zimbabwe by G. C. Martin (3), following his visit to the United States of America to learn something about the identification of root-knot nematode species, which resulted in the publication of a key to the perineal patterns of eight species together with photomicrographs (7). These four species, M. javanica, M. incognita var. acrita, M. hapla and M. arenaria were unchallenged until the publication of Whitehead's revision of the genus Meloidogyne (8). In his monograph, Whitehead set up several new species including M. ethiopica, one population of which he obtained from G. C. Martin as M. arenaria.

No work was done in Zimbabwe on the species and the name M. arenaria continued to be used, with workers in nematology (few in number) being aware of the problem but unable to start on a lengthy project of identification due to the involvement of all available staff on practical problems of pressing importance. Unfortunately, by the time G. C. Martin retired in 1976, the population of M. arenaria/M. ethiopica sent to Whitehead had ceased to exist in culture and its original source is unknown. The culture of M. arenaria maintained in the Nematology section at the time of G. C. Martin's retirement, and after, was obtained from an experiment station near Shamva in northeastern Zimbabwe.

In the 1977-78 season, some work was undertaken in the section on populations of root-knot nematode from food crops (in accordance with the IMP policy), using the host selection test. Results of these tests gave unexpected answers, leaving a large question mark over the identity of some of our populations. In 1980, work was started at the Tobacco Research Board with the aim of sorting the populations currently maintained as cultures, with the added intention of testing any and all populations available from other sources in an effort to solve the problem of population identity.

Single eggmass cultures were set up from the maintained 'pure' cultures while field populations were tested as obtained, in order to check for mixed populations. Detailed results of all this work will be given later, but the general result was to throw further doubt on the identity of the M. arenaria culture from the experiment station. This culture, after the testing of several single eggmass cultures, has been confirmed as M. incognita race 3. Later this season (January-February) more material is to be obtained from the original source and checked for a mixed population.

M. javanica has been found from all parts of the country, and with its distinctive perineal pattern, there has never been any doubt about its identity, nor is there any difficulty in the identification of new populations. While aberrant patterns do occur (one population was found near Fort Victoria with wings like *M. hapla*), the presence of lateral incisures provides a firm basis for identification.

According to our present knowledge, *M. incognita* is the second most common species. Several cotton crops have been found to be infected with this species, but in most cases, no attempt was made to identify the race. Each population was called *M. incognita* var. *acrita*, as originally identified by Martin (3).

M. hapla, with stipples on nearly all specimens and wings fairly common, is another easily identifiable species, although more specimens may have to be examined for a positive identification than in the case of *M. javanica*. This species has been found mainly in the cooler areas of Zimbabwe, our eastern highlands. Outside these areas, the two main hosts of *M. hapla* are strawberry and rose.

The distribution of *M. arenaria* is at present unknown, due to the doubt as to its identity, which may invalidate knowledge previously gained.

Programs Underway

Work is continuing on the identification of populations of *Meloidogyne* which are brought in to the laboratory and an attempt will be made next year to find a source of *M. arenaria*.

Work is being undertaken in an effort to find a quick and reliable method for a farmer (particularly a tobacco farmer) to decide whether or not it is necessary for him to fumigate his lands before growing his crop. While the emphasis is on the tobacco farmer, the method employed, if found to be practicable, should be of value to all farmers growing susceptible crops.

A preliminary pot trial in the 1980-81 season showed that there was a correlation between nemtode numbers in the soil and the root-knot nematode rating, on the Daulton scale (1) of 0 - 8 (Table 1), taken six weeks after inoculation of bioassay tomato plants. During the current (1981-82) season, a comparison is being made between root-knot nematode second-stage infective juveniles recovered from soil taken from the lands and the root-knot nematode rating (on the same 0 - 8 scale) of a tomato plant grown in a known quantity of the same soil. This will be done at approximately five-week intervals during the growing season.

During future seasons we intend to monitor the soil populations, perhaps extending our extraction method to include the recovery of eggs

Table 1. Root-knot nematode infection indices

Infection Class	Index Value	Description of degree of galling on roots of indicator plants
0	0	Free from galls
1	1	Trace infection, less than 5 galls
2	5	Very slight, trace to 25 galls
3	10	Slight, 26 to 100 galls
4	25	Moderate, numerous galls, mostly discrete
5	50	Moderately heavy, numerous galls, many coalesced
6	75	Heavy, very numerous galls, mostly coalesced, root-growth slightly retarded
7	90	Very heavy, mass invasion, slight root growth
8	100	Extremely heavy, mass invasion, no root development

Table 2. Alternative crops for winter production.

Brassica spp.*

Carthamnus tinctorius (safflower)

Cicer arietinum (chickpea)

Helianthus annus (sunflower)

Linum usitatissimum (linseed)

Lupinus albus (lupine)

Phaseolus aureus (mung bean)

P. vulgaris (garden bean)*

Vicia faba (broad bean)*

Vigna unguiculata (cowpea)*

*Already known to be susceptible.

and extend the comparisons to include root-knot nematode rating of plants grown in the soil in the land and the final yield figures in the field. The final results will, we hope, produce a chart showing at what level of root-knot population, determined by bioassay at a convenient time of the year, the farmer will find it economical to fumigate his lands.

Results of Past Work

The eight populations sent to IMP headquarters early in 1978 by Mrs. J. Richardson consisted of one mixed population of *M. incognita* and and *M. javanica* from banana (*Musa* sp.) in Chiredzi; a *M. incognita* race 3 from cowpea (*Vigna unguiculata*) in Panmure--this is our *M. arenaria*; five *M. javanica* samples from tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*), and bambara nut (*Voandzeia subterranea*) in Salisbury, Bulawayo, and Fort Victoria; and one *M. incognita* race 1 from okra (*Hibiscus esculentus*) in Bulawayo. Such work has confirmed that 1) *M. javanica* is common; 2) *M. incognita* race 3 is more common than *M. incognita* race 1, although populations of race 1 have been found in the Salisbury area, and at Kariba in addition to the one in the Bulawayo area; and 3) *M. hapla* is present in the Vumba area of the eastern highlands as well as in Inyanga.

Over the years a considerable amount of work has been carried out by nematologists in Zimbabwe in co-operation with Dr. J. Clatworthy, the government pasture legume specialist. Work has also been carried out on the screening of soybean varieties for resistance or tolerance to *M. javanica*.

More recently, testing for root-knot nematode resistance was carried out on a variety of grasses, in an attempt to expand the currently existing list. Of the grasses tested, a *Lolium* sp., *Paspalum notatum*, *P. notatum* var. *saurae*, *P. guenoarum* and *Bromus unioloides* were all found to be resistant to *M. javanica*. Unfortunately, a request to the herbarium for confirmation of identity of these grasses led to some doubt being placed on the identity of the three *Paspalum* species. The same five grasses and the Umgeni strain of weeping lovegrass, already known to be resistant to *M. javanica*, were subsequently tested against *M. hapla* and found to be resistant (6).

Ten legumes were tested at the request of the pasture legume specialist. Four were found to be uninfected and six were found to be susceptible.

The uninfected plants were Desmodium intortum, Glycine wightii cv. Cooper, Macroptilium atropurpureum cv. Siratro, and Stylosanthes guianensis cv. Oxley fine stem. The infected plants were Alysicarpus rugosus, Desmodium uncinatum cv. Silverleaf, Macrotyloma axillare cv. Archer, Lotononsis bainesii cv. Beit, Trifolium semipilosum and another strain of Stylosanthes guianensis. Later work covered Melilotus alba, strains of Trifolium semipilosum, several strains of T. repens and a strain of T. africana. None were found to be resistant. Of six strains of Stylosanthes guianensis, three were resistant and two strains of S. scaba tested were both resistant. A small infection was found on a Siratro plant.

Some plants were tested at the request of the agronomy section in government, where one of the agronomists was engaged in screening crops for suitability as alternatives to winter wheat. It is advisable to know which crops are susceptible to attack, even though M. javanica is not very active in winter (5). The plants under test by Agronomy are listed in Table 2. Pot trials showed that lupines, chickpea, mung bean, linseed and safflower were all susceptible, but safflower was only lightly infected (less than two on the scale of 0 - 8).

Publications

This work has been published only in the annual reports of the Plant Protection Research Institute and of the Tobacco Research Board.

Summary

Meloidogyne javanica is the most common and most damaging nematode present in the soils of Zimbabwe. Three other species are present: M. incognita (2 races), M. hapla, and a fourth species whose identity is currently uncertain but which may be a race of M. arenaria. Testing of populations for identity will continue. Screening of crops and new strains of crops previously found to be susceptible is a continuing excercise. A bioassay method is being sought whereby a farmer will be able to decide whether or not it is economically desirable to fumigate his land.

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REPORT TO THE THIRD REGIONAL CONFERENCE ON ROOT-KNOT NEMATODE RESEARCH HELD AT THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE, IBADAN, NIGERIA

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GENERAL

The root-knot nematode, especially Meloidogyne javanica, is by far the most important nematode pest of tobacco in Zimbabwe. Other nematodes, such as Pratylenchus brachyurus and Scutellonema brachyurum, are widely found but are not considered to be of importance in the field. The root-knot nematode was first recorded in Zimbabwe on potatoes in 1910 (10), and on tobacco in 1913 (1). Jack considered it to be the most serious pest of tobacco in the country (11, 12), and if it had not been for the introduction of DD and EDB in the late 1940's and early 1950's (3, 4, 5, 13, 14), this crop might not have been as successful as it is.

Surveys by Martin have shown that 99% of tobacco plants inspected are infected with M. javanica alone (15, 16, 17). M. incognita has been found in only five cases and M. arenaria in only two; in each instance, these species were associated with moist conditions. M. hapla has not been found on tobacco, except in the greenhouse. Subsequently, Whitehead identified one of Martin's M. arenaria cultures as M. ethiopica (19), and checks of alleged M. arenaria cultures with the IMP Host Selection Test have also cast doubt on the position of M. arenaria at present. Mixed populations are not commonly found under normal dryland conditions.

Martin has speculated that M. javanica is indigenous (16), and Daulton and Nusbaum have shown that the Zimbabwean strain is well adapted to our prevailing soil and weather conditions (8, 9). The root-knot nematode is capable of causing very serious losses in tobacco in Zimbabwe (Table 1). Such losses cannot be accepted, particularly at the price of Z$1,80/kg obtained this past season.

Recommended control measures are fumigation and rotation with root-knot nematode resistant crops. The most widely used resistant crops are the grasses: weeping lovegrass, Eragrostis curvula cv. Ermelo and Umgeni; Rhodes grass, Chloris gayana, cv. Katambora; and panic grass, Panicum maximum, cv. Sabi (2, 6, 18). Certain other grasses, notably some of the

Table 1. Effect of EDB fumigation on flue-cured tobacco yield

EDB 41%	Saleable yield, kg/ha			
	1972-73	1978-79	1979-80	1980-81
0	334	1 968	514	1 829
3 ml/plant station (44,5 litre/ha)	2 648	3 136	1 934	2 967

Table 2. The effect of length of Eragrostis curvula cv. Ermelo ley and fumigationon yield of tobacco (after Daulton, 1964).

Rotation	Yield (kg/ha)	
	Not fumigated	Fumigated
1 year grass	712	1 599
2 years grass	1 190	1 900
3 years grass	1 416	2 050
4 years grass	1 597	2 101

paspalums, are resistant to *M. javanica*, but do not fit into the tobacco rotation very well. Cotton, groundnut, and the sunhemp *Crotalaria spectabilis* are also resistant, but there are problems in their use.

Farmers are advised to fumigate their seedbeds with methyl bromide at $50 g/m^2$ and their lands with EDB at the rate of 9 to 11 litres a.i./ha depending on the method of application and the plant spacing. Land fumigation with EDB costs Z$40-50, depending on formulation used and plant spacing, and this cost can be recovered by the production of only 22-23 kg/ha of flue-cured tobacco at 1980-81 prices. A combination of fumigation and rotation gives the best results (Table 2).

The majority of large-scale commercial growers follow these recommendations and often grow a crop of maize immediately after the tobacco followed by three years of a grass. However, the root-knot nematode still causes large losses to the smaller scale growers of burley and oriental tobacco, but improved response to extension advice will, we hope, increase the understanding of the necessity for control.

CURRENT RESEARCH PROGRAM

Nematicide Trials:

Methyl bromide seedbed trials. Two trials, one on sandy soil and one on a heavy clay, are to compare the effect of five different intervals between fumigation with methyl bromide and sowing on germination of tobacco seed. The current recommendation states that seed may be sown immediately after removing the plastic sheet, and it is felt that this may not be the best method.

Rates and spacing for EDB seedbed fumigation. A comparison of different rates and spacings, which give the same amount of EDB/m^2, for nematode control and seedling growth is being carried out on both sandy and heavy clay soils.

Methods of application of metham-sodium. Metham-sodium is being applied by drenching or digging in to 10 cm. The treated area may or may not be covered with a plastic sheet for nematode and weed control in oriental tobacco seedbeds. Metham-sodium, which is very simple to apply, may give control good enough for the peasant farmer if we can find a more successful method of application. It is not likely to replace methyl bromide with the large-scale, commercial grower.

EDB fumigation for oriental tobacco. Various rates of water-miscible EDB applied either by simple spike applicator or by watering can are being compared to find a simple and effective method of controlling root-knot nematodes in the land. Also fumigation x fertilizer trials are being prepared in various sites to demonstrate to the peasant farmer the benefits of EDB and the correct use of fertilizer.

Rates of EDB and aldicarb. Two trials, one on lightly infested and the other on heavily infested soil, of all combinations of nil and 5 rates of aldicarb granules applied 1 day before planting, and nil and 2 rates of EDB 41% applied 14 days before planting are being compared for yield, root-knot control, and aphid control. This is the third experiment testing combinations of EDB with granular nematicides in an attempt to obtain the same yield and control as the recommended rate of EDB with reduced rates of EDB supplemented with aldicarb. The previous two experiments have given conflicting results.

Root Invasion and Development Trials

M. javanica-resistant breeding lines. Two previous trials have followed the invasion and development of *M. javanica* in some of our breeding lines. The trials have shown that, only one-fifth as many *M. javanica* juveniles invade the better breeding lines in comparison with susceptible cultivars, but that the development rate of those that do successfully invade is only slightly slower than in the susceptible cultivars. Another trial is currently underway to compare galling, invasion, and development rates in recent breeding lines.

Commercial maize cultivars. The *M. javanica* invasion and development rate in 10 commercially available maize cultivars is being studied. Maize is frequently grown after tobacco, and it is useful to know how susceptible it is and whether its growth will reduce the root-knot nematode population.

Movement of *M. javanica* in soil. The movement, both vertically and horizontally, of *M. javanica* juveniles towards a tomato root is being studied. We already have information on the volume of sandy soil effectively fumigated, and this will assist us in understanding the reinvasion of fumigated soil.

Breeding for resistance to *M. javanica*. Four sources of resistance are being crossed in various combinations to improve the level of resistance. The sources of resistance are: 1) *Nicotiana repanda* (code R),

2) _N. longiflora_ (code L), 3) _N. tabacum_ cv. SC72 (code S), and 4) _N. tabacum_ found in Zambezi Valley (code T).

The ST crosses are considered to be the most promising, and the best lines are being back-crossed to TL33, which has the S gene and also white mould resistance, to improve quality and white mould resistance. Also the ST lines are being crossed to NC89, which has the S gene, and TB22, which has a single dominant gene for white mould resistance.

The PL lines have been crossed to RKE 26, one of our earlier breeding lines having the L gene, to improve the flue-cured qualities. Selection and hybridization with male-sterile flue-cured parents should produce acceptable results. Similar programs are being carried out to produce _M. javanica_-resistant burley and oriental cultivars.

FUTURE RESEARCH PLANS

The resistance breeding program will continue to improve the agronomic qualities of the tobacco. Resistance in some flue-cured lines is high, but quality is not yet satisfactory. The position is similar in the burley and oriental programs.

There is not much new work being done on crop rotation systems. It is likely that the conservative rotations presently recommended, involving 3 to 4 years of grass, may become unpopular as the pressure to use land more intensively builds up. This is likely to occur first among peasant farmers and commercial farmers using irrigation. Much of the basic knowledge necessary for recommendation of suitable rotations is already at hand, and it should not be difficult to put this knowledge into practice. However new crops, such as cassava, are always being tried, and, therefore, such crops are being screened for susceptibility to _M. javanica_.

The chemical control program will continue to check any new materials that become available. As well, we will continue to try to reduce the amounts of EDB currently recommended, without lowering yields, to reduce the bromine residues in the cured leaf. This procedure may involve the use of small amounts of granular or liquid nematicides in combination with EDB to maintain a high level of control and yield as well as control of other pests, such as aphids. However, cost and safety may well be problems. In the oriental program, which is mainly for the benefit of the peasant farmer, the emphasis is always on low cost and simplicity.

Simple spike applicators for EDB have been designed, and all measures are related to readily obtainable containers, such as oil tins and similar domestic items.

SUMMARY

The most common and most important root-knot nematode in Zimbabwe is *Meloidogyne javanica*. There are three main lines of research in controling the root-knot nematode: 1) chemical control, 2) crop rotation control, and 3) breeding for resistance. Satisfactory chemical control methods using EDB and methyl bromide were introduced in the early 1950's. New materials and combinations of materials are always being tested, but have not proved to give better results than the original recommendations so far. Successful crop rotation control based on *M. javanica*-resistant grasses was introduced in the mid-1950's and has been widely used since. Increased pressure to make the land more productive may change this reliance on the grasses. The breeding program is well advanced and uses sources of resistance to *M. javanica* derived from *Nicotiana repanda*, *N. longiflora*, *N. tabacum* cv. SC72 and a *N. tabacum* line found in the Zambezi valley. Resistance in some lines is satisfactory, but it is necessary to improve their yield and quality.

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ROOT-KNOT NEMATODES, *MELOIDOGYNE* SPECIES, IN TANZANIA

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Mbeya, Tanzania

Introduction

Root-knot nematodes, *Meloidogyne* spp., are widespread and attack a wide range of hosts, both cultivated and uncultivated (9). Most of the research work on root-knot nematodes was conducted in the late 1950s and early 1960s and concentrated mainly on surveys and species identification. Since then, very little work has been done although the pest is reportedly a serious problem in tobacco- and pyrethrum-growing areas. A total of seven species of root-knot nematodes has been identified: *Meloidogyne javanica*, *M. incognita*, *M. hapla*, *M. ethiopica*, *M. decalineata*, *M. africana* and *M. kikuyensis* (9). Of these, the first three species are the most economically important.

Economic Importance

Little is known concerning losses due to root-knot nematodes in Tanzania. Whitehead indicated crop losses of 30% or more in tobacco farms in Iringa (8). Parlevliet reported crop losses of 50% in pyrethrum flower yields and a decrease in pyrethrin content in Kenya (3). Experience elsewhere indicates significant crop losses are incurred as a result of root-knot nematode attack (1, 2, 5, 6). In Tanzania, root-knot nematodes might be contributing significantly to crop losses, but so far precise investigations have not been undertaken to confirm this idea.

In surveys carried out by Whitehead in central, western and southern Tanzania, *M. javanica* and *M. incognita* were both widespread, but *M. javanica* was most predominant (9). In northern Tanzania, in Kilimanjaro and the Usambara mountains, *M. decalineata* was the predominant species in coffee, but *M. hapla*, *M. javanica*, and *M. incognita* were observed on several weedy hosts. At high altitudes in Kilimanjaro, more than 80% of the coffee trees were found to be infested with *Meloidogyne* spp. (10). *M. ethiopica* was found only in Mlalo Lushoto. *M. kikuyensis* was reported from coffee in Kilimanjaro. *M. africana* was cultured from forest soils from four locations (9). *Meloidogyne* spp. have also been observed in pyrethrum and currently are a serious problem.

M. javanica has been reported in banana, bean, cabbage, cotton, maize, pepper, pigeon pea, tobacco, pineapple, potato, pumpkin, sweet potato, and tomato (7, 9). *M. incognita* has been reported in banana, bean, cabbage, maize, pepper, pigeon pea, pineapple, pumpkin, tobacco, tomato, and cotton (4, 9). *M. ethiopica* has been observed on tomato, tobacco, pumpkin, potato, pepper, cabbage, and bean (9).

The Uyole Agricultural Centre, an agricultural training and research institute located in the southern highlands, has planned to undertake research on root-knot nematodes with particular emphasis on those affecting pyrethrum. The following research projects are planned:

1) collection and identification of species and races of root-knot nematodes in the southern highlands of Tanzania,
2) differential hosts test to detect pathogenic variation,
3) host susceptibility and/or resistance studies of major food and cash crops,
4) screening of nematicides to find ones suitable for use in nurseries to produce clean planting material,
5) screening of pyrethrum clones for resistance to root-knot nematodes,
6) evaluation of cropping patterns in pyrethrum-growing areas. Rotations involving pyrethrum, maize, wheat, and potato will be studied to find out if they have some effect on the population level of root-knot nematodes.

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INTERNATIONAL MELOIDOGYNE PROJECT REPORT IN MALAWI

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The first reports of the significant occurrence of root-knot nematodes in Malawi on tobacco were made by Smee (6) and Bulter (2) in 1928 who observed that no other disease was of great importance to this crop as these nematodes. Subsequent surveys have confirmed their observations and revealed that Meloidogyne javanica and M. incognita are widely distributed in Malawi. They not only reduce yields in tobacco, which is at present the largest foreign exchange earner, but also inflict heavy losses in crops such as potatoes, bananas, pigoen peas and vegetables (1, 3, 5).

Ideally the most practical and economic means of controlling root-knot nematodes is the use of resistant varieties and crop rotation. However in Malawi, a crop such as tobacco is grown by two types of farmers: the large grower who is highly mechanized, has large land holdings and, therefore, can afford rotation and nematicides; and the small grower who has an average of roughly 4 hectares and, therefore, cannot rotate efficiently. Also, due to high prices of nematicides, the small grower is unable to fumigate his fields like the large grower. Therefore, it is the small grower who suffers heavy losses from root-knot nematodes in tobacco.

The situation is worse in other crops like vegetables, potatoes, pigeon peas and bananas because these crops are grown primarily by small growers in small plots. Lack of resistant varieties, due to inadequate research in breeding these crops, makes it almost impossible to control M. javanica and M. incognita on potato, pigeon pea and banana.

Research Activities

Since the Nematology Section at Bvumbwe Research Station started to cooperate with the International Meloidogyne Project in 1978, work has concentrated on root- and soil-sample collection and testing of both local and foreign cultivars against M. javanica.

Root and Soil Samples Collection

Samples were collected from Bvumbwe on banana (*Musa paradisiaca*); from Kwenengwe on broad bean (*Phaseolus vulgaris*), tomato (*Lycopersicon esculentum*), and celery (*Apium graveolens*); and from Ngabu on cotton (*Gossypium hirsutum*). Egg masses placed in 1% NaCl solution and soil were sent to the Project Centre, and at the same time, identification was carried out at Bvumbwe by means of perineal patterns and differential host tests.

Pathogenicity Tests

After the identifications from Bvumbwe and the Project Centre revealed that the root-knot nematode in broad bean, tomato, celery and banana was *M. javanica* (Table 1), pathogenicity tests were initiated and are still underway. So far the following crops have been and are being tested: pigeon pea, Rhodes grass, garden pea, maize, cassava, chick pea, and groundnut. Each crop cultivar is replicated six times and inoculated with 20,000 eggs extracted using the method described by Hussey and Barker (4). The root-knot index (0-5) is used after 55 days to rate the roots.

Further tests both in the greenhouse and the field are needed. Significantly, the results (Table 2) from tests show that all cotton varieties, Rhodes grass (Katambora) and cassava (Masangwi), are immune to *M. javanica* and, therefore, can be used wherever possible in a crop rotation. On the other hand, cassava (Chithekele), garden pea (Davis) and cowpea (TVU 4576) are highly susceptible to this nematode and, therefore, cannot be recommended for any crop rotation where this species of root-knot is a problem.

A simple experiment was carried out last year in the greenhouse where bitter cassava "peel" (*Manihot esculenta* Crantz) and Tung cake (*Alaurites montana* (Lom)) were added to 600 g sterilized sandy loam at pH 6.8 in 15-cm pots at 0.10, 20, 30, 40, and 50 g/pot. Each treatment was replicated six times and incubated for 6 weeks. Each pot was then planted with a 2-week-old tomato seedling (*Lycopersicon esculentum*) variety Moneymaker. A week later 20,000 eggs of *M. javanica* were added to each pot and analyzed after 55 days. Extracts from both residues were tested on egg hatch for 8 days at room temperature (30^{o} C). Root-galling was reduced significantly (P=0.05) and larval emergence was inhibited. This work has been submitted for publication as a short communication in Nematologica.

Table 1. Identification of root-knot nematode from various locations in Malawi.

Place Collected	Common name	Host Plant	Meloidogyne species and races
Kwenengwe	Broad bean	*Phaseolus vulgaris*	*M. javanica*
Kwenengwe	Tomato	*Lycopersicon esculentum*	*M. javanica*
Kwenengwe	Celery	*Apium graveolens*	*M. javanica*
Bvumbwe	Banana	*Musa paradisiaca*	*M. javanica*
Ngabu	Cotton	*Gossypium hirsutum*	No infection

Table 2. Reactions of different crop cultivars to *Meloidogyne javanica*.

Crop	Variety	Root-knot Index after 55 days (a)
Pigeon pea (*Cajanus indicus*)	Cita - 1	2
	Probatat - 14	2
	Plant 4-2	2
	6-35	2
	Upas-120	2
	Pusa Agets	2
	Local	2
Rhodes grass (*Chloris gayana*)	Mbarara	2
	Giant	1
	Katambora	0
	Pikot	2
	Masamba	2
Cowpea (*Vigna unguiculata*)	Tvu 30-19	1
	Tvu 564-P1	1
	Tvu 6365	2
	Tvu 303	2
	Tvu 4539	2

Table 2 (continued)

Crop	Variety	Root-knot Index after 55 days (a)
	Williams	1
	Bossien	1
	Tvu 2000	2
	Tvu 4576	4
	Improved pelican	2
	Tvu 2470	2
Garden pea (*Pisum sativum*)	James	1
	Davis	4
	Rollito	1
Maize (*Zea mays*)	Tuxpens	2
	PNR 94	2
	TL 73B	2
	CCA C2	2
	MH 13	2
	CCB CO	2
	PNR 95	2
	PNR 651	2
	SR 52	2
	UCA C1	2
	MH 12	2
Cotton (*Gossypium hirsutum*)	ABJ	0
	ALA 54	0
	Makoka	0
Cassava (*Manihot esculenta*)	Bukali	2
	Piligodo	2
	Thipula	1
	Chithekele	4
	Masangwi	0
	T7	2
	Koloweke	1

Scale of 0-5 (0 = no galls, 5 = 100% galls)

An investigation of interaction of M. javanica and Fusarium udum in pigeon pea is underway. Pigeon pea as a crop is second to maize in most parts of the southern region and the Lakeshore areas of central and northern regions. However, for the past three years the yields have dropped substantially due to a wilt disease. During a survey carried out last year, it was observed that while Fusarium udum was the principal pathogen that was consistently isolated, M. javanica was also isolated especially in sandy soil. Wilt-resistant pigeon pea lines from ICRISAT are at present being screened at Bvumbwe Research Station, but at the same time, a greenhouse experiment has been set up to observe the effects on the interaction of M. javanica and F. udum. The treatments of the experiment are: Control (no pathogen), Fusarium udum alone, M. javanica alone, and Fusarium udum + M. javanica. Each treatment is replicated six times. The plants will be analyzed after 3 months.

Malawi currently has just received aid from the Agency for International Development of the United States to upgrade the Research Department through training. However, one of the objectives in this aid package is to set up farming systems research in the country. It is the intention of the Nematology Section at Bvumbwe Research Station to cooperate with the team from the University of Florida in the United States to evaluate the effects of farming systems on root-knot. It is hoped that some of the cultivars from the pathogenicity tests (Table 2) can be tested in the field and thereby eventually be utilized in crop rotation systems.

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ROOT-KNOT NEMATODES ON UPLAND RICE (ORYZA SATIVA & O. GLABERRIMA) AND CASSAVA (MANIHOT ESCULENTA) IN IVORY COAST

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After reading the reports of Merny (9) and Fortuner (7), one gets a good general idea of the *Meloidogyne* problems in the Ivory Coast. Most crops extensively grown in the country (food, fruit, fiber, vegetable and commercial crops) have their associated *Meloidogyne* population, although the corresponding potential damage is certainly very variable. Fortuner (7) indicates that *Meloidogyne* is the second most important genus after *Helicotylenchus* on upland rice in this country in terms of abundance and frequency, whereas Merny (9) states that this nematode is a minor parasite of cassava. Rice and cassava being two of our major food crops, we have conducted some research work on them with regard to their relationships to *Meloidogyne* spp.

Meloidogyne on Upland Rice

Meloidogyne is associated with upland rice in most countries where this crop is grown (8). Upland rice cultivars have been recently screened for resistance to *Meloidogyne* spp. by Babatola here in Nigeria (1) and by Sharma in Brazil (11). Results indicate that most cultivars are susceptible to this nematode although a few cultivars show some interesting levels of resistance. In Ivory Coast, we have screened 41 upland rice cultivars for resistance to *M. incognita*. We have also performed some microplot inoculations with and without fertilizers in order to roughly evaluate the damage done by *M. incognita* to a popular upland rice cultivar, IRAT 13.

Screening upland rice cultivars. Forty-one upland rice cultivars, including 21 cultivars of *Oryza sativa* and 20 of *O. glaberrima*, were screened for resistance to *M. incognita*. Twenty replicates of each cultivar were transplanted in PVC tubes (3 cm diam. by 28 cm long) at the rate of one plant/tube. Each tube was inoculated with 1,050 larvae of a mixture of three *M. incognita* populations. The data obtained 2 months later included count of characteristic roots (roots with apical swellings) and final populations in roots. Penetration and development were subsequently studied on 6 selected cultivars including three of each *Oryza* species using the technique described (2).

The results indicate that: 1) M. incognita generally reproduces better on O. sativa roots than on O. glaberrima roots, and 2) O. sativa cultivars have significantly more characteristic roots than O. glaberrima cultivars (Table 1). It is concluded that O. sativa cultivars are more susceptible to M. incognita than O. glaberrima cultivars. It must be noticed, however, that a few O. sativa cultivars (e.g. IS 335 and IS 358) show an interesting level of resistance. Nematode penetration into roots is not different between the two rice species, whereas development into adult females is better on O. sativa cultivars (Table 2). It seems that the more susceptible the cultivar in the terms defined here, the more adult females are obtained. Resistance is therefore related to the development rather than to the penetration.

The rice breeding team at IRAT in Bouaké has successfully made several interspecific crosses between O. sativa and O. glaberrima, but the progeny is always sterile. Breeding efforts are being pursued along this line.

Microplot inoculations. M. incognita eggs were inoculated to IRAT 13 growing in microplot with or without fertilizer at the rate of 100,000 eggs/microplot (≈ 300 eggs/dm3 of soil). The following treatments were used in a factorial setup with 6 repetitions: OO, no nematode, no fertilizer, ON, nematode alone; EO, fertilizer alone; and EN, fertilizer and nematode.

Results can be found in Table 3 and Figure 1. M. incognita does significantly decrease the number of tillers, the number of panicles, the plant height, and the yield of IRAT 13. All these characteristics can be improved by fertilization. This improvement by fertilization, although at its best in the absence of M. incognita, is significant in the presence of the nematode. It is concluded that under certain circumstances, fertilization can largely compensate the effects of M. incognita on upland rice. In the light of new findings, we have observed that this nematode may prevent rice cultivars from responding to fertilization.

One can conclude that resistant germplasm to M. incognita exists in upland rice cultivars and that fertilization may help alleviate Meloidogyne problems under certain circumstances.

Meloidogyne on Cassava

The role played by cassava (Manihot esculenta) in solving the food problem in the Ivory Coast has always been significant and is actually

Table 1. Final populations of *Meloidogyne incognita* and number of characteristic roots on *glaberrima* and *sativa* cultivars of upland rice in 2 months.

Glaberrima varieties	Nematode population (J_2/g)	Characteristic roots (per plant)	Sativa varieties	Nematode population (J_2/g)	Characteristic roots (per plant)
CA V6	156	0.3	ACC-10-18-55*	12,647	6.9
CG 11*	60	0.5	IGUAPE CATETO	6,840	6.3
CG 13	981	1.0	IRAT 13	6,607	5.4
CG 18	305	0.6	MOROBEREKAN	1,614	2.5
CG 24	464	0.6	IS 126	4,700	3.3
CG 45	247	0.7	IS 168	4,812	3.2
CG 67	114	0.3	IS 173*	14,372	11.8
CG 74	62	0.3	IS 220	5,357	4.2
CG 84*	1,930	0.5	IS 251	4,309	5.9
CG 15	1,109	0.5	IS 254	3,954	5.0
LG 009	489	0.3	IS 276	1,800	1.8
LG 052	138	0.7	IS 283	9,055	7.4
LG 061	293	0.4	IS 289	3,712	2.4
MG 007	134	0.3	IS 300	1,658	1.6
MG 021	511	0.3	IS 302	2,619	2.0
MG 029	844	0.9	IS 328	1,757	1.6
OG 1	347	0.8	IS 335	783	1.4
OG 008*	0	0	IS 337	1,053	1.6
OG 15	568	0.3	IS 338	2,102	3.3
TO 580	77	0.6	IS 340	2,386	1.8
			IS 358*	703	1.3
LSD 0.05	-	-		-	1.8
Means	44,145	0.5		4,421	3.8

*Varieties selected for penetration and development studies.

Table 2. Penetration and development of Meloidogyne incognita juveniles in the roots of few upland rice varieites.

Rice varieties	Percent[1/] penetration	Percent[2/] males	Percent[2/] females
OG - 008	10.1 d	2.1	0 i
CG 11	16.3 c	3.0	4.3 h
CG 84	20.3 b	1.9	7.9 g
ACC 10-18-55	14.4 c	0	25 f
IS 358	20.2 b	6.9	3.4 h
IS 173	23.3 a	3.0	70.4 e

[1/]Average percentage of the 50 juveniles initially inoculated.

[2/]Average percentage of the penetrated juveniles. Numbers followed by different letters are significantly different at 5%.

Table 3. Effects of Meloidogyne incognita on some characteristics of IRAT 13 with and/or without fertilization.

	Mean plant height (cm)	Mean panicle length (cm)	Panicle fresh weight (g/microplot)	Effective yield[1/] (g/microplot)	%[2/]
ON[3/]	94.9 a	22.2 d	124 f	84.7 j	100
OO	107.6 b	23.3 d	220 g	160.2 k	189
EN	115.1 bc	26.2 e	300.7 hi	194.8 kl	229.9
EO	124.9 c	27.8 e	338.4 i	235.5 l	278

[1/]Grain yield obtained after gravity separation of floating grains.

[2/]The effective yield of treatment ON is taken as 100.

[3/]OO = NO nematode no fertilizer; ON = nematode alone; EO = fertilizer alone; EN = fertilizer and nematode. Numbers followed by different letters are significantly different at the 5% level.

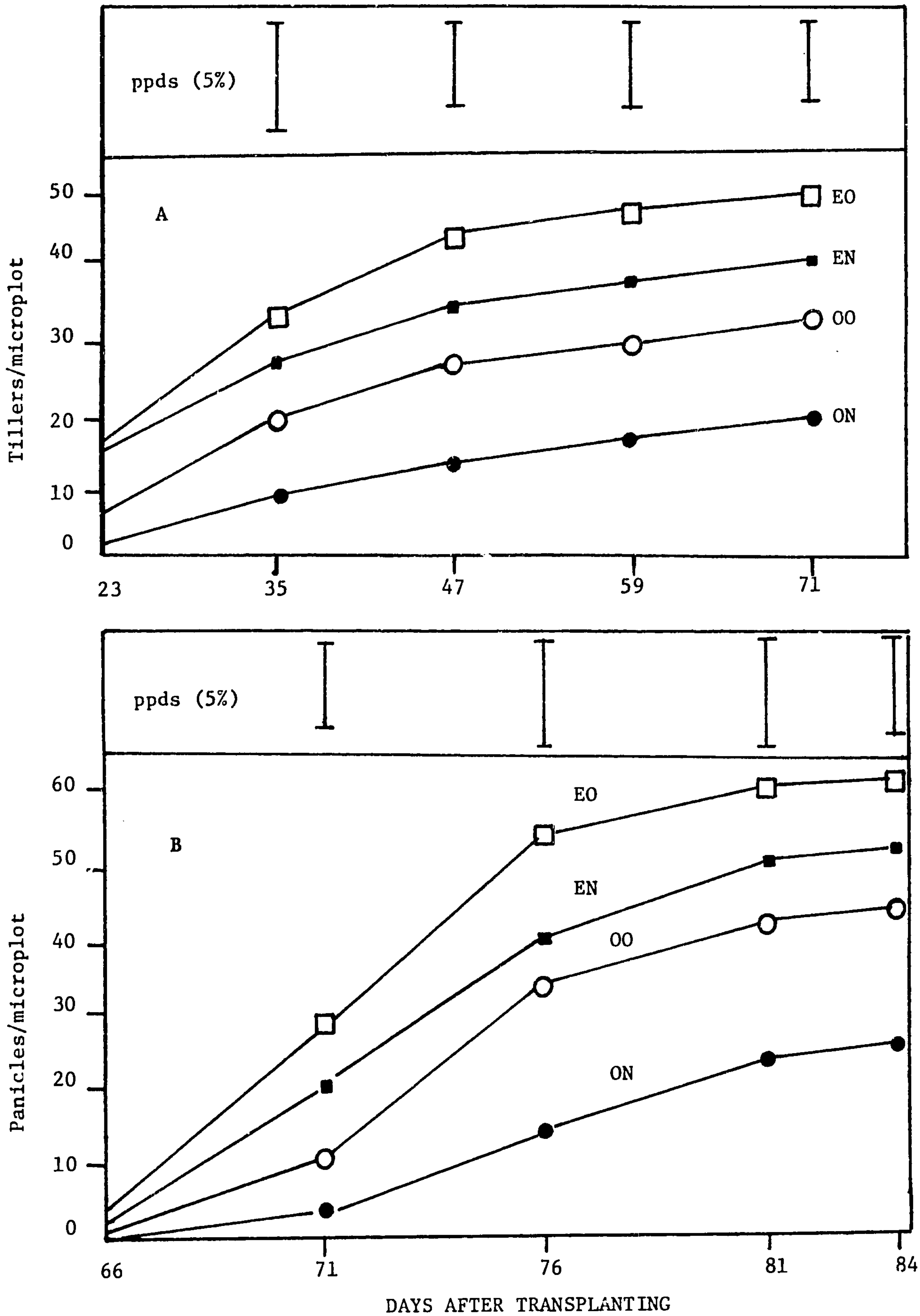

Fig. 1 (A-B). Effects of Meloidogyne incognita and/or fertilization on tillering (A) and panicle setting (B) of IRAT 13. OO= NO nematode no fertilizer; ON = Nematode alone; EO = Fertilizer alone; EN = Fertilizer and nematode.

increasing with large scale projects such as that of SODEPALM in Toumodi. More scientific attention is needed for this crop. From the paper of Dickson (4), it is apparent that nematodes have not been adequately studied on cassava on a worldwide scale. The work of Caveness (3) appears to be one of the major contributions in this area. We undertook this study in order to get an idea of the population dynamics of Meloidogyne spp. on two cassava cultivars. For this purpose, a test was set up on M. javanica-infested plots on the ORSTOM farm, and an inoculation test was conducted in the greenhouse. In the inoculation test, 7,060 juveniles of M. incognita and 7,000 Pratylenchus brachyurus were simultaneously inoculated to cutting-seedlings of the two most commonly used cassava clones (CB and Bonoua) in buckets. Non-inoculated controls were included in the test. Every 15 days, 2 buckets of each treatment were emptied and the roots of the plants put in the mist chamber. The field test involved a DBCP treatment of a plot with a non-treated control. Cuttings of CB and Bonoua were subjected to both treatments and every 15 days, 5 plants from each treatment were uprooted (removing as much of the root system as possible). The roots were put in the mist chamber.

Results can be seen in Table 4 and Figure 2. These two cassava cultivars are not good hosts for Meloidogyne incognita and M. javanica since these nematodes do not reproduce well on them. No difference was found in the tuber yield between DBCP-treated and non-treated plots. Plant heights seemed better in treated than non-treated plots, however. In the inoculation test only the root weight of Bonoua decreased significantly, probably due to Pratylenchus rather than Meloidogyne. Since cassava is commonly associated with many other crops in traditional farming, the two cultivars tested here could be useful in keeping Meloidogyne populations down. Since Saka & Makina have shown that bitter cassava extract has some nematicidal property in Malawi (10), we are looking into such possibilities with these two cassava cultivars.

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Table 4. Populations of *Meloidogyne javanica* and *Pratylenchus brachyurus* on CB and Bonoua roots 3 months after inoculation.

Cassava cultivars		Final populations: *M. javanica* (J_2/g of root)	Final populations: *P. brachyurus* (nemas/g of root)	Roots dry weight (g)
CB	Non-inoculated	0	0	7.25 a
	inoculated	242	4, 394	6 a
BONOUA	Non-inoculated	0	0	6.5 a
	inoculated	357	12, 683	3.2 b

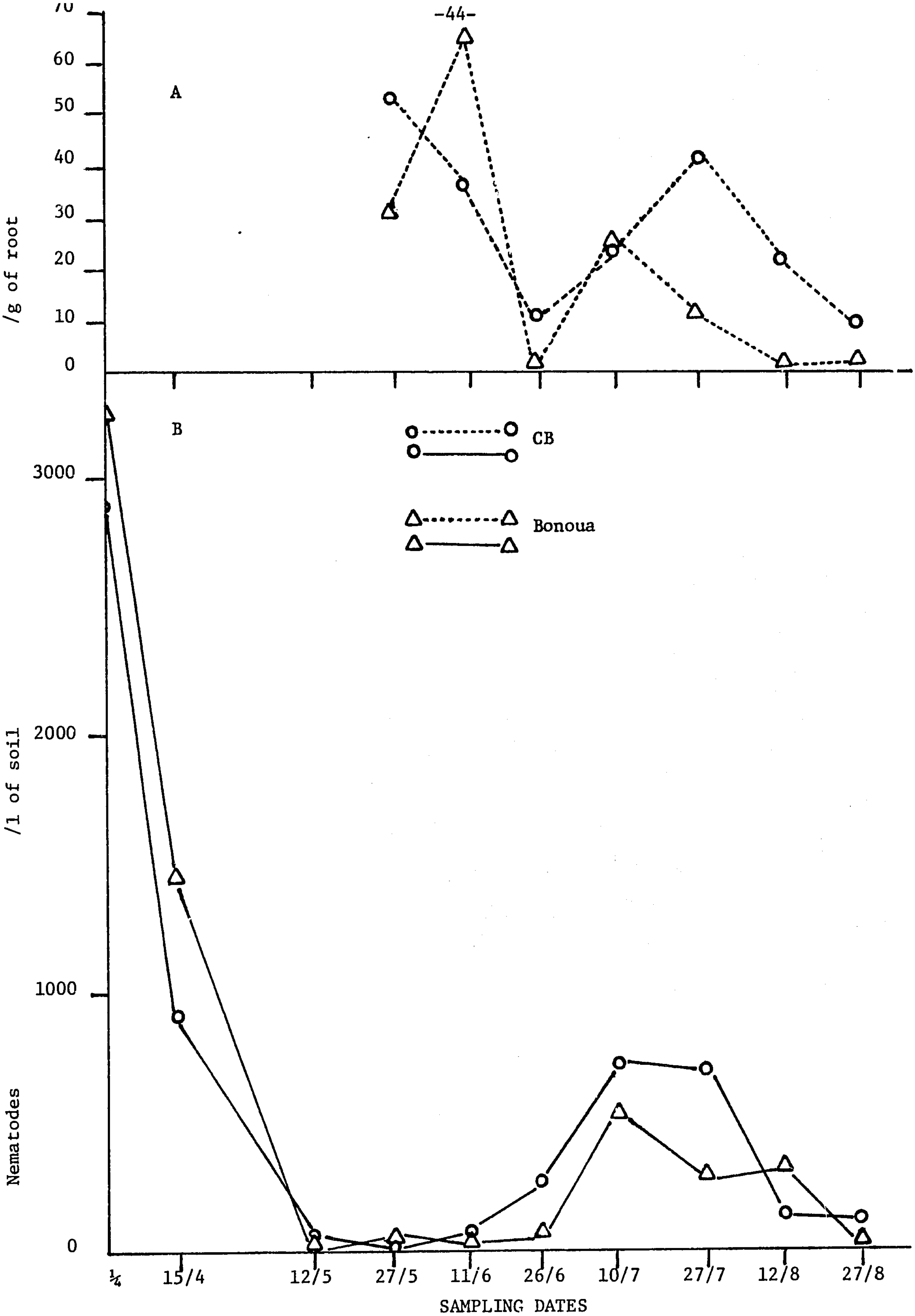

Fig. 2 (A-B). Populations of Meloidogyne javanica in the roots of CB and Bonoua (A) and in the soil (B) in 4 months.

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INTERNATIONAL *MELOIDOGYNE* PROJECT
REPORT FOR 1981

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Root-knot nematodes attack many crops in Ghana. These nematodes are widespread, and they are found in all the different ecological zones: namely, coastal Savanna, rain forest, and the northern Savanna. The economic importance of these nematodes was recognized in the early fifties when the research workers observed the characteristic galls on the roots of tomato and other vegetables which showed poor growth in the fields around Accra. It was observed that early infection of tomato seedlings resulted in stunted growth, and the plants failed to produce fruits. Eventually, premature death occurred while the healthy plants in the same field continued to grow and to produce good yield.

The species of root-knot nematodes that have been identified in Ghana are *Meloidogyne incognita*, *M. javanica*, and *M. arenaria*. Among these, the predominant species is *M. incognita*. Two or more species may attack one host, and mixed infection is common. Vegetable crops are highly susceptible and show the usual galling. The vegetables which are damaged most easily by root-knot nematode attack are tomato, okra, cowpea, pepper, garden egg, cauliflower, cabbage, cucumber, carrot and bean. Root crops like yam and potato are also attacked. The roots of banana, plantain, and cocoyam growing in inoculated soil showed the usual galls. Industrial crops like sunflower, cotton, tobacco, soybean, jute and kenaf all are attacked by the nematodes.

The research work has been directed toward the development of suitable control measures. Screening cultivars for resistance and field application of nematicides are important aspects of this endeavor. The work that has been done since the last conference held in Abidjan, Ivory Coast in 1978, includes study in the following areas: (1) screening soybean cultivars for resistance to *M. incognita*, (2) influence of *M. incognita* on vegetative growth of four maize cultivars, (3) effect of Vydate and carbofuran on the yield of maize, (4) effect of Vydate and carbofuran on the yield of yam, and (5) efficacy of selected nematicides for the control of root-knot nematodes.

Screening Cultivars of Soybean for Resistance to M. incognita

Many cultivars of soybean have been introduced into Ghana and subjected to field testing for determination of their suitability as a cash crop. This work was initiated to screen all the available cultivars for resistance to *M. incognita*.

A culture of *M. incognita* was established in sterile soil in pots. Two tomato seedlings were transplanted into each pot. Each plant was inoculated with 10 egg masses of *M. incognita* 20 days after transplanting. The plants were allowed to grow on benches outside the greenhouse. The tomato plants were uprooted 60 days after inoculation, and all the roots showing infection were cut into small bits and mixed with the soil in the same pot. Twenty seeds of each soybean cultivar were sown per pot. Some of the 32 cultivars showed poor germination. However, infection assessment was carried out on any number of seedlings alive 40 days after germination. For assessment of infection, the seedlings were uprooted and the roots washed. The number of galls per root was counted. Rating of infection was based on the following scale: (1) mean number of galls 57.00 to 95.00, highly susceptible; (2) mean number of galls 21 to 40, susceptible; (3) mean number of galls 10 to 20, moderately susceptible; (4) mean number of galls 5 to 9, very slightly susceptible; and (5) mean number of galls 2 to 4, slightly resistant.

Out of the 32 cultivars tested, five were slightly resistant, nine were slightly susceptible, eight were moderately susceptible, four were susceptible, and six were highly susceptible (Table 1).

Influence of M. incognita on the Vegetative Growth of Maize

Maize varieties Golden Crystal, La Posta, Composite 4, and Composite W are commonly grown in Ghana. Preliminary investigation showed that maize seedlings growing in soil inoculated with *M. incognita* failed to develop the characteristic galls, yet tomato seedlings which followed the maize in the soil were heavily attacked by *M. incognita* suggesting that maize supports *M. incognita* population. For elucidation of this finding four maize varieties were tested.

Seeds of the cultivars mentioned above were used. Two seeds were sown in sterile soil in pot. After germination, the seedlings in a pot were thinned out so that each pot contained one seedling. The number of replications per variety was four. Ten days after germination, plants

Table 1. Screening Cultivars of Soybean for Resistance to *Meloidogyne incognita*

	Cultivar	Mean No. of Galls	
1	P 10	2.33	
2	P 1	2.50	
3	P 26	3.67	Slightly resistant
4	P 39	4.00	
5	P 57	4.00	
6	HARDEE	5.67	
7	P 31	5.75	
8	JUPITER	6.00	
9	P 5	6.80	Very slightly susceptible
10	T a 6	7.00	
11	P 30	7.50	
12	P 37	7.50	
13	P 44	7.50	
14	P 32	9.00	
15	T a 7	10.00	
16	T a 16	10.00	
17	DAVIS	10.50	
18	T a 12	11.00	Moderately susceptible
19	T 7	11.65	
20	T a 9	13.00	
21	P 21	17.33	
22	71-32	20.00	
23	BONUS	21.00	
24	T a 8	24.60	
25	P 88	39.00	Susceptible
26	OTOOTAN	40.00	
27	T a 3	57.00	
28	Clerk 63 No.	61.25	
29	TGM249-5-5078	80.00	Highly susceptible
30	P 9	84.80	
31	P 25	86.00	
32	P 11	95.00	

Table 2. Influence of _M. incognita_ on Vegetative Growth of Maize

(a) Height (cm)

Inocula	0	30	60	90
Composite W	37.75	38.63	39.00	29.75
Composite 4	29.75	31.50	27.80	28.38
La Posta	32.63	31.00	33.75	26.00
Golden Crystal	32.63	30.00	34.75	25.75

(b) Shoot wt. (gm)

Inocula	0	30	60	90
Composite W	80.75 (9.36)	62.30 (7.82)	67.50 (9.25)	64.25 (8.96)
Composite 4	51.89 (9.26)	62.25 (7.82)	49.50 (7.04)	52.25 (7.10)
La Posta	70.25 (9.77)	51.00 (6.90)	65.00 (8.54)	64.30 (8.40)
Golden Crystal	75.25 (6.78)	74.00 (10.06)	73.50 (12.80)	64.05 (8.96)

(c) Root wt. (gm)

Inocula	0	30	60	90
Composite W	32.75 (5.65)	59.75 (5.47)	28.30 (6.12)	30.25 (7.49)
Composite 4	24.72 (3.98)	59.80 (5.47)	20.25 (3.82)	25.75 (3.84)
La Posta	47.00 (6.38)	25.00 (4.33)	34.75 (8.34)	30.25 (7.49)
Golden Crystal	40.00 (4.80)	33.25 (5.45)	37.25 (12.29)	30.25 (7.49)

Figures in brackets are dry weight.

were inoculated with 0, 30, 60, or 90 egg masses of *M. incognita*. Forty-six days after inoculation, records were taken on plant height and fresh and dry weights of shoots and roots (Table 2). The results showed that inoculation with 30 or 60 egg masses per seedling did not suppress the height of Composite W, but 90 egg masses per seedling suppressed the height. When the mean height of the uninoculated seedling was 37.75 cm, the height of the seedling inoculated with 90 egg masses was 29.75 cm. The various inoculum levels showed no marked effect on the growth of composite 4.

In La Posta and Golden Crystal, 90 egg masses markedly reduced the height, but the other treatments had inconsistent effects. The shoot weight of Composite W followed a trend similar to that of the height. While the mean fresh shoot weight of the untreated plant was 80.75 gm, the fresh weight of the inoculated plants ranged from 62.30 to 64.25 gm. The dry weight of the treated plants was slightly reduced, but did not follow a definite pattern. The shoot weights of La Posta and Golden Crystal were reduced by 90 egg masses, but in La Posta, 30 and 60 egg masses also reduced the weight.

In Composite W and Composite 4, an inoculum level of 30 egg masses stimulated root growth. Slight reduction in fresh root weight occurred when 60 and 90 egg masses were applied to Composite W. In Composite 4, only an inoculum level of 60 egg masses reduced the fresh root weight.

The results suggest that of the inoculation treatments studied, only 90 egg masses can markedly reduce maize growth. Composite 4 appears to have the least response to root-knot nematode attack.

The Effect of Vydate and Carbofuran on the Yield of Maize

The experiment was conducted in a forest-savanna transitional zone in a yam plot where the tubers had been attacked heavily by root-knot nematodes in the preceding season. Maize variety Composite W was sown in a randomized block design with four replications. Two rows of 20 plants formed a plot. Fertilizer (NPK 20-20-20) was applied two weeks after planting. Nematicidal treatments were Vydate at 20 and 40 kg/ha, and carbofuran at 20, 40 and 60 kg/ha. The nematicides were applied in granular furrows on each side of the stand 30 days after planting. All the nematicidal treatments produced better yield than the control. Carbofuran at 40 kg/ha produced the highest yield increase of 68.0% followed by Vydate at 20 kg/ha with an increase of 62.7%. Carbofuran at 60 kg/ha and 20 kg/ha produced 37.0% and 34.4% yield increases, respectively (Table 3). When applied to maize, carbofuran has increased persistently

Table 3. Maize yield (shelled weight in kg/plot)

Replicate	Control	Vydate*		Carbofuran*		
	0	20	40	20	40	60
1	1.05	3.00	1.80	0.40	1.40	1.50
2	1.00	1.50	0.80	1.40	0.70	1.10
3	0.90	1.30	1.50	1.85	2.00	0.90
4	0.80	0.30	0.15	1.40	2.20	1.40
Total	3.75	6.10	4.25	5.05	6.30	4.90
% yield increase		62.7	10.3	34.4	68.00	37.00

*Active ingredient of both nematicides is 10% of the material.

Table 4. Tuber weight (kg) per plot

Replicate	Control	Vydate	Carbofuran		
	0	40	20	40	60
1	5.80	7.64	6.90	6.04	6.30
2	5.37	4.55	2.72	3.43	7.90
3	4.28	11.36	11.40	6.67	2.75
4	8.70	8.20	10.90	10.15	15.10
5	10.32	9.55	6.40	5.97	10.10
Total	34.47	41.30	38.32	32.26	42.15
Mean	6.89	8.26	7.66	6.45	8.43
% yield increase		19.09	11.18	-	22.35

yield. However, the recommended dose of 20 kg/ha should be increased to 40 kg/ha, since this dose can double the yield. Since Vydate had not been tried previously on maize, more experiments have to be carried out for confirmation of its effectiveness.

The Effect of Vydate and Carbofuran on the Yield of Yam

Local yam cultivar "dendenpuka" was planted in a field with high root-knot nematode infestation. Four mounds formed a plot and each treatment was replicated five times. Stakes were provided when sprouting started.

The nematicides applied were Vydate at 40 kg/ha and carbofuran at 20, 40, 60 kg/ha. The nematicides were applied in furrows around the mounds after all the yam seeds had sprouted. Seven months after planting, plants were harvested, and weight of the tubers were recorded. The results are given in Table 4.

Vydate increased the yield by 19.09%, while carbofuran at 20 kg and 60 kg/ha increased the yield by 11.18% and 22.35%, respectively. Absence of yield increase when carbofuran was applied at 40 kg/ha was due to pilfering of tubers from the mounds before harvesting. Experience has shown that whenever more than one tuber develops in a mound, some of the tubers are removed by thieves who may cover the mounds as if nothing had happened. Such pilfering always mars the results of yam experiments. Despite the discrepancy, the general trend is that Vydate and carbofuran have increased the yield of yam by 11.18 to 22.35%.

Efficacy of Selected Nematicides for the Control of Root-knot Nematodes Meloidogyne spp. on Tomato

Several cultivars of tomato have been introduced into the country to step up tomato production to feed the local canneries. All the cultivars which have been tested are as susceptible to root-knot nematodes as the local types (1). Therefore, the need to search for effective control measure has engaged the attention of some growers in the country. The following paragraphs give the procedure and results of field trials with selected nematicides in the northern savanna and forest-savanna transitional areas in the country.

Nematicides were applied in rows, and untreated plots served as controls. Planting distance was 0.6 m by 0.9 m. Thirty-day-old tomato seedlings were transplanted 16 days after nematicidal application.

Stakes were provided to the tomato plants before flowering. The soil was sandy loam in the experimental sites. The first trial was carried out at Nyankpala in the northern savanna zone. Two systemic nematicides applied in granular formation were Nemacur (ethyl 4 - (methylithio) - m - tolyl isopropyl phosphoroamidate) at 5 kg/ha and carbofuran at 5 and 10 kg/ha. The experiment was replicated four times in a split-plot design. The rows were 4.5 m long and 1.8 m apart. Three rows formed a plot, and a distance of 2 m separated the plots at all sides. Seedlings of tomato cultivars Marglobe, Malenchue and St. Peters were transplanted. Records were taken on root weight, height, yield and root-knot nematode infection per plot.

The second experiment was sited at Ejura in the forest-savanna transitional zone. The number of nematicides was increased to six. The same dosage rates of Nemacur were applied as before. Carbofuran was applied at 3, 5, and 10 kg per hectare, Basamid as a wettable powder at 400 kg/ha, and Nellite (Phenyl N, N^1-dimethyl phosphoradiamidate) at 2 and 4 kg/ha. The following fumigants also were included: fumazone (1, 2-dibromo-3-chloropropane and related halogenated C_3 aliphatics) at 13 l/ha and Telone (1, 3-dichloropropene and related chlorinated aliphatics and chloropicrin) at 40.65 l/ha.

The fumigants were drenched in furrows 15 cm deep and 8 cm wide. The furrows were covered with soil immediately after drenching and sealed by stamping. Each treatment was replicated five times in a randomized block design, and seedlings of a local tomato cultivar were transplanted. Records were taken only on yield and infection.

The results obtained from the northern savanna zone showed that tomato cv. Marglobe was the most susceptible cultivar (Tables 5, 6). At the dosage rates applied, only Nemacur reduced infection in cv. Marglobe. Cultivars Malenchue and St. Peters appeared less susceptible as the tomato plants in the treated and untreated plots were slightly infected. However, better plant growth and higher yields proved the effectiveness of Nemacur and carbofuran, especially when yield increases ranging from 41 to 132% were recorded.

Field application of Basamid in spring had been found to increase the yields of cabbage, lettuce, celery and tomato by 20 to 23% (2). The results of this test have confirmed Basamid's effectiveness in controlling nematodes, but the phytotoxic effect reduced yield increase when compared with other nematicides (Table 7). Some plants in Basamid- and Fumazone-treated plots were stunted, and leaves were deformed and chlorotic. The severe phytotoxicity was probably caused by low and erratic rains which favored concentration of the nematicides in the root rhizosphere. As a result, no yield increase was recorded in the Fumazone-treated plots. No yield increase occurred when Nemacur at 5 kg/ha was applied in the transitional zone while the same dosage rate produced marked yield increases in the northern savanna zone. This finding probably can be attributed to differences in the cultivars grown in the two ecological zones.

When the various treatments with their respective controls were compared, it was apparent that better response to the nematicides occurred in the northern savanna zone than the transitional zone. The mean yield increase of the three cultivars grown in the northern savanna zone was 56.92%. The mean yield increase of individual cultivars Marglobe, Malenchue and St. Peters was 63.16%, 26.53% and 81%, respectively. In the transitional zone, the mean yield increase of the local cultivar was 32.69%.

Additional projects to be carried out include: (1) control of nematodes attacking pineapples, (2) studies on root-knot nematodes in the farming systems, and (3) ecological studies on root-knot nematodes.

References

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Table 5. Nematicidal effect on root-knot nematode infection and yield in the northern savanna zone

Dosage rate (active ingredients)	Cultivar	Infection index	Fruit weight (kg)	% increase in fruit weight
Nemacur 5 kg/ha	i	2.4	3.26	71.94
	ii	0.0	2.60	41.08
	iii	1.0	3.07	131.92
Carbofuran 5 kg/ha	i	3.6	3.32	75.38
	ii	0.0	2.02	9.37
	iii	0.0	2.10	50.18
10 kg/ha	i	2.3	2.70	42.18
	ii	0.5	2.38	29.15
	iii	0.3	2.13	61.05
Control	i	3.9	1.89	
	ii	0.0	1.85	
	iii	0.3	1.33	
L.S.D. 0.05		0.8	1.06	
0.01		1.1	1.51	

Cultivars: i = Marglobe, ii = Malenchue, iii = St. Peters

Table 6. Nematicidal effect on root and plant growth in the northern savanna zone

Dosage rate (active ingredients)	Cultivar	Root weight (gm)	Plant height (cm)
Nemacur 5 kg/ha	i	63.8	81.0
	ii	26.3	55.9
	iii	61.3	109.6
Carbofuran 5 kg/ha	i	47.3	74.5
	ii	27.3	53.1
	iii	51.3	23.6
10 kg/ha	i	63.3	74.4
	ii	34.8	50.3
	iii	66.3	82.6
Control	i	36.3	51.6
	ii	25.5	48.1
	iii	51.8	77.3
L.S.D. 0.05		12.4	7.5
0.01		17.8	10.7

Table 7. Nematicidal effect on infection and yield in the transitional zone

Dosage rate	Infection index	Fruit weight (kg)	% increase in fruit weight above control
Nemacur			
5 kg/ha	2.1	3.22	-
10 kg/ha	2.4	3.82	18.26
Telone			
46.5 l/ha	1.1	6.31	95.20
Fumazone			
13 l/ha	0.4	3.12	-
Carbofuran			
3 kg/ha	2.2	4.67	44.42
5 kg/ha	2.4	4.21	33.15
10 kg/ha	2.5	5.84	80.65
Nellite			
2 kg/ha	1.8	3.77	16.56
4 kg/ha	2.6	3.93	21.51
Basamid			
400 kg/ha	1.4	3.79	17.15
Control	3.9	3.23	
L.S.D. 0.05	1.1	2.47	
0.01	1.4	3.25	

All dosage rates except Basamid and Telone are expressed in terms of active ingredients.

THE ROOT-KNOT NEMATODE PROBLEMS IN GHANA: PAST, PRESENT AND FUTURE

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Introduction

The root-knot nematodes, Meloidogyne spp., are the most important plant-parasitic nematodes in Ghana. They are noted for their wide distribution throughout the country and the havoc they cause in almost all cultivated crops, including vegetables such as tomato, eggplant, okra, plantain, banana, yam, lettuce, carrot, cabbage, pepper, and grain legumes. They also attack weeds which serve as reservoirs in weedy fallow lands, and they attack tobacco, cotton, jute, and kenaf.

The main species of the root-knot nematode found in Ghana is Meloidogyne incognita which accounts for about 67% of the country's collections (Table 1) (8). It has been found alone, as well as in mixed population with Meloidogyne javanica in the forest zone and in the Greater Accra Zone (Table 2) (5). M. incognita race 1 was found at U. S. T. and M. incognita race 2 at Kwadaso both in the forest zone of Ghana. M. incognita race 3 and M. incognita race 4 were found in Nyankpala and Tamale, respectively, both locations are in the northern Havana zone of Ghana. M. arenaria has also been found in mixed populations with M. incognita in Kumasi, Tema and Goaso.

Post work on occurrence of root-knot nematode in Ghana has been outlined by Hemeng and Hemeng (5, 8). Edwards in 1953 gave the first report on the occurrence of root-knot nematodes on almost all the major crops listed earlier in this paper (4). In 1957, Peacock found that tomato was the most susceptible plant to Meloidogyne incognita (11, 12, 13, 14). Addoh reported that 141 plant species examined had root-knot nematode infection (1).

Research Program Underway

Major cultivars and lines of economically important food and other crops have been programmed for screening for resistance to the twenty different populations of root-knot nematodes now being maintained at U.S.T. and Kwadaso. The twenty populations were collected from all over

Table 1. Location, Soil Type, Host Plant, and Root-knot Nematode Species, Hemeng & Hemeng (1976)

Location	Soil Type	Host Plant	Root-knot Nematode
Kumasi	Dystric Nitosol	Papaya	*M. incognita* *M. arenaria*
Kwadaso	Dystric Rhegosol	Pepper	*M. incognita* *M. arenaria*
Tema	Dystric Rhegosol	Tomato	*M. incognita* *M. arenaria*
Sunyani	Systric Nitosol	Eggplant	*M. incognita*
Ejura	Ferric Acrisol	Tomato	Not identified
Dwenase	Dystric Gleysol	Cauliflower	*M. incognita*
Sefwi Wiawso	Dystric Gleysol	Okra	*M. incognita*
Kwadaso	Dystric Nitosol	Cowpea	*M. incognita* *M. arenaria*
Goaso	Eutric Nitosol	Okra	*M. arenaria*
Patasi	Dystric Gleysol	Eggplant	*M. incognita* *M. javanica*

Table 2. Location, Host Plant, and Root-knot Nematode Species, Hemeng (1976)

Location	Host Plant	Population	Root-knot Nematode
Kwadaso Sunyani Junction	Cabbage	001	Mixture of *M. javanica* and *M. incognita*
U.S.T. Horticulture	Tomato	002	*M. incognita* race 1
Sunyani Kwadaso Junction	Wild Tomato	003	*M. incognita* race 1
Kwadaso Agriculture Station	Cauliflower	004	*M. incognita* race 2
Ayigya	Eggplant	005	Mixture of *M. javanica* and *M. incognita*
Accra	Chinese cabbage	006	Mixture of *M. javanica* and *M. incognita*
U.S.T. Entomology field	Okra	007	*M. incognita* race 1
U.S.T. Pathology field	Cowpea	008	*M. incognita* race 1
Nyankpala	Tomato	009	*M. incognita* race 3
Tamale	Eggplant	010	*M. incognita* race 4

Ghana. An annual survey of important cultivated crops such as plantain, banana, citrus, sugar cane, and oil palm also has been initiated for root-knot and other nematode infections. A field study of an imported nematicide, Furadan granules, and its effect on root-knot nematode infection also has been completed.

Highlights of Research Completed as a Cooperator

Screening of seventeen cultivars and lines of tomatoes for resistance to 10 root-knot nematode populations. Tomatoes rank first among the vegetables in Ghana, and they are highly susceptible to root-knot nematodes. No main dish in Ghana is prepared without tomatoes. The Government of Ghana imports several tons of processed tomatoes either in the form of puree or paste or whole peeled tinned tomatoes in brine.

To save some foreign exchange money, the Government of Ghana has built three factories one at Wenchi and the second at Pwalagu to process tinned tomato puree and the third to process whole tinned tomato in brine. The local tomatoes which are bitter in taste and have several seeds are not suitable for processing. Therefore, several exotic cultivars and lines have been tested for suitability as processing fruits.

Tomato farming for local consumption and for processing in the factories is a lucrative business in Ghana in the Navrongo, Bolga, Zuarungu and Vea area in the Upper Region, Akomadan, Wenchi and other parts in the Brong Ahafo and Ashanti Regions, and Asesewa and Ada area. The high cost and unavailability of nematicides in the country has prompted the search for root-knot nematode resistant cultivars and lines.

Materials and Methods

Seeds of seventeen cultivars and lines of tomatoes were obtained from the Department of Horticulture, dressed with Aldrex 'A' at the rate of 1 gm of the chemical per ½ kg of seeds. These were raised in steam-sterilized sandy loam soil for three weeks. Four three-week-old seedlings of each of the seventeen cultivars (Table 3) were inoculated with over 2,000 eggs of root-knot nematode population 001 (see Table 2 for species of root knot). The same number of each of the seventeen cultivars of tomatoes were treated likewise with eggs of the other populations 002 to 010 in 25-cm plant pots with steam-sterilized sandy loam soil. The inoculated seedlings were watered daily and fertilized with "WELGRO" fertilizer at the rate of 1.5 teaspoonfuls per 4.5 litres of water.

Table 3. Tomato Cultivars and Country of Origin Tested for Resistance to Ten Populations of Root-knot Nematodes, Meloidogyne spp.

Tomato Cultivars	Suppliers	Country of Origin
California	Department of Horticulture, UST	-*
Clinton	Department of Horticulture, UST	-
Super Roma VF	Department of Horticulture, UST	-
AT-69 (BOG)	Department of Horticulture, UST	-
Super California	Department of Horticulture, UST	-
AT-70/24	Department of Horticulture, UST	-
AT-70/14	Department of Horticulture, UST	-
AT-30	Department of Horticulture, UST	-
UC-[illegible]5J	Department of Horticulture, UST	-
Improved Zuarungu	Department of Horticulture, UST	Ghana
Gevas 73	Department of Horticulture, UST	-
Intermech	Department of Horticulture, UST	-
AT-85	Department of Horticulture, UST	-
Gloriana	Department of Horticulture, UST	-
Local Asesewa	Department of Horticulture, UST	Ghana
Local Ada	Department of Horticulture, UST	Ghana
AT-70/11	Department of Horticulture, UST	-

*Supplier out of Ghana when research was completed.

After a period of fifty days, the plants were uprooted and brought into the laboratory; the roots were washed free of soil and root-knot nematode infection assessed. The key for rating galls and egg masses ranges between 0.00 and 5.00: 0.00 to 2.5 is highly resistant to resistant and 3.5 to 5.00 is highly susceptible.

Results

The results tabulated in Tables 4-8 show that among the seventeen cultivars and lines of tomatoes inoculated with population 001, which is a mixture of *M. incognita* and *M. javanica*, only tomato line AT-70/24 showed some resistance to the two species of root-knot nematodes by having an average root-gall index of 1.00 and an egg-mass index of 0.00.

The same line of tomato, that is AT-70/24, was also resistant to population 005 and 006 which are also a mixed population of *M. incognita* and *M. javanica*. AT-70/24 was also resistant to 007 and 009 which are *M. incognita* race 1 and race 3, respectively, and moderately susceptible to 008 and 010 which are *M. incognita* race 1 and race 4, respectively.

None of the rest of the seventeen cultivars and lines were resistant to populations 001, 002, 003, 004, 007 and/or 010. However, the cultivar Super California was moderately susceptible to 005 with an average root-gall index of 4 and egg-mass index of 2. Such a rating means that the plant is attacked, but the species involved cannot reproduce.

The cultivar Local Ada, which is locally grown, gave similar results: the plant was attacked by populations 005 and 006, and slightly attacked by 008 with root-knot indexes of 4.00, 4.00 and 3.00, respectively, but egg-mass indexes were very low, that is 3.00, 3.00 and 3.00, respectively.

Discussion and Conclusions

In 1977, field trials were conducted to assess infection of seventeen different tomato cultivars; namely, Ife No. 1, Floralou, Improved Zuarungu, Ace VF, Red Cloud, Piacenza, Floradel, Enterprizer, Alicante, Healani, London N65, Tropic, Nandom, Manapal, Small Fry, Local Asesewa, and Ronida. Of these, only Ronida and Floradel were slightly resistant to root-knot nematode *M. incognita* race 1.

The experiments with the seventeen cultivars and ten different populations revealed only one line of tomato AT-70/24 to be almost entirely resistant. However, this line was not completely immune to the different species of root-knot nematodes involved in the tests.

Table 4. Resistance/Susceptibility Test Ratings of 17 Tomato Cultivars with Population 001 and 002

Tomato Cultivars	Population 001 Mixture of *M. javanica* and *M. incognita*			Population 002 *M. incognita* race 1		
	a	b	c	a	b	c
California	4	4	HS	5	5	HS
Clinton	5	4	HS	5	5	HS
Super Roma VF	5	4	HS	5	5	HS
AT-69 (BOG)	5	4	HS	5	5	HS
Super California	5	5	HS	5	5	HS
AT-70/24	1	0	R	5	5	HS
AT-70/14	5	5	HS	5	5	HS
AT-30	5	4	HS	5	5	HS
U.C. 105J	5	4	HS	5	5	HS
Improved Zuarungu	5	4	HS	5	5	HS
Gevas 73	5	5	HS	5	5	HS
Intermech	5	5	HS	5	5	HS
AT-85	5	4	HS	5	5	HS
Gloriana	5	4	HS	5	5	HS
Local Asesewa	5	5	HS	5	5	HS
Local Ada	5	5	HS	5	5	HS
AT-70/11	5	5	HS	5	5	HS

a and b = Mean root gall and mean egg-mass indexes, respectively: 0 = no galls or egg mass; 5 = maximum number of galls or egg masses.

c = Resistance/Susceptibility ratings: HS= highly susceptible; S = susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant; HR = highly resistant.

Table 5. Resistance/Susceptibility Test Ratings of 17 Tomato Cultivars with Populations 003 and 004

Tomato Cultivars	Population 003 *M. incognita* race 1			Population 004 *M. incognita* race 2		
	a	b	c	a	b	c
California	5	5	HS	5	5	HS
Clinton	5	5	HS	5	5	HS
Super Roma VF	5	5	HS	5	4	S
AT-69 (BOG)	5	5	HS	5	4	S
Super California	5	5	HS	5	5	HS
AT-70/24	4	4	S	4	4	S
AT-70/14	5	5	HS	5	5	HS
AT-30	5	5	HS	5	5	HS
U.C. 105J	5	4	S	5	4	S
Improved Zuarungu	5	4	S	5	4	S
Gevas 73	5	4	S	5	5	HS
Intermech	5	5	HS	5	5	HS
AT-85	5	5	HS	4	4	S
Gloriana	5	5	HS	5	5	HS
Local Asesewa	5	5	HS	5	5	HS
Local Ada	5	5	HS	5	4	S
AT-70/11	5	5	HS	5	5	HS

Table 6. Resistance/Susceptibility Test Ratings of 17 Tomato Cultivars with Populations 005 and 006

Tomato Cultivars	Population 005 Mixture of *M. javanica* and *M. incognita*			Population 006 Mixture of *M. javanica* and *M. incognita*		
	a	b	c	a	b	c
California	5	5	HS	5	4	S
Clinton	5	5	HS	5	5	S
Super Roma VF	5	5	HS	5	4	S
AT-69 (BOG)	5	4	S	5	5	HS
Super California	4	2	MS	5	5	HS
AT-70/24	3	3	MS	2	2	MS
AT-70/14	5	5	HS	5	5	HS
AT-30	5	5	HS	5	5	HS
U.C. 105J	5	5	HS	5	4	S
Improved Zuarungu	5	5	HS	5	5	HS
Gevas 73	5	5	HS	5	5	HS
Intermech	5	5	HS	4	4	S
AT-85	5	5	HS	5	5	HS
Gloriana	5	5	HS	4	4	S
Local Asesewa	5	5	HS	5	4	S
Local Ada	4	3	MS	4	3	MS
AT-70/11	5	5	HS	5	5	HS

Table 7. Resistance/Susceptibility Test Ratings of 17 Tomato Cultivars with Populations 007 and 008

Tomato Cultivars	Population 007 *M. incognita* race 1			Population 008 *M. incognita* race 1		
	a	b	c	a	b	c
California	5	5	HS	5	4	S
Clinton	5	5	HS	5	4	S
Super Roma VF	5	4	S	5	4	S
AT-69 (BOG)	5	4	S	5	5	HS
Super California	5	5	HS	5	5	HS
AT-70/24	1	0	R	3	2	MS
AT-70/14	5	5	HS	5	4	S
AT-30	5	5	HS	5	5	HS
U.C. 105J	5	5	HS	4	3	S
Improved Zuarungu	5	5	HS	5	5	HS
Gevas 73	5	5	HS	4	4	S
Intermech	5	5	HS	5	3	S
AT-85	5	5	HS	5	4	S
Gloriana	5	5	HS	5	4	S
Local Asesewa	5	5	HS	5	5	HS
Local Ada	5	5	HS	3	3	MS
AT-70/11	5	5	HS	4	3	MS

Table 8. Resistance/Susceptibility Test Ratings of 17 Tomato Cultivars with Populations 009 and 010.

Tomato Cultivars	Population 009 *M. incognita* race 3			Population 010 *M. incognita* race 4		
	a	b	c	a	b	c
California	5	5	HS	5	5	HS
Clinton	5	5	HS	5	5	HS
Super Roma VF	5	5	HS	5	5	HS
AT-69 (BOG)	5	5	HS	5	5	HS
Super California	5	4	S	5	5	HS
AT-70/24	2	1	R	4	3	MS
AT-70/14	5	5	HS	5	5	HS
AT-30	5	5	HS	5	5	HS
U.C. 105J	5	5	HS	5	5	HS
Improved Zuarungu	5	5	HS	5	5	HS
Gevas 73	5	5	HS	5	5	HS
Intermech	5	5	HS	5	5	HS
AT-85	5	5	HS	5	5	HS
Gloriana	5	5	HS	5	5	HS
Local Asesewa	5	5	HS	5	5	HS
Local Ada	5	5	HS	5	4	S
AT-70/11	5	5	HS	5	5	HS

Researchers elsewhere in Region IV made similar observations. Ogunfowora reported on trials with 27 cultivars of tomatoes and found that none of the cultivars were immune to a mixed population of *M. incognita*, *M. javanica* and *M. arenaria* (10). He concluded, however, that Rossol, Nematex, and Enterprizer showed slight resistance.

Amosu found five out of thirty-five tomato cultivars, namely Atkinson, Nematex, Rossol, VEN 8 and Ife I, to be resistant to root-knot nematodes (2).

Netscher and Taylor reported on resistance-breaking biotypes that occur in tropical soils. Rossol, a resistant tomato variety, yielded as well in non-treated *M. javanica*-infested soil as the susceptible variety grown in nematicide-treated plots did (9).

These facts go to establish that a very serious problem exists in regard to the tomato cultivars and root-knot nematodes in Region IV. Therefore, a region-wide program should be drawn to initiate breeding work on tomato for resistance to root-knot nematodes to protect tomatoes against these nematodes and increase tomato production in the region.

Summary

Seventeen cultivars and lines of tomatoes were screened for resistance to ten different populations of *Meloidogyne* spp., mainly *M. incognita* races 1, 2, 3 and 4, and mixed populations of *M. incognita* and *M. javanica*, in mesh houses at the University of Science and Technology. Four 3-week-old seedlings of each of the seventeen tomato cultivars were inoculated separately with 2,000 or more eggs of each of the ten populations of the root-knot nematodes and allowed to grow for fifty days.

Results of the root-knot assessment showed only one promising line of tomato, that is AT-70/24. This line appeared to be highly resistant to population 001 and moderately susceptible to populations 005, 006, 007, 008, 009 and 010. None of the seventeen cultivars were resistant to any of the populations. Super California and Local Ada were attacked by some of the populations, but reproduction was greatly reduced.

A field study was carried out to find the effect of a second application of the nematicide Furadan on the control of root-knot nematode infection of Rutgers (tomato cultivar) with respect to yield. The nematicide application was made twice in the life of the crop: (1) a day before transplanting and (2) 38 days after the first application. Three rates were used; namely, high dosage (134.52 gm/100 m of row 30 cm apart), manufacturer's dosage (67.26 gm/100 m of row), and the low dosage (33.63 gm/100 m of row 30 cm apart).

Root-gall and egg-mass index assessments were conducted 36 days after each application. The results indicated highest control with the highest application rate, followed by the manufacturer's dosage, and lastly the low dosage. A similar trend occurred in yield value. Thus, those plots that received the high dosage showed a yield increase of 85.8% over the control, the manufacturer's dosage a 32.9% increase over the control, and the low dosage a 8.9% yield increase over the control.

It was observed, however, that yield values realized in the study were not significant over those values determined in the previous year's work in which the nematicide (Furadan) was applied only once in the life of the crop (a day before transplanting).

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Meloidogyne RESEARCH PROGRAM IN BENIN REPUBLIC

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Importance of the Root-knot Nematodes in Benin

The root-knot nematodes *Meloidogyne* species have long been recognized as parasites of many plants in Benin. Because there were no nematologists, the problem, although important, has always been neglected. These last two years, an effort has been made on a small level to increase grower recognition of nematode damage since the symptoms are easy to observe and the yield reduction is considerable. Now the economic importance of the root-knot nematodes is understood all over the country. Many plants are severely attacked and preliminary work has shown yield of infested tomato to decline by 55%. Yields of many food crops are significantly reduced as well as other fiber, tuber and commercial crops.

No sound research or identification of the species involved in the country has been done. Presently, the Laboratoire de Defense des Cultures (LDC) is the only research unit which gives attention in its national program to the nematode problem in general and to root-knot nematodes in particular.

Research Program

The Republic of Benin is composed of six main economic regions called provinces. The presence of root-knot nematodes in each of these regions necessitates rapid intervention by means of a good research program. The first step of our program is to increase knowledge of root-knot nematode distribution in each of these provinces. These efforts will be concentrated in the most heavily infested provinces.

The taxonomy of the *Meloidogyne* found in Benin will be studied by collection of a large number of strains from soil and plant materials all over the country. Morphological characters, mainly perennial patterns, and the differential host test will be used. The next step of our research is the host range study. This work will include the following crops which are economically important in Benin.

Food crops. Lowland and upland rices (*Oryza* spp.) will be tested in the provinces of Oume, Mono, Atakora and Borgou; cowpea (*Vigna unguiculata*) in Oueme, Zou, Mono and Atakora; soybean (Glycine soja) in Oueme, in cooperation with the National University of Benin; maize (Zea mays) all over the country; and sorghum (Sorghum vulgare) in Atakora and Borgou.

Vegetable crops. Meloidogyne species are major problems in all areas these crops are grown. Tomato (Lycopersicon esculentum)will be surveyed in the provinces of Oueme, Mono and Atakora; okra (Hibiscus esculentus) in Oueme and Mono; melon (Citrulus vulgaris) and pepper (Piper nigrum) in Oueme, Mono and Atlantique.

Commercial crops. Tobacco (Nicotiana tabacum)is severely attacked. Sugar cane (Saccharum officianarum), another important commercial crop, will be surveyed in the provinces of Oueme and Zou where the crop is grown on a large scale. Cotton (Gossypium spp.) is grown throughout the country and is an important cash crop, but its production is limited by the attack of the root-knot nematodes which occur in complexes with many fungi and bacteria. Our effort will now be seriously concentrated on cotton. Although for many years, the farmers preferred to grow other resistant plants, such as groundnut, this attitude is now being recognized as unprofitable for our government.

Screening for resistance. Screening of plant germplasm for resistance will be done for the most important crops such as tomato, cowpea, rice, soybean, tobacco, cotton and okra.

Breeding program. This step in our research program supposes that highly resistant or immune cultivars will exist. The program of our laboratory concerns mainly tomato, cowpea and cotton. I am sure cooperation with IMP will help us speed along in our research.

ROOT-KNOT NEMATODES ON COWPEA AND SOME SELECTED VEGETABLE CROPS

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Three species of root-knot nematodes, *Meloidogyne incognita*, *M. javanica* and *M. arenaria* in that order of abundance, are found in Nigeria. *M. incognita* is more prevalent in southern Nigeria, and *M. javanica* is more prevalent in northern Nigeria (4, 7, 10, 13, 14, 17). Cowpea is susceptible to all three root-knot nematode species (5, 14).

Vegetables feature regularly in different farming systems operative in Nigeria. In more recent years, vegetables are being grown as sole crops. Root-knot nematodes have been shown as the most serious nematode pests of vegetables in Nigeria (2, 5, 6, 9, 11, 12). Field sanitation and other cultural control methods are preferred to chemical control especially in leaf vegetables because of the short life of vegetables and the systemic nature of most of the available chemicals. Therefore, efforts at the Institute have been concentrated on identification and development of root-knot nematode resistant or tolerant vegetable cultivars through a combined effort of screening and synthesis of desired genotypes in collaboration with the plant breeders and also on the use of crop rotation for the control of root-knot nematode on susceptible vegetable crops.

The present study attempts (i) to identify sources of resistance to root-knot nematodes in cowpea and some vegetable crops and (ii) to determine the best crop rotation for the control of root-knot nematodes on tomato.

Field Screening of Cowpea Lines for Resistance to Root-Knot Nematodes

In replicated field trial on microplots, thirty-one lines of cowpea were screened for their resistance to root-knot nematodes, *Meloidogyne incognita*. After growing in the microplots for 10 weeks, nine plants from each cowpea line were sampled at random and the roots rated for degree of galling according to the method described by Daulton and Nusbaum (8). The index values used in the experiment are as follows:

0 = no evidence of galling, immune;

1 = trace of galling, resistant;

2 = light galling, slightly resistant;

3 = moderate galling, moderately susceptible;

4 = heavy galling, highly susceptible; and

5 = very heavy galling, very highly susceptible.

Results

None of the cowpea lines were immune to root-knot nematode attack. Two lines were slightly resistant while two others were moderately susceptible. All other lines were either highly or very highly susceptible (Table 1).

Screening of Amaranthus Vegetable for Resistance to Root-Knot Nematodes

Seedlings of 20 lines of *Amaranthus* were raised in steam-sterilized potting soil. Seedlings of uniform size of each line were transplanted into 5-litre plastic pots filled with thoroughly mixed field soil heavily infested with *M. incognita*. One seedling of each line was transplanted into each pot. The experimental design was a randomized block with three replicates each. The plants were allowed to grow in the open for six weeks before being carefully removed from the pots. The root system was washed and scored for degree of nematode galling on the scale 0 to 5 previously described.

Results

The initial root-knot nematode population was 645 larvae/100ml of soil. The results on root galling are presented in Table 2. Four of the twenty *Amaranthus* lines demonstrated resistance to *M. incognita* attack. Twelve lines showed slight resistance while only four lines showed moderate susceptibility.

Screening of Solanum Vegetables for Resistance to Root-Knot Nematodes

Twenty-four lines of *Solanum* vegetables were similarly screened (see above). Of the 24 lines, only one line demonstrated resistance to *M. incognita*. Eleven lines showed slight resistance, while the rest demonstrated moderate susceptibility (Table 3).

Crop Rotation Experiments

A preliminary report of this experiment was given in 1978 (13). Between 1978 and 1980, the same experiment was repeated at Ilora and Ikenne on root-knot-nematode-infested plots. Crops used in the rotation were groundnut (*Arachis hypogea*), rice (*Oryza sativa*), maize (*Zea mays*), tomato (*Lycopersicon esculentum*), Stylozanthes (*Stylozanthes gracilis*) in addition to bush fallow. At Ilora, rice was replaced with groundnut.

Table 1. Relative susceptibility of cowpea to root-knot nematode, *Meloidogyne incognita*.

Cowpea line	Range of root-knot index[a]	Resistance rating[b]
TVU 2	2 - 4	HS
TVU 16	4 - 5	VHS
TVU 1023	3 - 4	HS
TVU 1120	1 - 4	HS
TVU 1174	1 - 4	HS
TVU 1220	1 - 3	MS
TVU 1508	2 - 4	HS
TVU 1509	2 - 5	VHS
TVU 1846	1 - 4	HS
TVU 2994	0 - 2	SR
TVU 3629	3 - 5	VHS
TVU 3687	2 - 4	HS
TVU 3690	1 - 4	HS
TVU 4552	2 - 5	VHS
TVU 4557	2 - 5	VHS
TVU 4578	3 - 4	HS
TVU 6198	2 - 4	HS
TVU 10,451	0 - 2	SR
TVU 10,455	2 - 5	VHS
IBADAN WHITE	3 - 4	HS
2609 - 1	4 - 5	VHS
J 33	1 - 4	HS
BULK C 406	3 - 4	HS
IFE 3529	2 - 5	VHS
PRIMA	1 - 5	VHS
NIGERIAN B7	2 - 5	VHS
LIGHT BROWN	3 - 5	VHS
BIPEDUNCLE	3 - 4	HS
IMPROVED MALA	1 - 3	MS
IFE BROWN	3 - 5	VHS
DEEP BROWN	3 - 5	VHS

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

[b] Resistance rating: HR = highly resistant, R = resistant, SR = slightly resistant, MS = moderately susceptible, HS = highly susceptible, VHS = very highly susceptible.

Table 2. Relative susceptibility of *Amaranthus* vegetable to *Meloidogyne incognita*.

Line Code	Range of root-knot index[a]	Resistance rating[b]
V1	1 - 2	SR
V2	2 - 2	SR
V3	2 - 2	SR
V4	2 - 2	SR
V5	1 - 1	R
V6	2 - 2	SR
V7	1 - 2	SR
V8	2 - 2	SR
V9	1 - 2	SR
V10	1 - 2	SR
V11	3 - 3	MS
V12	2 - 3	MS
V13	3 - 3	MS
V14	2 - 2	SR
V15	2 - 3	MS
V16	1 - 2	SR
V17	1 - 2	SR
V18	0 - 1	R
V19	1 - 1	R
V20	1 - 1	R

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

[b]Resistance rating: HR = highly resistant, R = resistant, SR = slightly resistant, MS = moderately susceptible, HS = highly susceptible, and VHS = very highly susceptible.

Table 3. Relative susceptibility of *Solanum* vegetables to *Meloidogyne incognita*

Line Code	Range of root-knot index[a]	Resistance rating[b]
L1	3 - 3	MS
L2	2 - 2	SR
L3	2 - 3	MS
L4	2 - 3	MS
L5	3 - 3	MS
L6	1 - 3	MS
L7	1 - 2	SR
L8	1 - 3	MS
L9	2 - 3	MS
L10	1 - 2	SR
L11	1 - 2	SR
L12	1 - 1	R
L13	2 - 2	SR
L14	2 - 2	SR
L15	2 - 2	SR
L16	2 - 3	MS
L17	2 - 2	SR
L18	1 - 2	SR
L19	2 - 2	SR
L20	1 - 3	MS
L21	2 - 3	MS
L22	2 - 3	MS
L23	2 - 3	MS
L24	1 - 2	SR

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

[b]Resistance rating: HR = highly resistant, R = resistant, SR = slightly resistant, MS = moderately susceptible, HS = highly susceptible, VHS = very highly susceptible.

The test crop in the fourth (last) season was Ile No. 1 tomato (Table 4). Plot size was 6 x 5 m.

At the start of the experiment in late season 1978 and before the test crop was put in 1980, soil samples were taken to a depth of 15 cm and analyzed for pH, organic carbon (C), total nitrogen (N), available phosphorus (P), and available potassium (K). Soil samples were also taken before the beginning of the experiment and after each cropping. The soils were potted and one 3-week-old, Ife No. 1 tomato seedling was transplanted into each pot. There were six pots (six replicates) per treatment. After growing in the pot for six weeks, the tomato plants were lifted and scored for degree of galling on a scale of 0 to 5 to measure root-knot nematode control.

Crop yields after each cropping season were recorded. Also at crop maturity in the fourth season (early season 1980), yields of fresh tomato fruits were taken to measure the effect of various crop rotations. Common weeds found growing on the plots were noted.

Results

Table 5 shows the result of soil analysis before cropping the field in 1978 and in 1980, while Table 6 shows the effect of crop rotation on root-knot nematode field infestation after each successive cropping from 1978 to 1979. Table 7 shows the crop rotation and the resulting crop yields.

Statistical analysis of yield data for the indicator tomato crop (Table 7) shows no significant differences. However, growing non-host or resistant crops such as maize, rice, groundnut and stylo prior to growing tomato often greatly reduced root-knot nematode infection (Table 6) with economic increase in yield of tomato crop (Table 7). Continuous bush fallow (Test 8) gave some control of root-knot nematodes and good yield of tomato (Tables 6 and 7). Continuous stylo (Test 7) gave the best control of root-knot nematodes and also good tomato yields, except at Ilora. Continuous tomato cultivation, however, gave very poor control of root-knot nematodes and poorer tomato fruit yields than in some other treatments (Tables 6 and 7). Common weeds found growing in the plots were *Imperata cylindrica* (spear grass), *Rottboellia exultata* (corn grass), *Pennisetum* sp., *Eupatorium odoratum* (siam weed), *Aspila* sp., *Euphobia* sp., *Amaranthus* sp., *Celosia trigyna*, *Tridax procumbens*, *Corchorus capsuloria* and *Indigofera dandroides*.

Table 4. Rotations at Ikenne & Ilora (1975-1977)

Test No	1975 Late Season	1976 Early Season	1976 Late Season	1977 Early Season
		Crop Rotation		
1	Maize	*G'nut/Rice	Maize	Tomato
2	Tomato	G'nut/Rice	Maize	Tomato
3	Tomato	Maize	Maize	Tomato
4	Maize	G'nut/Rice	Bush fallow	Tomato
5	Maize	G'nut/Rice	Tomato	Tomato
6	Maize	Tomato	Stylo	Tomato
7	Stylo	Stylo	Stylo	Tomato
8	Bush fallow	Bush fallow	Bush fallow	Tomato
9	Cowpea	Bush fallow	Bush fallow	Tomato
10	Tomato	Tomato	Tomato	Tomato

*G'nut at Ilora, rice at Ikenne.

Table 5. Soil analysis before cropping in early season 1980

Test No.	pH		Org C(%)		Total N(%)		P(kg/ha)		K(kg/ha)	
	Ilora	Ikenne	Ilora	Ikenne	Ilora	Ikenne	Ilora	Ikenne	Ilora	Ikenne
*Control	6.3	5.3	2.00	0.64	0.14	0.05	41.4	20.8	407.5	62.9
1	6.2	5.3	0.94	0.93	0.08	0.08	20.2	41.8	316.8	182.2
2	6.4	5.1	1.20	0.76	0.10	0.07	24.2	30.8	396.0	146.5
3	6.2	5.4	1.09	0.75	0.09	0.07	32.6	30.8	475.2	142.6
4	6.5	5.5	0.99	0.63	0.08	0.05	10.6	18.9	415.8	162.4
5	6.3	5.3	0.94	0.74	0.08	0.06	24.2	35.2	376.2	142.6
6	6.5	5.5	0.90	0.63	0.08	0.05	23.3	19.8	336.6	154.4
7	6.6	5.8	1.12	0.75	0.09	0.06	21.1	15.0	495.0	186.1
8	6.5	6.0	0.88	0.77	0.08	0.06	16.2	34.3	455.4	184.1
9	6.4	6.1	1.23	0.65	0.10	0.05	24.6	26.4	455.4	130.7
10	6.3	5.8	1.58	0.66	0.12	0.05	32.6	21.6	433.6	146.5

*Samples for the control treatments were taken at the beginning of the trial in late season 1978.

Table 6. Effect of cropping sequence on root-knot nematode field infestation after each successive cropping

Test No.	1978 Late Season			1979 Early Season			1979 Late Season	
				Nematode Field Infection				
	Ilora	Ikenne		Ilora	Ikenne		Ilora	Ikenne
1 Maize	*2.0	1.0	Groundnut	3.0	2.7	Maize	2.3	2.6
2 Tomato	2.3	2.0	Groundnut	3.3	2.1	Maize	1.3	2.0
3 Tomato	4.0	5.0	Maize	2.0	2.3	Maize	1.0	2.0
4 Maize	1.7	1.0	Groundnut	1.7	2.4	Bush fallow	1.0	2.0
5 Maize	2.0	2.0	Groundnut	2.3	1.8	Tomato	3.0	3.6
6 Maize	1.0	1.0	Tomato	4.0	3.5	Stylo	2.0	1.8
7 Stylo	2.3	2.0	Stylo	2.0	1.3	Stylo	1.0	1.0
8 Bush fallow	3.3	4.0	Bush fallow	2.3	2.0	Bush fallow	1.7	2.0
9 Cowpea	4.0	4.0	Bush fallow	3.0	2.5	Bush fallow	2.0	1.5
10 Tomato	3.3	3.0	Tomato	3.0	3.5	Tomato	4.0	2.5

*Initial nematode field infection based on root-knot galls on tomato test crop for the experimental fields were 3.2 for Ilora and 3.0 for Ikenne. Galling index was on scale 0-5.

Table 7. Yields (tons/ha) of various crops in the rotation including the test crop (tomato cv. Ife No. 1)

Test	1978 Late Season			1979 Early Season			1979 Late Season			1980 Early Season Tomato Yields	
No	Crops	Ilora	Ikenne	Crops	Ilora	Ikenne	Crops	Ilora	Ikenne	Ilora	Ikenne
1	Maize	1.14	0.70	*G'nut/Rice	0.28	-	Maize	-	1.08	6.00	8.00
2	Tomato	7.70	13.50	G'nut/Rice	0.14	-	Maize	-	1.25	5.94	7.14
3	Tomato	8.00	12.80	Maize	0.30	0.47	Maize	-	1.13	4.39	5.84
4	Maize	0.73	0.94	G'nut/Rice	0.30	-	Bush fallow	-	-	5.14	4.85
5	Maize	1.09	0.75	G'nut/Rice	0.15	-	Tomato	3.90	13.30	5.67	8.53
6	Maize	0.95	1.47	Tomato	6.00	14.80	Stylo	-	-	5.12	3.87
7	Stylo	-	-	Stylo	-	-	Stylo	-	-	4.62	8.35
8	Bush fallow	-	-	Bush fallow	-	-	Bush fallow	-	-	5.50	4.35
9	Cowpea	0.11	-	Bush fallow	-	-	Bush fallow	-	-	4.46	7.88
10	Tomato	5.80	11.00	Tomato	3.3	12.7	Tomato	3.70	3.70	5.05	6.72

(-) Yield data were either not taken or crop failure due to rodent attack.

* Groundnut at Ilora, Rice at Ikenne.

Discussion

Although the resistance indicated in the screening trials does not approach immunity, the data suggest that discovery of greater resistance to root-knot nematodes awaits only the testing of a larger number of breeding lines as they become available. The susceptible lines appear to be of no value in a breeding program designed to develop resistant lines.

Yields of the indicator tomato crop in rotation experiments were in the range normally obtained in southwestern Nigeria (1, 18). Some treatment effects, though not significant, were observed in the yields of the indicator tomato crop at the end of the rotations. Inclusion of rice, maize, groundnut and stylo often led to decrease in root-knot nematode infection and economic increase in yield of tomato when compared with continuous tomato or inclusion of some bush fallow.

In this study, however, none of the rotations seemed to give a very high control of root-knot nematodes. Merny (15) working in Ivory Coast recommended one year tomato and two years of rice in large areas where commercial tomato production for canning is planned. Another factor of significance in this study is the nutrient status of the various treatment plots before the indicator tomato crop was planted in early 1980. The result of soil analysis (Table 5) indicated that both at Ilora and Ikenne, the nutrient status of the various treatment plots was in the range suitable for most arable crops including tomato. This high soil fertility possibly contributed to the insignificant differences in yield of tomato fruits obtained from the various treatments. Some of the weeds encountered on the plots have also been reported as hosts of root-knot nematodes (5, 16). The presence of such weeds in the plots may contribute to the buildup or maintenance of root-knot nematode populations, thereby resulting in the low root-knot nematode control observed on the plots. Therefore, for effective root-knot nematode control, a longer duration crop rotation with more resistant crop cultivars may have to be undertaken.

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IMPORTANCE OF ROOT-KNOT NEMATODES ON COWPEA *VIGNA UNGUICULATA* (L) WALP IN NIGERIA

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National Cereals Research Institute

The National Cereals Research Institute (NCRI) was created from the Federal Department of Agricultural Research by virtue of the Agricultural Research Institute order of 1975. This organization is one of 23 Research Institutes and centres under the aegis of the Federal Ministry of Science and Technology. Eighteen are Agricultural Research Institutes, and out of these, eight are mandated to work in conjunction with the eleven river basin authorities to increase food production for the teeming Nigerian population (estimated at 87,000,000).

The NCRI has twenty out-stations scattered widely in the country: 13 in the south forest zone and 7 in the north savannah zone. The administration is headquartered in Ibadan as are two powerful organizations for technology transfer: the National Food Production Project (NAFPP) and the Agricultural Extension and Research Liaison Services (AERLS). The research programme at NCRI is multidisciplinary and has responsibility to conduct research into the production of rice, maize, grain legumes, and sugarcane. Current research is along the following lines: (1) improvement of genetic potential of the mandated crops, (2) improvement of agronomic and husbandary practices, (3) improvement of mechanization for all farming processes, (4) control of pests and diseases, (5) improvement of utilization of by-products, and (6) integration of improved crop production practices into suitable farming systems. Nematology research, originally conducted in the Entomology Division, has had Division status itself since 1975 with the author as the head.

The Cowpea Crop

Cowpea *Vigna unguiculata* (L) Walp is an herbaceous, short-term, annual legume which is cultivated in many tropical and sub-tropical countries (20). It is usually referred to as black-eye pea, black-eye bean, Kaffir pea, southern pea, China pea and marble pea (34), and in Nigeria as bean (13). Cowpea is claimed to have originated in west Africa and possibly Nigeria (16, 36). It has been grown in Nigeria for centuries though extensive production started only around 1900 (13) after the British Cotton Growing Association introduced the crop for rotation with cotton (13, 16).

Cowpea, the most important grain legume in Nigeria, is grown mainly by peasant farmers as an inter-crop or relay crop in rotation with sorghum, pearl millet, maize, cotton, vegetables and root crops. The grains can be boiled; consumed in combination with maize, rice, yam or plantain; roasted and eaten as snacks; made into paste and used as sauce or soup; or ground into flour for use in making feed balls (Akara) or steamed bean paste (Moinmoin). The young succulent leaves and the green pods can be eaten as vegetables (16, 17), and the plant also can be used for fibres (41).

The grain provides a cheap, principal source of dietary protein ranging from 18 to 26% and accounts for up to 80% of the total dietary protein in-take (21, 32). The cowpea is not only an important food crop but also a cash crop (33). Estimates of annual cowpea production for 1979 stand around 800,000 tons (14, 15, 35) with the Sudan and Guinea Savannah zones of the North accounting for 80% of the production (Fig. 1). The average yield of the crop ranges from 118 to 291 kg/ha (4, 41), with a mean yield of 204 kg/ha. Such yield constitutes only about 9% of the potential yield which has been demonstrated experimentally to be about 3,000 kg/ha.

It is estimated that 64% of the Nigerian working population are engaged in agriculture yielding only 23% of the gross domestic product. Of the 74.036 million hectares of good agricultural land (i.e. 75.3% of the total area of 98.3 million hectares), only 34.8 million hectares are under cultivation, and these produce only 20 to 40% of the potential crop (4, 43). As a result, money is spent to import food: $35.2 million per month in 1976, rising to $56.8 million per month in the first month of 1977. This situation reflects poor management, especially of pest and disease problems which seriously threaten production of crops, including cowpea.

Root-Knot Nematode Importance

The root-knot nematodes constitute the primary economic problem limiting production of crops, including cowpea, in Nigeria. Hardly any crop or weed is free from the attack. The magnitude of the problem

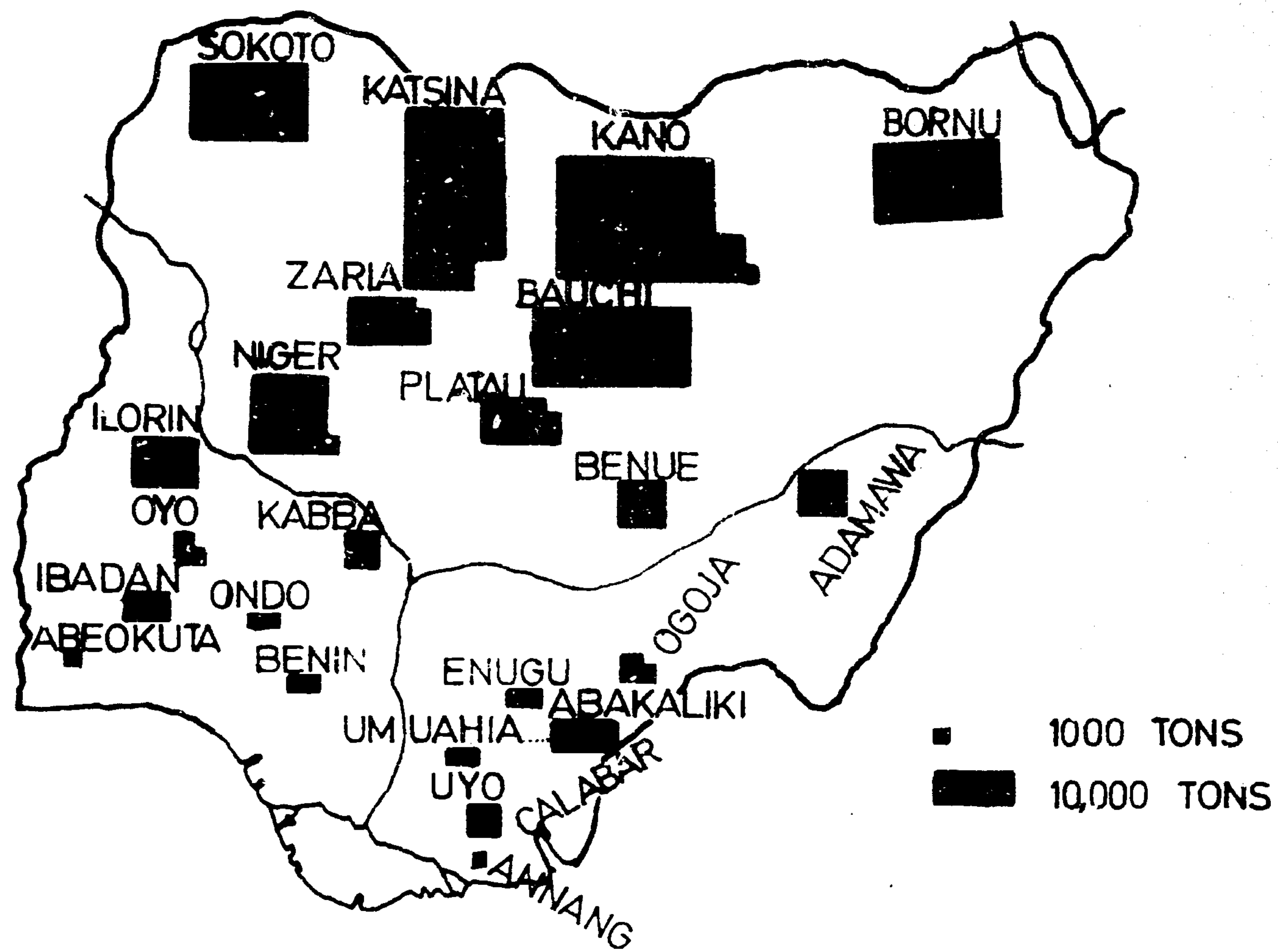

Fig 1 DISTRIBUTION OF COWPEA PRODUCTION IN NIGERIA

posed can be assessed from the fact that almost 90% of the nematologists (Table 1) in Nigeria work on root-knot nematodes. These nematodes are serious pests of food crops and can inflict yield losses as high as 75% (45). They occur widely in Nigeria under irrigated and upland conditions. This situation compares favorably with the world estimate of crop yield losses due to root-knot nematodes which ranges from 3% in rice to 43% in cowpea and 46% in tomato (37).

Twenty species of nematodes distributed among 15 genera are known to be associated with cowpea in Nigeria (Table 2), but only the *Meloidogyne* species and, to a lesser degree, *Rotylenchulus reniformis* (reniform nematode) affect cowpea production economically (11, 25, 26). Research work on root-knot nematode in Nigeria has not advanced a great deal. The first report on the economic importance of cowpea nematodes in Nigeria dates to 1931 when the root-knot nematode was implicated as the causal agent of an important disease of cowpea (44). Later in 1935, cowpea cultivars were screened for resistance to root-knot nematodes, and resistant cultivars were evaluated in yield trials during 1941 and 1942 (16). In 1958, *Meloidogyne incognita*, *M. javanica* and *M. arenaria* were identified from cowpea (12).

Distribution of Root-Knot Nematodes

In an extensive survey of the savannah zone in northern Nigeria, Wilson (45) reported the occurrence of three species of root-knot nematodes: *M. incognita*, *M. javanica* and *M. arenaria*, with the *M. javanica* being of wider distribution than others and *M. arenaria* in trace frequency. Caveness (11) in a similar survey conducted largely in the southern forest zones confirmed the presence of these three root-knot species. From 1976 to 1980, Olowe also conducted a comprehensive survey covering about 108 cowpea-growing areas in northern savannah and southern forest zones and found the same three species of root-knot nematodes (27, 28, 29, 30, 3[illegible]). Olowe confirmed the earlier finding of Wilson that *M. javanica* was more predominant in the north than *M. incognita*, but found the reverse to be true in the south (Tables 3 & 4). The two species were found to occur frequently as mixed populations in the south, whereas in the north, they occurred frequently as single species populations (Table 5).

Table 1. Nematologists in Nigeria

NAME	INSTITUTION WHERE ADVANCED DEGREES WERE OBTAINED	PRESENT ADDRESS
Mr. A. A. Idowu	Ahmadu Bello University (A.B.U.) Zaria	National Cereals Research Institute, P.M.B. 5042, Ibadan, Nigeria
Dr. J. O. Babatola	Imperial College, London, England	N.I.H.O.R.T., Idi-Ishin, Ibadan
Prof. M. O. Adeniji	Agricultural University Wageningen, Holland Netherlands	Dept. of Biology, University of Ibadan Ibadan, Nigeria
Mrs. O. A. Egunjobi	Massey University Palmerston North, North New Zealand	- do -
Dr. S. O. Adesiyan	University of Ibadan	"
Dr. Fawole	University of Cornell U.S.A.	"
Dr. R. A. Odihirin	North Carolina State Univ. Raleigh, NC, USA	University of Port-Harcourt, Port-Harcourt, Nigeria
Dr. J. O. Amosu	University of Illinois	University of Ife Ile-Ife
Dr. R. O. Ogbuji	Oregon State Univ. U.S.A.	University of Nigeria Nsukka, Nigeria
Dr. J. J. Smit	Netherlands	A.B.U., Zaria
*Dr. W. S. Bos	Netherlands	- do -
*Dr. P. O. Omiyi	Imperial College London, England	"
Mr. Afolami	University of Ibadan Ibadan, Nigeria	Cocoa Research Institute of Nigeria, Ibadan
Mrs. F. I. Onyenobi	Imperial College London, England	Institute of Management Education, Enugu, Nigeria
Mr. N. Ogiga	McGill, Canada	University of Port-Harcourt Port-Harcourt, Nigeria
Mr. Dele Awoyemi	University of Ibadan Ibadan	College of Education Ilesha, Nigeria

*Left the University.

Table 1. (Continued)

NAME	INSTITUTION WHERE ADVANCED DEGREES WERE OBTAINED	PRESENT ADDRESS
U. G. Atu	University of California Riverside, USA	National Root Crop Res. Institute, Umudike, Nigeria
Mr. Sam Booth	Ahmadu Bello University (A.B.U.) Zaria	-
Mr. S. S. Okatahi	- do -	-
Dr. T. Badra	Cairo University	National Horticultural Research Institute Ibadan, Nigeria
Dr. F. E. Caveness	--	International Institute of Tropical Agriculture; P.M.B. 5320, Ibadan
Dr. A. O. Ogunfowora	Imperial College London, England	Institute of Agricultural Res. & Training, Univ. of Ife, PMB 5029, Ibadan
Dr. 'Tayo Olowe	Imperial College London and Rothamsted Exp. Station, England	National Cereals Research Institute, PMB 5042, Ibadan, Nigeria
Mr. J. A. Onapitan	University of Ife Ile-Ife	- do -
Mr. E. O. Salawu	McGill University Canada	Federal Polytechnic Akure

Table 2. Plant-parasitic nematodes associated with cowpea in Nigeria

1. *Criconemoides* sp.
2. *Helicotylenchus cavenessi*
3. *Helicotylenchus pseudorobustus*
4. *Hemicriconemoides* sp.
5. *Hemicycliophora* sp.
6. *Hoplolaimus seinhorsti*
7. *Meloidogyne arenaria*
8. *Meloidogyne incognita*
9. *Meloidogyne javanica*
10. *Peltamigratus nigeriensis*
11. *Pratylenchus brachyurus*
12. *Radopholus similis*
13. *Rotylenchulus reniformis*
14. *Scutellonema bradys*
15. *Scutellonema clathricaudatum*
16. *Trichodorus* sp.
17. *Tylenchorhynchus* sp.
18. *Tylenchus* sp.
19. *Xiphinema americanum*
20. *Xiphinema basiri*

Table 3. Distribution of root-knot nematode in northern states of Nigeria

STATE	LOCALITY	ROOT-KNOT NEMATODE POPULATIONS	ROOT-KNOT NEMATODES *M. INCOGNITA*	*M. JAVANICA*
Bauchi	1	2	1	1
Benue	3	5	2	3
Borno	4	5	2	3
Gongola	2	3	1	2
Kaduna	1	2	1	1
Kano	3	3	1	2
Kwara	4	6	3	3
Niger	5	8	3	5
Plateau	5	5	2	3
Sokoto	2	2	1	1
Total	30	41	17 (41)	24 (59)

Relative frequency of occurrence (%) in parentheses.

Table 4. Distribution of root-knot nematodes in southern states of Nigeria

STATE	LOCALITY	ROOT-KNOT NEMATODE POPULATION	ROOT-KNOT NEMATODE *M. INCOGNITA*	*M. JAVANICA*	*M. ARENARIA*
Bendel	1	1	1	0	0
C/Rivers	2	3	2	1	0
Imo	1	2	1	1	0
Lagos	3	3	3	0	0
Ogun	3	5	3	2	0
Ondo	4	6	3	3	0
Oyo	6	11	6	4	1
Rivers	1	1	0	0	1
Total	21	32	19 (59)	11 (34)	2 (6)

Relative frequency of occurrence (%) in parentheses.

Table 5. Incidence of occurrence of root-knot nematodes as mono or mixed species in northern and southern states of Nigeria

		MONO SPECIES			MIXED SPECIES
REGION	LOCALITY	*M. INCOGNITA*	*M. JAVANICA*	*M. ARENARIA*	*M. INCOGNITA/M. JAVANICA*
North	30	9 (30)	10 (33)	0	11 (37)
South	21	9 (43)	1 (5)	1 (5)	10 (47)
Total	51	18 (35)	11 (22)	1 (2)	21 (41)

Relative frequency of occurrence (%) in parentheses.

Various factors contribute to the pattern of distribution. The vegetation and rainfall patterns of the two areas (North and South) differ markedly. The north has a savannah ecology and low rainfall ranging from 500 to 1,500 mm, while the south has a forest ecology with high rainfall ranging from 1,500 to 5,000 mm (Figs. 2, 3 & 4). Perhaps tolerance to dessication accounts for the predominance of *M. incognita* in the north savannah.

In the overall population, *M. incognita* occurs more frequently than *M. javanica*. A similar trend is also shown in the world population of root-knot nematodes of the developing countries where *Meloidogyne incognita* constitutes 64%, *M. javanica* 28%, and *M. arenaria* 8% of the world population collection of 400 (37). The incidence of these root-knot nematode species also was confirmed under irrigated conditions (6, 8, 40), in the eastern part of Nigeria (23), and in Ibadan (24). Bos (5, 6) reported that *M. javanica* occurred exclusively at high elevations of Jos Plateau in Nigeria.

Infestations of root-knot nematodes on cowpea or other crops were milder on local farms or local cultivars than on government farms or improved cultivars, and also on farms grown to cowpea mixed with cereal or groundnut than on farms with cowpea in monoculture (23, 26, 27). Insect galls caused by *Acidodes leucograma* at Eruwa (in south), Kano and Jos (in north) were found to be associated with root-knot nematode galls. Also a mealy-bug insect in Langtan (north), a fungus *Sclerotium* sp. in Kano and Langtan (in north), and a parasitic weed *Striga gesnoroide* in Kano, Langtang, Jos and Damaturu (in north) were found in association with galls of root-knot nematodes during the course of the survey (26, 27)

Biology

Little work has been done on the biology of root-knot nematode on cowpea. The life cycle of *Meloidogyne incognita* in cowpea has been shown to be completed within 21 days (10, 26, 27). Galling became apparent within 7 to 14 days of infestation and covered about 65% of the total root system. Cowpea seedlings were more susceptible to attack than older plants (26, 27). The effect of fertilizer NPK (30 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare), applied singly and in combinati on the severity of root galling and grain yield showed that treatments with nitrogen and phosphorus minimized root galling and gave highest grain yield (29, 30).

ECOLOGICAL ZONE IN NIGERIA

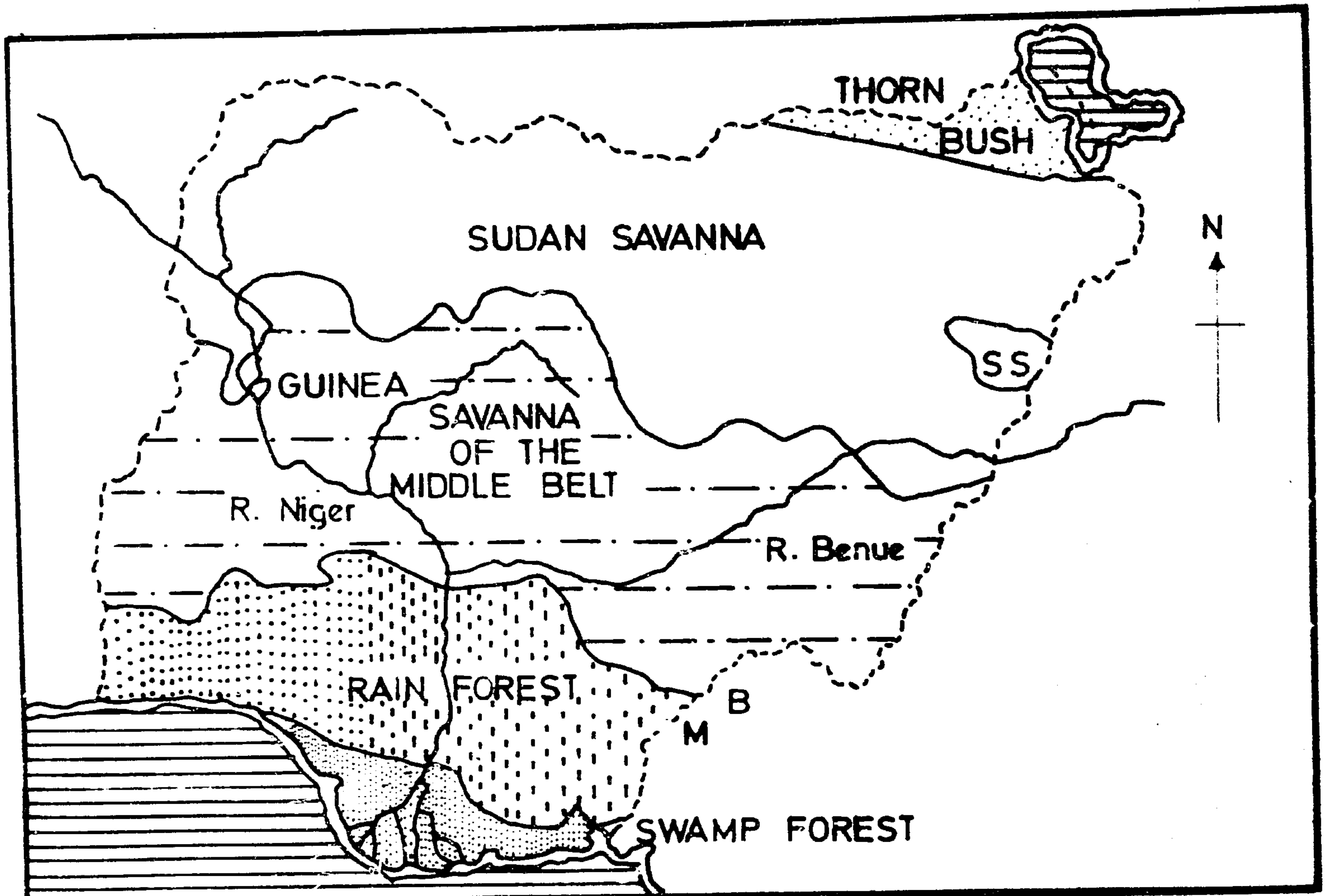

FIG. 2 ECOLOGICAL ZONE IN NIGERIA

CLIMATIC ZONE IN NIGERIA

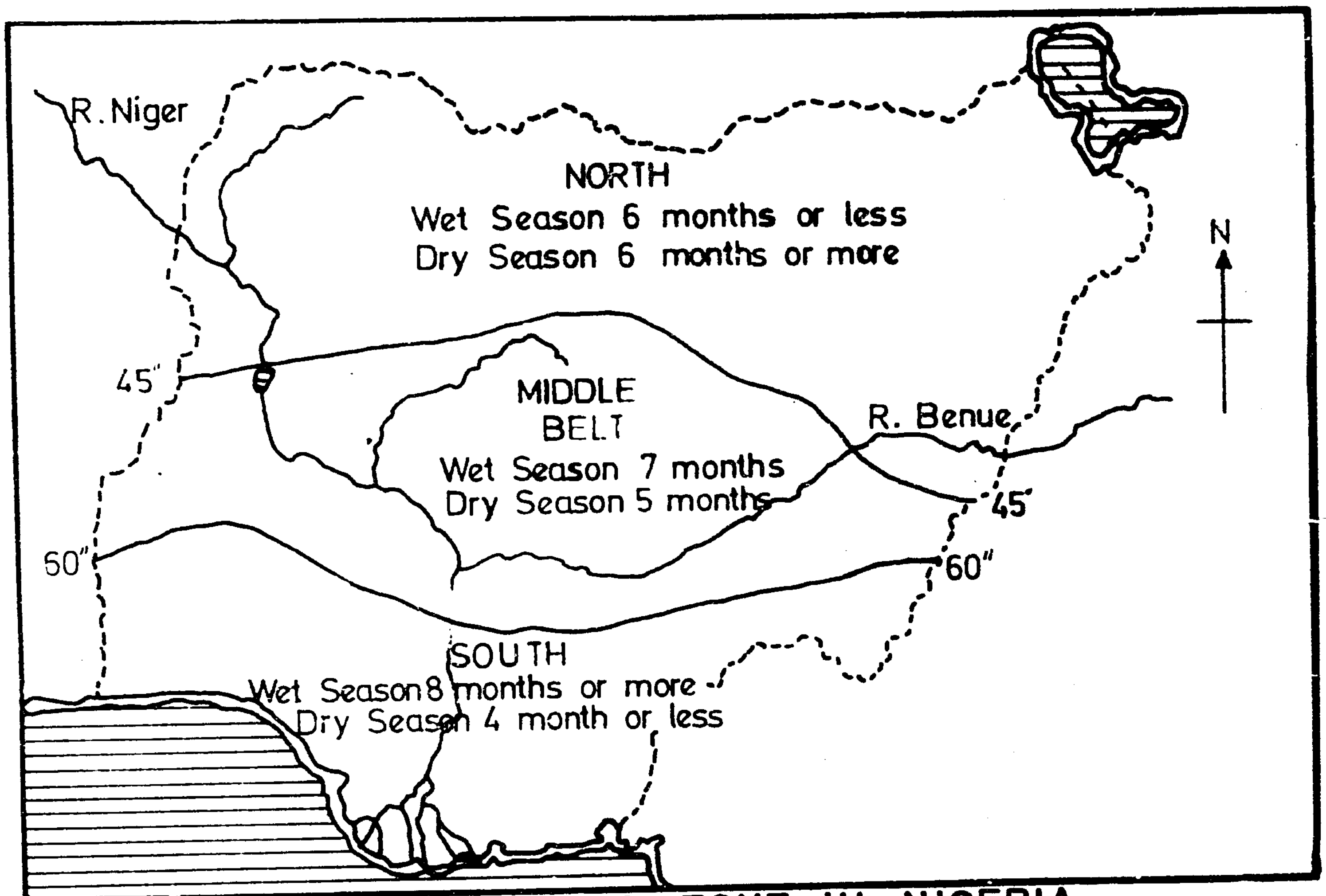

FIG. 3 CLIMATIC ZONE IN NIGERIA

ANNUAL RAINFALL

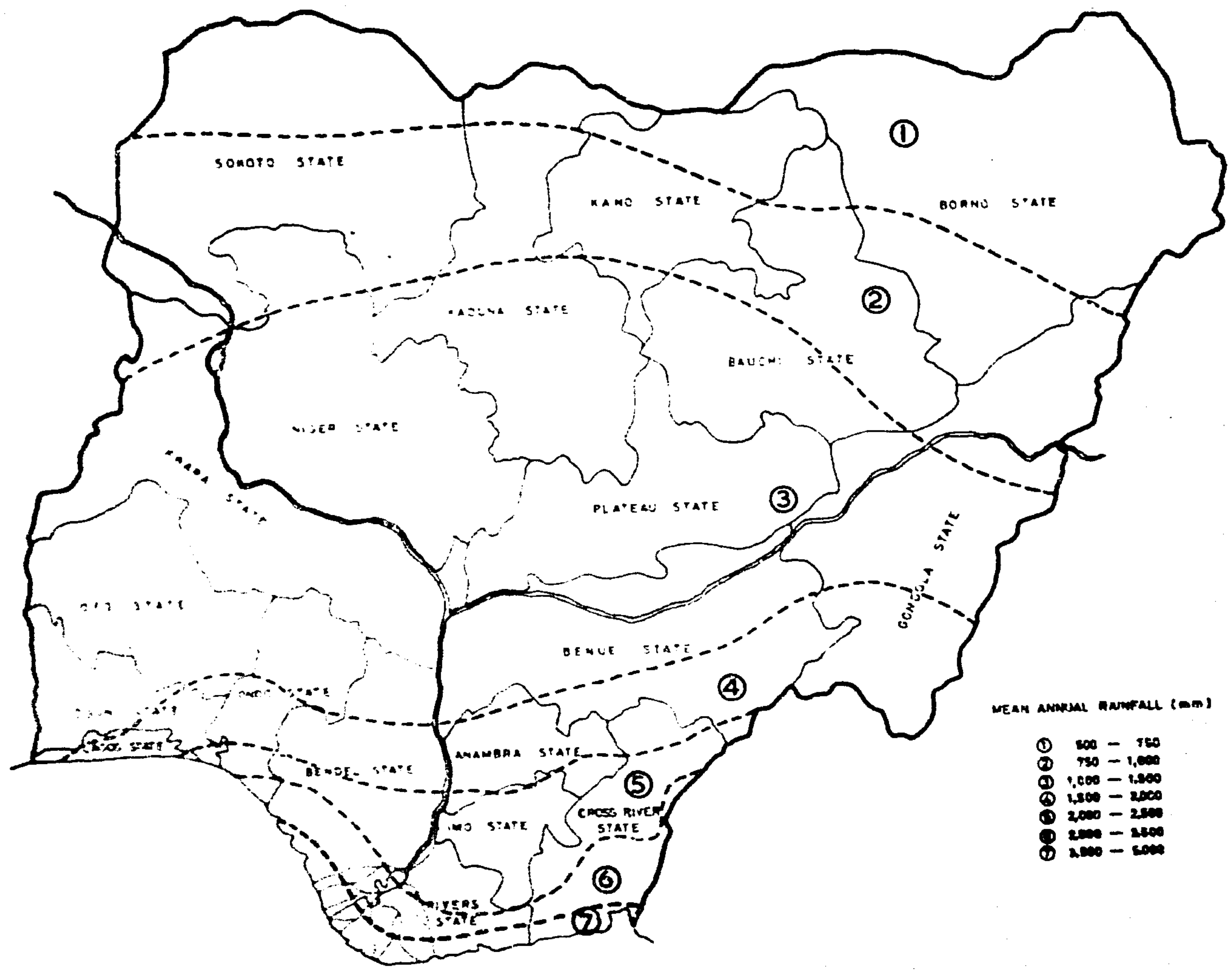

FIG. 4 ANNUAL RAINFALL IN NIGERIA

Crop Losses

Crop losses attributable to plant-parasitic nematodes are difficult to ascertain. However, world estimates given by Wilson (46), Jenkins and Taylor (18), and Taylor (42) showed a field loss ranging from 5 to 25%. Wilson (45) reported a yield loss of 75% on tomato in northern Nigeria. An estimate of yield losses caused by root-knot nematodes in developing countries showed an average loss ranging from 11% in Mexico, Central America, the Caribbean and Southeast Asia to 25% in West Africa. Losses among the crops ranged from 2% in rice to 46% in tomato, with cowpea having a 43% loss in West Africa (37). On cowpea in Nigeria, yield losses of 20 to 30% (11) and 59% (25) have been reported. Bridge (8) also reported that a yield loss of 40% could be expected under heavily infested crops, including cowpea. In potted experiments, Olowe (26, 27) also demonstrated a yield reduction of 25% at an inoculum level of 133 nematodes of *Meloidogyne incognita* per kg of soil or a 94% reduction with 13,300 nematodes/kg soil. Root-knot nematodes also pose constraints in food crop production under irrigation projects (5, 6, 19, 40).

CONTROL

Screening of Cowpea Cultivars for Resistance to Root-Knot Nematodes

Since environmental pollution, the hazards of application, and the high cost of chemicals all limit research on nematicides, research for control of root-knot nematodes emphasizes a search for sources of host plant resistance. In pursuance of this, Amosu reported a cowpea cultivar Mississippi Silver highly resistant to *M. incognita* in potted experiments (2). Caveness at IITA also developed a resistant cowpea variety Vita 3 which combines multiple disease resistance and tolerance to several insect pests (12, 38).

At the National Cereals Research Institute, 728 cowpea cultivars were evaluated in the screen-house for resistance to an Ibadan population of *Meloidogyne incognita* between 1976 and 1979. The assessment of resistance was based on the degree of root galling. A cultivar 64298 consistently showed high level resistance to races 1, 3, and 4, regardless of the year of evaluation. The cultivar also shows resistance to *M. arenaria* and mild resistance to viral infestation as well.

Other cultivars which also show moderate levels of resistance include Acc. 72011, 74001, 71012, 72001, 64287, 64006, 71013, IAR 339-1 and IAR 341 (Tables 6 and 7). Cultivar Acc. 70002 combines tolerance/resistance to root-knot nematode virus and fungal brown blotch disease with high grain yield. The cultivar Acc. 67010 shows resistance to *M. arenaria* (Table 6). Though the cultivars 64298 and 67010 exhibit resistance to *M. incognita* and *M. arenaria*, respectively, and compare favorably in grain yield with the elite variety Acc. 73001, they suffer from poor acceptability (Table 7). However, the cultivar Acc. 64298 has been submitted for use in the breeding program for improvement of the elite cultivar Acc. 73001 which is susceptible to all known root-knot nematodes.

Resistant Crops

In research on resistant crops for use in rotation experiments for cultural control of root-knot nematodes, the host status of an extensive list of food crops and weeds has been evaluated (1, 5, 6, 8, 9, 22, 29, 30, 39, 45). Some crops {onion, lettuce (8), groundnut, maize, sugarcane, cassava (23), and pepper cv. L. 3874BE, L5962-2 (5, 6)} and weeds {*Eupatorium*, *Tridaz* (23), *Cynodon dactylon* 1B-8 (2)} have displayed resistance to root-knot nematodes. Olowe (29, 30) also found that cereals (pearl millet, rice, maize and guinea-corn) and groundnut (cv. Upe 651) were inefficient hosts. Crop rotation studies for control of root-knot nematodes are now underway at University of Ife (3), University of Ahmadu Bello (40), Institute of Agricultural Research and Training (25), and IITA.

Screening of Nematicides for Control of Root-Knot Nematodes

Emphasis on chemical control at NCRI has shifted to a multidisciplinary approach. The aim is to develop broad spectrum pesticides effective against several pests and diseases of cowpeas. This effort is considered more amendable to the farmers.

Replicated field trials were conducted at Ibadan (southwestern forest zone with pH 5.5 to 7.0), Amakama (southeastern high rain forest and acid zone with pH 4.0 to 4.5), and Badeggi (northern middle belt Guinea savannah zone). Herbicides, insecticides, nematicides and fungicides were applied alone or in appropriate combinations (Table 8). Galex applied pre-emergence gave the most effective weed control, but it did not appear to affect the root-knot nematode population. Furadan gave

Table 6. Resistance/susceptibility of cowpea cultivars to *Meloidogyne incognita*

Year	Cowpea Cultivar	Total Rt. Sy. Galled (%) Rating	Resistance/ Susceptibility Rating
1976	1 (64298)	1 - 10	HR
	2 (72011) (74001)	11 - 30	MR
	7	31 - 50	S
	22	>50	HS
1977	1 (64298)	1 - 10	HS
	2 (71012) (72001)	11 - 30	MR
	2	31 - 50	S
	40	>50	HS
1978	1 (64298)	1 - 10	HR
	3 (64287) (64006) (71013)	11 - 30	MR
	5	31 - 50	S
	545	>50	HS
1979	1 (64298)	1 - 10	HR
	2 (IAR 339-1) (IAR 341)	11 - 30	MR
	2	31 - 50	S
	95	>50	HS

Table 7. Plant characteristics of cowpea cv. ACC64298, 67010, & 73001

Characteristics	Cowpea Cultivar ACC 64298	ACC 67010	ACC 73001
Growth habit	Semi erect	Climbing	Semi erect
Photoperiodic response	Day neutral	Day neutral	Day neutral
Length of maturity (days)	70	80	60
Parent crossing	?	Straight from farmers	Local brown + Westbred + Alabunoh
Seed coat color	Ash grey	Tan	Brown
Seed coat size	Medium	Small	Medium
Seed texture	Smooth	Smooth	Smooth wrinkled
Seed shape	Crowder	Kidney	Crowder
Seed eye color	Self	Self	Self
Origin	South Africa	Nigeria	Nigeria
Acceptability	Poor	Poor	Excellent
Grain yield (metric ton/ha)	1.5	1.0	1.5

Cowpea Cv. ACC 64298 - Resistant to *Meloidogyne incognita* and *M. arenaria*.

Cowpea Cv. ACC 67010 - Resistant to *M. arenaria*.

Cowpea Cv. ACC 73001 - (Elite variety) susceptible to all root-knot nematodes.

Table 8. Effect of pesticide application on the performance of cowpea Ife Brown at different locations

sticide	Rate kg/ha	Ibadan: Thrips/5 flowers DAP 35	42	49	Ibadan: Root knot nematode galling*	Brown blotch*	Weed wt. kg/plot	Grain yield kg/plot	Amakama: Root knot nematode galling*	Brown blotch	Weed wt. kg/plot	Grain yield kg/plot	Badeggi: Leaf area damage (%) 35 DAP	Grain yield kg/plot
Lex + Nuvacron	3.0+0.75	6.8	3.8	17.2	3	2.5	2.0	0.90	2	3.3	0.0	0.72	4.3	1.25
eforan + Nuvacron	3.0+0.75	6.6	2.6	24.8	3	1.9	3.0	0.79	2	3.3	0.0	0.71	5.0	0.82
Preforan														
vacron EC	0.75	5.2	5.2	14.2	3	2.4	5.4	0.86	2	3.0	1.8	0.87	7.3	0.88
imet G	3.0	5.2	35.0	267.0	3	0.2	8.3	0.002	2	3.8	2.6	0.50	4.0	1.05
ral EC	0.75	2.2	54.4	116.4	2	2.2	3.7	0.47	2	3.8	2.3	0.30	5.5	0.51
radan G	3.0	4.8	10.8	162.4	1	0.0	9.2	0.01	1	3.4	1.6	0.44	1.3	0.77
cap G	3.0	7.0	59.8	292.0	2	1.2	4.4	0.07	2	3.8	2.5	0.45	5.3	0.59
ral G	3.0	7.0	37.8	244.4	1	1.1	17.6	0.48	1	3.5	1.7	0.28	2.5	0.48
nlate G	1.9	6.2	5.4	86.6	3	2.2	5.1	0.11	3	3.3	2.9	0.39	7.0	0.45
nlate + Nuvacron (35, 49, 62 DAP)	1.9+0.75	5.4	5.4	32.8	2	1.0	8.7	1.68	3	1.3	2.8	1.44	6.8	1.42
radan + Nuvacron (35, 42 DAP)	3.0+0.75	5.8	5.2	8.2	1	1.3	7.0	0.45	2	3.5	1.7	0.78	1.3	0.99
radan + Nuvacron (35 DAP)	3.0+0.75	3.8	6.8	32.6	1	2.2	13.8	0.07	1	3.5	1.7	0.36	1.3	0.82
radan + Nuvacron (42 DAP)	3.0+0.75	6.8	23.8	15.0	1	2.1	12.8	0.14	2	3.3	4.0	0.78	1.0	1.31
iral + Nuvacron (42 DAP)	3+0.75	7.8	34.2	15.4	1	1.2	5.2	0.25	1	3.3	3.2	0.61	2.0	0.29
ontrol	-	6.0	68.0	274.0	4	1.0	7.4	0.02	3	4.5	1.4	0.40	4.3	0.54

0, no infection; 1, 1-10%; 2, 11-25%; 3, 26-50%; 4, 51-75%; 5, 76-100%. Mean of five replicates of plot size 5.4 x 4.20M (22.68M).
Furadan, Miral G, Mocap and Thimet were applied in furrow at planting. Preforan and Galex were applied as spray 2 days after planting (DAP)
Nuvacron and Miral E.C. were applied as foliar spray at 35, 42 and 49 (DAP) and Benlate G as seed dressing.

the best control of root-knot nematodes, and in combination with Nuvacron, it gave higher grain yield than when applied alone. Benlate applied as seed dressing gave poor grain yield and did not effectively control fungal diseases. However, Benlate in mixture with Nuvacron gave the highest grain yield irrespective of location. The pooled means for the locations is presented in Table 9.

In an earlier experiment, Furadan at 3 kg/ha showed promise of controlling root-knot nematodes better than Miral, Thimet, and Mocap. In addition, vegetative growth was stimulated more by Furadan than the other nematicides (Table 10). However, the effect is not translocated into the pods.

Nematology research proposals 1981. To develop economical, practical and effective methods of controlling cowpea nematodes.

Experiment 1

Title: Survey of plant-parasitic nematodes affecting cowpea.

Objective: To determine the distribution of nematodes affecting cowpea, assess field damage, and collect field populations for evaluation of root-knot nematode resistant cultivars and food crops in Experiments 2 and 4.

Experiment 2

Title: Screening for nematode resistance.

Objective: To identify sources of resistance to major nematode pests of cowpea for improvement of recommended cowpea varieties.

Experiment 3

Title: Screening of pesticides for efficacy in controlling nematodes, insects and fungi affecting cowpea.

Objective: To develop a pesticide with broad-spectrum activity against major insect, disease, and nematode pests of cowpea with a view toward provision of practical, economical, and operationally feasible means of control as a package for the local farmers.

Experiment 4

Title: Host status studies of various food crops to economically important nematodes.

Objective: To evaluate various food crops for resistance to root-knot nematodes for use in crop rotational experiments as a means of cultural control.

Table 9. Mean effect of herbicides, insecticides, fungicides and nematicides on cowpea pests, disease and grain yield of cowpea var. ACC. 73001 in Ibadan, Amakama and Badeggi

Treatment	Rate/Ha (kg)	Weed assessment 15 DAP	Insect damage + Thrip/5 flowers DAP			*Fungal disease index		*Nematode disease index	**Plant Vigor 60 DAP	Grain yield/ plot***(kg)
		Weed wt/plot (kg)	35	42	49	Web Bught	Brown Blotch	Root-knot nematode galling		
Galex + Nuvacron	3 + 0.075	0.51	6.8	3.8	17.2	1.8	2.4	2.3	3.0	0.96
Preforan + Nuvacron	6 + 0.075	0.77	6.8	2.6	24.8	1.6	2.1	2.3	2.5	0.77
Nuvacron	0.075	1.89	5.2	5.2	14.2	2.5	2.0	2.3	3.0	0.87
Miral EC	0.075	1.60	2.2	54.4	116.4	2.7	2.4	2.0	2.6	0.42
Thimet G	3	2.90	5.2	35.0	267.0	3.6	1.7	2.3	2.8	0.52
Furadan G	3	2.88	4.8	10.8	162.4	2.0	1.6	1.0	3.7	0.41
Mocap G	3	5.10	7.0	59.8	292.0	3.5	2.0	1.7	3.5	0.52
Miral G	3	4.85	7.0	37.8	244.4	3.3	2.0	1.7	3.5	0.28
Benlate G	0.04	2.02	6.2	5.4	86.6	3.0	2.2	3.0	2.5	0.32
Benlate W.P. + Nuvacron	1.0+ 0.750	3.11	5.4	5.4	32.8	0.9	1.1	2.3	2.9	1.51
Furadan G + Nuvacron 35, 42, DAP	3 + 0.750	2.23	5.8	5.2	8.2	2.6	2.0	1.3	3.4	0.74
Furadan G + Nuvacron 35 DAP	3 + 0.750	0.85	3.8	6.8	32.6	33.6	2.5	1.0	3.6	0.42
Furadan G + Nuvacron 42 DAP	3 + 0.750	4.25	6.8	23.8	15.0	3.4	2.2	1.3	3.7	0.74
Miral G + Nuvacron 42 DAP	3 + 0.750	2.14	7.8	34.2	15.0	2.7	1.9	1.3	3.2	0.38
Control	0.0	2.26	6.0	68.0	274.0	4.0	2.3	3.0	2.8	0.32

*0 = No infection; 1 = 1-10%; 2 = 11-25%; 3 = 26-50%; 4 = 51-75%; 5 = 76-100%.

**1 = Poor; 2 = Fair; 3 = Good; 4 = Very Good; 5 = Excellent.

+ = Only for Ibadan

***Plot size = 19.9 sq. m.

Table 10. Effect of nematicide/insecticide on yield components of cowpea cv. 73001

Nematicide/ Insecticide	Rate kg/ha a.i.	Dry top weight per stand (gm)	*Plant vigor at 35 days	Insect bored leaves at 35 days	Nematode killed stands at 62 days (%)	Stem rot killed stands at 62 days (%)	Total dead stands at 62 days (%)
Furadan (5%)	3.0	8.59	4.00	8.05	10	28	39
Miral E.C. (40%)	1.9	6.80	1.90	59.0	15	46	61
Miral G. (10%)	5.0	5.79	4.00	40.01	12	36	48
Thimet G. (10%)	3.0	5.79	3.00	57.73	18	51	69
Nuvacron E.C. (40%)	1.9	3.61	2.20	54.85	23	61	84
Mocap (10%)	3.4	3.11	2.00	63.30	13	47	60
Control	0.0	2.55	2.68	59.50	24	65	89

*5 = Excellent; 4 = Very good; 3 = Good; 2 = Fair; 1 = Poor.

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STUDIES ON ROOT-KNOT NEMATODE SPECIES AT THE INSTITUTE FOR AGRICULTURAL RESEARCH, AHMADU BELLO UNIVERSITY, ZARIA, UNDER THE INTERNATIONAL MELOIDOGYNE PROJECT

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Of recent in northern Nigeria, upland areas are being brought under irrigation in both small and large irrigation projects. This heavy, continuous cropping of land will permit the buildup of nematode populations to very high potentially damaging levels. More so, vegetable crops which are highly susceptible to root-knot nematode attack are among the range of crops grown under these irrigation schemes. As a consequence, the nematode problem on irrigated areas has formed the basis of recent nematological studies in northern Nigeria notably by Bridge (1) and Bos (2).

Under the supervision of Ir. W. S. Bos. I co-opted to work on the International Meloidogyne Project, as a post-graduate student. Ir. J. J. Smit helped in initiating and securing most of the IMP materials used for the study.

Field Survey

Root-knot nematode populations were collected from the main vegetable-growing areas of the northernmost parts of Nigeria from both irrigated and non-irrigated fields (Figure 1). In these fields, vegetable crops like tomatoes, peppers and eggplants, as well as weeds, were examined for root-knot nematodes. In each location a composite sample consisting of galled roots of infected plants and surrounding soil was collected in polythene bags slightly moistened when necessary and brought to the laboratory for analysis. A composite sample consisted of at least three galled root systems and their surrounding soils collected at different distances. The vicinity of each crop was studied and field data sheets were filled in at the time of sampling.

Identification of Meloidogyne Species

Identifications of *Meloidogyne* species were made following the preparation of perineal patterns. The diagnostic features described by Taylor,

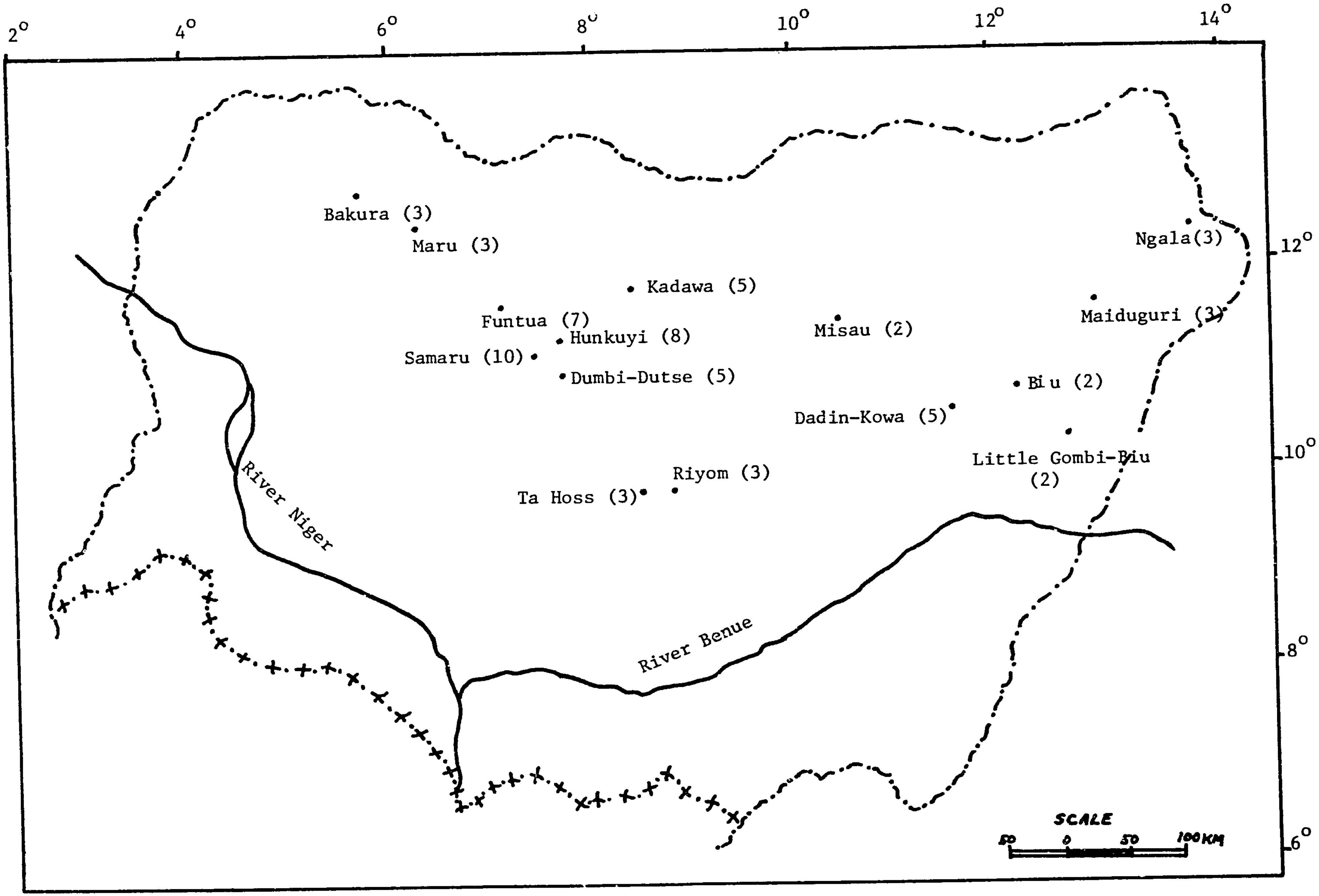


Figure 1. The vegetable-growing localities in northern states of Nigeria sampled for the occurrence of root-knot nematodes *Meloidogyne* species.

Dropkin and Martin (6), Whitehead (7), and Esser, Perry and Taylor (3) were used for species differentiation. No distinction was made between *M. incognita incognita* and *M. incognita acrita*; both were regarded as *M. incognita* (Sensu Lato). Before a conclusion was made as to the identity of each species, at least 10 perineal patterns of adult female nematodes from each population collected were examined.

Host Differential Studies

In greenhouse trials, we studied the physiological reactions of some selected root-knot nematode populations on five of the North Carolina host differential plants namely tomato, watermelon, cotton, tobacco and pepper.

Seedlings of each host differential plant were inoculated with about 20,000 eggs of a given population per pot in four replicates. The pots were arranged in a randomized block design on glasshouse benches. Infection assessment was carried out 45 days after inoculation. Ten perineal patterns were prepared of the original population and after infection assessment for each host population combination. The purpose was primarily to detect and follow mixed populations.

Results and Discussion

Details of the sampled sites and crops with associated weeds are given in Tables 1 and 2.

As in most of the other survey reports of root-knot nematodes attacking crops in northern Nigeria (1, 2, 5, 8), *M. javanica* was found to have the widest distribution and *M. arenaria* the smallest. *M. incognita* occurred sporodically within the examined root-knot nematode populations. Since all our samples were collected from cultivated fields, the species distribution may not necessarily reflect the actual influence of the natural vegetation, but may be influenced by the crops grown, environmental factors, and the fact that irrigation changes the environment radically. Worth mentioning in this respect is the fact that, except for one instance, pepper cultivars were observed to be attacked only by *M. incognita*. In some of the locations, pepper varieties inter-cropped with tomatoes and eggplants were free from galling though the other two crops were heavily galled. Thus, sampling only peppers at a given site could reveal the presence of only *M. incognita*, leaving out the other species. The influence of pepper varieties on root-knot nematode populations still has to be properly assessed.

Table 1. A list of all plants that were observed galled, their plant families, localities where found, status at different localities and extent of galling.

Plant Infested Under Their Plant Families	Localities Where Found	Status On Locations	Galling Index
CHENOPODIACEAE			
Spinacoa oleracea	Lake Alau	Weed	2.0
(Spinach)	Riyom	Crop	3.0
COMPOSITAE			
Ageratum conyzoides	Riyom	Weed	4.0
"	Samaru	Weed	4.0
Ethulia conyzoides	Bomo Lake	Weed	1.0
Galinsoga ciliata	Riyom	Weed	3.0
Lactuca sativa	Lake Alau	Weed	1.0
(Lettuce)			
Senecia claranceanus	Ta Hoss	Weed	3.0
Vernonia nester	Riyom	Weed	2.0
Vernonia pauciflora	Dumbi-Dutse	Weed	4.0
CONVOLVULACEAE			
Ipomoea batatas	Riyom	Crop	2.0
(Sweet potato)			
"	Ta Hoss	Crop	4.0
CRUCIFERAE			
Brassica nigra	Lake Alau	Hedge-plant	1.0
(Black mustard)			
Brassica oleracea	Lake Alau	Crop	3.0
(Cabbage)			
LABIATAE			
Leucas martinicensis	Samaru	Weed	4.0
LEGUMINOSAE			
Phaseolus vulgaris	Kadawa	Crop	2.0
(French-bean)			
LINACEAE			
Linum usitatissimum	Hunkuyi	Weed	4.0
(Flax)			
MALVACEAE			
Hibiscus esculentus	Bakura	Weed	1.0
(Okra)			
"	Dumbi-Dutse	Crop	3.0
"	L. Gombi/Biu	Crop	4.0
"	Misau	Crop	1.0
"	Riyom	Crop	3.0
POLYGONACEAE			
Polygonum lanigarum	Lake Alau	Weed	3.0

Table 1. Cont'd.

Plant Infested Under Their Plant Families	Localities Where Found	Status On Locations	Galling Index
PORTULACACEAE			
Portulaca oleracea	Lake Alau	Weed	4.0
"	Samaru	Weed	4.0
SOLANACEAE			
Capsicum sp. (Pepper)	Dumbi-Dutse	Crop	4.0
"	Funtua	Crop	3.0
"	Maru	Crop	3.0
"	Samaru	Crop	3.0
"	Bakura	Crop	2.0
Lysopersicon esculentum (Tomato)			
"	Dadin-Kowa	Crop	4.0
"	Dumbi-Dutse	Crop	4.0
"	Funtua	Crop	5.0
"	Hunkuyi	Crop	5.0
"	Kadawa	Crop	4.0
"	Lake Alau	Crop	5.0
"	Ngala	Crop	5.0
"	Samaru	Crop	5.0
"	Ta Hoss	Crop	3.0
Physalis anoulata	Riyom	Weed	4.0
Solanum melongena	Lake Alau	Crop	5.0
(Eggplant)			
"	Riyom	Crop	4.0
"	Samaru	Crop	5.0
Solanum nigrum	Lake Alau	Weed	4.0
Solanum tuberosum	Bomo Lake	Crop	3.0
(Irish potato)			
"	Riyom	Crop	3.0
"	Ta Hoss	Crop	1.0
TILIACEAE			
Corchorus olitorius (Jews mallow)	Samaru	Crop	3.0
VERBENACEAE			
Stachytarpheta angustifolia	Bomo Lake	Weed	4.0

Table 2. A summary of the field data sheets.

Locality	Topography[1] Of Locations Sampled	Soil Type[2]	Soil Drainage	Cropping System[3]	Crops Planted	Origin of Seed/ Seedling	Crops in the Neighborhood	Previous Vegetable Class	Frequency of Cultivation	Last Season's Crop	Weed Condition	Remarks
Dumbi-Dutse	Depression	Sandy-Loam	Fair	Multi-Cropping	Pepper Tomato Okra	Local	Groundnut Maize & Onion	Grasses & Shrubs	Twice	Yam	Very Weedy	This was a peasant's farm. The field was rain-fed and fertilizer was not applied. Field floods occasionally.
Riyom	Bottom-Slope	Sandy-Loam	Good	Multi-Cropping	Okra Spinach Potato	Local	Pumpkin & Maize	Grasses & Shrubs	Once	Various Vege-tables	Very Weedy	This was a "backyard" farm. The field was rain-fed. Urea and Super-phosphate fer-tilizers were applied.
Riyom	Upper-Slope	Sandy-Loam	Good	Mono-Cropping	Eggplant	Local	Maize & Potato (Irish & Sweet)	Grass-Land	Once	Maize & Sweet Potato	Not Weedy	A "backyard" farm also.
Ta-Hoos	Depression	Clay-Loam	Good	Inter-Cropping	Tomato Potato	Local	Rice & Maize?	Grasses & Shrubs	Twice	Maize	Slightly Weedy	The field was being managed by a group of farmers. During the dry season it is irrigated. Superphosphate fertilizers were applied.

Table 2. Cont'd.

Locality	Topography[1] Of Locations Sampled	Soil-Type[2]	Soil Drainage	Cropping[3] System	Crops Planted	Origin of Seed/ Seedling	Crops in the Neighborhood	Previous Vegetable Class	Frequency of Cultivation	Last Season's Crop	Weed Condition	Remarks
Bakura	Bottom-Slope	Sandy-Loam	Good	Mono-Cropping	Tomato	I.A.R. (Samaru)	Maize & Millet	Shrubs & Grasses	Twice	Millet & Tomatoes	Very Weedy	In the dry season the field was irrigated. Superphosphate fertilizer was applied.
Funtua	Mid-slope	Sandy-Loam	Fair	Multi-Cropping	Tomato Maize Gourd	Local	Cotton Okra & Pepper	Trees, Shrubs & Grasses	Once	Millet	Not Weedy	This was a peasant's farm It is solely rain-fed. Amonium sulphate fertilizer was applied.
Funtua	Mid-slope	Sandy-Loam	Fair	Inter-Cropping	Okra & Pepper	Local	Cotton Maize Gourd & Tomato	Trees Shrubs & Grasses	Once	Millet	Not Weedy	Field managed by the same farmers. Clean of weeds and crop was growing well. Some fertilizer was applied.
Maru	Mid-slope	Sandy-Loam	Fair	Multi-Cropping	Okra Maize Pepper & Groundnut	Local	Millet	Shrubs & Grasses	Once	Pepper Millet Maize Okra Tomato	Very Weedy	A peasant's farm. It was a small holding and solely rain-fed.

Table 2. Cont'd.

Locality	Topography[1] Of Locations Sampled	Soil-Type[2]	Soil Drainage	Cropping[3] System	Crops Planted	Origin of Seed/ Seedling	Crops in the Neighborhood	Previous Vegetable Class	Frequency of Cultivation	Last Season's Crop	Weed Condition	Remarks
Samaru (I.A.R.)	Bottom-Slope	Sandy-Loam	Good	Mono-Cropping	Eggplant	I.A.R. (Samaru)	Tomato Spinach	Grasses & Shrubs	Twice	Tomato	Slightly Weedy, With Some Volunteer Crops	This was an experimental/ demonstration plot. In the dry season, crops planted were irrigated in furrows with rubber-hoses. Super-phosphate fertilizer used.
Samaru (I.A.R.)	Bottom-Slope	Sandy-Loam	Good	Mono-Cropping	Tomato	Ronita (I.A.R.)	Eggplant Cowpea Onion Spinach	Grasses & Shrubs	Twice	Tomato	Very Weedy With Volunteer Crops	
Lake Alau	Bottom-Slope	Sandy	Poor	Multi-Cropping	Eggplant Tomato Pepper	Ministry & Local	Cabbage Lettuce Mustard	Grasses & Shrubs	Twice	Cowpea	Weedy	This was mainly a vegetable 'garden,' consisting of small holdings by peasants and a portion used for mul-tiplication by the Ministry.

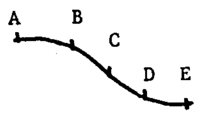
Table 2. Cont'd.

Locality	Topography[1] Of Locations Sampled	Soil-Type[2]	Soil Drainage	Cropping System[3]	Crops Planted	Origin of Seed/ Seedling	Crops in the Neighborhood	Previous Vegetable Class	Frequency of Cultivation	Last Season's Crop	Weed Condition	Remarks
Lake Alau	Bottom-Slope	Sandy	Poor	Mono-Cropping	Tomato	Ministry	Eggplant Cassava	Grasses & Shrubs	Twice	Onion	Not Weedy	Crop rotation was practiced. There was overhead irrigation by sprinklers & in other places the "Shaduf" system was used. Superphosphate & ammonium sulphate were the fertilizers used. Field gets waterlogged.
Dadin-Kowa	Depression	Sandy-Loam	Good	Mono-Cropping	Tomato	Exotic (Roma Ven)	Cabbage Watermelon	Grasses & Shrubs	Once	Tomato	Not Weedy	This field is operated for commerical purposes. The sole crop is tomato and there is no crop rotation. Fertilization is done with Nitro-phoska/ Urea and Potash. Main crop is in the dry season, so field is irrigated. On a (continued on next page)

Table 2. Cont'd.

Locality	Topography[1] Of Locations Sampled	Soil-Type[2]	Soil Drainage	Cropping System[3]	Crops Planted	Origin of Seed/ Seedling	Crops in the Neighborhood	Previous Vegetable Class	Frequency of Cultivation	Last Season's Crop	Weed Condition	Remarks
Dadin-Kowa	Depression	Sandy-Loam	Good	Mono-Cropping	Tomato	Exotic (Park V)	Carrot	Grasses & Shrubs	Once	Tomato	Not Weedy	particular field the Tomato variety "VFN" was found to be severely galled. All other tomato varieties grown were seriously galled.

(1) The classification of the topography was visual and based on the following sketch using the accompanying code: (After the forms for Ecological Studies. International Meloidogyne Project)



A = Upland
B = Upper slope
C = Kid-slope
D = Bottom slope
E = Depression

(2) Mechanical analysis of soil was done at the soil survey section, I.A.R., Samaru, Zaria, using the Bonyoncos hydrometer.

(3) The cropping system was based on the following code:
(a) Mono-cropping means only one crop was grown solely at a location.
(b) Inter-cropping means the growing of two crops at intervals on the same location.
(c) Multi-cropping means the growing of more than two crops at intervals on the same location.

(4) Refer to Table 1 for the names of the predominant host-weeds found at various localities.

All the root-knot nematode populations tested on the host differential plants infected and reproduced well on tomatoes and watermelon, while most populations neither infected nor reproduced on cotton. Until recently, cotton was not found attacked by root-knot nematodes in northern Nigeria (1, 4).

From our results, it seems a combination of the North Carolina differential host test reactions and perineal pattern studies gives a more reliable identification and characterization of *Meloidogyne* species present within a field population of root-knot nematode than each criterion taken separately. The mixed populations usually exhibit physiological reactions typical for only one of the species present, although perineal patterns made from galled roots of host differential plants often reveal the presence of more than one *Meloidogyne* species.

We are also of the opinion that, except for the purposes of population maintenance, tomato could be conveniently left out as one of the host differential plants for purposes of characterizing the root-knot nematode populations in northern Nigeria.

Summary

Meloidogyne research at I.A.R., Zaria, covered field surveys, identification of *Meloidogyne* species and weed hosts and studies on the physiological reactions of some northern Nigerian root-knot nematode populations on host differential plants. A combination of the North Carolina differential host test and perineal pattern studies have been found most reliable in species differentiation.

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A REVIEW OF ROOT-KNOT NEMATODE WORK ON MAIZE AT NATIONAL CEREALS RESEARCH INSTITUTE, IBADAN, AND PROSPECTS FOR FUTURE STUDIES

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The National Cereals Research Institute has the mandate to carry out research on maize, rice, sugarcane, and grain legumes throughout the Federation of Nigeria. Each crop is constituted into a program, and the institute's researchers, including the nematologists, are divided within the programs with their work forming an integral part of the overall research within the various programs.

Under the maize program, five major centers have been identified for maize improvement based on observed genotype-environment interactions (Fig. 1). The nematology work, therefore, is aimed at complementing maize improvement in these environments. Maize nematology research work within the institute now has more attention in that Dr. Olowe was formerly handling this crop along with both cowpea and soybean also.

Investigations to date

The bulk of the maize produced in Nigeria is from areas where nematodes, root-knot nematodes inclusive, are endemic. Between 1975 and now, a lot of surveys, mainly by Olowe, were conducted to determine the occurrence and distribution of nematodes associated with maize. These surveys covered the major areas for maize production in Nigeria. *Meloidogyne* spp. larvae were extracted from soil samples taken about the rhizosphere of growing maize plants, but root galls were never observed in the field. This intimacy of association of root-knot nematodes with maize plants in the field may suggest a potential significance of the nematode in maize production. Figure 3 shows the observed distribution of *Meloidogyne* sp. on maize in the major producing areas.

One of the experiments being conducted at present involves the study of the reactions of maize inbred lines and hybrids to economically important nematodes. One group of nematodes under study is the root-knot nematodes. We carried out some inoculations in the greenhouse, but the

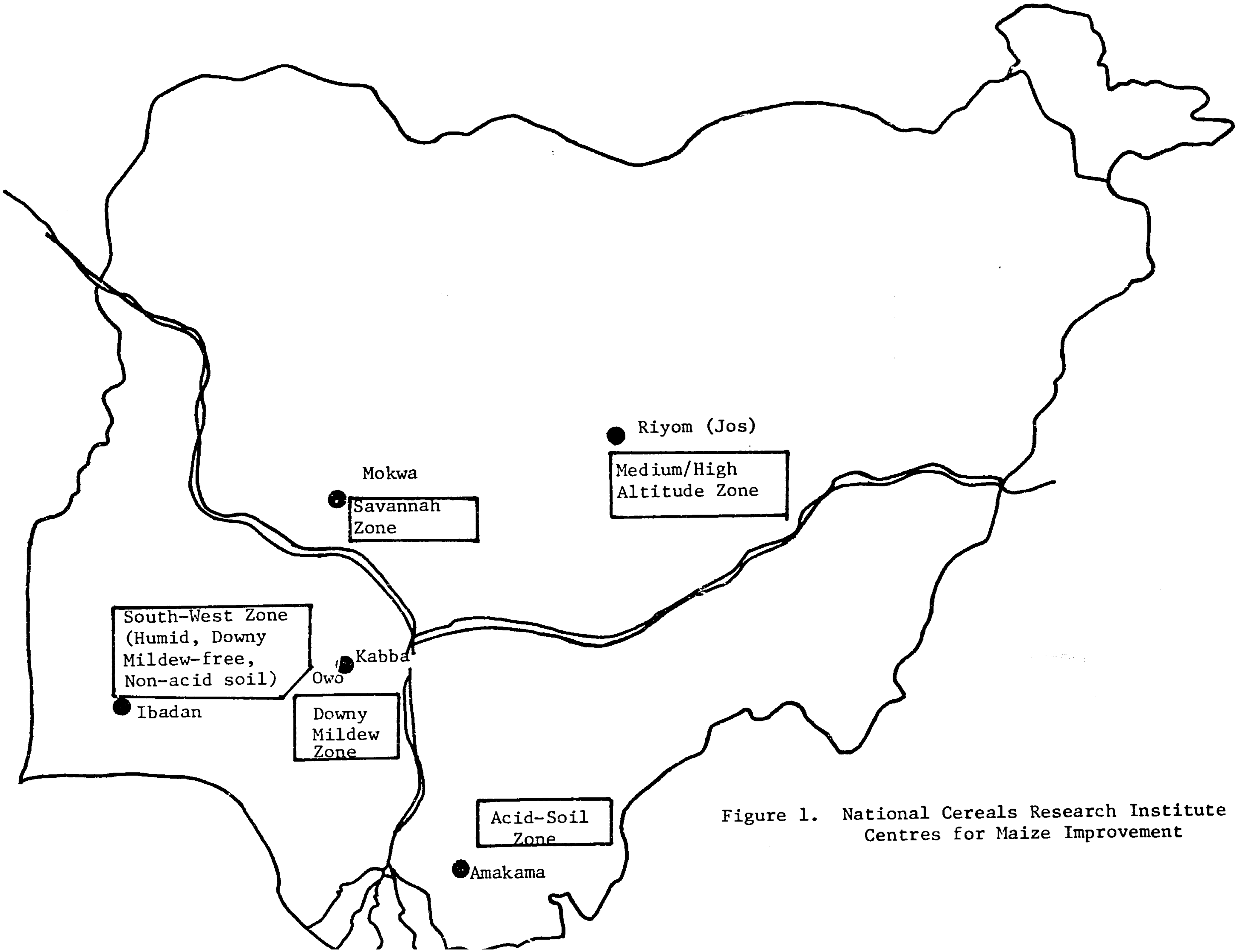

Figure 1. National Cereals Research Institute
Centres for Maize Improvement

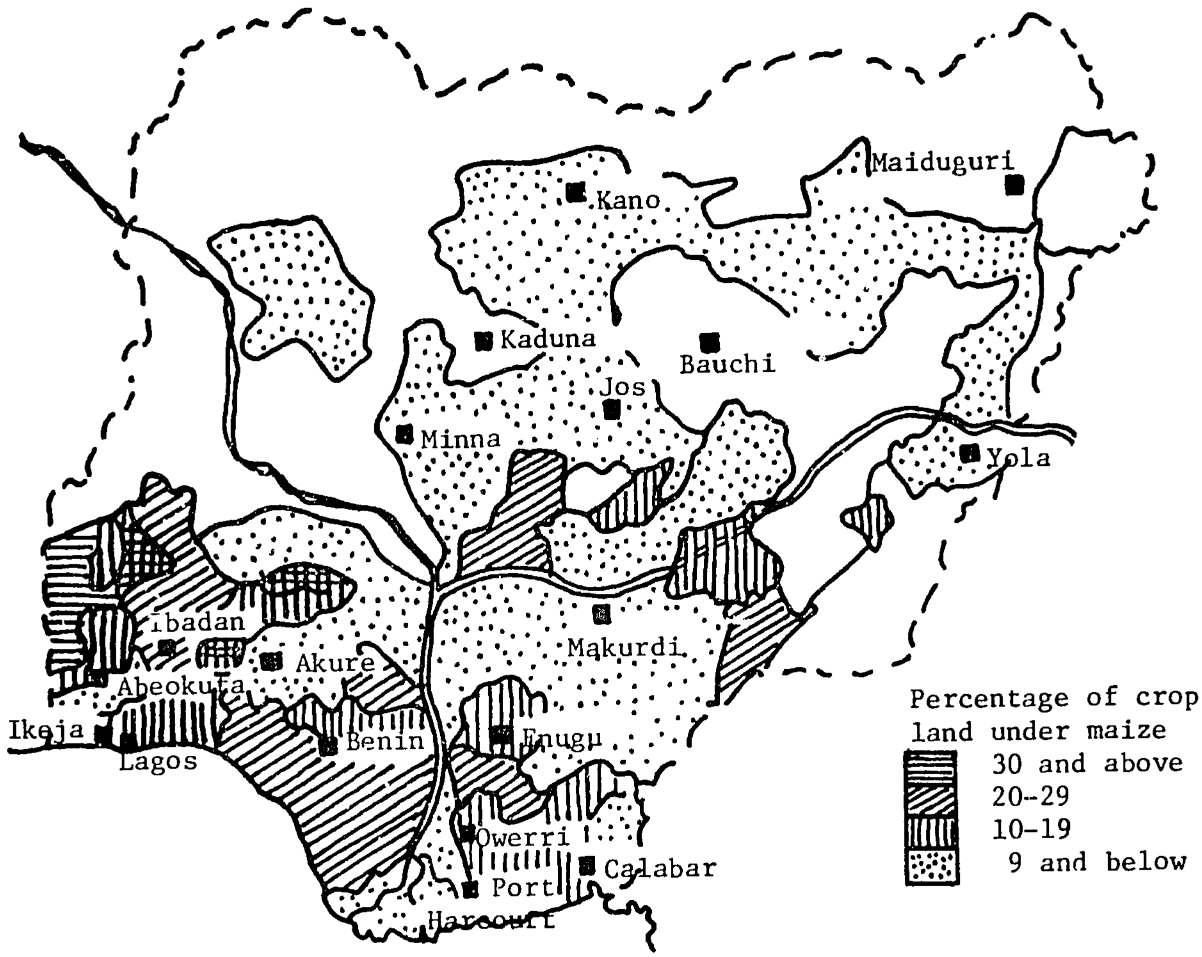

Figure 2. Nigeria: Land Use Under Maize (After Agboola, 1979)

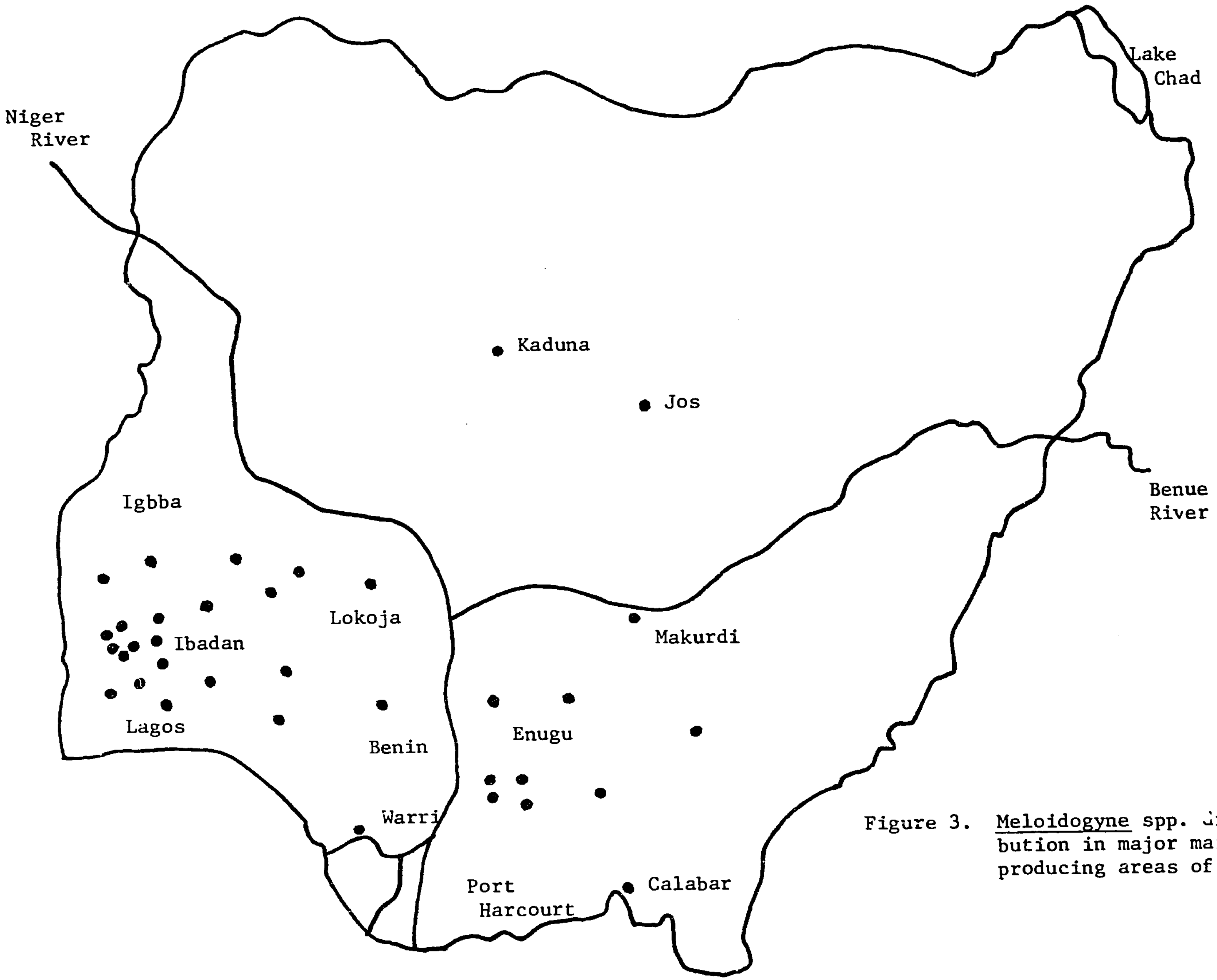

Figure 3. Meloidogyne spp. distribution in major maize-producing areas of Nigeria.

results are very tentative. As for now we cannot speak conclusively about the susceptibility or resistance of our tested varieties. The striking feature of our tests is the possibility of coming across root-knot nematode population-suppressing varieties which may be useful in a crop-rotational program.

Outlook

The activities for cooperation under the IMP could include the following among others.

Determination of susceptibility and/or resistance of the currently grown food crops in each region to the root-knot nematodes which are present. In Nigeria, maize is one of the most popular cereals grown by the farmers. As of now, there are a lot of local and improved varieties being grown. There is the possibility that some of these are resistant or can help suppress root-knot nematode populations in the soil. Efforts will be directed towards this goal by mass screening of maize varieties against root-knot nematodes.

Determination of the species and biotypes of the root-knot nematodes associated with food crops. Maize cultivation cuts across ecological zones in Nigeria. The species and biotypes in these areas may differ. In essence, it could be worthwhile to collect root-knot nematode populations from maize in major growing areas to see if they exhibit similar or different pathogenetic reactions on selected cultivars or varieties of maize and other food crops. Field trials could later on be set up at the five major centers already identified by the institute for maize improvement.

Summary

Root-knot nematode work at N.C.R.I. is still at its infancy. *Meloidogyne* species larvae have been associated with maize, but we have not come across the characteristic galls in the field.

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THE DISTRIBUTION OF ROOT-KNOT NEMATODES (MELOIDOGYNE SPECIES) IN RELATION TO ELEVATION AND SOIL-TYPE IN VEGETABLE-GROWING AREAS OF UPPER NORTHERN NIGERIA*

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Abstract

A survey of root-knot nematode (*Meloidogyne* species) in major vegetable-growing areas of upper northern Nigeria showed that the distribution of these nematodes is influenced by environmental factors, notably elevation and soil-type.

The distribution pattern observed suggests that *M. incognita* is rare over 900 meters and was not found in samples taken under 300 meters, whereas *M. javanica* does not seem to have a preference. In different soil types, *M. javanica* occurred more frequently than *M. incognita*. In sandy loam soils, *M. javanica* was found about 50% more frequently than M. incognita. The data obtained from clay-loam soils, though this soil type was rarely encountered, also indicated a greater frequency of *M. javanica* than *M. incognita*.

Introduction

Several reports have indicated that the distribution, density and survival of root-knot nematodes could be influenced by a) temperature (2, 4, 13), b) rainfall (8), c) elevation (6), and d) soil type (7, 10, 12). Each of these factors could act independently under controlled experiments, but it should be appreciated that each is a part of the total environment influencing nematode distribution.

The role of environmental factors in influencing the geographical distribution of *Meloidogyne* spp. in Nigeria is not yet fully studied. This paper reports on a survey of root-knot nematode distribution in major vegetable-growing areas of upper northern Nigeria and provides information on the role of elevation and soil type on the pattern of distribution.

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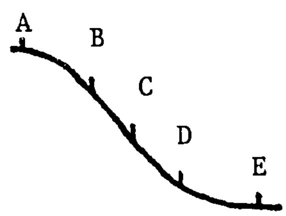
*This paper was not presented at the conference, but was submitted later for inclusion in the proceedings.

Materials and Methods

Collection of nematode populations. Farms in six of the northern states of Nigeria were surveyed for the presence of root-knot nematodes. In these locations, vegetable crops (tomato, pepper and eggplant) and weeds were examined for root-knot nematodes. In each location a composite sample, consisting of galled roots of infected plants and surrounding soil, was collected in polythene bags, slightly moistened when necessary, and brought to the laboratory. A composite sample consisted at least of three galled root systems and their surrounding soils collected at different distances. Number of sites sampled depended on size and topography of the area and on the variety of crops grown. Where more than one crop was grown in the same location, each crop was sampled separately, and the root-knot nematode present on each was treated as a separate population. Mechanical analysis of soil samples for physical properties was done using the Bonyoncos hydrometer.

Classification of the topography. The topography of each field was based on the following sketch using the accompanying code (after the forms for Ecological studies, International *Meloidogyne* Project):



A = Upland
B = Upper slope
C = Mid-slope
D = Bottom slope
E = Depression

Identification of *Meloidogyne* species. The diagnostic features described by Taylor, Dropkin and Martin (11), Whitehead (14), and Esser, Perry and Taylor (3) were used in identifying the *Meloidogyne* species. No distinction was made between *M. incognita incognita* and *M. incognita acrita*; both were regarded as *M. incognita* (Sensu Lato). Before a conclusion was made as to the identity of each species, at least 10 perineal patterns of adult female nematodes from each population collected were examined.

Results

Influence of elevation. The topography of areas visited ranged from uplands to depressions. *M. javanica* was present within each category of elevation while *M. incognita* was rare at elevations greater than 900 meters and was not found at those less than 300 meters (Table 1). The spatial distribution of the *Meloidogyne* species in the areas sampled is given in Figure 1.

Table 1. Frequency of occurrence of Meloidogyne spp. at different elevations in northern Nigeria.

	No. of perineal patterns		
Elevations	M. arenaria	M. incognita (Sensu lato)	M. javanica
Less than 300 meters	-	-	108
300 meters to 900 meters	3	171	239
More than 900 meters	-	10	107

Table 2. Frequency of occurrence of Meloidogyne spp. in different soil types in northern Nigeria.

	No. of perineal patterns		
Soil types	M. arenaria	M. incognita (Sensu lato)	M. javanica
Sandy loam	2	109	233
Clay loam	-	5	28
Sandy	-	-	98

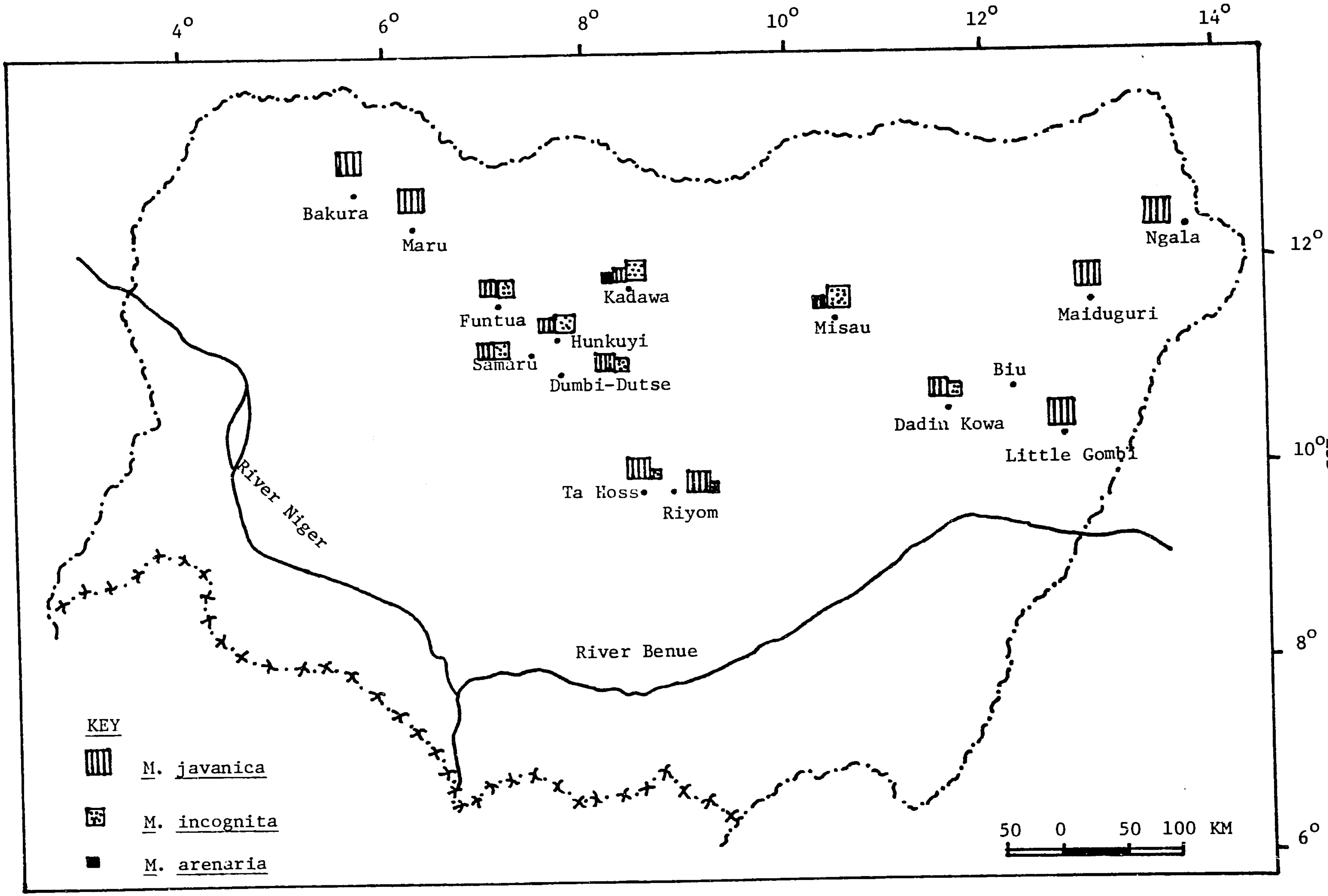


Figure 1. The relative distribution of Meloidogyne species in vegetable-growing localities in the upper most parts of northern Nigeria sampled for root-knot nematodes.

Influence of soil type. In sandy loam soil, M. javanica was about 50% more frequently found than M. incognita. M. arenaria was observed in this soil type, but only rarely (Table 2). Only M. javanica was observed in sandy soils. In clay loam, more M. javanica was also obtained.

Discussion

The study of 66 Meloidogyne populations from diverse localities in upper northern Nigeria showed that elevation and soil type are individually important in influencing the distribution of the root-knot nematodes.

In the Plateau Region {elevations greater than 900 meters, annual mean temperature 18°C and less, and mean annual rainfall 1400-1800 mm (1)}, M. javanica was until now the only Meloidogyne species reported present, so also at Lake Alau and Gamboru Ngala {elevations less than 300 meters, annual mean minimum temperature 18-21°C, and mean annual rainfall of 600-800 mm (1)}. In the present study, M. incognita was observed among the samples from Riyom and Ta-Hoss on sweet potato, Irish potato, and a weed Vernonia nestor collected from the sweet potato field. We tend to believe that, in this case, M. incognita was introduced into these fields through the planting of infected tuber crops and other planting materials from areas outside the Plateau region. The occurrence of M. incognita when present among the perineal patterns examined from these areas was less than 30% of each population. M. javanica was the only species recorded from Lake Alau and Gamboru Ngala. M. arenaria was encountered only at elevations ranging between 300 meters and 900 meters.

This distribution pattern seems to suggest that out of the three Meloidogyne species encountered only M. javanica occurs at all elevations. However, this may be due to the influence of other environmental factors like temperature and rainfall which are greatly correlated with elevation and may individually or collectively be overriding factors in nematode distribution. It may be that M. javanica can withstand extremes of these conditions better than the other two species.

The type host plant is another important single factor that can control the distribution of the Meloidogyne species. Since we sampled various host plants and weeds, we have likely removed the host factor bias.

Mechanical and physical factors determine porosity aeration and water-holding capacity of soils. All of these conditions collectively influence the multiplication and distribution of nematodes in a soil type.

M. javanica, M. incognita and M. arenaria were all recovered from the fairly well-drained, sand-loam soils; M. javanica and M. incognita were recovered from clay loam while only M. javanica was recovered from the well-drained, sandy soil. Such findings go to show that Meloidogyne species normally can be recovered from all soil types, but at varying degrees. M. javanica occurred more frequently than M. incognita in soil types where both existed. Minton (7) also found root-knot nematodes in light to heavy clay soils.

A survey of this nature shows distribution trends, but is restricted in its usefulness as far as defining root-knot nematode problems across different elevations and soil types, unless adequate controlled experiments are set up as reference.

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ROOT-KNOT NEMATODE PROBLEMS OF HORTICULTURAL CROPS IN NIGERIA

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Fruits and vegetables are very important components of a balanced diet. Peasant farmers in Nigeria pay very little attention to their production because of the hitherto low financial returns. Nematodes, particularly *Meloidogyne* spp., have been known to be associated with fruits and vegetables. The widespread occurrences of three *Meloidogyne* spp. throughout Nigeria and their very wide host range (11, 4) account for the pest status of the nematodes on horticultural crops. The mixed-crop farming system which is a common feature of peasant agriculture in Nigeria also has encouraged the maintenance of high populations of *Meloidogyne* spp. in cultivated fields. Horticultural crops are grown all over Nigeria depending on the ethnic preference for particular crops.

Previous Investigations

Vegetables. Most root-knot nematode work on vegetables in Nigeria has been concentrated on tomato (1, 9, 10). However, Caveness and Wilson (6) and Ezekwesili and Ogbuji (7) have reported yield reductions in sokoyokoto (*Celosia argentea*) and African spinach (*Amaranthus* spp.) respectively.

It also has been observed that okra (*Hibiscus esculentus*), Jews mallow (*Corchorus olitorius*), tomato, (*Lycopersicon esculentum*), red pepper (*Capsicum annum*), sweetpepper (*Capsicum frutenscens*), *Brassica* spp., onion (*Alium cepa*), watermelon (*Citrullus vulgaris*), and eggplant (*Solanum melongena*, *Solanum incanum*) are good hosts of *Meloidogyne* spp. (4, 8). Complete crop losses are possible in tomato when soil populations of *Meloidogyne* spp. are very high (10). Some resistance to *Meloidogyne incognita* has been found in some tomato cultures (1, 9). The occurrence of more than one species per given area appears to complicate resistance studies in the field. The effects of *Meloidogyne* spp. were measured in terms of quantity and quality of two leafy vegetables, Jews mallow and sokoyokoto (2, 3). Complete crop losses were observed in both crops at 4,000 eggs and second-stage juveniles per litre of soil. All eleven cultivars of Jews mallow screened were susceptible to Meloidogyne incognita. Field surveys at the Ibadan station of the National Horticultural Research Institute in October, 1980, confirmed that the root-knot nematodes are very important pests of tomato, sokoyokoto, Jews mallow, and okra (3).

Fruits. Root-knot nematodes have been reported to be associated with fruit trees like coconut Cocos nucifera, mango Mangifera indica, banana and plantain Musa spp., and citrus Citrus spp. These nematodes are also parasitic on pawpaw Carica papaya (4). Very high populations of Meloidogyne spp. have been recovered from roots of plantain and banana, pawpaw, pineapple (Ananas comosus) and guava (Psidium guajava) in fruit orchards of the National Horticultural Research Institute at Ibadan and Kano. Heavy galling of roots, general chlorosis of leaves, and dieback have been observed on the guava trees. Similar galling patterns also have been observed on roots of pawpaw, banana and plantain where root growth has been terminated and rot organisms have set in. Proliferation of lateral roots occurs around areas of infection on banana and plantain roots. Heavily infected stands have very short roots which increase the incidence of toppling during strong winds. Effective chemical control of M. javanica with other nematodes, however, is possible (5).

ON-GOING RESEARCH

Vegetable-Varietal Screening

Tomato. Available tomato germplasm collections from Nigeria and other tropical countries are being screened for reactions to Meloidogyne species both in the field and under shadehouse conditions. Special attention is being paid to the three tomato selections made by NIHORT'S breeders from germplasm collection of local and exotic tomato cultivars.

Okra. Root-knot infection on okra is manifested by severe chlorosis, wilt, leaf and flower drop and eventual death. Roots of such dead plants are usually heavily galled and rotten from the tips. After a field screening of 289 lines of okra accessions, shadehouse screening now is being conducted on 27 lines suspected to have escaped Meloidogyne infection in the field. All other accessions are susceptible to root-knot nematodes. Reactions to the three widely occurring species singly will follow.

Jews mallow, Corchorus olitorius. A total of twenty accessions of C. olitorius held by NIHORT to date have been found to be susceptible to Meloidogyne spp. under field conditions. Reactions to the different species and races are being tested under shadehouse conditions. Work on race identification has been delayed by lack of viable seeds of differential host crops.

Sokoyokoto, Celosia argentea. All three of the available cultivars TLV 8, Local green and Local red have been found to be susceptible to Meloidogyne spp. under field conditions and to M. incognita under shadehouse conditions.

African spinach, Amaranthus spp. The two commonly cultivated vegetable amaranthus species are A. cruentus and A. dubius. All forty-five vegetable amaranthus accessions already screened in the field have shown some level of resistance to Meloidogyne spp. Very high populations of M. incognita have been observed to be necessary for infection of amaranthus roots (3). This observed resistance in amaranthus is important because of its potential advantage in crop rotation with other root-knot-susceptible vegetable crops. Therefore, population studies of Meloidogyne spp. on amaranthus are essential for understanding the host-parasite interrelationship. Shadehouse screening is currently in progress on 45 amaranthus accessions for reactions to M. incognita.

Pathogenicity Studies

Jews mallow, Corchorus olitorius. Three cultivars, selected on the basis of leaf type (digitate, oval and lanceolate), currently are being assessed for effects of graded inoculum levels of Meloidogyne incognita. Growth analysis, yield and quality of the vegetables are important parameters being measured.

Tomato. Field observations of the wilt complex in tomato have shown on NIHORT'S fields that over 90% of seedlings and stands killed by wilt were infected by the root-knot nematodes. Wilt organisms, mainly fungi (Fusarium spp.) and bacteria, are being isolated by the plant pathologist. Single and concommitant effects of the root-knot nematodes and wilt organisms will elucidate the role of Meloidogyne spp. in tomato-wilt complex.

Nematode Control

Tomato. Chemical control of nematodes, especially root-knot nematodes associated with tomato, is in progress. Candidate nematicides include Furadan, Aldicarb, Miral and Marshal. Urea as a nitrogen source also is included as a treatment because of its known nematicidal activity. Residue analysis will be conducted at harvest on the fruits from each nematicide treatment. Some soil amendments such as cured poultry manure, horse dung, cow dung, township refuse, and Lafia Canning Factory waste are being evaluated for their control of root-knot infection in tomato, Jews mallow, and sokoyokoto. The soil amendment trials are important, especially for leafy vegetables, which are harvested within 45 days by which time residue and metabolites of systemic nematicides may still be very high in the soil and in the crop.

Fruits. Available accessions of pawpaw currently are being screened for reactions to *M. incognita*. The effects of graded inoculum levels of *M. incognita* on pawpaw seedlings will follow. Similar programs of research have been scheduled for other fruits especially guava and pineapple.

Summary

Meloidogyne research on horticultural crops in Nigeria has been restricted mainly to vegetables. However, some surveys of nematode associations with horticultural crops have been carried out. Efforts are being made to identify sources of resistance to root-knot nematodes from available germplasm of the different crops. Chemical and cultural control practices for root-knot nematodes also are being investigated for tomato, sokoyokoto, and Jews mallow.

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ROOT-KNOT NEMATODE PROBLEMS ON RICE IN NIGERIA

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Introduction

The distribution of root-knot nematodes in Nigeria appears to cut across the major rice ecological zones. The drive for increased rice production has necessitated the utilization of land hitherto under other crops or fallow for rice cultivation.

Agronomists have hitherto explained all nematode disease symptoms on rice in terms of nutrient deficiencies in the soil both in rainfed and lowland rice. Studies on the identity, pest status and nature of disease of nematodes, particularly root-knot nematodes, on rice are essential so that all constraints in rice production may be investigated and removed. Hence studies on cultivar resistance and root-knot nematode pathogenicity on rice have commenced.

Survey of Plant Parasitic Nematodes Associated with Upland Rice

Rainfed upland rice is grown mainly in the southern rainforest and derived savanah zone of the country. Some isolated cultivations, however, are carried on in Niger, Kaduna and Plateau States which are in the Guinea and Sudan savanah zones (Fig. 1). Surveys were carried out on state basis with the cooperation of the states' Ministries of Agriculture. Root-knot nematodes are known to occur widely in these areas (4). Nematodes encountered include the spiral nematodes *Helicotylenchus* spp. (100% occurrence), *Meloidogyne* juveniles, *Heterodera* juveniles, *Hoplolaimus* spp., the root lesion nematode *Pratylenchus* spp. (100% occurrence), *Tylenchorhynchus* sp., *Tylenchus* sp., *Scutellonema* sp., *Xiphinema* sp., *Longidorus* sp., and *Trichodorus* sp. (1, 3, 5).

Terminal galling was observed on rice roots in some cases. Infected rice plants were chlorotic and wilted readily under water stress. The similarity of symptoms in cases of severe root-knot infection was probably because cv. Os6 was the only commonly grown cultivar throughout the upland rice zone. A summary of the occurrences of the root-knot nematodes is presented in Table 1. By use of tomato cv. Ife 1 (a root-knot susceptible

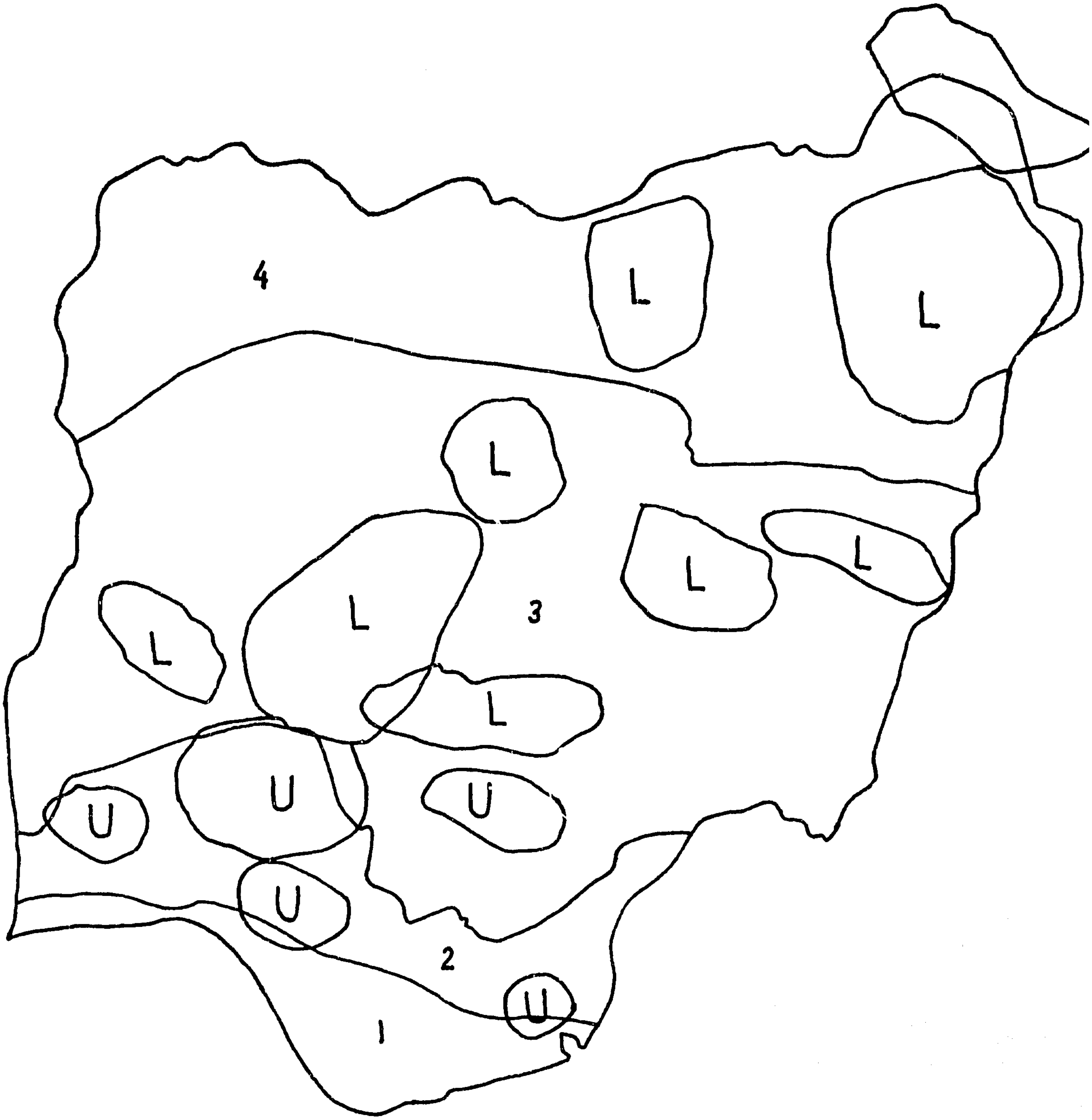

Fig. 1. Map of Nigeria showing the major lowland and upland rice areas and the vegetational zones. U, upland rice area; L, lowland rice areas; 1, Mangrove Swamp; 2, rain forest; 3, Guinea savanah; 4, Sudan savanah.

Table 1. Survey of *Meloidogyne* associations with upland rice

Major Rice Areas By States	Major Growing Areas Visited	% Occurrence of *Meloidogyne* spp.
Oyo State	14	Mi 100%
Ondo State	28	Mi, *M.* spp 100%
Ogun State	16	Mi 100%
Bendel State	23	Mi 100%
Benue State	14	*M.* spp 100%
Imo State	12	Mi 100%

Mi = *M. incognita*

Table 2. Summary of growth and yield data of Os6 inoculated with *M. incognita*

Inoculum levels Eggs & J_2/litre of soil	Panicle Number	Grain Yield per Stand	Root-knot Score	Population of Juveniles
0	41	64.1	1*	0
1,000	36	38.6	3	7
2,000	31	21.2	4.5	110
4,000	23	12.7	5.8	235
5,500	18	7.2	6	443

*1 = no galling, 6 = highly susceptible.

cultivar), Meloidogyne incognita, M. arenaria and M. javanica were identified in the soil samples collected. However, M. incognita was most prevalent in the major upland rice areas (1, 4). Soil type in all areas sampled varied from sandy to sandy-loam and spread through the rainforest zone to the derived savanah.

Screening program. Screening program in rice involved two groups of plant-parasitic nematodes, the root-lesion nematodes Pratylenchus sp. and the root-knot nematodes Meloidogyne spp. Both field and glasshouse screening of 44 rice cultivars were carried out with the field populations of Meloidogyne spp. and Meloidogyne incognita respectively.

Cultivars Var $13a^2$/103/F2591/9/3, IR20 Va54/6/6/6, Ikong Pao I.E.T 1444, and Igua pelatelo were found to be highly resistant, whereas cultivars Os6, Perola, Farox56/30, BKN 6517 -23 - 3 - 2, Tos 4106, and Tos 4121 were very susceptible. The roots usually have terminal galling. Although two or three galls occur on some roots, four to five egg masses were observed around the galled root tip. Field reactions were generally resistant because of low field populations (2).

Pathogenicity trials. Seeds of rice cv. Os6 were planted in 10 litres of steam-sterilized, loamy soil in plastic buckets. Four inoculum levels 1,000, 2,000, 4,000 and 5,500 eggs and J_2 per litre were used. Summary of results are in Table 2. Considerable yield reductions occurred, depending on the inoculum level. Complete crop losses are possible at high inoculum levels.

Nematicidal Trial

Nematicidal trial in upland rice. Three levels each of Furadan, Miral and Nemacur were tried in rainfed upland rice in Ibadan. Rice cv. Os6 was used at a spacing of 30 cm x 30 cm, and plot size was 6m x 6m. No differences were observed in the 80% flowering dates and tiller count at 90 days. However, grain yields were higher than those of the control with Furadan 2kg a.i. per hectare (42.3%), Miral 2.5kg a.i. per hectare (28.8%) and Nemacur 2kg a.i. per hectare (52.5%) applied at seeding by broadcasting. Only Furadan at 2kg a.i. per hectare kept the population of nematodes low at grain harvest (Table 3). Numbers of M. incognita juveniles were consistently higher than those of other parasitic nematodes in the final population of all the treatments.

Table 3. Nematicidal trial summary of growth and yield data

Treatments	50% flowering (days)	Tillering at 90 days	Yield tons/ hectare	Initial nematode count (all parasitic 200ml soil)	Final nematode count per 200ml soil (all nematodes)
Furadan 10G. 1kg a.i.	92.2	28.25	2.55	179	862
Furadan 10G. 2kg a.i.	88.6	28.25	3.36	286	259
Furadan 10G. 3kg a.i.	90	29.25	2.16	311	272
Miral 10G. 2.5kg a.i.	92	25.00	3.04	274	870
Miral 10G. 5kg a.i.	91	28.00	2.24	731	1085
Miral 10G. 7.5kg a.i.	90.6	29.75	2.43	273	247
Nemacur 5G. 1kg a.i.	94.8	23.75	1.94	192	636
Nemacur 5G. 2kg a.i.	88.6	25.50	3.60	170	794
Nemacur 5G. 3kg a.i.	88.6	26.75	2.57	273	694
Control	92.2	25.75	2.36	230	866

Lowland Rice

The lowland rice ecology falls mainly along the flood plains of the major rivers in Nigeria. Plant-parasitic nematodes encountered in the survey of lowland rice fields include *Hirschmanniella spinicaudata*, *H. oryzae*, *Helicotylenchus* spp., *Heterodera* sp., *Meloidogyne* sp., *Aphelenchoides besseyi*, *Tylenchorhynchus* sp., *Xiphinema* sp., *Tylenchus* sp., *Hemicriconemoides* sp., *Hoplolaimus* sp., *Pratylenchus* sp., and *Longidorus* sp. It is remarkable to note that very low populations of *Meloidogyne* sp. were encountered in this survey (Table 4). No galling was observed on actively growing lowland rice roots (1, 3, 7).

Future Plans

The survey of root-knot nematode association with rice will continue and identification of *M. incognita* and *M. arenaria* will be made to race levels. *Meloidogyne* collections from different rice ecologies will be assembled and assessed for possible differences. More rice cultivars will be assessed for reaction to root-knot nematodes for identification of more sources of resistance. Breeding and selection programs incorporating nematode resistance into acceptable agronomic characters will be initiated with rice breeders.

Conclusion

The drive towards increased rice production in Nigeria means that more areas will be opened up for rice cultivation. Hence, survey of plant-parasitic nematodes should be a continuous process. The state of knowledge about the species and races (7) present in Nigeria should be used to advantage. The resistance to *M. incognita* in cv. IR20 observed by Babatola (2) and to *M. graminicola* by Roy (6) suggests a horizontal resistance to *Meloidogyne* spp. Rice cultivars resistant to *Meloidogyne* spp. in Nigeria and other countries should be used in breeding programs.

Control of root knot should integrate all forms of control measures for effectiveness. Screening of chemicals for control of nematodes, especially root-knot nematodes, should take into consideration the residue and metabolite levels in the harvested crop. Cultural control measures within the reach of farmers are likely to be preferred because of the limited resources at the farmer's control. An integrated approach which involves the use of resistant cultivars and improved cultural practices hold promise for the future of rice production in Nigeria.

Table 4. Root-knot nematodes in lowland rice fields

Lowland rice areas by states	Major rice farms samples	*Meloidogyne* sp.	Percent Occurrence
Imo State	22	-	0
Anambra State	9	-	0
Benue	28	Mi M. spp.	87.5%
Plateau	18	Mj	50%
Cross River	6	-	0
Bendel	4	-	0
Kwara	10	Mj	10%
Niger	34	Mi Mj	

Mi = *M. incognita*; Mj = *M. javanica*; M. spp. = *Meloidogyne* species.

Summary

Root-knot nematodes, Meloidogyne spp., occur in both rainfed and lowland rice cultures. Some upland rice cultivars resistant to M. incognita have been identified and will be useful in breeding programs. M. incognita reduced rice yield depending on the population levels in the soil. Control of nematodes, including Meloidogyne spp., with corresponding yield increase occurred in rice cv. Os6 which was treated with Furadan at 2 kg a.i. per hectare applied just before seeding.

The survey for plant-parasitic nematodes is a priority in continuous and breeding programs that will incorporate observed resistance to Meloidogyne spp. in acceptable rice cultivars.

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SYMPTOMS OF ROOT-KNOT NEMATODE INFECTION ON *THEOBROMA CACAO* L. - A PRELIMINARY INVESTIGATION

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Introduction

The root-knot nematodes (*Meloidogyne* spp.) which often produce conspicuous, gall-like swellings on the roots of their hosts are among the best known plant-parasitic nematodes. However, very little work has been done on the effect of these nematodes on *Theobroma cacao* L. Cotterel suggested that difficulties experienced in Sao Tome and the Congo in the establishment of new cacao on old cacao land were due to root-knot nematode infestation (4). Ghesquire also considered that die-back of cacao which he described as 'coup de soleil' was due to a complex of factors, root-knot nematode being the most important one, in association with other organisms (6). Recent investigations in Brazil (5, 8), Costa Rica (9), and Ghana (2) have indicated that the growth and productivity of *T. cacao* could be hampered by root-knot nematodes. *Meloidogyne* spp. and many other plant-parasitic nematodes have been found in association with adult cacao trees in Nigeria (1, 3). Some plots in which cacao establishment had been difficult were found to be heavily infested with root-knot nematodes, This paper reports a preliminary investigation on the effect of *Meloidogyne* infection on the survival, growth and development of seedlings of Amazon and Amelonado cultivars of cacao.

Materials and Methods

Seedlings of Ife 1 variety of tomato (*Lycopersicon esculentum* Mill.) were planted in plot E8/3 of the Gambari Experimental Station of the Cocoa Research Institute of Nigeria (CRIN) as indicator plants to detect the presence of the root-knot nematode and to raise the population for use in the greenhouse. Twelve weeks later, the seedlings were carefully uprooted and examined for galls. Soil around the galled root systems was taken, bulked, and mixed up thoroughly and divided into two portions. One half was steam-sterilized at 15 lbs/in^2 (1.05 kg/cm^2) for 15 minutes, and the other half was not. Ten 4-litre clay pots were filled with part of the naturally infested soil in which four-week-old seedlings of

Amelonado and Amazon cultivars of cacao raised in sterile soil were planted. The population of Meloidogyne larvae was estimated to be 10,000 per pot. Ten 4-litre pots were also filled with steam-sterilized soil, and each was inoculated with about 10,000 Meloidogyne eggs obtained from tomato roots raised in the plot. Five seedlings of each of the two cacao cultivars were also planted in this set of pots. Five seedlings of each of the two cultivars were planted in 4-litre pots filled with steam-sterilized soil from the same plot to serve as control. Visual observations were made over a period of 32 weeks. The pots were topped with gravel to prevent exposure of roots during watering.

Results

During the 12th week of exposure to the nematode, no obvious symptom of infection was recognized on Amazon cultivar. However, Amelonado seedlings parasitized by the nematode began to show chlorotic symptoms. In the 16th week, one infected Amelonado seedling had died back from the meristematic bud to the lower leaves. The other parasitized seedlings were visibly stunted. At the 24th week, all but one parasitized Amelonado seedling had wilted in spite of daily watering. Leaves of the wilted plants hung intact for some time on the stem (Fig. 1). The only Amelonado seedling that survived was very stunted and unthrifty, with small leaves originating from the base of the stem (Fig. 2).

Seedlings of the Amazon cultivar began to show symptoms of parasitism by the nematode in the 24th week. These symptoms included yellowing of leaves and leaf wilt. When the wilted leaves dropped from the stem, new leaves emerged from the base of the plant (Fig. 3). A new stem was produced in one case. No seedling of this cultivar died completely throughout the experiment, but comparison with uninfected plants revealed a reduction in the growth of infected seedlings (Fig. 3).

Roots of infected seedlings were scanty, and feeder roots were few (Fig. 4). These roots had tiny galls which were not obvious except on very close examination. Microscopic examination revealed the presence of females and their egg masses in the galls (Fig. 5 and 6). Infected tap roots of Amelonado seedlings tended to swell and terminated abruptly.

Discussion

Many plant-parasitic nematodes have been found on cacao by previous workers, many of whom have associated certain disease symptoms on cacao

Figure 1. Uninfected and Meloidogyne-infected Amelonado cacao seedlings growing in 4-litre pots in the greenhouse, 24 weeks after inoculation; note the stunted, unthrifty growth and the wilted leaves hanging intact on infested plant.

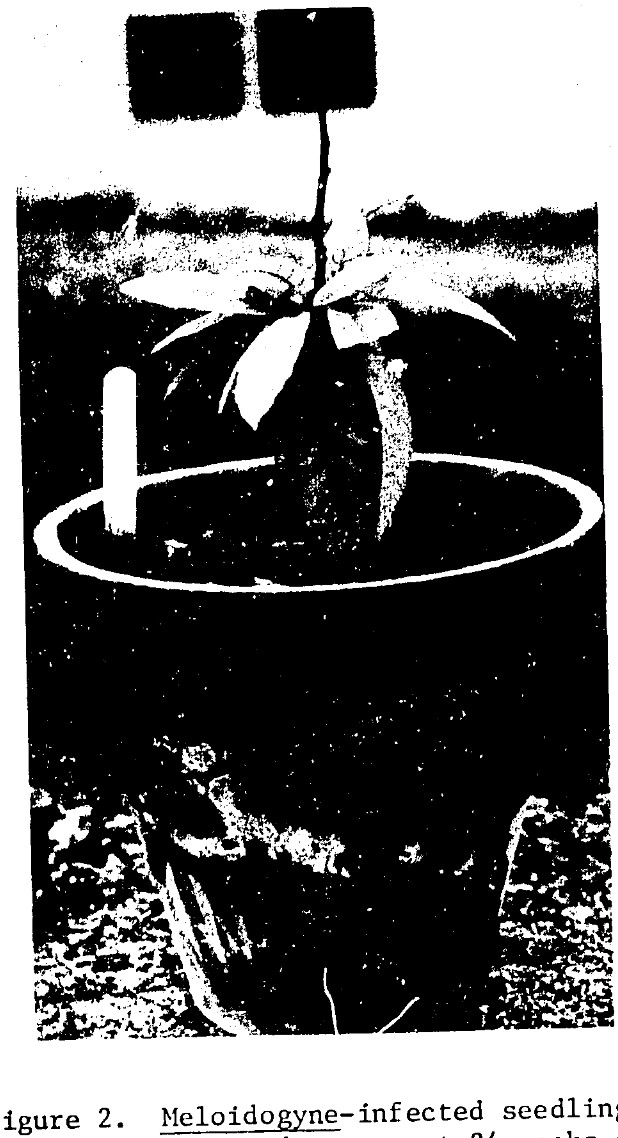

Figure 2. Meloidogyne-infected seedling of Amelonado cacao at 24 weeks showing small leaves originating from base of stem after older leaves have wilted and fallen.

Figure 3. Uninfected (center) and Meloidogyne-infected (right) seedlings of Amazon cacao grown in 4-litre pots in the greenhouse 32 weeks after inoculation; note the defoliated stem of the infected seedling, and the new leaves sprouting from the lower parts of the stem.

Figure 4. Meloidogyne-infected (left) and uninfected (right) roots of Amelonado cacao seedlings grown in the greenhouse; note the abrupt end of the taproot and also the scanty feeder roots in the infected root.

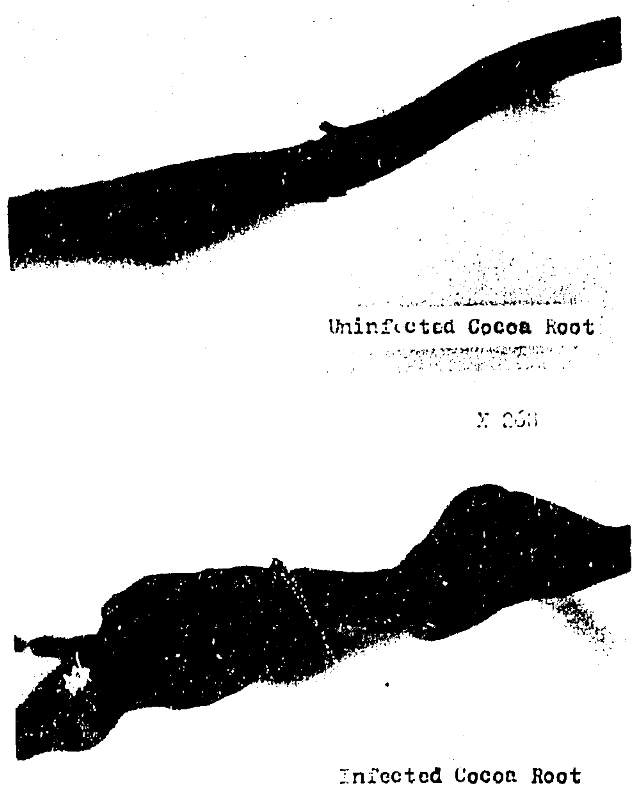

Figure 5. Meloidogyne-infected and uninfected roots of cacao as seen under the compound microscope; note the swellings (galls) on the infected root.

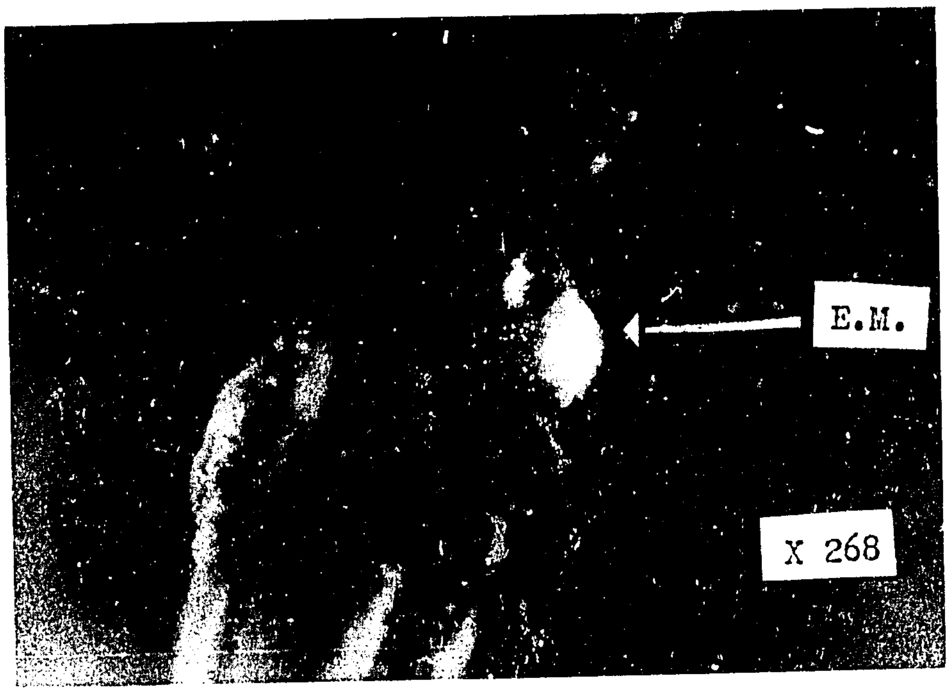

Figure 6. A close view of infected cacao seedling root under a compound microscope (incident light); note the egg mass of the female Meloidogyne (EM) protruding from the swollen portion of the root.

seedlings with some of these nematodes (10). It is only in recent years that efforts have been directed toward finding the specific effects of nematode attack on the cacao plant. Sharma and Maia showed that growth of 'Catongo' variety of cacao was seriously hampered by Meloidogyne incognita inoculated on two-week-old seedlings in the greenhouse (8). Jimenez found that sudden death of cacao, which is widely reported in Brazil, could be reproduced in the greenhouse by growing cacao in soil naturally infested with M. incognita. More recently, Asare-Nyako and Owusu reported that M. incognita caused significant reductions in root weight and seedling height (2). In this experiment, stunting, wilting and changes in leaf color and size were observed. These findings are further proof that root-knot nematodes may play a very important role in the slow growth and death of cacao seedlings in the field. Seedling wilt is a common disease of cacao in the nursery. Nursery-raised seedlings could be under severe attack by nematodes which are bagged along with unsterilized soil. Further work, therefore, is planned towards screening recommended cacao cultivars for resistance to root-knot nematodes, and also towards investigating the role of root-knot and other nematodes in the failure of establishment of cacao in the field.

Summary

Soil naturally infested with root-knot nematodes (Meloidogyne incognita), steam-sterilized soil inoculated with eggs and juveniles of the nematode, and steam-sterilized uninoculated soils were planted to Amelonado and Amazon cultivars of Theobroma cacao L. seedlings in 4-litre pots and observed for 32 weeks. Each treatment was replicated 5 times.

Stunting, wilting, yellowing of leaves and small leaves were symptoms expressed by Amelonado cultivars parasitized by Meloidogyne incognita. Symptom expression started in the 16th week of the experiment. Seedlings died back and wilted. All but one Amelonado seedling exposed to the nematode had wilted permanently by the 24th week. Amazon cultivars began to express similar symptoms in the 24th week. No permanent wilting occurred in this cultivar.

Roots of both cultivars were observed to have tiny galls which were obvious only on close examination. Microscopic examination revealed the presence of Meloidogyne females and their egg masses in the tiny galls.

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Acknowledgement

I am grateful to the Director, Cocoa Research Institute of Nigeria (CRIN) for permission to present and publish this paper. The assistance rendered by Mr. S. Owoyomi is also appreciated.

COMPARISON OF METHODS AND RATES OF APPLICATION OF SOME SHORT RESIDUAL TOXICANTS FOR THE CONTROL OF *MELOIDOGYNE INCOGNITA* ATTACKING SOME VEGETABLE CROPS

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Although many classes of chemicals have been used with some degree of success in the developing countries to control plant-parasitic nematodes and other classes of pests, very little attention is being paid to the effect of such chemicals on other components of the environment. Even though individual voices of warning were heard, it is still thought by some people that much of the material written about the immediate seriousness of toxic chemicals were presented from an emotional and exaggerated point of view. The Department of Agricultural Biology of the University of Ibadan has given serious thought to this problem, hence the establishment in 1977 of a miniature Pollution Laboratory in its Environmental Biology unit.

Unfortunately for some time to come, one of the efficient means of controlling root-knot nematodes will be by treatment with nematicides especially where the value of the crop is sufficiently high to justify the cost of the massive doses of nematicides often required. However, there is now an increasing awareness among toxicologists that the choice of chemicals should be governed by the following criteria.

(1) The chemical should be non-persistent, thereby avoiding any prolonged environmental contamination. Therefore, the short-residual toxicants are preferred.

(2) Application of a chemical will be economical for use only if found to be effective in low doses.

(3) There should be facilities for residue analysis of such chemicals in various parts of the world.

(4) The chemical should have a broad spectrum of activities in addition to being systemic. A nematicide that is capable of being translocated within the plant offers possibilities of sustained protection to the crop.

(5) There should be adequate information on its breakdown products, i.e. metabolism, and should not be phytotoxic.

With these criteria in mind, three research students and myself started to work a couple of years back on the efficacy of some of the short-residual toxicants (i.e. organophosphates and carbamates) in controlling *Meloidogyne incognita* attacking various crops and vegetables, namely lima bean (*Phaseolus lunatus L.*), okra (*Abelmoschus esculentus*), and soybean (*Glycine max* (L) Merrill). Specifically, we were interested in the comparison of methods and rates of application of these chemicals as they affect the root-knot nematodes and yield components in plants.

Lima Bean (Phaseolus lunatus L). Under greenhouse conditions, different methods and rates of oxamyl were compared for the control of *Meloidogyne incognita* on lima bean. Two rates of application, 600 and 1,200 ppm of oxamyl, were used. A single application of foliar spray at both rates was not completely effective in protecting plants inoculated with 1,000 *Meloidogyne incognita* eggs. A single soil drench, as well as a combination of foliar spray plus soil drench at both rates, effectively controlled the nematode. The treated plants had significantly better growth, a longer life span and enhanced yields. The results obtained in this study indicate that direct nematicidal action of oxamyl is a very efficient way of checking the root-knot nematodes even though from this work and others (1, 3, 4) there is some attestation to the systemic action of oxamyl. The combination of foliar spray plus soil drench provided the most effective control of root-knot nematodes. This effectiveness is possibly due to the drench augmenting the action of the initial foliar spray. Between the two doses (i.e. 600 and 1,200 ppm), however, there was only a marginal difference in the yield characters, for which reason it might be economical to recommend the lower rate, i.e. 600 ppm.

Okra (Hibiscus esculentus) variety 47-4. Okra is known to be particularly susceptible to the root-knot nematode *M. incognita* which is a major limiting factor in okra production. Because of the short life cycle of okra, the nematicide that can be safely used without much danger of leaving residues in the crop must be short-lived, hence the choice of carbofuran--a carbamate.

Preliminary toxicological tests on egg hatch in the laboratory revealed that carbofuran (Furadan) at concentrations of 25, 50, 75 and 100 ppm reduced the number of eggs that hatched into larvae, while the higher percentages of egg hatch at 10 ppm suggest a stimulatory effect of carbofuran on egg hatch. The higher the temperature, the more the inhibitory are the effects of 25, 50, 75, and 100 ppm carbofuran in suppressing nematode egg hatch. The results suggest that within a certain range of temperature, the active ingredient in carbofuran may be activated to release its potent nematicidal components faster, and hence effect a better control.

In the field trials, the ratings of roots for root-knot infestation show that the least galls were obtained for all plants treated at 100 ppm (i.e., soil drench, soil drench preceded by foliar spray). At 50 ppm, a treatment combination of soil drench and foliar spray was more effective in reducing root galls than 100 ppm and 50 ppm of carbofuran as foliar sprays. This finding may suggest that carbofuran acts directly on the root-knot nematodes in the soil thereby preventing or limiting hatching of eggs and the movements of larvae into roots. However, the fact that foliarly treated plants had less galls than control plants suggests a basipetal movement of carbofuran in okra. As regards the yield characters, generally, treated plants performed much better than the untreated. On the whole, complete suppression of nematodes was not achieved at 50 and 100 ppm. One would think that where a high population of nematodes exists, higher rates of carbofuran may be needed to effect a considerable level of control.

Soybean (Glycine max (L) Merrill). In potted experiments, two varieties of soybean (Bossier and TGM 294) were grown in autoclaved sandy loam soils. The pots were each inoculated with 1,000 root-knot nematode eggs. These were later treated with different rates of phorate (250, 500 and 1,000 ppm) using different methods of application as before. Two rates, 500 and 1,000 ppm, controlled the nematodes and increased the yield of Bossier variety compared to the control, whereas application of the 250 ppm controlled the root-knot nematode effectively in the TGM variety (apparently a resistant variety). The three rates of application also protected the plants from secondary invaders like fungi and bacteria, and also from insect attack. However, phorate applied at the rate of 500 ppm by a combination of foliar and drench method proved to be most effective in controlling the nematodes. It also increased significantly the dry weight of the shoot and seeds over that of the controls. Application of phorate at 1,000 ppm was observed to cause phytotoxicity at all stages of plant growth (from germination to maturity). This finding is in agreement with observations of Adesiyan in 1980 who found that 1,000 ppm of phorate resulted in phytotoxicity in stored yam tubers (2).

Conclusion and Future Research Needs

In these studies, it was demonstrated that applications (at high doses) of oxamyl (Vydate), carbofuran (Furadan), and phorate (Thimet) could lead to improved growth and yield of vegetable crops and at the same time give some degree of control of root-knot nematodes. Because of the problem of applying a soil drench treatment under Nigerian field conditions and the risk of environmental pollution, the desirability and efficacy of a multiple foliar application needs further investigation. The problem of preparation and handling of the chemical and design of appropriate application equipment also needs to be tackled.

With the increasing awareness of the detrimental effects of pesticides on environmental pollution by the public at large, it is absolutely essential that more facilities for residue analysis be set up in different parts of the country. It is also necessary to train many more toxicologists to handle the monitoring of residue levels of chemicals in treated crops and in the environment. Each pollution laboratory should also be adequately equipped for carrying out formulation analyses of chemicals being imported into the country.

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ROOT-KNOT NEMATODES ON YAMS IN EASTERN NIGERIA

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In Nigeria, the edible yam (Dioscorea spp.) is a major contributor to the staple carbohydrate food requirement (7). Most of the yams produced annually are marketed fresh and only a small proportion are marketed in the processed form which is primarily yam flour. The fresh tuber is eaten in various forms such as boiled yam, pounded yam, yam "fufu," mashed yam, fried yam, roasted yam or baked yam. Although primarily a source of carbohydrates, yams are also a significant source of iron, thiamine and ascorbic acid (vitamin C) (5). Yams supply minor quantities of protein, calcium, riboflavin and nicotinic acid.

In addition to the above, a considerable amount of ritualism surrounds yam production and utilization. "New yam festivals" are still being celebrated in several parts of the country today. Though over 600 *Dioscorea* spp. are known, only *D. rotundata* Poir, *D. cayenensis* Lamk, *D. alata* L. and *D. dimetorum* Pax are widely cultivated in Nigeria. *D. bulbifera* L. and *D. esculentum* Burk. also may be seen, especially in Agricultural Research Centres.

Yams are grown mostly in the southern states of Nigeria, but substantial quantities also are grown in Kwara, Benue and part of Plateau States. The annual yield represents over half of the world's production. For example, in the 1965-1976 period, Nigeria produced 13.619 million tons of yam tubers, which represented 76% of total world production for that period (6).

Reports of root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) associated with yams in Nigeria are various (1, 2, 3, 4, 8). This paper is a report on some aspects of the relationship between root-knot nematodes and yam culture in eastern Nigeria.

Root-Knot Nematodes Attacking Yams

A survey of the four eastern States of Nigeria--Anambra, Cross River, Imo and Rivers States--was conducted. Galled tubers were collected and taken to the Nematology Laboratory at the University of Ibadan. Adult *Meloidogyne* females were dissected out of the tubers. From these, perineal patterns were prepared for identification.

Observations showed that only D. rotundata and D. alata were galled while the other yam species were not galled. Only M. incognita was identified from D. alata, while both M. incognita and M. javanica were identified from D. rotundata. M. arenaria was not recovered from any of the Dioscorea species examined.

Effect of Root-Knot Nematode Infection on Yam Tubers

Market value. Galled tubers are unattractive in appearance and thereby reduced in market value. A survey of Aba, Owerri and Umuahia markets in Imo State showed a reduction of 39-52% in the price of diseased tubers when compared to healthy ones. Most farmers, however, normally keep galled tubers for use as planting materials or for home consumption because of the low selling price. Besides, galled tubers are considered to be "sweeter" than healthy ones.

Loss in weight. The weight changes of healthy and galled tubers of D. rotundata cv. Okwocha were monitored over a storage period of four months. It was observed that after four months of storage, galled tubers lost more weight (27.4%) than healthy ones (18.2%).

Loss from peels. Galled and non-galled tubers were peeled (as would normally be done prior to consumption) after various months in storage. Pre- and post-peeling weights of the tubers were recorded. Results showed that losses were higher from the galled tubers than from the healthy ones (Table 1). Also, the amount of loss was progressively higher as the storage period increased suggesting that there was a progressive deterioration of tubers in storage due to the presence of the root-knot nematodes.

Depth of penetration. The depth of penetration is important because it influences the method of denematizing galled tubers which are mostly used as planting material. It is also important because the infected areas invariably become necrotic and must be peeled off before consumption.

Blocks of yam tissue were made from apical, middle and distal parts of galled tubers of D. rotundata and D. alata. From the peridermal surface, 2-mm slices were cut off and teased under the dissecting microscope, then the number of female nematodes in each slice was recorded.

In D. rotundata, root-knot nematodes were concentrated at depths of between 4 and 6 mm though a few were recovered at 14 mm. In D. alata,

Table 1. Mean* percentage losses from peels of galled and healthy yam tubers in storage.

	Storage Period		
	2 Months	3 Months	4 Months
Galled	34.2 $\pm$ 2.5	37.2 $\pm$ 4.5	41.6 $\pm$ 7.0
Healthy	16.0 $\pm$ 2.5	16.4 $\pm$ 1.8	17.3 $\pm$ 1.6

*Means are from 10 replicates.

Table 2. Eggs and second-stage larvae of root-knot nematodes extracted from peels of stored galled tubers

Storage Period	Eggs/g peel	Larvae/g peel	% Egg Hatch
2 months	97 $\pm$ 33	23 $\pm$ 6	30 $\pm$ 5
3 months	70 $\pm$ 47	15 $\pm$ 2	31 $\pm$ 8
4 months	21 $\pm$ 8	4 $\pm$ 2	29 $\pm$ 3

the nematodes were concentrated in the first 2 mm, and none were found beyond the 8-mm depth. In *D. rotundata*, the number of adult females recovered at the different depths was similar in the three portions. In *D. alata*, the numbers were similar only in the middle and distal portions. Fewer nematodes were recovered in the apical portion at the depths of the *D. alata* tubers examined. It was also noted that more galls were present in the distal portion of *D. alata* tubers.

Effect of galling on rotting and sprouting of yam tubers. Observations were made on the amount of rotting and sprouting of healthy, non-galled tubers that have been stored in the traditional manner for four months. Only 27% of galled tubers sprouted, while 99% of healthy ones did. Only 1% of healthy tubers rotted, while 14% of galled tubers were rotten after four months in storage. *Aspergillus* spp., *Penicillium* spp. and *Monilia* spp. were isolated from the rotten tubers. Also, it was observed that while galling suppressed sprouting, it enhanced the proliferation of rootlets from the galls on the tubers.

Biology of Root-Knot Nematodes on Yams

Seed yams were planted in 10-litre plastic pails containing steam-sterilized, sandy loam soil. After 13 weeks when the new tubers were sizeable enough, they were exposed by means of a water jet. The young tubers then were inoculated with *M. incognita* by application of a concentrated solution of second-stage larvae and were covered with soil immediately after inoculation. The tubers were harvested at 24-hour intervals. Portions of the tubers were teased and examined under the microscope.

Second-stage larvae were recovered from the yam tissues 24 h after inoculation. Increase in size was obvious by the fourth day, and by the ninth day after inoculation fusiform larvae were observed. Moulting was observed on the tenth day (i.e. the second moult). The third moult was observed on the eleventh day, and the fourth and final moult was observed on the thirteenth day after inoculation. A juvenile female with the old cuticles cast off was observed on the fourteenth day after inoculation. A saccate female was observed on the eighteenth day while an empty gelatinous matrix was observed nineteen days after inoculation. Eggs were not observed until the thirtieth day after inoculation, but because of the advanced stage of embryogenesis of some of the eggs, they might have been laid earlier than the thirtieth day. Second-stage larvae were found within the egg mass on the thirty-fifth day after inoculation. The only male observed, a fourth larval stage coiled within three cuticles, was discovered on the thirty-first day after inoculation.

Survival of Root-Knot Nematodes in Yam Tubers

Galled tubers of D. rotundata cv. Okwocha were collected from Umudike, Imo State, and stored in a local yam barn in the crop garden of the Dept. of Agric. Biology, University of Ibadan. The tubers were stored for 4 months although samples were periodically collected from amongst the tubers. Each tuber collected was peeled. Eggs and second-stage larvae of root-knot nematodes then were extracted from the peels. Eggs so collected were left at room temperture for 10 days and the percentage egg hatch was recorded. After four months of storage, some of the peels were mixed with steam-sterilized, sandy loam soil after which seedlings of tomato (Lycopersicon esculentum L. cv Ife 1) were planted into the soil-peel mixture). Some unpeeled, galled tubers also were planted in large capacity pails containing steam-sterilized, sandy loam soil.

Root-knot nematodes survive in yam tubers during storage. The tomato roots when examined 4 weeks later were galled. The new tubers which developed from the unpeeled galled tubers planted in pails also were galled. Eggs and larvae were recovered at all times, although there was a decrease in the egg and larval population in the stored tubers with time (Table 2). Percentage egg hatch, however, remained fairly constant at 29 to 31%. White saccate adult females were recovered throughout the study, but it is not clear whether or not they were actively laying eggs at the same time. In any case, eggs and larvae serve as a source of inoculum for further spread when galled tubers are used as planting materials.

Effect of Root-Knot Nematode Population Density on Yield of Yam

Thirty microplots, each measuring 60 x 60 x 60 cm, were filled with sandy loam soil free from root-knot nematodes. Sprout seed yams each weighing approximately 450 g were planted one in each microplot. Freshly collected second-stage root-knot nematode larvae were distributed in a furrow 10 to 15 cm deep and 10 to 15 cm away from the base of each yam stand. Population levels of 0, 100, 1000, 10,000 and 100,000 per plant were used. Each was replicated 6 times in a randomized block design.

Although yield decreased with increasing initial nematode population density, the differences were not statistically significant. Degree of galling on the new tubers increased slightly with increasing initial population density, but again, these increases were not significantly different.

Control

Since some farmers, contrary to advice, insist on using infested tubers as planting stock, there is the need to find an economical and acceptable method of disinfesting planting materials. In one experiment, galled tubers were immersed in hot water maintained at 50 to 51^{o}C for various time intervals. Tubers immersed for 30 minutes were effectively denematized. Those immersed for less than 30 minutes were not disinfested completely, while those immersed for 35 minutes or more were disinfested completely, but did not sprout. Thus, immersion of galled tubers in hot water maintained at 50 to 51^{o}C for 30 minutes will disinfest the tuber without its suffering from physiological damages.

Future Research

1) Why does *M. arenaria* not attack yam species?
2) Biochemical comparison of *Dioscorea* species susceptible (*D. rotundata* and *D. alata*) and non-susceptible (*D. dumetorum* and *D. cayenensis*) to root-knot nematodes.
3) Biochemical changes induced in galled tubers that make them "sweeter."
4) Nematicidal dips as a means of disinfesting planting materials.

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LIPID ANTI-OXIDANT CONTROL OF ROOT-KNOT NEMATODES

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The importance of root-knot nematodes in Nigeria and other parts of the world has been reported by various workers (1, 4). It has not been possible yet to be very precise about the annual losses caused by root-knot nematodes in Nigeria. However, given the nematodes' wide distribution, extensive host range, and possible involvement in disease complexes, the toll must be running into several millions of naira every year. It then becomes inevitable that root-knot nematodes must be controlled in order to increase the yield and quality of food and fiber crops whose demand is ever increasing.

The most effective method of nematode control is the use of nematicides. However, these chemicals cannot be recommended for use by the poor, and often illiterate, rural farmers because they are expensive and possess high dermal and oral toxicities which cause them to require very careful handling. Other control measures, such as resistant cultivars and crop rotation, have been used with only limited success because of a dearth of information specific to the agro-ecological conditions in Nigeria.

A method undergoing trial is the use of lipid anti-oxidants for the control of root-knot nematodes. These lipid anti-oxidants have been used successfully in the control of atmospheric pollutants (3) and in nematode damage reduction (2). Root-knot nematodes oxidise lipids in the host root tissues, and this leads to symptoms of aging in plants. Since root-knot nematodes must oxidise lipids to be pathogenic, it is believed that their damage can be reduced by protecting roots of host plants with lipid anti-oxidants which inhibit the oxidation of lipids in plant roots. If the lipids in roots are not available for oxidation, the nematodes will be forced to use their own lipid reserves. A reduction in the lipid reserves in nematodes leads to a decrease in nematode activity and infectivity. The nematodes start aging and will eventually die.

Lipid anti-oxidants are heterogeneous groups of chemicals which are considerably cheaper than the common nematicides. Although critical tests have not been carried out, it is believed that these chemicals are largely non-toxic and leave little or no residues. Some of them, such as ascorbic acid, are natural components of foods.

This paper is a report of preliminary studies on the control of root-knot nematodes with some lipid anti-oxidants. Both in vitro and in vivo studies were conducted.

In Vivo Studies

In this study, the effects of the lipid anti-oxidants ascorbic acid (AA) and piperonyl butoxide (PB) on root-knot nematode control were investigated. Their effect also was compared with that of 1, 2-dibromo-3-chloropropane (DBCP).

In the first experiment, one tomato (*Lycopersicon esculentum* L. cv Ife 1) seedling was transplanted into each of 64 21-cm-diameter plastic pots filled with steam-sterilized, sandy loam soil. When the seedlings were 3 weeks old, the following treatments were applied:

1) 0.2% PB + Nematodes,
2) 0.1% PB + Nematodes,
3) 0.2% AA + Nematodes,
4) 0.1% AA + Nematodes,
5) 0.2% PB,
6) 0.2% AA,
7) Nematodes only, and
8) Control - no nematodes, no lipid anti-oxidant.

Each treatment was replicated eight times. All treatments with nematodes were inoculated with approximately 1,000 eggs of *M. incognita* per pot. The plants were sprayed to run-off with the respective concentration of either PB or AA. Thereafter, the plants were sprayed at five-day intervals until the experiment was terminated 6 weeks after inoculation. The pots were randomized on the roof of the Department of Agricultural Biology building.

No significant differences in fresh root and dry top weight, and height of plant were found. The plants with the heaviest biomass were those sprayed with 0.2% PB, while the least biomass was from the control plants. The least total number of nematodes per pot (suggesting best control of nematodes) were extracted from pots sprayed with 0.2% PB, while the poorest control was from 0.1% AA. However, it was noticed that plants sprayed with AA and PB produced early and considerably many more flowers than the others. This physiological advantage can be used to force early production of tomato fruits, especially where such enjoy a high premium.

In a second experiment, M. incognita was first multiplied in 24 115-litre concrete microplots filled with sandy loam soil and in which Ife 1 tomatoes were growing. After three months, all the tomato p were removed from the microplots and the nematode population in e was estimated. Six of the microplots were treated with DBCP (75kg/ha). Three days later, 3 2-wk old seedlings of the Ife 1 tomatoes were transplanted into each microplot. Three weeks later, the other following treatments were initiated:

1) 0.2% PB sprays,
2) 0.2% AA sprays, and
3) Control (Nematodes only).

As with the DBCP treatment, there were 6 replicates for each of the other treatments too. The sprays were applied at an interval of about 6 days. Six sprays in all were applied before discontinuation. The experiment was terminated 3 months after the tomato plants were transplanted.

The plants with the heaviest biomass were those sprayed with 0.2% AA, although the differences were not statistically significant. The highest yield, both in terms of total number of fruits harvested and the individual fruit weight, was obtained from the plants sprayed with 0.2% PB. These differences also were not significant. No significant differences among numbers of M. incognita extracted per microplot were found. The results showed that treating the soil with PB, AA or DBCP was a better alternative than not controlling the nematodes at all. Also, DBCP was more effective than either PB or AA in controlling M. incognita populations.

In Vitro Studies

These experiments were designed to detect whether or not lipid anti-oxidants possess any nematicidal or nematostatic properties. Four lipid anti-oxidants--Methionine (Me), Xylocaine (Xy), Ascorbic Acid (AA) and Sodium Benzoate (SB)--were used in the experiments. Zero, 10, 100, 1,000 and 10,000 ppm concentrations of each lipid anti-oxidant were prepared. One-hundred eggs and 100 second-stage larvae of M. javanica were introduced into the several concentrations of the lipid anti-oxidants listed above. Each concentration was replicated eight times. Percentage egg hatch was recorded for each concentration at time intervals of 24h, 48h, 72h, 96h, and 120h. Hatching rate decreased with increase in concentration of each lipid anti-oxidant. The highest hatching rate was recorded for 0 ppm, and the least hatching rate for 10,000 ppm of the anti-oxidants. Me was found to inhibit hatching most, followed by AA, SB, and Xy, respectively.

Larval mortality was recorded at 4h, 8h, 24h and 48h. The higher the concentration, the higher was the level of larval mortality. The highest death rate was recorded for 10,000 ppm and the least for 0 ppm. Me had the most lethal effect on the larvae, followed by AA, SB, and Xy, respectively.

It thus appears that lipid anti-oxidants not only reduce damage caused by root-knot nematodes by disrupting the host-parasite relationship but also are nematicidal at appropriate dosage levels. It is suggested that because of the linear nature of the dosage-response curves, the lipid anti-oxidants are nematicidal by their disruption of regulatory mechanisms in the nematodes.

Future Research

a) Best concentration of lipid anti-oxidants to use *in vivo*.

b) Best spraying schedules both in terms of timing and number of sprays and the age of plant at time of spraying.

c) A closer and more detailed study of physiological changes, e.g. flowering induced by lipid anti-oxidants on various crops.

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ROOT-KNOT NEMATODE RESEARCH
AT NATIONAL ROOT CROPS RESEARCH INSTITUTE (NRCRI)

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Tropical root-crops (cassava, yam, cocoyam and sweet potato) are major food crops for most Nigerians. The crops which have their fleshy economic or edible portions in the soil are exposed to nematodes. They can be severely damaged by the root-knot nematodes, *Meloidogyne* spp. A susceptible crop like yam (*Dioscorea* spp.) may be damaged by the nematodes, which could result in reduced tuber quality, storage life and market value (1, 2, 3).

Attacked tubers are known to be predisposed to fungal and bacterial rot organisms both in the field and in the storage barn. When this happens, post-harvest deterioration is often rapid (4). Observations in farms and barns in Anambra and Imo States indicate that about 20% of yams harvested can be lost by the end of the storage period due to nematode-related rot organisms. In preliminary studies, *Fusarium* spp. were the most common fungi with *M. incognita* in the yam-tuber rot complexes. As few as 20 root-knot nematode eggs per litre of sterilized sandy loam soil inoculated with some fungal propagules induced extensive rot on the tubers. This rot symptom differed significantly from tubers produced in pots inoculated with only root-knot nematode *M. incognita*. At Lafia in Plateau State, many farmers have reported abnormal development of rootlets on the tubers ("bearded tubers"). This condition is often associated with root-knot nematode infections.

Research on integrated nematode pest management has been undertaken at the Institute in the following areas:

1. Screening for resistance of root-crop varieties and their intercrops on the common root-knot nematode *M. incognita*. Farmers are reluctant to abandon the practice of mixcropping in their farms (Odurukwe, personal communication, 5). Some inter-crops are very susceptible.

2. Effect of coverplants used in traditional fallow lands on root-knot nematode population.

3. Use of carbofuran (Furadan, Curater) for control of root-knot nematodes in fields.

In the Umudike-Umuahia area of Imo State, the dominant *Meloidogyne* sp. attacking white guinea yam (*D. rotundata*) and vegetable intercrops (African spinach, yam beans, pumpkin, tomato and okra) is *M. incognita*. In Jos Sub-Station of NRCRI (Potato Division), the species attacking roots of potato (*Solanum tuberosum*) was identified as *M. javanica*.

Future Research Plans

The following areas will be considered in root-crop research (nematology) at National Root Crops Research Institute:

1. Intensive screening of different *Dioscorea* spp., cultivar groups, cultivars and lines of white guinea yam from the NRCRI Yam Division Germplasm accessions for resistance to root-knot nematodes.

2. Effect of different cropping combinations, sequences and rotations on root-knot nematode populations.

3. Suppressive effects of different cover plants used or found in fallow lands on root-knot nematode population.

4. Assay of nematicides for the control of root-knot nematodes in root-crop fields. Consideration will be given to rates of application of carbofuran. The granular nematicide/insecticide is relatively safe based on dermal toxicity rating. The small-scale farmer can easily apply the granular material.

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DEATH IN EARLY DWARF OKRA CAUSED BY THE ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA*

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It is obvious that root-knot nematodes are injurious to crops in Nigeria (2, 3, 7, 8, 9). They are considered the most important vegetable nematodes. Many weeds are included in the vast host range of root-knot nematodes (6). They stunt plants and produce characteristic galls on roots. Distribution is country wide (3). Reliable data that would encourage 'belief' of actual crop losses due to *Meloidogyne* are not available. However, from estimates representing losses in developed countries, losses in Nigeria may be as much as 25% to 50% over wide areas of the available farmland of the country (10). Root-knot nematode injury to plants include: 1) tissue abnormalities or malformations which result in dwarfing or distortion; 2) direct feeding which deprives the plant of water and food necessary for growth; and 3) wounds or lesions through which other disease organisms may enter.

In fields, target-spot areas of retarded growth may indicate a serious infection of root-knot nematodes, but an opinion holds that nematode species capable of killing plants are found infrequently (5). It is argued that such an attribute would have had a very limited adaptive value since nematodes require the presence of living plants for food. This paper reports that *Meloidogyne incognita* killed Early Dwarf okra before and during its fruiting stage and resulted in total crop failure reminiscent of late blight of potato (*Phytophthora infestans*).

Root-knot nematodes are highly evolved in terms of their host-parasite relationships. Why did Early Dwarf okra collapse when a Lady Finger cultivar in adjacent plots survived and bore fruits in spite of heavy root-knot infections?

Field and Lab Trials

A portion of the University of Nigeria farm had previously been cropped with Ronita tomato in September 1979. Roots of this tomato cultivar were rarely attacked by *Meloidogyne incognita* as previously reported (7). The land was fallowed for six months before being put to another use.

Eight raised beds (1 m x 18.3 m) were made in June 1980. A composite soil sample was taken from each of the eight beds. A 100-gram soil sample was drawn from each of the composite samples after thorough mixing. Nematodes were extracted from the 100 grams of soil by Altman's modification of the Baermann funnel method (1) and counted.

Seeds of Early Dwarf okra and Lady Finger okra were sown separately on four replicated beds as sole garden crops. Depth of sowing = 1.3 cm; intra-row spacing = 60 cm; and inter-row spacing = 45 cm. Germination occurred in 4 to 6 days. There were twenty-four stands of seedlings/row and forty-eight seedlings/bed. Flowering in Early Dwarf okra occurred in five weeks; fruits were observed six days later. Flowering in Lady's Finger formed in eight weeks, and fruits ten to eleven days later. Soil samples were again taken from around plant roots in each bed, and nematodes were extracted from 100-gram samples as described above. Uninfected pieces of okra roots (0.6 cm in length) were dipped into 0.5% Clorox for 2 min and drained on sterile paper towel. Two pieces were each placed in previously prepared PDA and observed after 2 days.

Greenhouse Trial

Germinated seeds of Early Dwarf okra were placed singly in sterilized sandy loam soil contained in 15-cm clay pots and inoculated with 500 *M. incognita* larvae. Both the control and the inoculated plants were replicated four times. Growth conditions were observed (Figure 1).

Results

Meloidogyne juveniles extracted from soil samples before planting and after plants had grown for 35 days or longer are summarized in Tables 1A and 1B. Some other tylenchid and saprozoic nematodes were seen but in comparatively fewer numbers. The number of juveniles recovered from around plant roots had more than tripled.

Tables 2A and 2B show okra stands killed by, or surviving, attacks of *M. incognita* (Figures 2, 3, 4). Fungal colonies observed on PDA medium were molds. Greenhouse, inoculated Early Dwarf okra showed disease symptoms identical to those observed in the field.

Figure 1. Early Dwarf okra: *M. incognita* infected (left); control (right).

Figure 2. Death of Early Dwarf okra (flowering stage) due to *M. incognita* infection.

Figure 3. Early Dwarf okra roots heavily galled by M. incognita.

Figure 4. Death of Early Dwarf okra (fruiting stage) due to M. incognita infection.

Table 1A. Nematodes extracted from soil samples from beds planted to Early Dwarf okra.

Bed	Nematodes before planting Total	M	O	S	Nematodes after planting* Total	M	O	S
1	92	53	15	24	173	151	8	14
2	102	61	10	31	197	175	6	16
3	76	24	12	20	158	140	7	11
4	81	49	7	25	168	148	6	14

*35 days after planting.

M = *Meloidogyne*; O = other Tylenchida; S = saprozoic nematodes.

Table 1B. Nematodes from beds planted to Lady Finger okra.

Bed	Nematodes before planting Total	M	O	S	Nematodes after planting* Total	M	O	S
1	85	52	10	23	179	154	7	18
2	111	65	13	33	216	187	8	21
3	88	49	11	28	197	172	8	17
4	101	62	10	29	209	190	4	15

*35 days after planting.

M = *Meloidogyne*; O = other Tylenchida; S = saprozoic nematodes.

Table 2A. Dead or surviving Early Dwarf okra, due to root* attacks by *Meloidogyne incognita*.

Bed	Planted	Killed (35 days)	Killed (40 days)	Survived 40 days	Dead (%)	Survived (%)
1	48	18	26	4	91.7	8.3
2	48	20	27	1	97.9	2.1
3	48	14	30	4	91.7	8.3
4	48	16	30	2	95.8	4.2

*Root index: scale 0-4, where 0 = no galls; 1 = light galling; 2 = moderately heavy galling; 3 = heavy galling; 4 = very heavy galling.

Mean root galling = 3.5 (not in Table).

Table 2B. Dead or surviving Lady Finger okra, due to root* attacks by *M. incognita*.

Bed	Planted	Killed (35 days)	Killed (40 days)	Survived 40 days	Dead (%)	Survived (%)
1	48	2	0	46	4.16	95.84
2	48	0	0	48	0	100
3	48	0	0	48	0	100
4	48	1	0	47	2.08	97.92

*Root index: scale 0-4, where 0 = no galls; 1 = light galling; 2 = moderately heavy galling; 3 = heavy galling; 4 = very heavy galling.

Mean root galling = 3.6 (not in Table).

Discussion

The root-knot disease on Early Dwarf okra resulted in severe damage at different stages. Younger plants were dwarfed and wilted readily. Death was quick. Plants that reached flowering and fruiting stages suddenly showed progressive decline in vigor. They became permanently wilted and eventually died. Depletions due to nematode attacks caused flowers to abort; developing fruits became slimy to touch and later decayed. In contrast, Lady Finger generally held out. The above-ground portions of plants showed little evidence arising from root infections. In face, solid fruits were harvested from plants.

Despite similarities in susceptibility to the root-knot nematode, the two okra cultivars showed obvious differences in their reactions: Lady Finger apparently was tolerant; Early Dwarf was not. Was the difference physiological?

According to Christie (4), when roots of a highly resistant plant are invaded, the (root-knot) larvae live for such a short time that the damage to the roots is slight. If the plant is moderately resistant, but not resistant enough to prevent the nematodes from reaching maturity, the damage may be severe. Apparently Early Dwarf okra is in this category. Perhaps, this is what is referred to as hypersensitive reaction. Are there merits then in putting such crops in a field infested by *Meloidogyne* spp?

Summary

On the Experimental Farm of the University of Nigeria, Nsukka, two okra cultivars (Early Dwarf and Lady Finger) were found highly susceptible to *Meloidogyne incognita*. While most Early Dwarf okra plants were killed prematurely, most Lady Finger plants survived to maturity. The rare and dramatic loss observed on Early Dwarf has demonstrated the significance of root-knot nematodes as disruptive factors in tropical agriculture.

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ROOT-KNOT NEMATODES ON CASSAVA

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For many of the millions of people who live in the world's tropic regions, cassava (Manihot esculenta) is one of their major sources of food energy. The demand in recent times for food for more people, special starch uses, a source of animal feedstuffs, and a raw material for industrial uses has greatly increased the global importance of cassava. Cassava production exceeds 100 million tons of raw roots annually thereby making it of considerable importance in the total world output of foodstuffs. Cassava is also of considerable social, economic and political importance in that it is almost totally a product of developing countries.

The study of nematode pests of cassava has received little attention in view of the fact that the crop is one of mankind's major sources of carbohydrate and is a major factor in the economies of some countries. However, reports of widespread nematode infection of cassava have long been documented (1, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20). Sasser (17) estimates that about 6 percent of the world production is lost to nematode attack. A loss of 6 million tons of carbohydrate is highly significant in a food-short world. This paper reports on the parasitism of two root-knot nematode species on two cultivars of cassava.

Materials and Methods

Two cultivars of cassava, TMe 30555 and TMe 30572, were planted in microplots at IITA in the rain forest zone of Nigeria. The microplots were concrete pipe and had a surface area of 0.26 m^2 with a soil depth of 1 meter. One month prior to planting, each microplot was fumigated with an overdose of D-D Mixture at 600 l/ha to eradicate all nematodes. The soil surface was sealed with black plastic sheeting. Three weeks after planting cassava stakes, roots had developed, and each microplot was inoculated with 10,000 eggs of Meloidogyne incognita race 2 or M. javanica. Noninoculated control plots were included. The trial was a completely randomized design with 20 replications. The root-knot nematode cultures had been reared on tomato in the greenhouse. The eggs were harvested using the sodium hypochlorite method of Hussey and Barker

(8). The cassava stakes were planted at the beginning of the rains and were not irrigated through the four-month dry season which began eight months later. The cassava was harvested 15½ months and 3½ months into the rainy season of the second year.

Soil populations of the root-knot nematode juveniles were determined by taking three 100-cm^3 cores from each microplot with a soil sampling tube 2.5 x 20 cm. Nematodes were isolated from the soil by the modified Baermann funnel method (21) and concentrated by the settling-siphon method (2).

Results and Discussion

Soil sampling showed a wide variation in root-knot nematode juvenile population levels. For analysis, populations were grouped from none to very high (Table 1). Root-knot index means show greater feeder-root-gall expression by *M. incognita* on both cassava cultivars than by *M. javanica* (Table 2). No gall formation was observed on storage roots. *M. incognita* reproduction was not significantly different on either cassava variety while *M. javanica* showed a greater rate on TMe 30572 than on TMe 30555 (Table 3). *M. javanica* juvenile populations ranged from low to very high on both cassava cultivars, while *M. incognita* had juvenile populations up to medium on TMe 30572 and high on TMe 30555. *M. incognita* juvenile populations did not reach very high densities on either cassava cultivar. This finding shows *M. javanica* to be the more aggressive parasite on these two cultivars.

The grand means of both nematodes on the two cassava cultivars were significantly different (P = 0.05) for each population level for stalk height, stalk weight and storage root weight (Fig. 1). The phenomenon of increased plant growth under light nematode parasitism (Fig. 1, Table 4) has been reported previously (3, 4, 19).

Summary

The root-knot nematodes, *Meloidogyne incognita* race 2 and *M. javanica*, significantly (P = 0.05) reduced stalk height, stalk weight, and storage root ("tuber") weight of two cassava (*Manihot esculenta*) cultivars, TMe 30555 and TMe 30572, after a 15½-month growing period in the tropical rain forest zone of southern Nigeria.

Table 1. Categories of soil populations of root-knot nematode juveniles after 15½ months of parasitism on cassava by *Meloidogyne incognita* race 2 and *M. javanica*.

Root-knot nematode population density	Mean no. juveniles per liter of soil	Range
None	0	0
Very low	117	200 - 34
Low	450	500 - 400
Medium	950	1,300 - 600
High	2,150	2,500 - 1,800
Very high	5,150	7,500 - 2,800

Table 2. The root-knot index means (0-4) on cassava feeder roots after 15½ months of parasitism by *Meloidogyne incognita* race 2 and *M. javanica*.[a]

	Cassava		
Nematode	TMe 30572	TMe 30555	Mean
M. incognita	2.95	2.7	2.82
M. javanica	1.9	2.2	2.05
Mean	2.42	2.45	

[a]Means of 20 replications.

Table 3. Mean numbers of root-knot nematode eggs/g of cassava feeder root tissue after 15½ months of parasitism by *Meloidogyne incognita* race 2 and *M. javanica*.[a]

Nematode	Cassava TMe 30572	Cassava TMe 30555	Mean
M. incognita	432	503	467
M. javanica	1,230	112	671
Mean	831	308	

[a]Means of 20 replications.

Table 4. The grand summary of storage root weight means of cassava after 15½ months of parasitism by the root-knot nematodes *Meloidogyne incognita* race 2 and *M. javanica*.

Root-knot nematode population density	Storage root weight %
None	100
Very low	106
Low	104
Medium	83
High	50
Very high	2

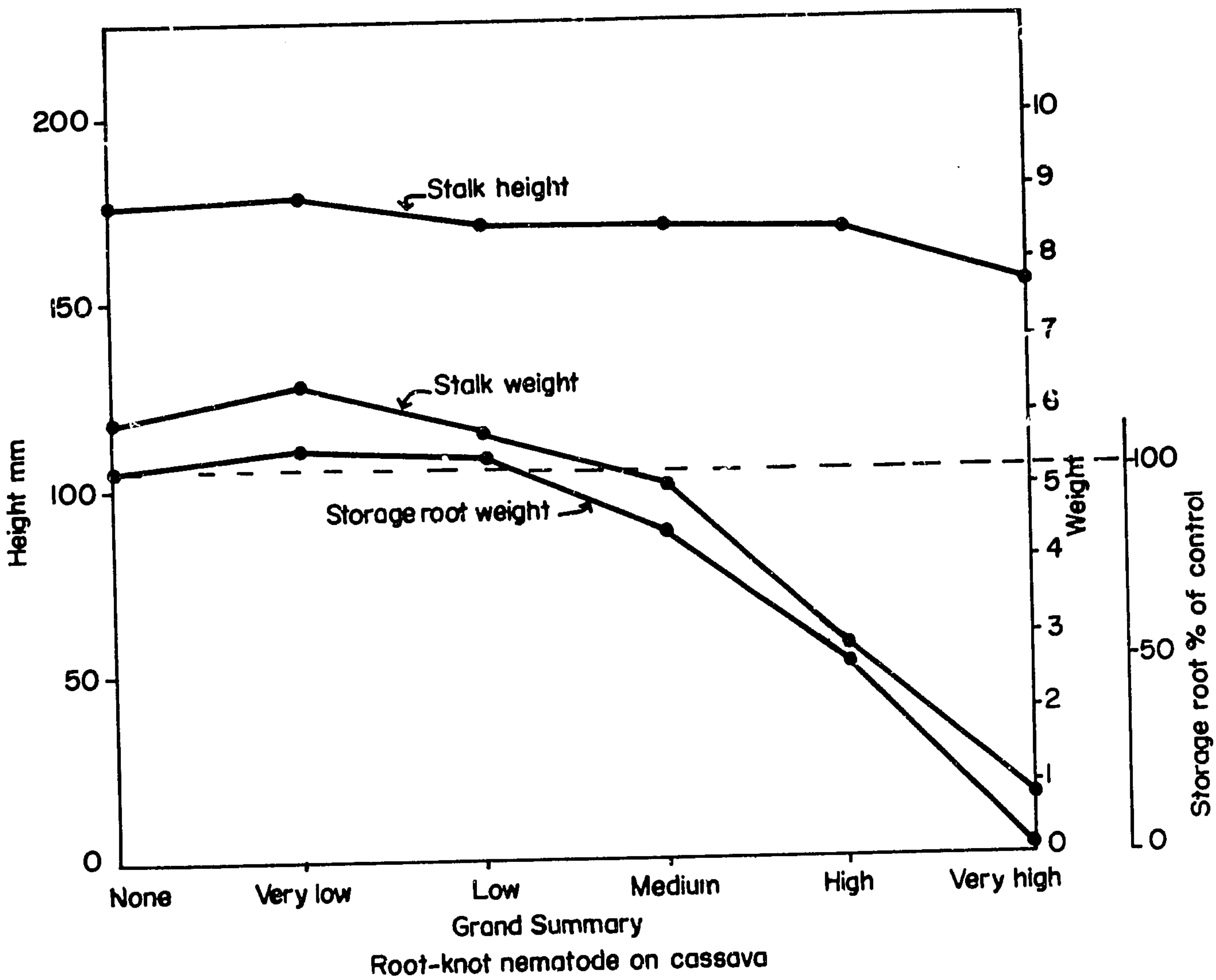

Figure 1. The grand summary of two root-knot nematodes, *Meloidogyne incognita* race 2 and *M. javanica*, on two cassava cultivars, TMe 30555 and TMe 30572, after a 15½-month growing period.

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EFFECTS OF GIBBERELLIC ACID ALONE AND IN COMBINATION WITH ALDICARB ON PLANTAINS INFESTED WITH MELOIDOGYNE JAVANICA AND HELICOTYLENCHUS MULTICINCTUS

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Summary

Three sprays of GA at 150, 300 and 450 ppm; two soil treatments of aldicarb nematicide at a total of 3 g ai/tree; and combinations of GA and aldicarb were applied to 4-month-old plantains grown in field micro-plots to study dosage effects on plant growth and associated populations of *Meloidogyne javanica* and *Helicotylenchus multicinctus*. The two higher rates of GA alone increased plantain elongation and number of developing suckers (P = 0.05). Aldicarb alone markedly increased the height and girth, number of developing suckers, and induced plants to flower and produce fruits earlier.

M. javanica and *H. multicinctus* in soils of GA individual rates increased to peak populations above the untreated, while aldicarb alone or in GA combinations were comparatively suppressive. After subsequent treatments of GA alone at 450 ppm, nematodes declined to low (*M. javanica*) or continued to increase to peak (*H. multicinctus*)numbers in the soil. Aldicarb controlled *H. multicinctus* better than *M. javanica*. Nematode densities in soil fluctuated with rainfall records during the wet season and species were variably correlated with average and total rainfall and number of rainy days. *M. javanica* infestation was higher than that of *H. multicinctus* in roots. Residual effects of GA rates on root populations were striking 8 weeks after the last treatment, but had little prolonged effect 20 weeks thereafter.

Introduction

Multiple infections of banana and plantain roots by several nematodes such as *Radopholus similis* (Cobb) Thorne, *Helicotylenchus multicinctus* (Cobb) Golden, *Meloidogyne javanica* (Treub) Chitwood, and *M. incognita* (Kofoid & White) Chitwood were reported in tropical West Africa and elsewhere (4, 8, 11, 12, 15, 20). Recently, fumigant and contact nematicides such as DBCP, prophos and phenamiphos; and quite recently, systemics such as aldicarb, carbofuran, oxamyl and miral were found effective in controlling destructive nematodes on Musa spp. and increased yields dramatically in Ivory Coast (18), Cameroon (18), and Nigeria (3, 6). With the advent of the extravagant overgrowth of human population, it has become increasingly important to improve yields and production efficiency and to cope with rising market-consumption demands. Plant growth regulators such as abscisic acid and daminozide or ethephon and GA promoted or delayed flowering and setting of Musa plants, thus offering local and foreign markets an early or late supply as needed (10). Since sub- and supra-rates of growth regulators could alter sex differentiation in nematodes (2, 7, 16) and nematode-plant interactions (1), we investigated the dosage effects of GA alone and in combination with aldicarb on plantain growth and population behavior of associated M. javanica and H. multicinctus to further study these interrelationships.

Materials and Methods

Homogenous suckers of plantain (Musa AAB) cv. Agbagba were planted in early March, 1979, in 71-cm diam. concrete field plots filled with sandy loam soil brought from a plantain field heavily infested with M. javanica and H. multicinctus. Treatments were: individual rates of gibberellic acid (GA) at 150, 300 and 450 ppm; aldicarb nematicide (Temik 15G®) at a total of 3 g ai/plant; combinations of both; and an untreated control. Gibberellic acid 10 WP was sprayed on the foliage (150 ml/tree plus 0.5% Tween 80® sticker) in July, September, and October, 1979, while aldicarb 15G was incorporated into the soil in September and October 1979 (1.5 g ai/plant). A completely randomized design with four replications of one tree each was used. Plants were left to grow under natural rainfall conditions without supplemental irrigation throughout the wet season (till early December 1979) and irrigated at weekly intervals during the dry season. The trial was terminated at the beginning of the new wet season (April 1980). Nematode numbers in the soil were monitored monthly using the modified Baermann technique (19) and concentrated by the settling-siphon method (5). Nematodes were extracted from chopped 50 g/tree composite root samples in December 1979, and March 1980. Data on trunk circumference 25 cm above the soil surface, plant height, number of leaves and suckers were recorded in July 1979 (pre-treatment), January 1980 (8 weeks post cease-treatment), and March 1980 (20 weeks post cease-treatment). Observations on flowering and setting dates were also recorded. Nematode data were subjected to computation of regression b and correlation r values and those of host growth parameters to analysis of variance (13).

Results

Host growth. Plants treated with GA at the two higher rates were higher (P = 0.05) than untreated at either data interval, whereas GA combinations with the nematicide tended to reduce pseudostem elongation, excepting that of the highest rate (Table 1). Aldicarb alone had produced the tallest and thickest plants in time. The average circumference of plants sprayed with GA at 150, 300 and 450 ppm in presence of aldicarb were only 2, 1 and 3.2 cm greater than untreated by March 1980, respectively. Individual treatments of either aldicarb or GA at 450 ppm were the only treatments increasing the number of suckers produced per plant. No treatment affected leaf numbers. By early January 1980, stands on aldicarb-treated soil had flowered. Plants untreated or given GA alone flowered in late January and early March, 1980. Normal bunches and ripe fruits were reported on aldicarb and control plots in early March and early April, 1980, respectively, in contrast to developing fruits seen on other plots till mid-April 1980 (at termination).

Nematode populations. Numbers of *M. javanica* juveniles (Fig. 1) and *H. multicinctus* nematodes (Fig. 2) in soils of GA individual treatments were generally higher than levels of untreated during the trial, whereas GA combinations with the nematicide were suppressive. In comparing the nematode species-dosage response relations, *M. javanica* and *H. multicinctus* appeared to react differently to GA rates. While *M. javanica* continued to increase after the repeated applications of GA lowest rate (150 ppm) and to decrease after the highest (450 ppm) (Fig. 1), *H. multicinctus* increased steadily at all GA rates used (Fig. 2). The degree of nematode control displayed by aldicarb alone was remarkable but varied with nematode species, being higher against *H. multicinctus* (b = +1.5) than *M. javanica* (b = -60.3), as to receptive controls.

The population carry-over into the new growing season (March 1980) shows diminishing and increasing infestation trends of *M. javanica* (Fig. 1) and *H. multicinctus* (Fig. 2) in soil, respectively. Individual rates of GA tended to provide the new growth cycle with relatively

Table 1. Effect of gibberellic acid alone and in combination with aldicarb on advancing growth rate of plantain[a]

Treatment ppm or g a.i./tree	January 8, 1980 Height increase[b] cm	Circumference increase at 25 cm[b] cm	Leaves/tree no.	Suckers/tree no.	March 21, 1980 Height increase[b] cm	Circumference increase at 25 cm[b] cm	Leaves/tree no.	Suckers/tree no.
GA 150	63.2	15.0*	6.0	0.3	65.7	16.0	7.0	0.7
GA 300	67.7*	13.0	6.7	1.7*	76.0*	14.0	7.0	1.7
GA 450	66.3*	14.3	6.8	2.0*	76.8*	16.4	8.0	2.8*
Aldicarb 3	63.0	16.5*	7.4	3.4*	82.8*	18.0*	7.9	3.8*
GA 150 + Aldicarb 3	50.0	13.0	6.6	1.2	60.0	16.0	7.0	2.0
GA 300 + Aldicarb 3	53.9	12.0	6.1	1.3	61.0	15.0	6.7	1.7
GA 450 + Aldicarb 3	70.4*	15.6	6.8	1.5	78.5*	17.2	7.8	2.5
Untreated	53.3	11.2	5.8	0.8	58.1	14.0	6.1	1.5
Significance	S	S	NS	S	S	S	NS	S

[a] Means of four replications of one tree each.

[b] Height or circumference increase represents the difference in the measurements taken at the beginning of the trial and till date.

*Statistically significant from untreated at 0.05.

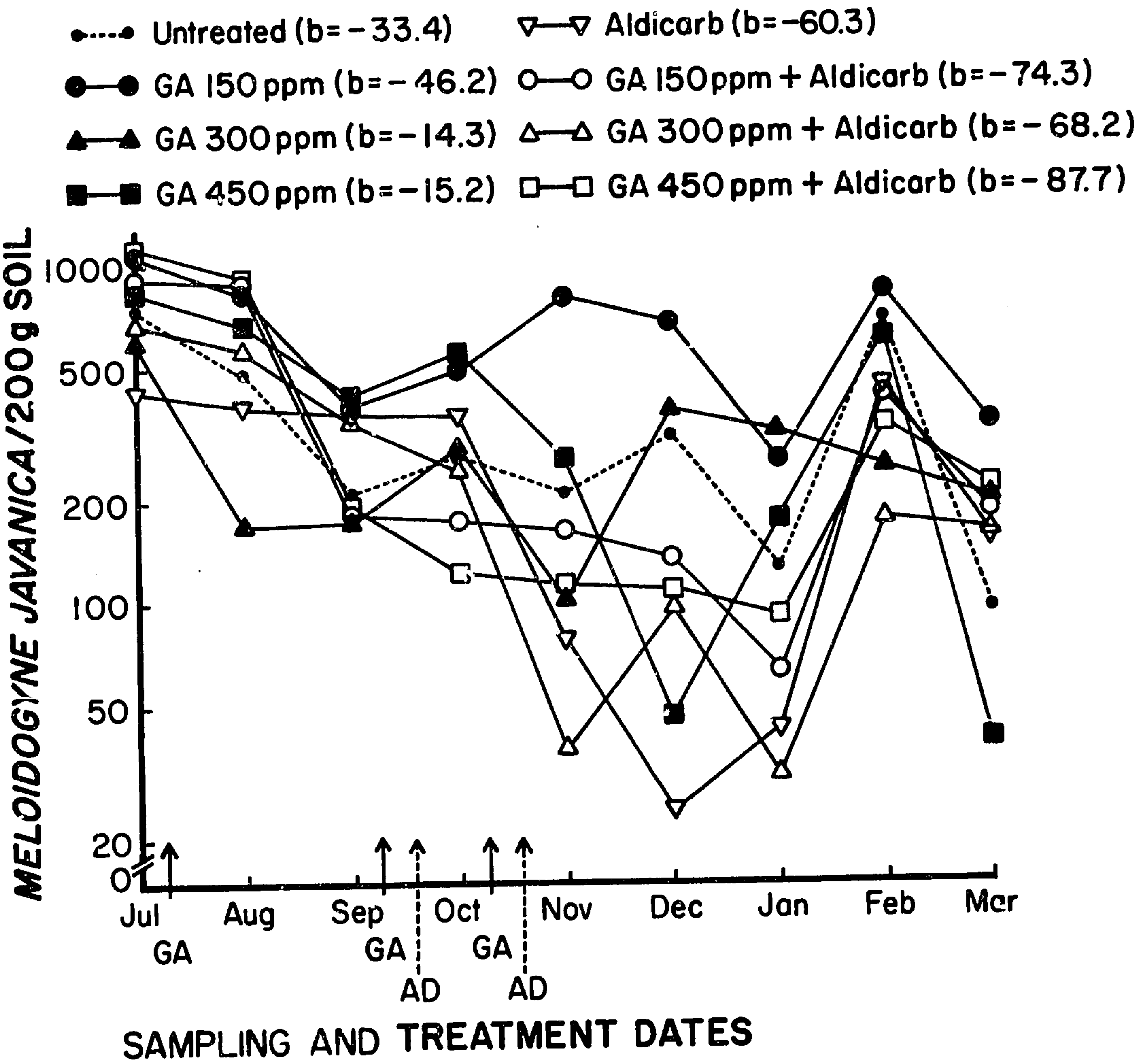

Fig. 1. Fluctuations of Meloidogyne javanica juveniles in soils with application of gibberellic acid and/or aldicarb rates. Arrows indicate application dates of gibberellic acid (↑) and aldicarb (⇡).

higher infestation of *M. javanica* (two lower rates) and *H. multicinctus* (lowest and highest rates) than untreated. Combinations of GA (two higher rates) with the nematicide dropped *H. multicinctus* infestation in soil (Fig. 2); the lowest population was by aldicarb alone.

Soil population levels of *M. javanica* and *H. multicinctus* (Figs. 1 & 2, respectively) appeared ascending and descending with rainfall records in the wet season (Fig. 5). *M. javanica*, dissimilar to persistant *H. multicinctus*, fell with the decreased rainfall toward the end of the wet season (from October till December 1979) and then rebuilt in response to the irrigation water given beyond December sampling. In untreated soils, *M. javanica* juveniles had insignificant positive correlations with rainfall records, whereas *H. multicinctus* nematodes showed significant negative correlations with total and average daily rainfall and number of rain days per month (Fig. 5).

Numbers of root nematodes (Figs. 3 & 4) in December 1979, (beginning of the dry season) and in March 1980, (under irrigation) show roots to harbour generally higher infection of *M. javanica* than *H. multicinctus*. The residual effects of GA rates on nematode buildup, especially with *M. javanica*, were distinct in December 1979, i.e., 8 weeks post cease-treatment (Fig. 3), but their prolonged effects were little marked in March 1980, i.e., 20 weeks thereafter (Fig. 4). The same antagonistic (*M. javanica*) or synergistic (*H. multicinctus*) effects of GA supra rate (450 ppm) recorded earlier in the soil were evident in December root counts (Fig. 3) and apparent in March (Fig. 4). On either count date, the nematicide alone or in combination with GA considerably reduced *M. javanica* and *H. multicinctus* below levels of untreated plots. *H. multicinctus* in GA 150 and 300 ppm combinations with aldicarb dropped to undetectable levels within a given 50-g root composite made in December 1979 (Fig. 3).

Discussion

Present advanced or delayed flowering and setting dates of plantains following aldicarb and GA individual treatments are in agreement with the findings of Jones (9) and Lockard (10) on banana plants so treated in South Africa and Malaysia. The shortening or prolongation of the bunch-to-bunch interval by certain treatments can be useful and is implemented on large-scale farms to supply local and foreign markets with an adequate supply to meet with the consumers' needs continually. Although late applications of GA on fruits were not investigated in this

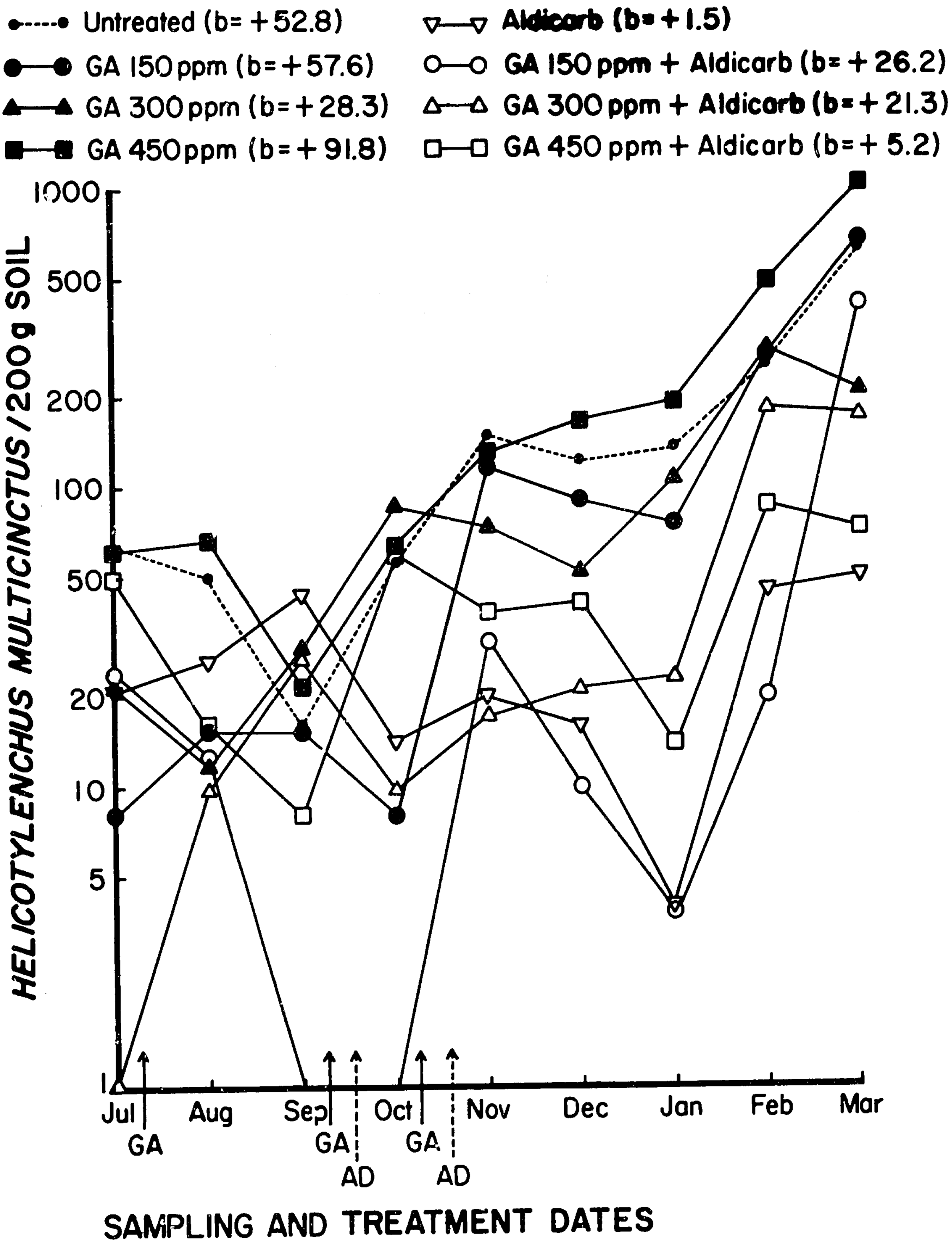

Fig. 2. Fluctuations of Helicotylenchus multicinctus nematodes in soils with application of gibberellic acid and/or aldicarb rates. Arrows indicate application dates of gibberellic acid (↑) and aldicarb (⇡).

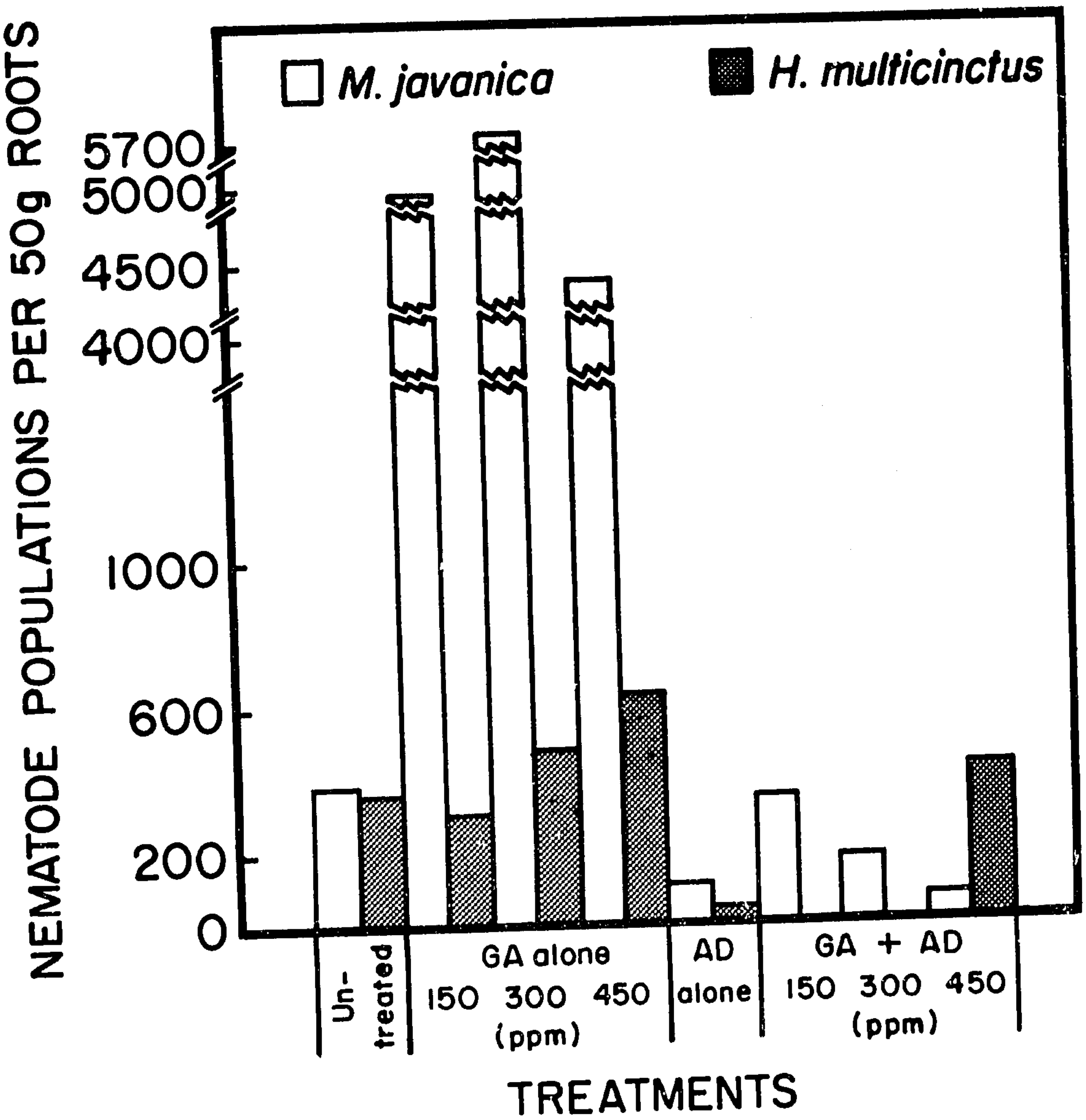

Fig. 3. December numbers of <u>Meloidogyne javanica</u> and <u>Helicotylenchus multicinctus</u> in plantain roots as influenced by gibberellic acid and/or aldicarb rates.

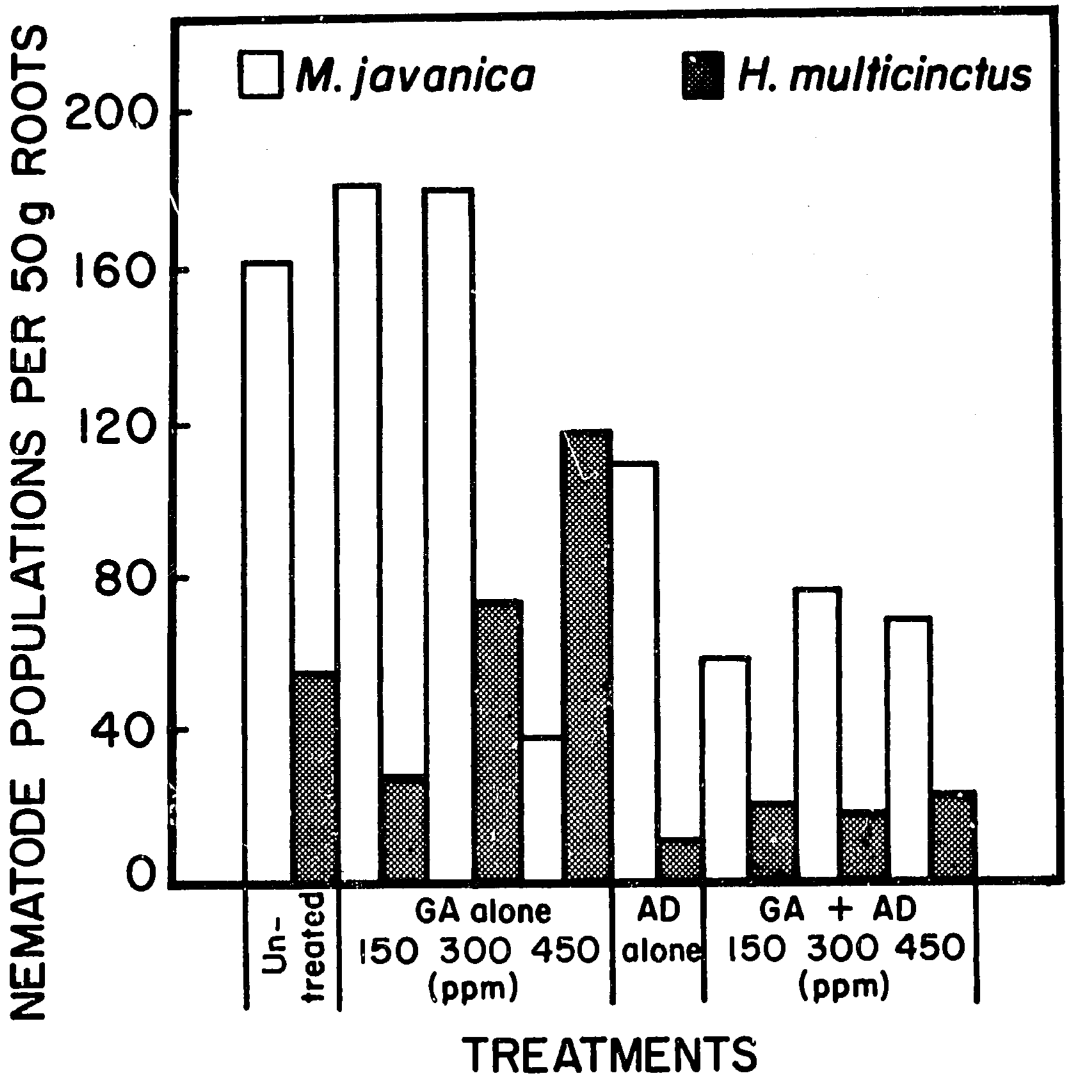

Fig. 4. March numbers of *Meloidogyne javanica* and *Helicotylenchus multicinctus* in plantain roots as influenced by gibberellic acid and/or aldicarb rates.

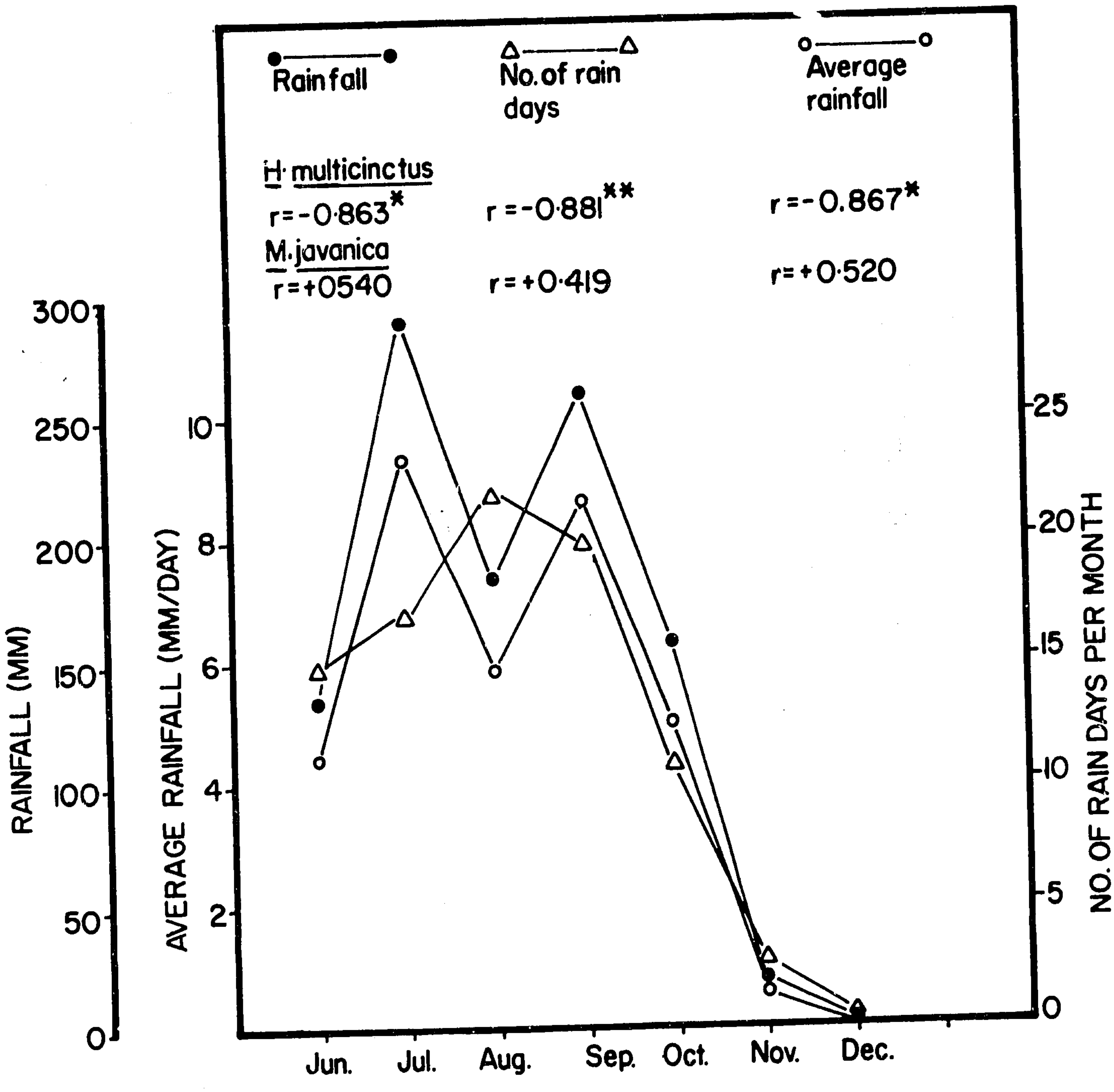

Fig. 5. Rainfall records on experimental plantain during 1979 wet season.

trial, reports indicate their effectiveness to even further delay ripening of *Musa* fruits and, thus, to extend their availability in markets over a longer period and/or supply remote markets elsewhere (4, 17).

GA alone favored a buildup of large populations of *M. javanica* and *H. multicinctus* in soils and roots with a species tendency to decrease or increase following supra doses. These data are in accord with information that the effects of plant growth regulators, including GA, on nematode populations are dosage dependent and refer to alterations in the biochemical pathways in the treated plants (1, 2). Davide and Triantaphyllou attributed increases in the percentage of *M. incognita* and *M. javanica* males after supra rates of maleic hydrazide to an unidentified metabolic mechanism which had reduced giant cell development and led to abnormal sexual differentiation of the larvae to males (7). Ungiven data indicate that a higher ratio of monophenols to auxins present in root tissues was associated with the low nematode populations found in treatments of aldicarb alone and in combinations with GA, and vice-versa with the stimulative rates of GA alone. It seems possible to attribute present increase or decrease in nematode numbers to this metabolic mechanism which was earlier responsible for increased and decreased *M. incognita* galling on guava roots treated with sub- and supra-optimal doses of GA or other plant growth regulators (1).

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THE ECOLOGY OF *MELOIDOGYNE* SPP. IN NIGERIA

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Ecology is the study of the relationships that exist between an organism (e.g., *Meloidogyne* spp.) and the varying environmental conditions that surround it immediately or distantly. These environmental conditions can be broadly classified as climatic (relating to the atmosphere), edaphic (relating to the soil) and trophic (relating to the food source). Ecology seeks to understand the habits of the organism and especially the behaviour of its population over space and time under the different or specified environmental conditions. With regard to the nematode pests of plants, population behaviour is emphasized in that it often is directly related to crop performance and economic returns.

The principal goal of the IMP is the control of *Meloidogyne* spp. with resultant increases in crop production (32, 33). With regard to this objective, the study of the ecology of *Meloidogyne* spp. becomes symbolic in that the performance of a crop in the presence of parasitic nematodes varies with the prevailing ecological conditions. Cropping system is one such ecological condition. A crop may perform very poorly in the presence of only a few nematodes if under stress or predisposed. The same crop may produce high yields when parasitic nematodes abound, if fertilized or grown in complementary mixtures. Similarly, *Meloidogyne* spp. populations may either decrease or increase to damaging levels on the same crop when exposed to certain ecological conditions. Such variations in both crop and nematode behaviour make predictions based on controlled experiments, or generalizations from localized observations unrealistic. Ecological studies, therefore, become essential for each location, each cropping system, and each crop management scheme. In discussing the ecology of *Meloidogyne* spp. in Nigeria, the following headings will be used for convenience to emphasize areas of research needs:

1. Spatial distribution of *Meloidogyne* spp. in Nigeria.
2. Seasonal distribution of *Meloidogyne* spp. in Nigeria.
3. *Meloidogyne* spp. as affected by soil type, soil solutes, soil moisture and soil temperature in Nigeria.

4. Survival of *Meloidogyne* spp. in adverse periods in Nigeria.
5. *Meloidogyne* spp. as influenced by cropping systems in Nigeria.

Spatial Distribution of Meloidogyne spp. in Nigeria

Three to four species of the genus *Meloidogyne* Goeldi, *M. javanica*, *M. incognita*, *M. arenaria* and *Meloidogyne* sp., have been widely reported in the literature (2, 3, 8, 11, 13, 27). These three had earlier been described as "thermophils," surviving in soils above 10^{o}C (36). Available data suggest unrestricted distribution of these species throughout the country (6, 23, 27, 39).

The ecological zones of Nigeria are illustrated in Figure 1. The seasons of each zone are as follows: wet season = 6- months, dry season = 6+ months for Thorn bush and Sudan Savanna zones; wet season = 7 months, dry season = 5 months for the Guinea Savanna zone; and wet season = 8+ months, dry season = 4- months for the rain and swamp forest zones. Wilson (38) recorded *M. javanica* and *M. incognita* in the Nigerian savanna areas. *M. arenaria* was less widespread. Bridge (7) confirmed these findings. While *M. arenaria* and *M. incognita* were the most commonly encountered in the southern areas (11, 23, 27), *M. arenaria* was "only rarely found" in the northern areas of the country (34). *M. javanica* was least common in the southwestern parts (11) and the most common in the northern areas (2, 3, 7, 34).

The most comprehensive review of the geographic distribution of *Meloidogyne* spp. in Nigeria has been given by Caveness (11). This was based on available information to that time. This and subsequent distribution studies for the northern regions (34) are based on the presence of these species. Although their relative abundance has not been studied in these areas, it appears that one species or another of this genus is to be found in one of every two available square km of the 913, 072 km^2 of land that comprises this country. The incidence may be higher than now known.

Seasonal Distribution of Meloidogyne spp. in Nigeria

No direct information is available on the seasonal population behaviour of *Meloidogyne* spp. in Nigeria. However, in the southern rain forest areas, *Meloidogyne* spp. are known to multiply mainly on food crops during the two annual cropping seasons (3, 20). In the savanna areas, two situations exist. First of all, in field plots without irrigation, only

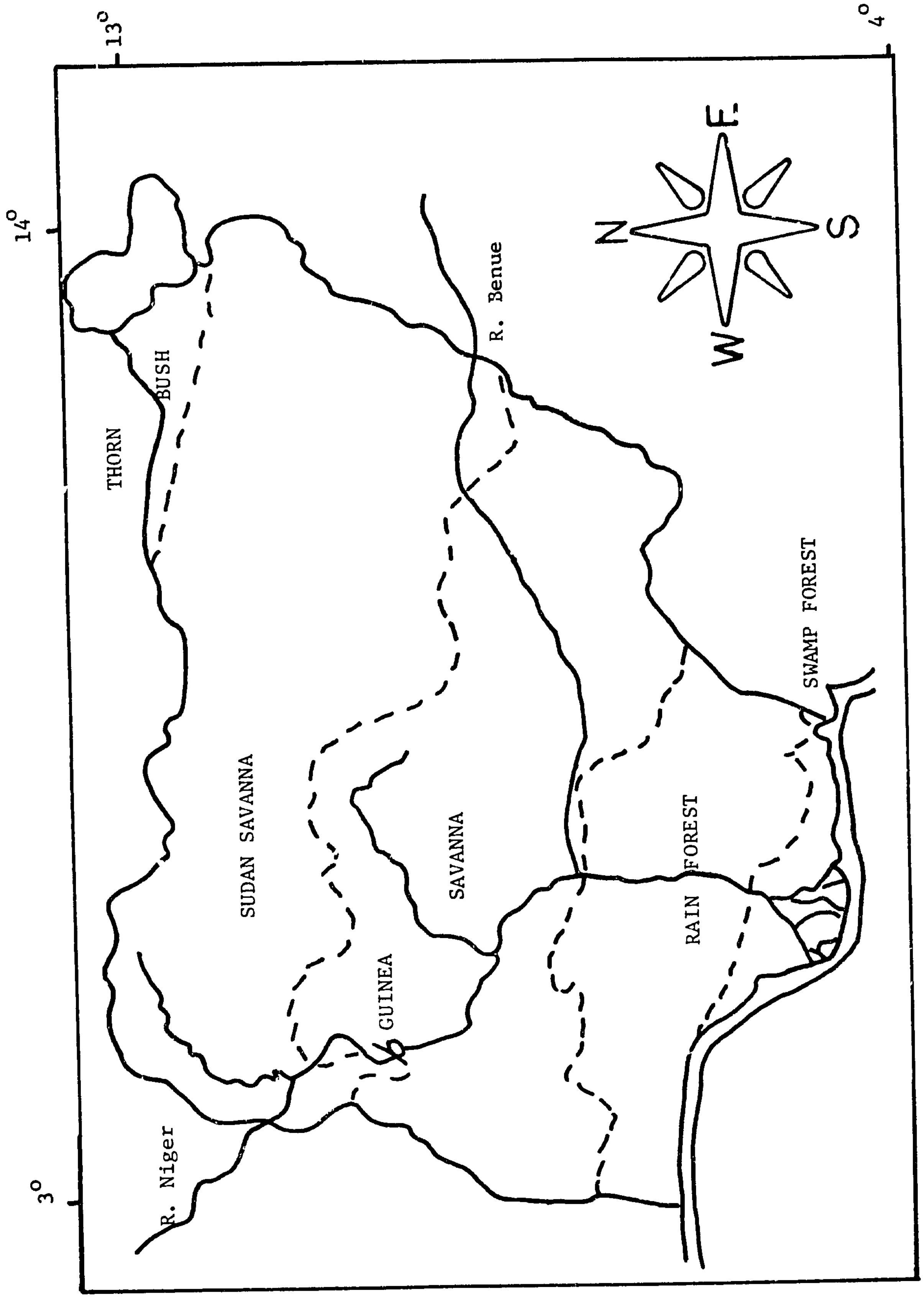

Fig. 1. Map of Nigeria showing the main ecologic zones.

small population increases occur during the single annual cropping season, with natural checks during the hot, dry intercrop periods. Secondly, where irrigation is practiced, high populations are maintained the year round, as long as suitable host crops persist (6, 7).

From these data, the following pictures of seasonal population dynamics present themselves to mind. In Figure 2, which represents the expected curve for southern rain and swamp forest areas of the country, two annual peaks are normal. The first peak occurs anytime between May and August, corresponding with the early crop growth peak; the second one occurs between mid-October and December. The exact time for the population peak will depend on the specific crop and the specific *Meloidogyne* species.

Figure 3 depicts a situation where one main crop is grown annually when rains are adequate. Severe soil desiccation causes natural checks and the peaks remain small each year.

Figure 4 illustrates the expected population fluctuations in cultivated lands under irrigation in the northern Sudan savanna areas. The broken part of the curve represents the initial population growth state, which might cover a period from a few months to several years. Bos (6) indicated that the root-knot nematode became a major pest on crops only after 10 years under irrigation in this area. The population, once established and in the presence of host crops, remains constantly high. Research is needed to confirm or reject these hypotheses.

Meloidogyne spp. as Affected by Soil Type, Soil Solutes, Soil Moisture and Soil Temperature in Nigeria

The preference of *Meloidogyne* spp. for sandy loam to heavy clay soil (31), and course-textured to fine-textured soil (19, 36) in the USA and elsewhere have been reported. In East Africa, Whitehead (37) found no correlation between *Meloidogyne* spp. and soil texture. Although there are reasons to believe that *Meloidogyne* species damage to crops is worse on sandy soils (28), no records are available of their soil type preferences in Nigeria. Available data suggest wide occurrence, irrespective of soil type (7, 11, 23).

It is well known that certain solutes, root exudates, organic substances, moisture contents, temperatures, and pH regimes in the soil affect *Meloidogyne* spp. activity, multiplication and survival. These

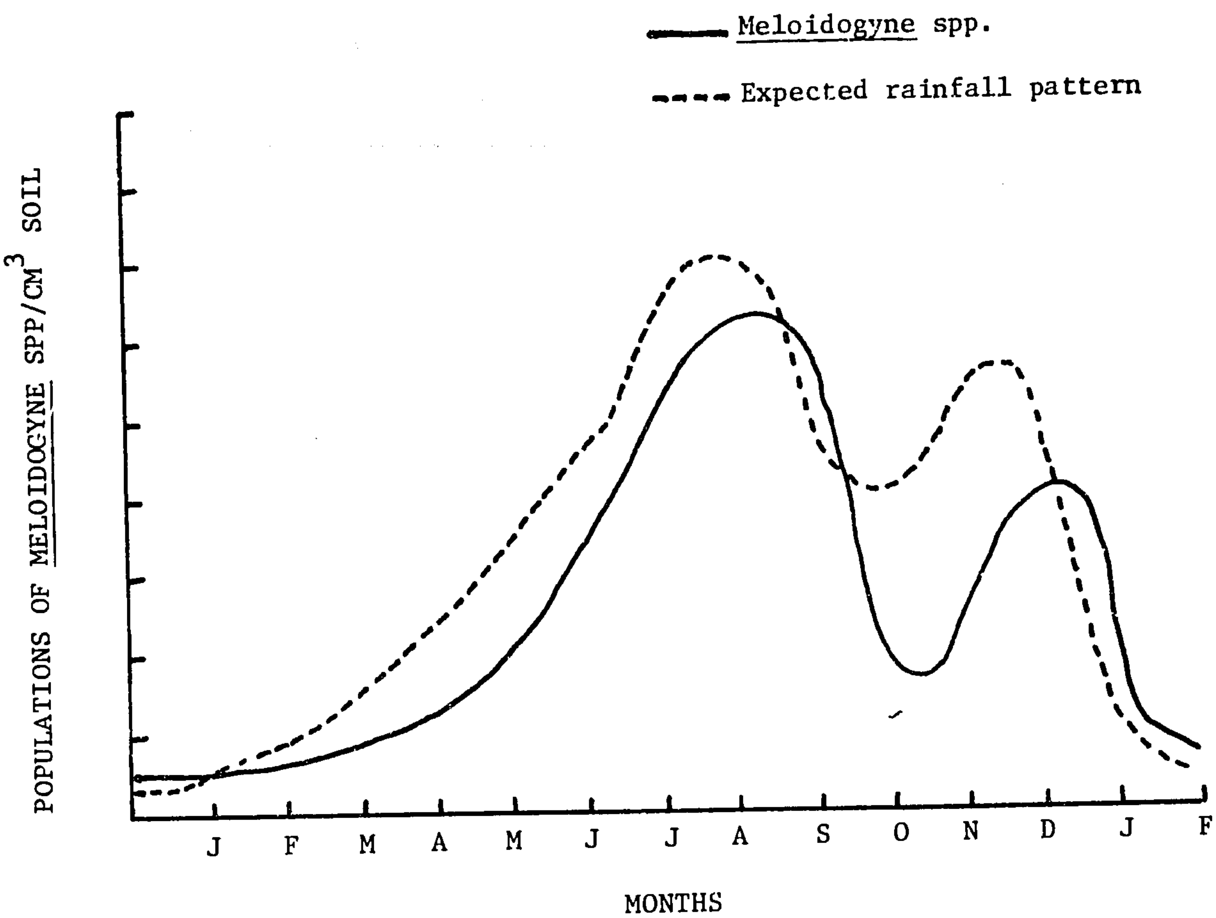

Fig. 2. Hypothetic seasonal population curve of Meloidogyne spp. in cultivated land in southern rain and swamp forest areas of Nigeria.

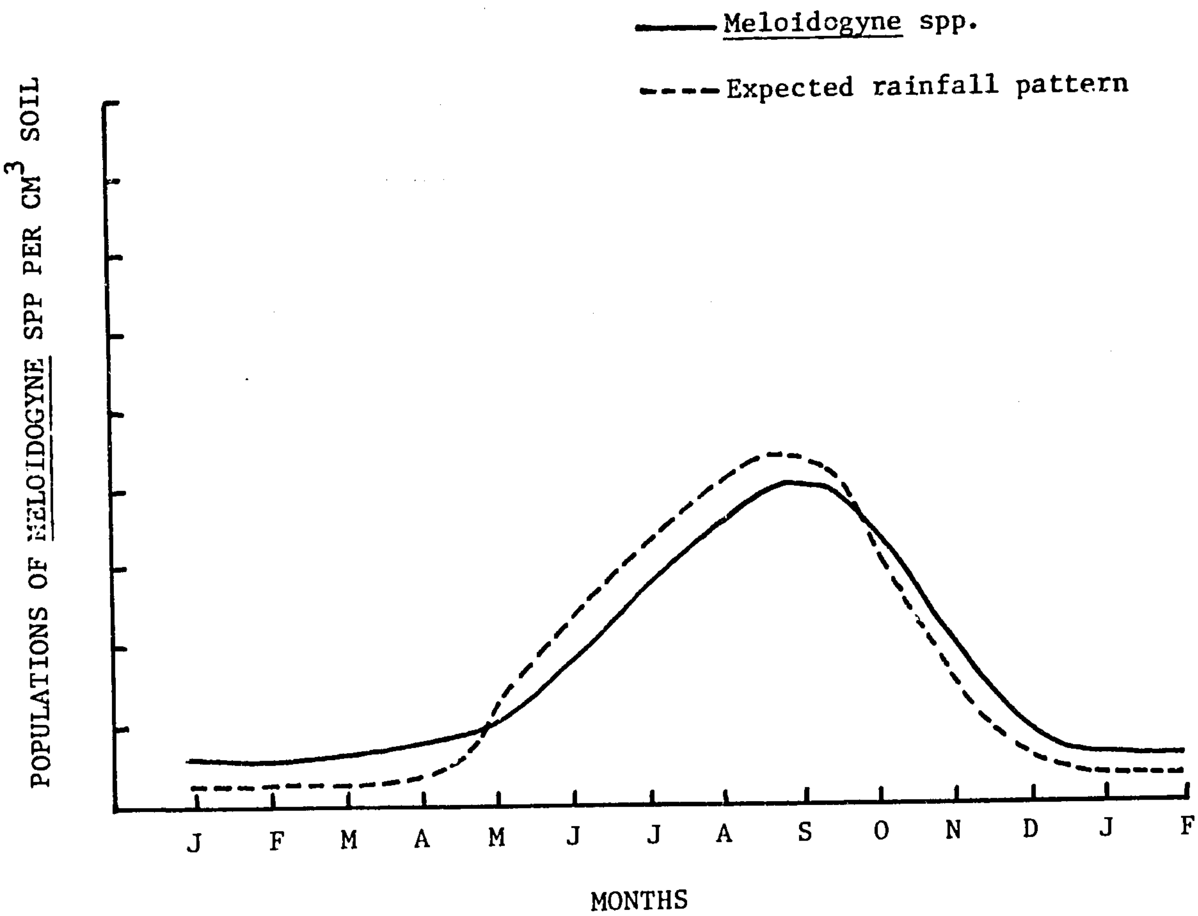

Fig. 3. Hypothetic seasonal population curve for *Meloidogyne* spp. in cultivated savanna areas of Nigeria.

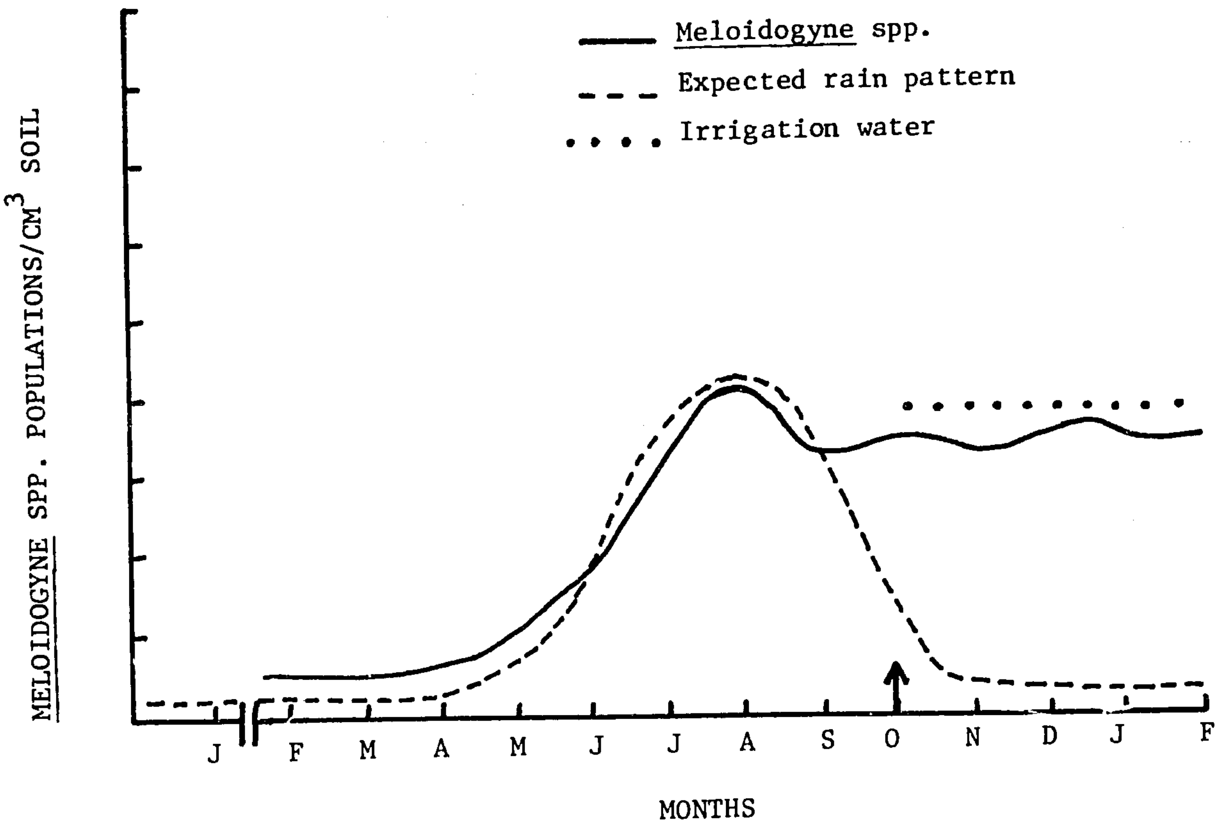

Fig. 4. Hypothetic seasonal population curves of Meloidogyne spp. in cultivated land under irrigation in the savanna area of Nigeria, ↑ indicates beginning of irrigation.

factors have been discussed (36) and exhaustively analyzed by Ferris and Van Gundy (16). Whereas these factors are closely interrelated and exist in a dynamic state under natural conditions, the tendency is to study each in isolation, thus producing a multitude of results from which it is difficult to make useful conclusions. Of these, only soil pH appears to have been studied in Nigeria. Ogbuji and Okonkwo (25) found that pH 5.6 was optimum for M. incognita development on tomato (Roma VF) in southeastern Nigeria, whereas pH 7.8 was optimum for M. hapla on the Rutgers cultivar of tomato at Oregon, U.S.A. (26). They (Ogbuji & Okonkwo) concluded ". . . optimal pH for growing a specific crop could vary substantially from one geographical location to another."

Caveness (11) tried to associate certain environmental factors, including vegetation type, annual maximum and minimum temperature and rainfall, with geographic distribution of Meloidogyne spp. in Nigeria. His extrapolations could have been of better value were all regions equally intensively investigated for Meloidogyne spp. distribution. While the geographic distribution of Meloidogyne spp. may not be influenced by temperature, their distribution over time, and especially their relative abundance may probably vary with differences of more than 11% between, for example, Sokoto and the Jos Plateau. Further research on these aspects is called for in Nigeria.

Survival of Meloidogyne spp. in Adverse Periods in Nigeria

In Nigeria, root-knot infested plants are hard to come by during the dry intercrop periods between the months of November and February, even where the rain falls for 9 of 12 months in the year; however, crops become infested soon after sprouting. This finding has prompted curious workers like Odihirin (20) to seek the hibernation sites of Meloidogyne spp. In the southern parts of the country, reproduction is continuous throughout the year. The crops provide multiplication loci during the favourable seasons. The weeds, particularly members of the families Portulacaceae, Euphorbiaceae, Amaranthaceae and Compositaceae, act as reservoir hosts during unfavourable periods (3, 20, 22). In the savanna areas of the country, irrigation sustains high populations in adverse times (7, 35).

Dispersal is mainly through human activities, along irrigation channels, or on farming implements. The weed hosts boost the already large host range of Meloidogyne spp. in Nigeria (3, 24) bringing the number above 140 (11).

Meloidogyne spp. as Influenced by Cropping Systems in Nigeria

The role of cropping systems in nematode ecology cannot be overemphasized. With respect to nematode pest management, which remains our ultimate goal, Nusbaum and Ferris (18) have demonstrated that cropping systems are of paramount importance.

Nigeria is unique in her complexity of agricultural practices; most known systems of cropping are practiced here. Traditionally, shifting and mixed cropping systems are practiced, with or without irrigation, in the savanna areas (6, 7, 29). The monoculture system was adopted as a crop improvement practice. So also were other crop improvement practices like the use of chemical fertilizers and pesticides. The advantages of the monoculture system as a "crop improvement" practice over the so-called "unproductive" traditional methods of cultivation are today in debate (17, 30). Information on the population behaviour of *Meloidogyne* spp. under these systems in relation to crop performance in Nigeria is scanty; discussion is as follows.

Irrigation. Bos (6) stated that irrigation causes a quick build up of *Meloidogyne* spp. to epidemic proportions in the northern savanna areas. He noticed that *Meloidogyne* spp. occurred wherever shadoof irrigation is practiced and that repeated growing of vegetables led to high levels of infestation and low yields. Specific data is required to define "epidemic proportions."

Shifting cultivation. Caveness (10) investigated five traditional shifting cultivation systems. He reported increases in *M. incognita* populations under such cultivations. He suggested that populations of phytophagous nematodes are maintained in lower numbers under this system, as compared to large increases under extensive monoculture.

Mixed cropping systems. Ogbuji (23) observed that damage caused by the root-knot nematodes was most acute under the "modern method" agricultural practices, and much less in traditional farms in southeastern Nigeria. Olowe (28) made similar observations.

Crop rotation. Adeniji and Chheda (1) found that crop rotation involving two years of giant star grass, *Cynodon nlemfuensis* var. *nlemfuensis* and five other *Cynodon* varieties significantly reduced field populations of *Meloidogyne* spp. with benefits to the subsequent tomato crop. Amosu (4) studied population changes of *Meloidogyne* spp. under an 8-course rotation scheme at Ile-Ife, southwestern Nigeria.

He reported negligible populations on all crops in the rotation. These crops included yam, maize, melon, cotton, groundnut, cassava, rice and pigeon pea.

In another crop rotation trial, 16 crops were grown for 6 months after a crop of a susceptible leafy vegetable. Of these, 15 were found to reduce *M. incognita* juvenile population significantly (12). The groundnut (*Arachis hypogaea*) was one such crop. In a cover crop (live mulch) trial, Caveness (12) found that 8 of 9 cover crops tested significantly reduced *M. incognita* juvenile populations 24 months after establishment.

Tillage. Caveness (9) studied, among other things, population changes of *M. incognita* juveniles in fields under seven consecutive monocultures of maize, pigeon pea, soybean, cowpea and weed fallow under tillage and no tillage management regimes. *M. incognita* juvenile populations were 3½ times greater in no tillage soils over tilled soils.

Chemical fertilizers. Information is lacking on the effects of chemical fertilizers on population levels and virulence of *Meloidogyne* spp. in Nigeria.

Other crop or nematode management practices. Caveness investigated the effects of soil desiccation (8) and soil mulching (12) on population dynamics of *Meloidogyne* spp. Monthly and bimonthly reridging to desiccate soil during the dry intercrop period significantly reduced *M. incognita* populations on Moor Plantation, Ibadan. In addition to this, yields of vegetables and tobacco increased significantly. Mulching was found to cause general increases in juvenile populations of *M. incognita* at IITA. When used as soil amendments, four of the five plant residues tried (including groundnut hay) caused population reductions of *M. incognita* in pot experiments at Moor Plantation, Ibadan (8).

Conclusions

There are obvious gaps in our knowledge of the ecology of *Meloidogyne* spp. in Nigeria. To bridge some of these gaps and to provide quick solutions to our *Meloidogyne* problems, a systems approach to the study of *Meloidogyne* ecology in Nigeria is proposed.

Such an approach will investigate in detail each of the different cropping systems currently in use in relation to the population behaviour of *Meloidogyne* spp. and their consequences upon crop production. As far as possible, investigations should be carried out in the field to yield practical results. Economic threshold levels should be determined for *Meloidogyne* spp., singly or in combination for each cropping system and under different climatic and edaphic conditions. Tolerance limits of important economic crops need similarly to be determined.

Our long neglected traditional mixed cropping systems deserve special attention. It is now believed that mixed cropping systems probably have both pest management properties and agronomic as well as economic advantages (5, 14, 17, 30).

Superimposed on cropping systems is the use of chemical fertilizers, which has become an accepted practice in our agriculture. The short and long-term effects of fertilization on *Meloidogyne* spp. ecology and on yield returns under each cropping system call for studies. For example, it is now known that the application of NPK fertilizer to maize once a year leads to increases in early maize yields with large losses in the late season yields. The growing of maize in association with certain grain legumes proves a better substitute with respect to maize yield and total economic returns on *Pratylenchus brachyurus*-infested land in southwestern Nigeria (15).

There is need to elucidate the complex interactions in the ecological web operating under each cropping and management system. Further research is needed on the possible uses of plant residues and other forms of agri-byproducts in mitigating *Meloidogyne* spp. infestations on economic crops in Nigeria. Each cropping and management system should be tried on different soil types to determine optimum conditions for the system relative to mitigating *Meloidogyne* spp. infestations. No information is available on planting dates to avoid *Meloidogyne* spp. attacks in Nigeria. Investigation in this area might yield fruitful results.

Finally, there is need to coordinate all results in order to formulate a viable integrated control scheme for the country. I expect such a scheme to contain management variables adaptable to each ecological condition which will be sequential in operation and, if judiciously integrated, would yield maximum benefits to mankind.

Research Proposal

Studies of the ecology of *Meloidogyne* spp. under tomato grown in association with groundnuts.

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

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

Identifications are initially based on host response and perineal patterns of adult females. Oftentimes, additional morphological, cytological or biochemical studies are necessary. Although some variation has been found within populations of the same species, uniformity of characters, including pathogenicity, far outweighs the variability. For the widely distributed and agriculturally important species *M. incognita*, *M. javanica*, *M. hapla* and *M. arenaria*, there is a strong correlation between the standard characters used for identification and the behavior of the individual nematode species. These studies suggest that once the identity of the nematode is known, its pathogenicity can be predicted except for variations among races. If future studies continue to confirm these correlations, it may be practical to develop resistant cultivars and conduct host range studies at a single location and expect the results to be applicable throughout the world. Studies involving a few populations of each of the major species could be conducted under standard conditions and at minimum cost. These studies should make breeding cultivars for resistance to root-knot more attractive, since breeding lines can be tested against a small number of populations. Once a resistant cultivar has been developed, it can be marketed with assurance that results in the field will be satisfactory. Furthermore, a much larger, indeed a world-wide market, is open to producers of seed of resistant cultivars.

MORPHOLOGICAL CHARACTERS USEFUL IN THE IDENTIFICATION OF *MELOIDOGYNE* SPECIES

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

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

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

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

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

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

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

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

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CYTOGENETIC AND BIOCHEMICAL STUDIES AS AN AID TO IDENTIFICATION

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

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

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

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

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

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

PLANT BREEDING FOR RESISTANCE TO ROOT-KNOT NEMATODE

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Introduction

Plant breeding is the process of progressive selection usually following specific crosses in order to bring about improvement in the plants. When compared with the parent plants, the improvement is usually in form of the overall yield, quality and other traits acceptable to the consumers. In the humid tropics, because of the unique ecological, climatic and edaphic factors, resistance to diseases and pests has become an important trait for consideration by breeders especially since it is the most economical control method. This control method is more important for locally consumed crops, which are regarded as non-cash crops since income derived from them is rather low. Insect pests and diseases have formed such a formidable force in the breeding programs that many breeders tend to forget about selection for resistance to nematodes which could be even more destructive and could cause high reduction in yield. In this paper, the specific problems in breeding for resistance to root-knot nematode are examined and suggestions are made for a breeding program to be followed. Cowpea, *V. unguiculata*, has been cited as an example.

Breeding Programs

Although there are many possible breeding programs for nematode resistance, three major programs currently being employed by other scientists for pest and disease resistance would first be examined to assess their specific suitability in breeding for resistance to nematodes (1, 2, 4).

The nature of nematode infestation makes diagnosis of the symptoms rather difficult for non-nematologists as the symptoms can be easily confused with other disease symptoms. Also, screening for resistance can also pose a serious problem to breeders since it involves destructive sampling and may necessitate vegetative propagation of resistant lines. Collaborative work with nematologists is therefore essential in order to obtain truly resistant lines. Resistance can be monogenic as in sweet potato, Ipomea spp., or polygenic as in the soybean, Glycine spp. It can also be dominant or recessive (5).

Although resistance is usually dominant while virulence is recessive, occasional recessive genes have been found to control resistance as in the case of resistance to cyst nematode in soybean (5). Monogenic dominant resistance is usually easier to detect in a screening program than polygenic resistance. In the former case, resistance to a specific species or strain is observed and is usually unstable. This type of resistance is referred to as vertical resistance.

On the other hand, polygenic resistance is more stable. Resistance to a number of species or strains of the pathogen is observed at the same time. The pathogen would need to mutate at a number of different loci or several of the pathogens would have to undergo mutation at specific loci simultaneously before this type of resistance could break down. This latter type of resistance is referred to as horizontal resistance, and it is more preferable in a breeding program.

Understanding the mechanism and the genetics of resistance is important for planning a good breeding program. However, much preliminary information can be obtained on these subjects during the screening exercise, hence the need for the breeder and the nematologist to work together right from the inception of the program.

Although the amount of information available on breeding for nematode resistance is rather limited, probably as a result of some of the problems mentioned earlier, such a program is not expected to differ appreciably from breeding for pest and disease resistance. It is expected to be less difficult than breeding for insect resistance because of the high migratory nature of insects but possibly more difficult than breeding for disease resistance since most pathogens are less mobile than nematodes.

In cases where totally resistant lines cannot be obtained, it is important to settle for tolerant lines while the search for the resistant lines continues. It should be noted that some highly resistant lines may have poor agronomic traits. In cases where there is a choice, resistant lines having good agronomic traits should be used in the initial crossing.

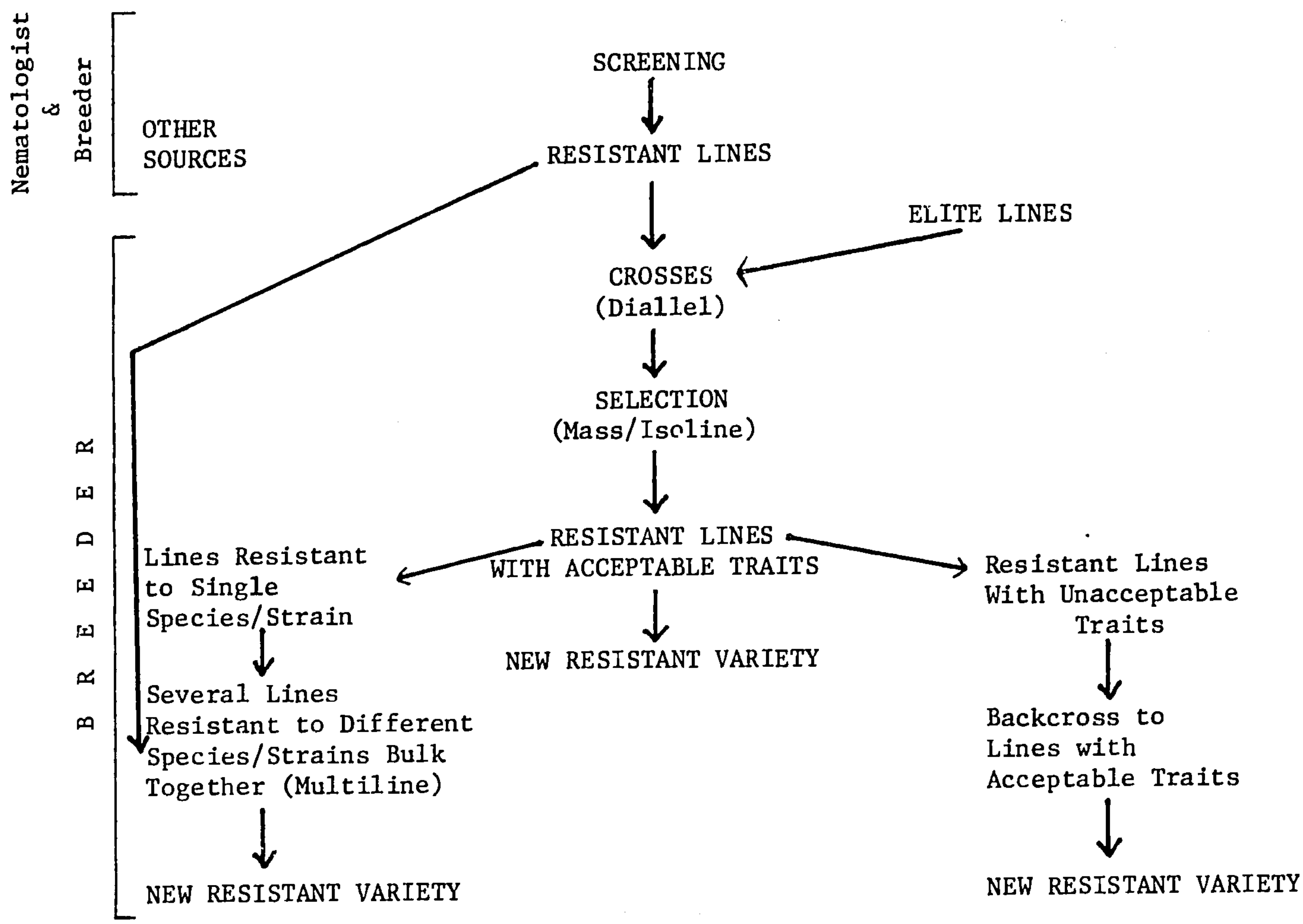
If resistant lines are easy to identify during the screening exercise, a simple experiment should be designed to confirm possibility of monogenic dominant inheritance so as to help in designing subsequent breeding program. Recessive, oligogenic, polygenic or a more complex inheritance system is usually associated with cases in which resistant lines are more difficult to find during the screening exercise. Mass selection is suggested if polygenic inheritance is suspected. This process involves selecting a large number of resistant or tolerant lines with good agronomic characteristics from the segregating generations following crosses of a number of resistant lines. This type of selection will minimize the possibility of losing useful genes for good agronomic traits and for resistance to many species and strains of nematodes, diseases, and other pests. Also, being horizontal, the resistance does not break down easily.

An isoline or multiline breeding program is suggested for monogenic type of inheritance. This program could be followed by a backcross program using the resistant lines as the recurrent parent to incorporate good agronomic traits on a resistant line or to combine a number of resistant lines into a single variety. This type of breeding program involves selecting for resistance to a single or a few strains or species of nematode at a time, assuming a gene-to-gene inheritance system (vertical resistance). This type of breeding program could be used in areas with known specific nematode infestation or where the existing resistant variety has broken down and an isoline with the new virulent strain is available. A backcross program could be used to produce a new resistant variety. A number of isolines with specific resistance to a number of strains or species known to be present in a particular area could be combined to form a multiline for the area. A schematic drawing showing the suggested breeding program for nematode resistance is shown in Fig. 1.

Breeding for Root-Knot Nematode Using Cowpea *V. unguiculata*

A breeding program to incorporate nematode resistance into the elite lines of cowpea was embarked upon at the Department of Agricultural Biology of the University of Ibadan a few years ago. The screening exercise which was started at the beginning of the project in collaboration with a nematologist was soon abandoned as a result of the insufficiency

Fig. 1. Schematic Diagram of a Breeding Program
For Resistance to Nematode



of the nematode population to create enough selection pressure. However, nematode-resistant lines were collected from other nematologists and together with other lines with good agronomic traits, a diallel crossing scheme was designed.

The segregating generation was handled by a mass selection scheme. Selection was made for all the essential agronomic traits, such as earliness, long and well-filled pods, and medium-sized seeds as well as for nematode resistance. Selection was carried up to the seventh generation. A greenhouse test was made for root-knot nematode resistance and for some of the more common diseases. The seeds were then sent back to some of the nematologists collaborating in the program for field tests. The results are still being awaited. Meanwhile, the variety has been released as AGRIB-V_1, with some reservation as to its quality as a nematode-resistant variety. It is hoped that if the nematologists' results are not favorable, a backcross program would be designed to concentrate the resistance into the new variety. The picture (Fig. 2) shows the variety growing on the field during the selection program.

Conclusion

Breeding for nematode resistance is still at its infancy in Nigeria. This state of affairs exists because there are comparatively very few breeders in the country and most of those breeders concentrate their efforts on breeding for resistance to other pests and diseases whose inheritance systems are well understood. Also, nematologists are quite few in number in Nigeria.

In order to combat nematode infestation of most of our crops, conscious efforts must be made to encourage collaborative work between nematologists and breeders. Although screening programs should be designed to produce a single variety resistant to as many species and strains of nematodes as possible, lines resistant to single specific species or strains should be given to breeders who could use them in the isoline, multiline or the backcross breeding program.

It is hoped that in the near future, many more crops resistant to nematodes and with good agronomic traits would be available for distribution to farmers.

Fig. 2. A stand of the variety AGRIB-V_1 suspected to be resistant to root-knot nematode.

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SCREENING OF SOME WEST AFRICAN COWPEAS *VIGNA UNGUICULATA* FOR RESISTANCE TO ROOT-KNOT NEMATODES *MELOIDOGYNE INCOGNITA* AND *M. JAVANICA*

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Abstract

Cowpeas, *Vigna unguiculata* and other members of the bean family, are showing significant promise as a quick source of protein in the staple foods of developing countries. Good harvests are being threatened by various disease agents including root-knot nematodes, *Meloidogyne* spp. Discovery and use of resistant varieties will reduce dependence on chemical control measures with its attendant environmental pollution. In glasshouse potted experiments, cowpea lines from Senegal and Nigeria were screened for resistance to 3 races of *M. incognita* and one race of *M. javanica*. The Bambay cowpea lines from Senegal were selectively bred for quick maturity and high yield while TVU cowpea lines from Ibadan, Nigeria, were selected for resistance to defoliating insects.

The Bambay lines B12, B13, etc. showed some very desirable qualities like quick growth, quick maturity, large grain size, high yield and good taste, but all the lines tested were highly susceptible to *M. incognita* and *M. javanica*. The TVU lines from Ibadan, Nigeria, had both susceptible and resistant lines. TVU 401 and TVU 1560 are slightly resistant to root-knot nematodes. They showed more resistance than the Bambay lines tested, but the resistance is not strong enough for nematode-resistance breeding purposes. TVU 857 was the most resistant line. It shows evidence of resistance to both *M. javanica* and the 3 races of *M. incognita* tested. It is highly resistant to *M. javanica* and races 1 and 3 of *M. incognita*. Numerous egg masses had been produced per root system in Bambay lines after 4 weeks of inoculation, but no eggs had appeared in the root systems of TVU 857 inoculated with *M. javanica* and races 1 and 3 of *M. incognita*, and only smallish egg masses of between 1 and 2 per root system had appeared from those inoculated with *M. incognita* race 2. This indicates slow development or inability to develop to adult state on TVU 857 cowpea by *M. javanica* and races 1 and 3 of *M. incognita*.

The resistance showed by cowpea cultivar TVU 857 against M. *javanica* and the 3 races of *M. incognita* is high. This cultivar is therefore recommended for further testing and nematode-resistance breeding purposes. It is one of the very few cowpeas found to possess considerable resistance to both *M. incognita* and *M. javanica*, the 2 root-knot species most commonly associated with cowpeas all over the world. The Bambay cowpea lines have some very desirable qualities. These qualities are needed very much in the Sahel region of West Africa where the rainfall lasts for only 3 months per year. Cross-breeding of the Bambay lines with a resistant line like TVU 857 is highly recommended for the future.

INTRODUCTION

Agronomic Desirability of Cowpeas

Cowpeas and other members of the bean family are the poor man's quick source of protein, especially in the tropics, because of their rapid growth from seedling to edible fruit and seed and because of their relatively high protein content when compared with other West African staple foods. Recent research findings that have brought cowpeas more and more into agronomic prominence include: (a) nitrogen fixation in association with root nodule bacteria is more efficient than in soybean; (b) some cultivars spread on the ground and prevent soil erosion and weeds; (c) the leaves add quick organic manure to soil; (d) cowpeas are easy to intercrop profitably with other West African staples like yams, maize and cassava; Some maize cultivars have higher yields when intercropped with cowpeas than when cropped singly; (e) some cultivars are suitable for use as a green vegetable; (f) cowpea is one of the plants in which gene manipulation is relatively easy. As a result, desirable qualities can be introduced into a particular cultivar by plant breeders from the available gene pool which is very large and varied. In fact, both domesticated and wild cowpea cultivars exist in large numbers in West Africa.

MATERIALS AND METHODS

Cowpea cultivars (*Vigna unguiculata*) from 2 different parts of West Africa were screened for resistance against the two most important root-knot species found in West Africa, *M. javanica* and *M. incognita* (3 races).

The cowpea cultivars used were B12, B13, B14, B15, B21, B22, B23, B24 which were bred in Bambay, Senegal, for quick maturity and resistance to Sahelian drought, and TVU 401, TVU 857 and TVU 1560 which were selected in Nigeria for resistance to defoliating insects like leafhoppers. The races of root-knot nematodes used (M. javanica and races 1, 2, 3 of M. incognita) were cultured on "Rutgers" tomato plants grown in pots in the glasshouse. These plants received a weekly application of 20 cm^3/plant of full strength Hoagland's complete nutrient solution. Eggs were extracted from mature tomato plants by macerating roots in NaOCL solution. Egg suspensions were prepared in tap water to enable the desired inoculum density per plant to be made in 5 cm^3 of water.

Experiment 1. Eight cultivars of the Bambay lines of cowpeas and TVU 401, TVU 857, and TVU 1560 were planted in plastic cups containing steam-sterilized blow sand (92.4% sand, 3.9% silt and 3.7% clay). A heavy nematode inoculum of 20,000 eggs per cup was used in this experiment with 5 replicates for quick recognition of resistant and susceptible lines. The 2 species of root-knot nematode used were M. javanica (California J-7c-54) and M. incognita (California 6A), and each of the 7.5 cm-d plastic cups received 280 cm^3 of the blow sand. Ambient temperatures in the glasshouse ranged between 21c and 30c. Observations were made on growth rates and flower and seed production. The plants were harvested 8 weeks after inoculation.

Experiment 2. An inoculum of 10,000 eggs per plant was used in similar cups with TVU 401, TVU 857, TVU 1560 and B23. M. javanica and races 1, 2, 3 of M. incognita were inoculated with 3 replicates. One cup with each treatment was harvested one week, 2 weeks, and 4 weeks after inoculation. The roots were preserved for larval penetration and egg mass formation studies. Each cultivar was also planted in a nematode-free cup as a check.

RESULTS

The Bambay cowpeas bred in Senegal for quick maturity and high yield showed evidence of quick growth and seed production, but all the lines tested were highly susceptible to Meloidogyne incognita and M. javanica. Gall rating based on the IMP Scheme (0 - 5) found them mostly at index 5 with big coalescing galls. TVU 401 and TVU 1560 had a gall index of 4 with non-coalescing galls. On the contrary, TVU 857 showed a measure of resistance with a gall index of 1.0 with M. javanica and 1.5 on M. incognita despite the high inoculum.

The second experiment showed a similar trend with TVU 857 as the most resistant line. TVU 401 and TVU 1560 showed a resistance that is a little higher than all the Bambay lines tested. However, this resistance is not high enough because the egg masses formed per root system will constitute a heavy inoculum for a succeeding crop on the field.

In this experiment with an initial inoculum of 10,000 eggs per plant, egg masses were formed 4 weeks after inoculation in all the Bambay lines as well as in TVU 401 and TVU 1560, but no egg masses had developed on TVU 857 infected with _M. javanica_ and races 1 and 3 of _M. incognita_. Tiny egg masses of between 1 and 2 per root system were produced on TVU 857 by _M. incognita_ race 2. Galling index averaged 0.5 for both _M. javanica_ and _M. incognita_ except race 2 which averaged 1.0. Preliminary counts of larval entry one week after inoculation showed no larval entry with _M. javanica_ on TVU 857 and very few larvae with _M. incognita_ race 1 and 3 (average of 4 larvae per root system). Larvae of _M. incognita_ race 2 entered in large numbers (see Table 1). Table 2 further reveals that larvae penetrated TVU 857 in comparatively smaller numbers in the second week than the other cultivars. Fewer _M. javanica_ larvae penetrated TVU 857 than did _M. incognita_ larvae.

In all cases, no egg masses were recorded on the roots in the first and second weeks after inoculation. Between 70% and 80% of the roots were showing visible signs of galling in the first week with B23 roots. Only 40-50% of the root system of TVU 401 and TVU 1560 showed visible signs of galling in the first week. The root systems of TVU 401 and TVU 1560 averaged 50-60 egg masses per root system 4 weeks after inoculation while B23 had over 100 egg masses per root system.

CONCLUSION/SUGGESTIONS

Cowpea cultivar TVU 857 shows strong resistance against both _M._ javanica and 3 races of _M. incognita_. Larval penetration studies show that a few larvae penetrate into the roots. The basis for resistance is not failure to penetrate because larval penetration takes place, although at a slower rate than in susceptible cultivars.Inability to develop to maturity or very slow development of root-knot larvae on TVU 857 is the probable basis for resistance. The TVU lines of cowpea from Ibadan, Nigeria, have brighter prospects for root-knot resistance. Therefore, further screening of other TVU lines is advisable.

Table 1. Penetration of cowpea roots by Meloidogyne larvae after one week.

Cultivar/ Treatment	No. of larvae in cortex	No. of larvae in vascular tissue	No. of root tips
TVU 857 MJ	0	0	644
B23 MJ	0	24	837
TVU 401 MJ	0	8	827
TVU 857 R1/MI	0	7	308
TVU 857 R2/MI	0	62	830
TVU 401 R2/MI	0	141	960
TVU 1560 R2/MI	0	70	995
B23 R2/MI	0	138	475

Table 2. Penetration of cowpea roots by <u>Meloidogyne</u> larvae

Cultivar/ treatment	No. of root tips	No. of larvae	No. of root tips/larvae
TVU 401 R1/M1	426	52	8.2
TVU 401 R2/M1	1662	686	2.42
TVU 401 R3/M1	929	259	3.6
TVU 401 MJ	987	34	29
TVU 857 R1/M1	1241	180	6.9
TVU 857 R2/M1	401	319	1.3
TVU 857 R3/M1	1441	100	14.4
TVU 857 MJ	1046	22	47.5
TVU 1560 R1/M1	740	160	4.6
TVU 1560 R2/M1	791	430	2.0
TVU 1560 R3/M1	1118	602	2.0
TVU 1560 MJ	686	141	5.0
TVU 1560 MJ	939	179	5.0
B23 R1/M1	3520	845	4.0
B23 R2/M1	2416	898	2.6
B23 R3/M1	3028	560	5.4
B23 MJ	1724	83	2.1

The Bambay lines have some very desirable qualities like quick growth, quick maturity, large grain size, high yield and good taste. Such qualities are very much needed in the Sahel region of West Africa. Therefore, cross-breeding of Bambay lines with TVU 857 is highly recommended for the future.

ACKNOWLEDGEMENT

The author wishes to acknowledge the financial support for this work given by Fulbright-Hays Fellowship Foundation, The University of Port Harcourt (Nigeria), the Dean of the College of Agriculture, University of California, Riverside. He is also very grateful to Professor Van Gundy, the Chairman, Nematology Department and the entire academic and technical staff for their advice and for providing the space and other facilities used for these experiments at Riverside, California. The help and collaboration of IITA (Ibadan), Dr. Anthony Hall (UCR) and Professor J. N. Sasser who provided the various lines of cowpeas is also thankfully appreciated.

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TOWARDS IMPROVED CROPPING SYSTEMS FOR THE HUMID TROPICS

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Introduction

It is now well known that the world food problem is centered in the tropics where agricultural productivity is no longer keeping pace with population growth and the associated food demand. This picture is in striking contrast to the developed countries where, through modern technological development, food supply often exceeds the requirement of the population. The main difference here is that while scientific research has led to the development of more productive agricultural systems in the developed temperate countries, very little scientific research has been done in the tropics, and the little that has been done was aimed at transferring technologies developed in temperate regions to the tropics. Invariably such transfer efforts have been unsuccessful and, in many cases, have done severe harm to the land.

Since it is now clear that transfer of technology does not offer a solution to agricultural development in the humid tropics, the responsibility now falls on scientists to identify the constraints hindering increased agricultural productivity and production and devise new methods of overcoming these limitations.

Cropping System

Before an attempt is made to describe the cropping systems of the humid tropics and to consider research activities aimed at their improvements, some definitions are necessary. A cropping system may be broadly defined as an ecosystem in which man uses plants to direct the flow of energy for his own benefit, i.e. to obtain food, fibre, shelter and fuel. The crops must be so manipulated that the yields supply quantities essential for the survival of the human population over 12 months, as dictated by the seasonal cycle. It must be emphasized that regardless of the actual length of the cropping period, the yield must equal the community's needs if the community is to survive and flourish.

Climate determines to a large extent the cropping period and the cropping systems. The major difference between temperate and tropic regions is that low temperature limits the cropping period in the temperate regions, while low soil moisture, due to cessation of rainfall, is the limitation in the tropics.

The humid tropics, the area under consideration, is defined as that part of the tropical lowlands where precipitation exceeds evapotranspiration for more than 7 months annually (5, 6). Within this range, fall a number of climatic conditions, but space and time do not allow for detailed discussions of them all. Thus, only a general picture based on the medium conditions will be discussed.

The Bush Fallow

Bush fallow is a cropping system in which land is cropped for a short period of usually 1 to 2 years and is allowed to rest or lay fallow for many years before subsequent cropping. During the fallow period, the land is colonized by natural vegetation which may include herbs, shrubs and trees. During the fallow period, the soil fertility and desirable soil structure are restored by the occupying flora and fauna. In addition, the land undergoes some form of cleaning as harmful organisms are usually destroyed or reduced below economic thresholds.

In a bush fallow system, man and the rest of the ecosystem are in perfect harmony until man's population exceeds that which the normal biological system can support. As the demand for food increases, effort to increase food production is first directed towards increasing the area under production. Consequently, the reduction in the area under fallow and in the fallow period limits not only the sterilizing effects on parasitic and pathogenic organisms, but also the restoration of fertility and physical properties with resulting yield decline.

The number of people supportable by a given land area in a bush fallow system depends on the innate soil fertility and other properties, the length of the fallow, plant species in the fallow and climatic condition. No workable prediction equation exists on the area of bush fallow cropping system required to support a given population, but Ruthenberg (6) has defined the land-use ratio as $L = \frac{C}{C+F}$ where C = period under crop, F = period under fallow, and L = land-use ratio. This equation shows the pressure on the land and can be used to predict imminent over-population or increased food demand on the land.

Since production area expansion cannot continue forever without consequential ill effects and since large-scale production technologies of temperate regions are unsuitable for the humid tropics, the need now exists for developing improved technological methods.

In-situ Mulch

Early efforts at developing an alternative to bush fallow centered on the green manure system which has been successfully practiced in temperate regions for centuries (7). Though experiments gave favorable indications, these systems never became popular in the tropics. Two main reasons appear responsible for the poor adaptation of green manure in the tropics: 1) The temperate planting season follows a cool, wet period with the green-manure legume in green, high-moisture condition which allows for rapid decomposition and release of nutrients. The tropical planting season, on the other hand, follows a dry, warm period which leaves most legumes dead or inactive with more dry than green tissue for incorporation. These dry tissues are poor in nutrients, decompose slowly, and adversely affect microbial activity and nutrient release. 2) Farmers in the tropics do not always have the equipment or the power for incorporating large quantities of organic matter. In addition, plowing and incorporation of organic residue expose the soil to the erosive forces of the heavy tropical rains. Thus, the damage caused by erosion exceeds the contribution of the legumes and soil deterioration and yield decline is the result. Problem one, being a climatic imposition, is difficult to correct. Problem two, being a cultural practice, can be overcome by alternate methods.

Chemical land preparation and no-tillage crop establishments have been combined with herbacious, leguminous cover crops in what has been designated the "in-situ mulch" system. In this system, the dried residue of the cover crop is retained on the surface as a mulch, and the new crop is established by opening or disturbing the residue only where it is essential for planting the seed. Some cover crops, e.g. Mucuna utilis (Mucuna), die naturally during a dry season of more than 4 months leaving a fairly uniform mulch cover. Others, such as Pueraria phasioloides and Centrosema pubescens, survive a 4-month dry season and must be killed by a herbicide in order to obtain an in-situ mulch. The nutrient contribution from in-situ is not expected to equal that of green manure, but the mulch creates a more favorable root environment which enhances growth and yield. The mulch also protects the soil from the erosive forces of the heavy tropical rains thereby preventing soil loss, a major contributor to yield decline and low productivity in the tropics. Good weed suppression, with the possible elimination of pre-emergence herbicides or post-plant weeding, is a strong point in favor of in-situ mulch.

In-situ mulch has worked successfully with vegetables, maize and cassava (4) and is presently being tested on other crops. Maize has been established successfully with a standard no-tillage planter in in-situ mulch from Mucuna utilis.

Live mulch adaptation of herbacious cover crops for utilization in the tropics is based on the same principle as in-situ mulch. However, the cover is only killed in narrow strips where the crops are established, and a selective growth retardant is used to suppress the cover but not the crop. The continuous cover provides good protection against erosion and good weed suppression and may even contribute to the nitrogen available to the crop (3). Pests, especially nematodes, can be eliminated or suppressed by the inclusion of selected cover crops in the rotation (11).

Alley Cropping

Bunting and Milsum (1) have long indicated that upright shrub legumes may be more effective than herbacious legumes in soil improvement in the tropics. Though they did not exactly state it, their conclusion most likely was derived from the observation that green leaves were still available on the shrubs at the end of the dry season or the start of the planting season. These green leaves were available for soil enrichment. This concept is now being developed in "alley cropping," a system in which crops are grown in alleys formed by tree or shrub legumes. At the beginning of the cropping season, the legumes are cut back and the leaves and twigs added to the soil. The stems are taken away for use as stakes or firewood. To prevent shading or other forms of competition with the crop, the legumes are kept pruned (almost leaf free) during cropping. At the end of the cropping season, pruning ceases and the land goes to fallow under these legumes which are regarded as efficient soil-restoring species. The potential nutrient contribution from the first prunings of selected legumes are shown in Table 1.

Table 1. Potential nitrogen contribution from leaves of tree/shrub legumes at 200 x 50 cm spacing after a month fallow period.

Legume	Leaf yield kg/ha dry wt.	N Content %	Potential N kg/ha
Leucaena leucocephala	3090	4.2	129
Tephrosia candida	5110	3.8	194
Gliricidia sepium	3000	3.7	111
Cajanus cajan	4100	3.6	151

Table 2. Yields of maize and cassava in pure stand and intercropping

	Maize (kg/ha)	Cassava (kg/ha)	LER
Pure stand	4,355	18,140	
Intercropping	3,984	16,807	1.5
LSD 0.05	NS	NS	

Alley cropping is regarded as a form of bush fallow in which more efficient species are planted in an organized pattern to facilitate land recovery, planting operation and rapid regeneration. By allowing these efficient species to dominate the fallow, soil restoration and other benefits derived from the bush fallow would be generated in a shorter time. Results available indicate that alley cropping may facilitate annual cropping without the expected soil deterioration and yield decline associated with this practice in the humid tropics.

An in-situ stake support system, for climbing crops such as yam and bean, developed from a modified alley-cropping offers a unique method of re-introducing staking into areas where the shortened fallow period has prevented development of suitable stake-producing plants in the naturally regenerated fallow (10, 12).

Intercropping

The maximization of resource exploitation through crops depends on the crops, their genetic composition, and the management practices. Tropical man discovered ages ago that in his environment and with his crop, maximum resource exploitation was achieved when two or more crops were grown in association. The universal and independent evolution of mixed cropping or intercropping and bush fallow in various regions of the humid tropics is indicative of the suitability of these systems to the soils and climate.

Until recently, mixed cropping was regarded as a primitive practice, and farmers grew a combination of crops solely as a guarantee against envisaged food shortage should one crop fail (6). Now it has been experimentally shown that most tropical crop combinations are more efficient than the related pure stands (8, 9, 13). For example the maize/cassava combination commonly practiced in the tropics is by far more efficient than the pure stand (Table 2). The advantage seems to be associated with their different maturity period and the drought tolerance of cassava. Cassava recovers readily from the early suppression due to competition from maize and flourishes in the drier season when other crops cannot grow. Similar efficiencies have been noted for maize/bean, cowpea/cassava, cowpea/maize, plantain/cocoyam, plantain/maize, etc. (2, 8, 9).

A major disadvantage connected with crop associations is that many are not compatible with available plant protection chemicals or mechanization techniques. However, these problems are not unsurmountable, and trends indicate potentials for development of both chemicals and machines suitable for improved intercropping combinations.

Conclusion

In the humid tropics food production has lagged behind population demand because research efforts have failed to identify and solve the problems limiting production increase. Previously, research emphasized the testing of improved technologies developed for temperate regions in the tropics. Presently, emphasis has shifted to a better understanding of the indigenous cropping systems with a view toward understanding the underlying principles and developing practices which enhance productivity. In-situ mulch appears a potential alternative to green manuring. Alley cropping as an improved bush fallow system may provide rapid soil restoration under reduced fallow period. Its effect in producing stakes and firewood offers promise to those areas where deforestation threatens fuel supply and environmental stability. The exploitative efficiency of locally evolved crop combinations should be developed along with other combinations developed to suit new technologies and demands.

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PRELIMINARY STUDIES ON THE CONTROL OF *MELOIDOGYNE* SPP.

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From a number of highly resistant clones of sweet potato previously selected (3), C.D.H., a line multiplied at the Centre pour le Développement de l'Agriculture, Camberène, Senegal, was retained for further studies.

Different populations of different species of *Meloidogyne* collected at different sites of Senegal and Mauretania were inoculated to cuttings of sweet potato cv C.D.H. which had been planted two weeks earlier in 250-cm^3 pots filled with sterile sandy soil. Each population was inoculated to three cuttings at the rate of 1,000 juveniles per plant. Six weeks after inoculation, plants were uprooted and the roots were carefully washed free of soil and examined under the dissecting microscope for the presence of galls and egg masses. Subsequently, roots were placed in a mist chamber to extract juveniles.

Results of inoculation experiments are given in Table 1. No significant reproduction was observed in most populations. However, populations 14,009 and 14,010 badly parasitized this cultivar and provoked extensive galling. Juveniles collected from the roots of plants infected by these two populations remained virulent when reinoculated to C.D.H. The few juveniles produced by other populations failed to reproduce when they were inoculated to C.D.H.

Cuttings of C.D.H. were inoculated with juveniles of *M. incognita* immediately after planting in 100-cm^3 pots filled with sterile sandy soil. Five series each of twenty pots were inoculated respectively with 13,500, 6,750, 3,375, 1,688 and 0 juveniles per pot. Plants were placed in an air-conditioned room with a 10-hour light period. Temperatures fluctuated between 22^o (night temperature) and 26^o (day temperature). One week after inoculation, cuttings of 10 pots of each series were uprooted and washed free of soil. After drying with tissue paper, the roots were removed with a sharp scalpel and weighted on a Mettler balance. This

Table 1. Numbers of juveniles of *Meloidogyne* recovered six weeks after inoculation of 1,000 juveniles from roots of sweet potato cv CDH.

Designation	Locality	Species	Number of Juveniles
11,304	Koumbia	*M. incognita*	0
11,310	Sokone	*M. javanica*	0
11,327	Thiaroye	*M. javanica*	18
11,575	Kirène	*M. incognita*	0
11,622	Sébikotane	*M. incognita*	62
12,185	Keur Massar	*M. incognita*	0
12,186	Keur Massar	*M. incognita*	0
14,009	Cambérène	*M. arenaria*	18,600
14,010	Dakar	*M.* sp.	31,700
14,401	Kiffa	*M. javanica*	0
14,403	Kiffa	*M. javanica*	0
14,404	Sani	*M. javanica*	117
14,405	Kankossa	*M. javanica*	60
14,411	Kaedi	*M. incognita*	8
14,413	Kaedi	*M. incognita*	0
14,414	Guede	*M. javanica*	1
Camb A	Cambérène	*M. javanica*	0
Camb B	Cambérène	*M. javanica*	0

Table 2. Mean weight (mg) of roots of cuttings weighed one and two weeks after inoculation with different numbers of juveniles of *M. incognita*.

	Inoculum level (juveniles per pot)				
Age of cuttings	13,500	6,750	3,375	1,688	0
1 week	11	53	96	79	411
2 weeks	800	1,490	1,722	1,340	1,501

operation was repeated after another week when the remaining 10 pots of each series were examined. When cuttings were examined two weeks after inoculation, differences in root growth between controls and treatments were less pronounced than after one week (Table 2).

Roots of cuttings inoculated with 13,500 juveniles were fixed in F.A.A. and stained with saffranine - fast green. Sections of stained roots showed juveniles inside disrupted and necrotic tissues. These observations demonstrate that the resistance of C.D.H. is based on a strong hypersensitivity of the roots to *Meloidogyne*.

Thanks to its great potential for root formation C.D.H. cuttings are capable of forming new roots after initial roots are destroyed by penetrating juveniles of *Meloidogyne*. Therefore, this cultivar is suitable to be used in crop rotations designed to limit root-knot nematode populations in the soil. However, as it has been shown in this study that populations exist which are capable to break the resistance of this line, it will be necessary to test soil populations of *Meloidogyne* present at a given locality to make sure that no resistance-breaking populations are present.

Good results were obtained with C.D.H. when it was tested together with a poor host (millet), a good host (cowpea), and a resistant crop (groundnut) as a crop preceding eggplant in a sandy soil, heavily infested by *M. javanica*. Results of this trial show that under the influence of C.D.H. and groundnut *Meloidogyne* populations had drastically decreased and yields of eggplant grown after these two previous crops were more than 400% of those obtained after cowpea. Nevertheless, at the end of the trial when the root systems of all eggplants present were examined, not a single plant had escaped serious damage by *Meloidogyne* (Table 3). Plants grown after sweet potato and groundnut all had a root-knot rating of 4 whereas plants grown after cowpea and millet frequently had a rating of 5 (roots completely destroyed by rot, following excessive attack of *Meloidogyne*). This difference can be explained by the fact that following groundnut or C.D.H. abundant populations of *Meloidogyne* develop starting from the few juveniles present in the soil thanks to the great multiplication of *Meloidogyne*. Thus the final populations will be very great independent of the previous crop. However, after a bad host, the massive attack by *Meloidogyne* will take place at a later moment as compared with the attack after a good host. This delay makes it possible to produce

Table 3. Effect of *Vigna*, millet, groundnut and sweet potato on a subsequent crop of eggplant.

Previous crop	Number of juveniles/ 250 cm^3 of soil after previous crop	Root rating eggplant	Yield (tons/ha.)	% Missing plants
Vigna	770	4.7	7.8 a	46.3
Millet	22	4.7	33.2 b	35.5
Groundnut	9	4	36 b	34.3
Sweet potato	9	4	37.4 b	29.6

a reasonable crop after C.D.H. or groundnut. In later stages of the vegetation, production is seriously impaired after the roots are badly parasitized by large numbers of nematodes.

A recent survey of 50 ha of farmland at ORSTOM, Abidjan, has shown that all land was more or less infested by Meloidogyne apart from land grown with Panicum maximum. Very severe infestations were found on land grown with Pueraria phaseoloides, a cover crop extensively grown in the southern part of Ivory Coast. Infestations were so heavy that dry land rice, a crop only moderately susceptible to root-knot, suffered badly when grown on land which had been cropped previously with Pueraria (1).

On the basis of these observations, a trial has been started in which the influence of three root-knot resistant plants, Panicum, Crotalaria spp., and groundnut, will be compared with that of Pueraria. Every four months, a square of 1 x 1 m will be cleared from strips of 6 x 1 m planted with these respective four plants. After clearing, eggplant is grown in order to measure the buildup of the populations after the respective plants. The trial is carried out on land heavily infested with Meloidogyne and on another plot apparently free from root-knot nematodes. The first results of the trial carried out on heavily infested soil are given in Table 4. On the land free of Meloidogyne, no nematodes were found after the first four months of the trial. It is hoped that by this trial, information will be obtained about the minimum time land infested by Meloidogyne must be cropped with a non-host to free the soil from these parasites and how long Pueraria can be grown on uninfested land before a Meloidogyne problem will occur.

In many of the dry areas of the region, vegetable crops suffer badly from wind damage, especially after the very dry Harmattan winds. In order to prevent the crops from damage, wind breaks of generally very susceptible plants like Prosopis sp. and Euphorbia balsamifera are planted around the gardens. These plants send out feeder roots to the irrigated soil, i.e. to the sites of the vegetables. Any control measure, whether chemical or cultural, will fail as long as the reservoir of Meloidogyne formed by these infected roots is present. In order to replace these wind breaks by others adapted to the climatic conditions, a number of shrubs and trees were tested to 11 Meloidogyne populations from Senegal. Three species show promise as wind breaks: neem (Azadirachta indica), cashew (Anacardium occidentale) and Eucalyptus camaldulensis. All three

Table 4. Effect of a period of 5-month culture of *Pueraria phaseoloides*, *Panicum maximum*, groundnut and *Crotalaria* sp. on the population density of *Meloidogyne javanica*.

Pueraria		*Panicum*		Groundnut		*Crotalaria*	
Roots juveniles/g	Soil juveniles/ 250 cm^3	Roots juveniles/g	Soil juveniles/ 250 cm^3	Roots juveniles/g	Soil juveniles/ 250 cm^3	Roots juveniles/g	Soil juveniles/ 250 cm^3
1802	1014	7	15	1	0	10	35

plants were completely resistant to all the populations of Meloidogyne tested (2).

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CROPPING SYSTEMS FOR CONTROL OF ROOT-KNOT NEMATODES

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Nematodes are primarily soil-borne pathogens and should be considered an integral part of the soil biosphere that interacts continuously with the fluctuating conditions in soil micro-environments. Therefore, every manipulation of the soil affects the level of activity or the balance of its microbial population.

Plant-parasitic nematodes are obligate parasites and require suitable hosts for development. Intelligent use of the cropping system can therefore provide natural deterrents to nematode population build-up. The density of the nematode population depends on the quality and quantity of food available as well as the influence of the environment. Any population regulation program must take these factors into consideration.

In discussing cropping systems for root-knot nematode control, it is necessary to distinguish between cropping systems and crop rotation. Cropping system and crop patterns are defined as follows by Okigbo (8): "Cropping system is cropping pattern utilized on a given farm in addition to the management of resources based on available technology all of which determine the nature or makeup of the system." "Cropping pattern is the yearly sequence and spatial arrangement of crops, or the alternation of crops and fallow on a given area. The fallow crop may be natural or planted." In essence, cropping system will include crop rotation which is the systematic growing of different kinds of crops in recurrent succession on the same piece of land.

Crop rotation has been used for preventing or reducing crop losses as specific nematode problems are identified and their economic importance demonstrated.

In principle, cropping systems are adaptable to a wide variety of nematode problems and offer great flexibility in application. The success of this management practice depends upon how well the rotation crops meet the following requirements:

a) prevent development and reproduction of the parasite the root-knot nematode,

b) compensate for the farmer's expense in working the land,

c) enrich or conserve the soil, and

d) encourage dense, vigorous growth to choke out weedy hosts susceptible to root-knot nematodes (3).

The resistance, susceptibility or tolerance of crops to root-knot nematodes is the basis for planning and developing a cropping system approach to root-knot nematode control. However, in the selection of cropping systems for the control of root-knot nematodes, consideration must be given to other species of plant-parasitic nematodes that can establish dominance and cause economic crop damage under the given cropping system. Therefore, in the evaluation of the performance of any cropping system, attention should be given to the performance of rotation crops and also to the effects upon population of other plant-parasitic nematode species.

Various studies of the effects of crop rotation on the population dynamics of root-knot nematodes have been carried out in Africa (2, 5, 7, 9, 11, 12), in the United States (3, 4, 6, 10), and elsewhere. With the information from these studies, it is possible to design a partial control program of root-knot nematodes by crop management systems.

In an effort to develop cropping systems for the control of root-knot nematodes in the West African region (Region IV) of the International Meloidogyne Project (IMP), a committee of 4 members--J. O. Amosu (Chairman), A. O. Ogunfowora, T. O. Olowe, and F. E. Caveness--was commissioned to draw up a rotation scheme. The drafted rotation scheme is presented as Appendix I. The scheme can be modified to suit a particular geographical area by substituting other proven or known, non-host crop plants for those in the scheme.

The host suitability of many crops to the more important species and races of root-knot nematode is sufficiently well known to allow planning of cropping systems to regulate the complex and mixed population of root-knot nematodes in a particular area. Amosu (1) has given in tabular form the crop reaction of 36 crops to 14 species of plant-parasitic nematodes, including 4 species of the root-knot nematodes. In the list cotton and rice are regarded as non-host crops to *M. arenaria* Groundnut and sweet potato are regarded as non-host crops to *M. incognita*. Wilson and Caveness (12) have also reported the following crops to be non-host plants to *M. incognita*: *Arachis hypogaea*, *Centrosema pubescens*, *Desmodium trifolium*, *Indigofera sublata*, *Pueraria phaseoloides*, *Leucaena leucocephala*, *Stylosanthes gracillis*, *Crotalaria juncea*, *Cynodon* species 1B-8, *Digitaria decumbens*, *Paspalum notatum* and *Amaranthus hybridus*. The soil populations of the root-knot nematode juveniles were found to be significantly reduced within six months under the host plants listed above.

In tropical Africa, vegetables are among those plants most damaged by *Meloidogyne* spp. Root-knot nematode is the main problem of vegetable growers in the region. Therefore, legume cover crops and other crops known to be non-hosts to root-knot nematodes (1, 12) should be incorporated into cropping systems with vegetables.

Research in the area of cropping systems for the control of root-knot nematodes in both field and vegetable crops needs re-emphasis, especially in the humid tropics in order to improve the productivity of small-holding and mixed-cropping farmers. These farmers find the cost of chemical control to be prohibitive, and, in many cases, the chemicals are not readily available. Cooperators of the International *Meloidogyne* Project (IMP) in the humid tropics should direct some of their research efforts to development of appropriate cropping systems for the control of root-knot nematode.

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Appendix I. Crop Rotation Schemes for Control of Root-knot Nematode

Rain Forest Zone

I. Year	1	Yam i.p.w. Lima bean i.p.w. Early Maize
	2	Melon r.p.w. Early Maize r.p.w. Cassava
	3	Cassava Contd. f.b. Cowpea/Sorghum/Soybean
	4	Bush fallow/Legume fallow
II. Year	1	Rice f.b. Late Maize/Sorghum i.p.w. Yam
	2	Yam contd. i.p.w. Early Maize f.b. Cowpea/Soybean
	3	Castor bean/Sweet potatoes
	4	Bush fallow/Legume fallow

Savannah Zone

I. Year	1	Early Maize f.b. Sorghum/Late Maize i.p.w. Yam
	2	Yam contd. i.p. Early Maize i.p.w. Cassava
	3	Cassava contd. f.b. Cowpea/Pigeonpea/Soybean
	4	Bush fallow/Legume fallow
II. Year	1	Early Maize f.b. Cowpea/Soybean f.b. Yam
	2	Yam contd. i.p.w. Melon i.p.w. Cassava
	3	Cassava contd. f.b. Pigeonpea/Soybean/Sorghum/Sweet potato
	4	Legume fallow/Bush fallow

Dry Savannah

I. Year	1	Millet Sorghum
	2	Groundnut (peanut)
	3	Millet-Sorghum-Cowpea
	4	Fallow
II. Year	1	Millet-Sorghum
	2	Cowpea
	3	Millet-Sorghum i.c.w. Chillies
	4	Fallow

Terms Abbreviated

i.c.w.	Inter-cropped with
i.p.w.	Inter-planted with
r.p.w.	Relay planted with
f.b.	followed by
Contd.	Continued
/	denotes other possible alternatives

Legume Fallow Crops

Centrosema spp.

Cynodon spp IB-8

Crotolaria juncea

Indigofera sublata

Pueraria phaseoloides

Leucaena ieucocephala

CONTROL OF ROOT-KNOT NEMATODE BY CULTURAL PRACTICES

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Introduction

The management of root-knot nematode population should take cognizance of the total environment which includes resistant crop varieties, cultural practices, biological enemies and chemical control. Many of the specific principles involved in the control of soil pathogen by land management and cultural practices have been used in tropical countries or in the temperate countries when the cost of chemical control is uneconomical. In this study, attention was focused on the use of non-chemical methods of control. The study manipulated the host and, through the host, the environment in the control of root-knot nematode population.

Crop rotation represents one of the oldest approaches to disease control. It is regarded as an effective practice for the control of plant-parasitic nematodes (2, 3, 14). Many studies have been conducted to determine the influence of crop rotation on nematode population (2, 3, 9, 11, 14, 17).

Roots of several plants have also been shown to contain chemicals that when leached into the soil are toxic to some plant-parasitic nematodes (1, 4, 6, 7, 10, 12, 15, 18). Orr and Morey (12) investigated the resistance reactions of *Ricinus communis* (castor) and *Cyanopsis tetragonoloba* (guar) to root-knot nematode infection. Hackney and Dickerson (6) showed that root and soil populations of *M. incognita* were significantly fewer from marigold, castor bean and chrysanthemum than from tomato and the surrounding soil.

Also Yadov (18) reported that root exudate of *Euphorbia hirta* inhibited the hatching of *M. incognita* eggs. Extracts from margosa *Azadirachta indica* were more toxic to root-knot nematodes and better inhibitors to larval hatch than marigold root exudates (1). Plant and soil samples from lands infested with *Eupatorium odoratum* (siam weed) have shown scanty population of root-knot nematodes (Olunuga, personal communication).

The study reported at this conference covers (a) investigation of the various durations of crop rotations for the control of root-knot nematode and (b) effect of water soluble root extracts of E. odoratum, R. communis, Lycopersicon esculentum and Vigna unguiculata on root-knot nematode population.

Crop Rotation

In 1976, 1-, 2-, 3-, and 4-yr crop rotations were set up on a piece of land that had earlier been planted to kenaf (Hibiscus sabdarifa) cv Cuba 108 for two years to build up the population of root-knot nematodes. The details of the cropping sequences are given in Appendix 1. Each treatment was replicated three times in a randomized complete block design. Twelve borings (cores) were taken from top 20 cm of soil (2.1 x 20 cm) at the end of each growing season from each treatment and composited. The soil was mixed thoroughly and 3 1-pt cups were filled with the mixture. Four seedlings of root-knot susceptible tomato Ife were transplanted to each cup. The susceptible tomato seedlings were used as indicator plants (5, 13). The seedlings were rated for root-knot nematode galls, 65 days after transplanting. The ratings are:

0 = no galling;
1 = light infection, small scattered galls;
2 = numerous small galls, some have grown together, roots functional;
3 = about 25% of root system heavily galled and non-functional;
4 = about 50% of root system heavily galled and non-functional;
5 = about 75% of the root system heavily galled and non-functional;
6 = completely galled roots and rotting.

The data have been processed for publication. It was found that the root-knot galling index was consistently high where root-knot susceptible crops (tomato Ife 1, and cowpea Ife Brown) follow each other. However, low root-knot galling index was recorded in crop sequences with rice, groundnut, maize and cassava.

Effect of Some Root Extracts on Root-knot Nematode Population

The test plants E. odoratum, R. communis, L. esculentum and V. unguiculata were harvested, and the soil was washed carefully from the roots. Twenty grams of roots from each test plant species were ground in 300 ml of distilled water using waring blender. The extract solution obtained was filtered through Whatman No. 1 filter paper, and the solution made up to 500 ml with distilled water. Two dilutions, half and one quarter of standard solution, were prepared. Four milliliters of S, S/2 and S/4 were introduced into 50-ml petri dishes. These treatments were replicated three times.

Root-knot nematode eggs were extracted from roots of infected tomato plants with a 10% clorox solution (sodium hypochlorite) (8). Larvae of root-knot nematodes are obtained by placement of the egg suspension in a modified Baermann funnel apparatus (16). Two ml of egg suspension containing 4,000 eggs were introduced into the petri dishes containing fresh solution of each of the root extract. The total number of hatched larvae was counted after 60 hours. In addition, two ml of suspension containing 500 nematode larvae were also introduced into another set of petri dishes containing the root extracts. The number of dead and moribund nematodes was counted after 1, 5, 10, 20, 30 and 70 hours.

All concentrations of the four root extract types were inhibitory to the larval hatch of *M. incognita*. The inhibition of larval hatch increased with increase in concentration and, for all concentrations, the larval hatch was significantly lower in siam weed extract than in the other root extracts at 0.01 level. All concentrations of the tested root extracts were toxic to *M. incognita* larvae. Statistical tests showed that there was, for all exposure time periods and all concentrations, no significant differences in mortality occurring in the different root extract types at 0.05 level of significance. The direct relationship between mortality of larvae and dilution and that between larval hatch and dilution all agree with the findings of earlier workers (2, 6, 10). The toxic property of *E. odoratum* and *R. communis* to root-knot larvae is a direct pointer to their suitability for controlling *Meloidogyne* population in the soil. They could be effective in crop rotation programs with highly susceptible crop plants to reduce high populations of root-knot nematode. *R. communis* may be a better rotation crop than *E. odoratum* to control root-knot nematode, since *E. odoratum* is a noxious weed, difficult to control. However, root extracts of *E. odoratum* were found to be more effective in inhibiting the hatching of *M. incognita* eggs than in causing the death of larvae after they have hatched. Therefore, the application of water soluble root extract of *E. odoratum* on root-knot nematode infested beds a few days before root-knot susceptible seedlings are transplanted may likely prove to be an effective and economical way of utilizing *E. odoratum* for the control of root-knot nematode.

Outlook

Areas of future research concentrations include:

a) examination of the effectiveness of root extracts of E. odoratum for the control of root-knot nematode on nursery beds,

b) interaction of root-knot nematode (M. incognita races) with soilborne pathogens such as Sclerotium spp, Rhizoctonia spp, Trichoderma spp and Fusarium spp.,

c) cooperation with a plant breeder when available to incorporate resistance discovered from certain tomato and cowpea cultivars into susceptible ones,

d) determination of the host-parasite relationship and mechanism of resistance in some selected vegetable crops,

e) further evaluation of various management practices and cropping systems for ability to suppress root-knot nematode in order to attain maximum yield production from susceptible vegetable and grain legumes.

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Appendix 1 - Crop rotation scheme for the control of root-knot nematodes

The acreage is approximately 2.0 ac. Each plot is 7 x 4.5 meters.

Treatment

1 YR. One-year cropping system growing cowpea every late season.

A	B	C	D	E	F
E. Maize Cowpea	E. Maize I.P.W. Melon Cowpea	Rice Cowpea	Groundnut Cowpea	Fallow/cover Cowpea	Tomato Cowpea

2 YR. Two-year cropping system growing cowpea every other late season.

	A	B	C	D	E	F
1	Rice L. Maize	E. Maize Cassava	Rice Cassava	Yam + Melon	Rice L. Maize	Tomato Cowpea
11	Rice Cowpea	Cassava contd. Cowepa	Cassava contd. Cowpea	E. Maize Cowpea	Fallow Cowpea	Tomato Cowpea

3 YR. Three-year cropping system growing cowpea in late season every third year.

	A	B	C
1	Rice L. Maize	Yam	Tomato Cowpea
11	E. Maize Fallow	E. Maize + Melon Cassava	Tomato Cowpea
111	Rice Cowpea	Cassava contd. Cowpea	Tomato Cowpea

4 YR. Four-year cropping system, growing cowpea in late season every fourth year.

	A	B	C
1	Yam	Rice L. Maize	Tomato Cowpea
11	E. Maize L. Maize	Rice Cassava	Tomato Cowpea
111	Rice Fallow/ cover	Cassava contd. Fallow/ cover	Tomato Cowpea
IV	Fallow/ cover Cowpea	Fallow/ cover Cowpea	Tomato Cowpea

REPORT OF THE COMMITTEE ON "BREEDING FOR RESISTANCE"

1. Source of germplasm for cultivars is needed. Suggested centers for germplasm availability, e.g., in Nigeria: IITA; National Cereals Research Institute; Moor Plantation, Ibadan; National Horticulture Research Institute; National Root Crop Research Institute, Umudike, Umuahia; Institute of Agriculture Research, Zaria.
   Other countries to provide information about similar centers in their countries.
2. Availability of inoculum: Central availability of root-knot inoculum in institutes like IITA; NCRI; Moor Plantation, Ibadan.
3. Evaluation of cultivar germplasm for resistance to nematodes.
4. Breeding for root-knot resistance. Needed: cooperation between plant breeders and nematologists.
5. Zonal trials on a national basis.
6. Exchange of resistant material, nationally and internationally.
7. IMP to provide current information on resistant cultivars in USA and other countries.
8. Technology transfer: extension services.

CROPPING SYSTEMS RESEARCH EVALUATION FOR AFRICA SOUTH OF THE SAHARA

Preamble

Cropping systems are adaptable to a wide variety of nematode problems and are being widely used in all the countries represented in the group. Farmers are using different cropping systems that guarantee food production for the population. The group agreed that the system should be subjected to scrutiny with the objective of improving the system for better food production.

Plan of Work

a) Identify the various types of cropping systems/cropping patterns in the different countries represented.

b) Evaluate and assess nematode problems in these cropping systems. Establish the need to control root-knot nematode in these cropping systems.

c) Evaluate/manage the population of other plant-parasitic nematodes in the system.

d) Continuous evaluation of host range of vegetable crops to root-knot nematodes with a view of identifying non-host crops to root-knot nematodes.

e) Integrated system approach should be the outlook in the control of root-knot nematode in vegetable production.

f) Need for cooperation with other scientists in the area of agronomy, ecology, plant breeding and soil management in order to evolve a better package of cropping systems recommendations.

g) Exchange of research results in cropping system with all IMP cooperators.

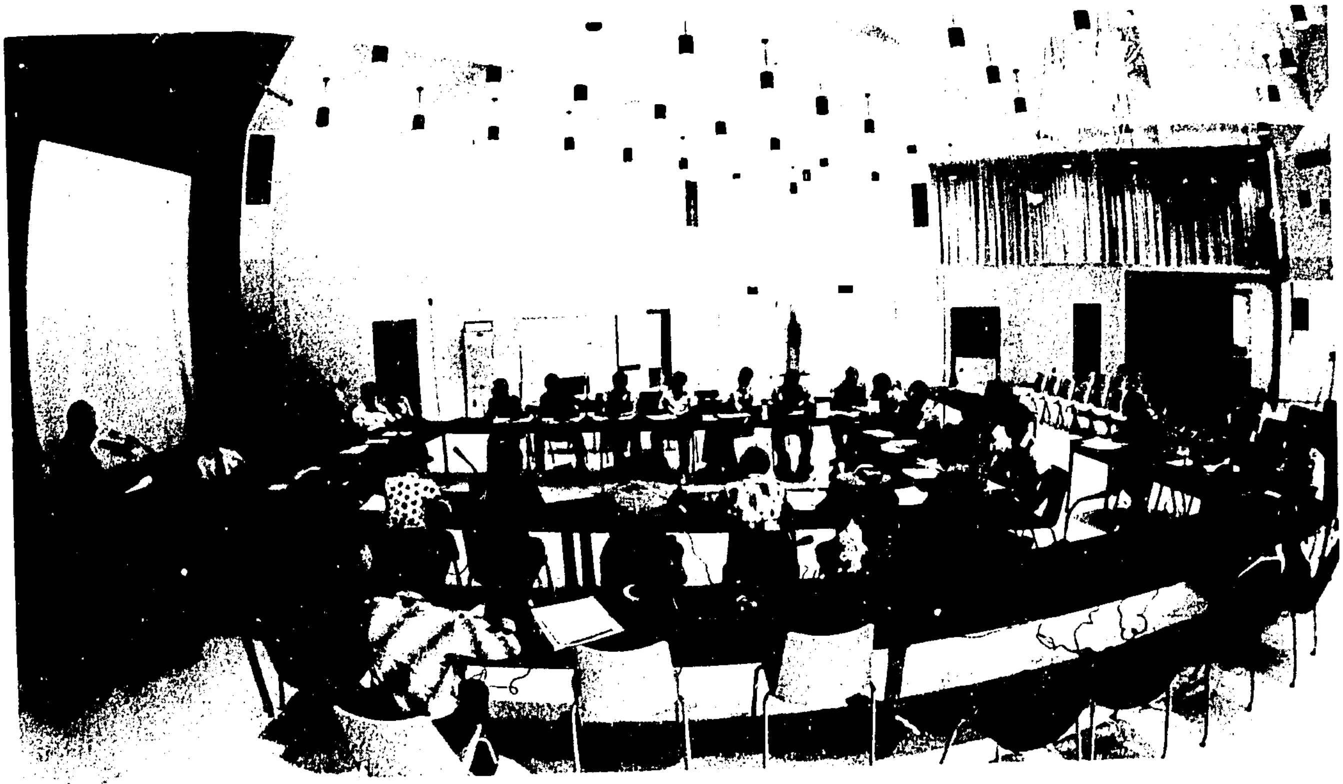
h) Only research results that have been proved to work should be presented to the farmers.

TRANSFER OF TECHNOLOGY RECOMMENDATIONS

1. IMP to make "awareness movie" which will focus on the *Meloidogyne* spp. Such movies or other audio-visual aids, e.g., slides should be distributed to cooperators in the different regions. The cooperators will then show the movies to their respective governments. Hopefully, the governments, having become aware, can support research on nematology in their respective countries.

2. IMP should help in updating the professional competence of cooperators through workshops, conferences, or short-term, subject-specific courses that will be conducted at the project headquarters in Raleigh, N. C.

3. IMP should assist in the provision of funds and/or research support equipment and materials to cooperators.



IITA Conference Room.

B. N. Okigbo delivering opening address.

Field trip.

WORK GROUPS

Committee on Breeding for Resistance.

Committee on Cropping Systems Research.

Committee on Technology Transfer.

Bernadette Bakar, Conference Coordinator.

CONFERENCE DELEGATES

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Front row (L to R): B. Fawole, F. E. Caveness, E. Nwauzor, J. O. Babatola, A. A. Idowu.

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Zimbabwe: J. I. Way (left) and J. A. Shepherd (center);
Malawi: V. W. Saka (right).

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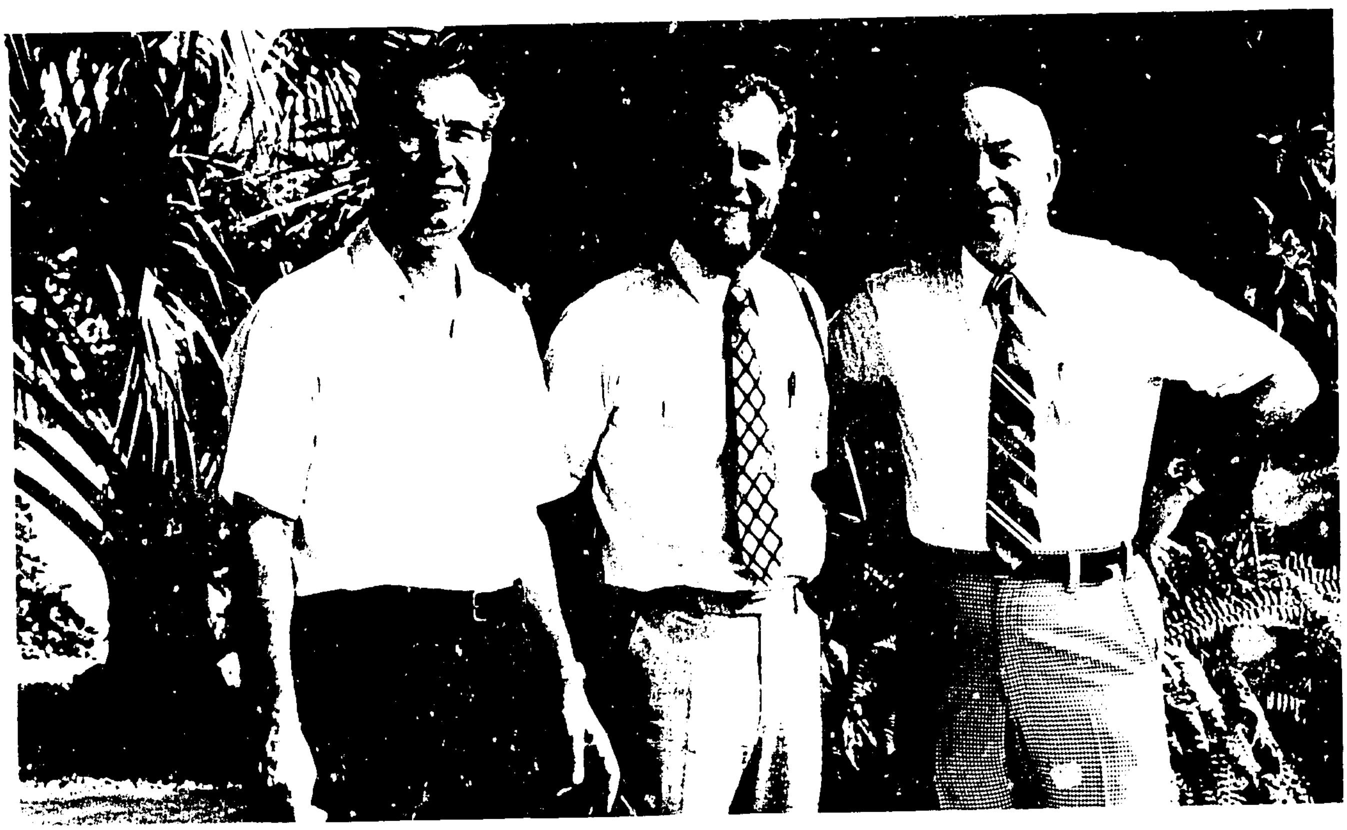

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