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INTERNATIONAL MELOIDOGYNE PROJECT

PROJECT REVIEW

PROJECT NO. 931-0614

FEBRUARY 6-7, 1980

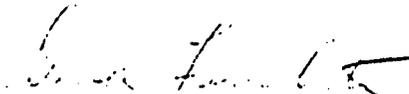
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Dr. George W. Bird, Team Leader



Dr. Clanton Black



Dr. George Fassuliotis

Dr. Edward Rice

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SUMMARY

The International Meloidogyne Project (IMP) is in the final phase of the current funded project. North Carolina State University has requested renewal of IMP from June 30, 1980 through June 29, 1985. The current project is progressing in a very excellent and timely fashion. Project outputs include the following six contributions:

1. Development of an interactive global network of 104 cooperating scientists in 58 developing countries. These are divided into eight regions (Region I, Mexico, Central American and the Caribbean; Region II, South America; Region III, Brazil; Region IV, West Africa; Region V, East Africa; Region VI, Southeast Asia; Region VII, Mid East; Region VIII, India). Fifty-three of the international cooperators reported that a total of \$727,587 of local resources were used in the project in 1979. The network has significantly enhanced the problem solving capabilities of the cooperators and the plant protection resources of the developing countries.
2. IMP made a major scientific contribution through completion of a crop loss assessment survey. Seventy-five of the international cooperators participated in the evaluation and indicated that about 15% of the principal food and fiber crops of these countries are lost to damage caused by Meloidogyne.
3. The project evaluated more than 700 living populations of Meloidogyne. About 99% of the populations belong to only six of the 41 described species. This finding allows future pro-

grams to focus on these species. IMP has also succeeded in clarifying the physiological race situation in relation to two of the most important species of *Meloidogyne*.

4. Progress has been made in the identification of *Meloidogyne*-resistant food crops, cultivars and germ plasm. Advancement has also been made in the area of environmental parameters associated with *Meloidogyne* host-parasite relationships. Progress has been considerably slower, however, in the identification of effective rotation schemes for *Meloidogyne* control, and in the use of information developed by the project in implementation of plant protection schemes.
5. The project has developed productive associations with several international crop development centers, including Centro Internacional de la Papa, International Institute of Tropical Agriculture, Centro Internacional de Agricultura Tropical and International Crops Research Institute for the Semi-Arid Tropics.
6. Project publication productivity is excellent, and includes 182 contributions in the following categories: Research Center NCSU, 41; Region I, 24; Region II, 15; Region IV, 47; Region V, 1; Region VI, 26; Region VII, 28.

The request for an extension of the project from June 30, 1980 through June 29, 1985 is important for continued global scientific progress in relation to *Meloidogyne* and the design of appropriate nematode control

~~relation to Meloidogyne and the design of appropriate nematode control~~
programs for small farmers in developing countries. The justification, original and updated objectives, methods for dissemination and utilization of research results and plan of work are sound. It is recommended the favorable action be taken on the renewal request, and the project funded for three years (June 30, 1980 through June 29, 1983). This should include the following six recommendations, and a three-year budget of \$1,774,723. At the end of this period, the project should be reviewed and appropriate recommendation made concerning funding for the final two years.

1. An additional professional position should be added in the area of technology transfer. This is very important for proper implementation of appropriate technology by small farmers in developing countries. The position should include both research on technology transfer procedure, and work with the international cooperators in implementing procedures designed to reduce Meloidogyne losses. An additional \$225,000 has been recommended for this activity. One of the two Research Associate positions should be revised to provide research support for crop rotation systems.
2. Additional training is needed for the international cooperators. A budget increase of \$150,000 is recommended for this activity.
3. A plant breeder should be selected to serve as a consultant to IMP. This individual should attend the international conferences. Plant breeders in the developing countries should be invited to interact with the international cooperators and

consulting plant breeder. A budget increase of \$50,000 is recommended for this activity. The second Research Associate position should be revised to provide additional support in this area.

4. The project should acquire the services of a consultant in ecology. This should enhance the scope of the project in this important area.
5. Regional coordinators and cooperators should be appointed and terminated at the discretion of the principal investigator.
6. IMP should work as closely as possible with the USDA/SEA/CR Committee on Crop Loss Assessment Systems.

INTRODUCTION

A team of four scientists conducted a comprehensive review of the IMP on February 6-7, 1980. The review was held at the Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina.

REVIEW TEAM

Dr. George Bird, Team Leader

Plant nematologist, Michigan State University, (MSU), has extensive background in the broad aspects of plant nematology including research, teaching and extension, has served as President of Society of Nematologists, Chairperson of the Intersociety Consortium for Plant Protection and is a former Acting Chairperson in the Department of Entomology, MSU.

Dr. Clanton Black

Department of Biochemistry, University of Georgia and member of Research Advisory Committee (RAC). Plant biochemist and physiologist, has extensive teaching and research experience, research area concentrates on photosynthesis and plant productivity (i.e., yield, plant production). Past President of American Society of Plant Physiologists.

Dr. George Fassuliotis

Agriculture Research, Science and Education Administration, USDA; U.S. Vegetable Laboratory, Charleston, South Carolina. Research concentrated on developing resistance to root-knot nematodes in vegetables; member of Society of Nematology Plant Resistance Committee; co-editor of Journal of Nematology; Vice-President, Organization of Tropical American Nematologists.

Dr. Edward Rice

Agriculture and Rural Development for Asia Bureau, A.I.D., extension background in international aspects of crop protection; former Project manager for US AID-IMP.

CHARGE

The review team was charged with the following responsibilities;

1. Review all project statements related to the initial contract and subsequent Project Evaluation Summaries (PES).
2. Assess the project goals and objectives in relation to their impact on small farmers in developing countries.
3. Evaluate the planned results of the project.
4. Review the assumptions in relation to anticipated End-of-Project Status (EOPS).
5. Evaluate the adequacy and correctness of the overall project design in relation to the following specific areas of research and methodology:
 - A. Characterization of root-knot nematode populations (i.e. frequency and importance of *Meloidogyne* species, occurrence and significance of races, morphology, cytogenetics and biochemical studies).
 - B. Ecological studies.
 - C. Resistant germplasm and resistance breeding.
 - D. Evaluation of cropping systems useful in root-knot control.
 - E. Establishment of an information network.
 - F. Association with international, agriculture development centers.
 - G. Project publication output.
6. Assess the following problems and issues:
 - A. Direction and scope of the project during the next three-five years, including adequacy of project design, budget

and utilization of results by regional centers and small farmers in developing nations.

- B. Current and future plant breeding efforts to incorporate resistance into agronomically acceptable crop cultivars for small farmers worldwide.
- C. Current and future plans to develop crop rotation systems to reduce root-knot nematode losses in developing countries.
- D. Working relationships with other U.S. institutions and international agriculture development centers.

The review consisted of two components; an evaluation of Project No. 931-0614, and an assessment of the proposal for an extension of five years. The review team found that the project is on schedule and that the objectives are being completed in an excellent and timely manner. This document is designed to report the results of the comprehensive review of the project and evaluation of the proposed renewal.

METHODOLOGY:

The comprehensive review was conducted by a team of 4 scientists on February 6-7, 1980, at the Department of Plant Pathology, North Carolina State University, Raliegh. The Project Manager, Dr. Mark A. Smith was present. The following seven representatives of North Carolina State University participated in the review:

Dr. Durward Bateman, Director, Agric. Expt. Sta.

Dr. J. Lawrence Apple, Assoc. Director, Agric. Expt. Sta.

Dr. Robert Aycock, Head, Department of Plant Pathology

Dr. J. N. Sasser, Professor and Principal Investigator (general nematology)

Dr. A. C. Triantophyllou, Professor (cytogenetics)

Dr. H. H. Triantophyllou, Professor (taxonomy and morphology)

Dr. J. D. Eisenback, Asst. Professor (taxonomy and morphology)

The Project Manager forwarded the members of the Review Team a proposed agenda, scope of work and the following 16 documents on January 8, 1980:

1. Project Paper for current approved period, June 30, 1977 to June 29, 1980.
2. Renewal Research Project Proposal with Appendices and Summary June 30, 1980 to June 29, 1985.
3. Current Contract - AID/ta-c-1234.
4. RAC minutes concerning Root-knot nematode project, December 1974.
5. RAC minutes concerning Root-knot nematode project, March 31 -- April 1, 1977.
6. PAR (Project Appraisal Report), December 28, 1976.
7. PES (Project Evaluation Summary), January 4, 1979 (date of evaluation).
8. Biology, Identification and Control of Root-knot nematodes.
9. Crop Cultivars Resistant to Root-knot Nematodes, Meloidogyne Species.
10. Experimental and Agronomic Use of Nematicides.
11. Proceedings of the Research Planning Conference on Root-knot Nematodes Meloidogyne, spp., January 12-16, 1976, Raleigh, North Carolina.
12. Proceedings of the Research Planning Conference on Root-knot Nematodes Meloidogyne, spp. June 7-11, 1976, Ibadan, Nigeria.
13. Proceedings of the Regional Planning Conference of the International Meloidogyne Project, September 1976, Panama.
14. Proceedings of the Research Planning Conference on Root-knot

Nematodes, Meloidogyne spp. January 29 - February 2, 1978, Giza, Egypt.

15. Photographs of Perineal Patterns of Certain Root-knot Nematodes, Meloidogyne, spp. for Use in Species Identifications.
16. Selected Recent Publications resulting from the IMP. Other publications and reports will be available for inspection at NCSU during the in-depth team evaluation, February 6-7, 1980.

The Review Team Leader, Project Manager and Principal Investigator met on February 5, 1980 to discuss the review process. The formal review consisted of the following agenda:

Wednesday, February 6

Morning

- 8:30 Welcoming remarks
- Dr. J. L. Apple, Associate Director, Agricultural Research Services, Coordinator International Programs, NCSU
- Dr. Robert Aycock, Head, Department of Plant Pathology, NCSU
- 8:50 Introduction of Team Members
- Dr. Mark A. Smith, Project Manager
- 9:00 Scope of evaluation
- Dr. George W. Bird, Team Leader
- 9:15 General Overview of the International Meloidogyne Project (IMP)
- a) A statement of the problem
 - b) Rationale, goals and objectives of the IMP
 - c) The approach, organization and implementation
- Dr. J. N. Sasser

- 10:00 Coffee
- 10:00 Characterization of root-knot nematode species and populations as a basis for development of effective control strategies
- a) Frequency of Meloidogyne species encountered and their relative importance
 - b) Occurrence of host races and their significance
- Dr. J. N. Sasser
- 11:00 c) Morphology and Taxonomy
- 1) Current status, some problems, and needs -
Dr. Hedwig H. Triantaphyllou
 - 2) New morphological characters of Meloidogyne species -
Dr. J. D. Eisenback
 - 3) Thesis research - Morphological and Serological Studies of the M. arenaria species group -
Ms. Gean Cliff
- 12:00 Lunch
- Afternoon
- 1:30 d) Cytogenetics of root-knot nematodes, Meloidogyne spp.
Dr. A. C. Triantaphyllou
Steve Bost, Thesis research: Genetic variation in Meloidogyne. Joanna Papdopoulou, Thesis research: Development and sexuality of Meloidogyne.
- 2:30 e) Biochemical studies
Dr. A. C. Triantaphyllou
Dr. A. Janati

3:15 Coffee
3:30 Ecological Studies
Dr. J. N. Sasser
4:15 General Discussion
5:00 Adjourn
6:00 Informal Meeting of the review team.

Thursday, February 7

Morning

8:30 Research emphasis and progress within cooperating countries
a) Pathogen variability studies
b) Discovery and development of resistant germ plasm
c) Evaluation of cropping systems
d) Cooperation with international agricultural research centers
e) Enhancement of the problem solving capabilities of cooperators in developing countries
f) Utilization of results by country cooperators
9:30 Additonal benefits derived from the project
Dr. A. C. Triantaphyllou
10:00 Coffee
10:15 Comments by the Research Service Director - Dr. Durward Bateman
10:30 Proposed future direction and scope of project
a) Adequacy of project goals, objectives and design to meet needs in developing countries
b) Discussion of possible expansion of IMP to include 2 or 3 additional genera of nematodes
c) Budget and staffing needs
Dr. J. N. Sasser

11:45 Comments by Dr. Aycok

12:00 Lunch

Afternoon

1:30 Review Team Meeting

5:00 Adjourn

The Review Team met on the evening of February 6, 1980 to discuss the progress of the review in relation to the charge. The Review Team met on the afternoon of February 7, to outline the contents of the review report. The Review Team Leader and Project Manager remained at North Carolina State University on the morning of February 8 to discuss the format of the report. The Review Team Leader was charged with the responsibility of writing a first draft of the team report, distributing it and forwarding the final report to the Project Manager.

The Review Team evaluated the results of a questionnaire developed by the principal investigator to obtain input about the project from the international cooperators. The questionnaire consisted of the following two questions:

1. "In what ways has your involvement in the IMP helped you with your work?"
2. "Should IMP continue for an additional five years, what recommendations would you have for improving its effectiveness?"

Before and after the comprehensive review, the review team leader contacted several U. S. nematologists not participating in the project. They provided additional information about the indirect influence of the project on the science of nematology and U.S. agriculture.

The Review Team Leader forwarded a draft of the review report to the team members and project manager on February 25, 1980. The review report was sent to the Project Manager on April 2, 1980.

OVERVIEW

IMP has developed an impressive interactive global network of 104 cooperating scientists in 58 developing countries. Fifty-three of the international cooperators reported that a total of \$727,587 of local resources were used for support of this project in 1979 (Table 1). AID funding was responsible for approximately 23% of the total 1979 project resources (Table 2). The project has made outstanding progress in characterizing Meloidogyne problems related to small farmers in developing countries. Seventy-five of the international cooperators participated in a crop loss survey. The assessment indicated that circa 15% of the principal food and fiber crops of these developing countries are lost to Meloidogyne (Table 3). The project has also made outstanding progress in basic research related to the taxonomy, morphology and cytogenetics of Meloidogyne. Satisfactory progress has been made in the area of identification of Meloidogyne-resistance food crops, cultivars and germ plasm, and in the area of evaluation of environmental parameters associated with Meloidogyne host-parasite relationships. Progress has been considerably slower in the evaluation of crop response in the relation to effective rotation schemes for Meloidogyne control, and in the use of information obtained from the project in implementation of plant protection schemes.

North Carolina State University has requested \$250,000 for extension of IMP for the period of June 30, 1980 through June 29, 1985. The review team strongly recommends that favorable action be taken as soon as possible to renew this project. It is important that action be taken in a timely manner to avoid program discontinuity. The review team recommends that the renewal be approved and funding allocated for three years (June 30, 1980 through June 29, 1985) for \$1,774,723 (Table 4). After this period, the project should be reviewed and recommendations made for funding for the final two years.

Table 1. International cooperator resources (U.S. \$) allocated to the International Meloidogyne Project, exclusive of US AID and North Carolina State University funds.

Region	Cooperators reporting	Research years		Resources (\$)		
		Professional	Technical	Salary	Operating	Total
I	5	1.2	3.0	38,115	25,200	63,315
II	8	2.4	5.6	27,800	27,580	55,380
III	3	0.8	1.3	34,720	31,000	65,720
IV	4	1.6	1.7	24,024	27,100	51,124
V	1	0.8	2.3	6,700	22,500	29,200
VI	11	2.9	12.1	95,467	82,751	178,218
VII	12	4.6	11.8	96,900	76,500	173,400
VIII	9	2.7	9.9	44,230	67,000	111,230
TOTAL	53	17.0	47.6	367,956	359,631	727,587

Table 2. Total 1979 resources allocated to the International Meloidogyne Project.

Source	Research years		Resources (\$)		
	Professional	Technical	Salary	Operating	Total
Cooperators	17.0	47.6	367,956	359,631	727,587
North Carolina State University	2.0	2.5	91,250	8,000	143,324 ¹
U. S. AID	2.8	3.0	93,907	169,444	264,810 ¹
TOTAL	21.8	53.1	553,113	537,075	1,135,721

¹Includes indirect costs (48.3%) of on-campus personnel.

Table 3. Estimated crop losses due to *Meloidogyne* spp. in major geographical regions of the tropics

Region I	Region II	Region III	Region IV	Region VI			
Mexico, Central America and the Caribbean	South America	Brazil	West Africa	Southeast Asia			
Crop	% LOSS CROP	% LOSS CROP	% LOSS CROP	% LOSS CROP			
banana	7	banana	10	banana	7	bean (common)	18
bean (common)	16	bean (common)	24	bean (common)	11	black pepper	16
cassava	5	cassava	10	cassava	3	cassava	5
chayote	38	coffee	13	citrus	5	cocoyam	23
citrus	7	cucumber	33	coffee	24	cowpea	43
coffee	10	eggplant	20	cotton	17	eggplant	29
cowpea	10	grain legumes	19	grapes	6	lima bean	27
guava	35	grapes	5	papaya	15	lowland rice	5
maize	8	papaya	18	rice	4	maize	14
pigeon pea	8	peach	6	soybean	23	melon	33
pineapple	11	pepper	22	sugarcane	9	okra	42
plantain	11	pineapple	5	tomato	25	papaya	12
pumpkin	12	plantain	10	yam	15	peanut	15
rice	10	potato	3			pineapple	10
soybean	8	sugarcane	6			rice	2
sugarcane	7	sweetpotato	15			sorghum	4
tomato	38	tomato	27			soybean	10
yam	16	watermelon	23			sugarcane	8
						sweetpotato	6
						tea	13
						tomato	24
						yam	8
Mean % loss (all crops)	15		15		13		23
							11

Reproduced from Lasser, J. N. 1979. Economic importance of *Meloidogyne* in tropical countries, pp. 358-374 (IN) Root-knot Nematodes (*Meloidogyne* spp.) Systematics, Biology and Control, F. Lamberti and C.E. Taylor (Eds). Academic Press, N.Y. 477 pp.

Table 4. Summary of the IMP renewal budget recommended by the Review Team for 1980-81, 1981-82 and 1982-83.

A. <u>Salaries and Wages</u>	<u>1980-81</u>	<u>1981-82</u>	<u>1982-83</u>
1. Principal Investigator (Partial)	\$21,000.	\$22,500.	\$24,075.
2. Visiting Professors (Consultants)	7,458.	7,458.	7,458.
3. Research Associate (Full-time) ¹	19,795.	21,180.	22,662.
4. Research Associate (Full-time) ²	19,795.	21,180.	22,662.
5. Graduate Assistants (Four)	24,000.	24,000.	24,000.
6. Agr. Research Tech I (Two Full-time)	27,493.	29,417.	31,476.
7. Research Tech II (Two Full-time)	23,578.	25,228.	26,994.
8. Secretary-Clerical	9,048.	9,681.	10,359.
Changes recommended by the Review Team	\$152,167.	\$160,644	\$169,686.
¹ Biochemistry (1980-81), Resistance (1981-83)			
² Morphology (1980-81), Rotations (1981-83)			
 B. <u>Equipment and Supplies</u>			
1. Supplies and Expendable Equipment	7,500.	7,500.	7,500.
2. Contractual services including computer time	4,000.	4,000.	4,000.
3. Communications	8,000.	8,000.	8,000.
4. Publications	4,000.	4,000.	4,000.
	<u>\$23,500.</u>	<u>\$23,500.</u>	<u>\$23,500.</u>
 C. <u>Equipment and Supplies</u>			
1. Developing countries cooperators (96 @ \$750/year)	72,000.	72,000.	72,000.
2. Conference expenses (8 regions) 4/1980-81; 4/1981-82; interpreters, local travel, supplies @ \$1500/conference	6,000.	6,000.	
	<u>\$78,000.</u>	<u>\$78,000.</u>	<u>\$72,000.</u>
 D. <u>Travel</u>			
1. Travel for Principal Investigator to geographical regions	9,000.	9,000.	9,000.
2. Travel and per diem for DC cooperators to regional conferences 12/region @ \$1000/ cooperator	48,000.	48,000.	48,000. ³
3. Travel and per diem for Principal Inves- tigator and visiting professors to regional conferences	24,000.	24,000.	24,000. ³
4. Domestic Travel	4,000.	4,000.	4,000.
	<u>\$85,000.</u>	<u>\$85,000.</u>	<u>\$85,000.</u>

Continued

Table 4. Continued

	<u>1980-81</u>	<u>1981-82</u>	<u>1982-83</u>
E. Fringe Benefits 18% (A1,3,4,6,7,9)	\$21,728.	\$23,253.	\$24,881.
F. Indirect Costs* 53% (A1,3,4,5,6,7,8)	\$76,696.	\$81,188.	\$85,980.
Additions recommended by the Review Team.			
G. Technology Transfer Position (Salary, operating, travel, benefits and indirect costs)	75,000.	75,000.	75,000.
H. International Cooperator Training	50,000.	50,000.	50,000.
I. Plant Breeding Consultant (Travel and consulting fees)	20,000.	15,000.	15,000.
TOTAL REQUEST	582,091.	591,585	601,047

Grand Total for
Three-Year Period: \$1,774,723

*Effective July 1, 1979 , overhead rate will be 44%. This negotiated fixed overhead rate accepted March 27, 1979, applicable to period 7-1-79, 6-30-80.

CERTIFICATIONS:

1. No person will, on the grounds of race, color or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under this program.
2. North Carolina State University does not discriminate on the basis of sex, or handicap, and is an affirmative action equal employment institution.

CURRENT PROJECT

IMP is in the final phase of the current funded project. North Carolina State University has requested renewal of IMP from June 30, 1980 through June 29, 1985. The current project is progressing in a very excellent and timely fashion. Project outputs include the following six contributions:

International Resources. -- Development of an interactive global network of 104 cooperating scientists in 58 developing countries. These are divided into eight regions (Region I, Mexico, Central America and the Caribbean; Region II, South America; Region III, Brazil; Region IV, West Africa; Region V, East Africa; Region VI, Southeast Asia; Region VII, Mid East; Region VIII, India). Fifty-three of the international cooperators reported that a total of \$727,587 of local resources were used in the project in 1979 (Table 1). Sixty-two percent of 55 reporting cooperators have the Ph.D. degree and a mean of 10 years of post-doctoral professional experience (Table 5). The average cooperator is 42 years old, and 47% are employed by universities (Table 6). The network has significantly enhanced the problem solving capabilities of the cooperators and the plant protection resources of the developing countries.

Significance of Meloidogyne Problems. -- IMP made a major scientific contribution through completion of a crop loss assessment survey. Seventy-five international cooperators participated in the evaluation and indicated that about 15% of the principal food and fiber crops of developing countries are lost to damage caused by Meloidogyne (Table 3). This information was not previously available. It will serve as an excellent base for institutional, production system and

Table 5. Education of cooperators associated with the International Meloidogyne Project.

Region	Cooperators reporting	Highest degree				Year	Geography				
		B.S.	Eng.	M.S.	Ph.D.		Europe	U.S.	South American	Far East	Asia & Africa
I	6	0	0	3	3	1973	2	4	0	0	0
II	7	0	5	0	2	1968	0	1	6	0	0
III	3	0	0	1	2	1972	0	2	1	0	0
IV	3	0	0	1	2	1973	1	2	0	0	0
V	1	0	0	0	1	1978	0	1	0	0	0
VI	13	3	0	2	8	1970	3	5	0	5	0
VII	13	2	0	4	7	1970	7	2	0	2	1
VIII	9	0	0	0	9	1970	1	4	0	4	0
TOTAL	55	5	5	11	34		14	21	7	11	1

Table 6. Age and employment of the International Meloidogyne Project international cooperators

Region	Cooperators reporting	Age	Employment			
			Ministry of Agric.	University	Expt. Sta.	Extension
I	6	36	3	3	0	0
II	7	38	5	1	1	0
III	3	45	0	2	0	1
IV	3	42	2	1	0	0
V	1	38	1	0	0	0
VI	13	43	3	6	4	0
VII	13	44	2	7	3	1
VIII	9	46	1	6	2	0
TOTAL	55	42	17	26	10	2

natural resource decision making. It is also an appropriate framework for the development of future crop loss assessment technology.

Characterization of Meloidogyne Problems. -- The project evaluated more than 700 living populations of Meloidogyne. This was done jointly by the cooperators in the developing countries and scientists at the Research Center at North Carolina State University. About 99% of the populations studied belonged to only six of the 41 described species. This finding is very significant and allows future research and implementation programs to focus on these species. IMP has also succeeded in clarifying the physiological race situation in relation to two of the most important species of Meloidogyne. This was possible because of the basic IMP research contributions in the areas of taxonomy, morphology, cytogenetics and biochemistry. The international cooperators have received appropriate feedback concerning their specific Meloidogyne populations.

Crop Resistance, Ecology, Crop Rotation and Implementation. -- Progress has been made in the identification of Meloidogyne-resistant food crops, cultivars and germ plasm; and in the area of environmental parameters associated with Meloidogyne host-parasite relationships. Progress has been considerably slower, however, in the identification of effective rotation schemes for Meloidogyne control, and in the use of information, developed by the project in implementation of plant protection schemes.

International Development Center Interaction. -- The project has developed productive associations with several international crop development centers. These include interactions with the Centro Internacional de la Papa, International Institute of Tropical Agriculture, Centro Internacional de Agricultura Tropical and International Crops Research Institute for the Semi-Arid Tropics.

Publications. -- The project publication productivity is excellent. It includes 182 contributions in the following categories:

Research Center NCSU	41
Region I	24
Region II	15
Region IV	47
Region V	1
Region VI	26
Region VII	28

RENEWAL REQUEST

The request for an extension of the project from June 30, 1980 through June 29, 1985 is important for continued global scientific progress in relation to Meloidogyne and implementation of nematode control programs by small farmers in developing countries. The justification, original and updated objectives, methods for dissemination and utilization of research results and plant of work are sound. It is the opinion of the review team that several budgetary changes are need to accomplish the proposed objectives. These include several additions to the budget, and alterations in the responsibilities of the two Research Associates. It is the recommendation of the review team that favorable action be taken on the request in a timely manner. It should be approved funded for a period of three years (June 30, 1980 - June 29, 1985) for a total of \$1,774,723 (Table 4).

The review team recommends the following modifications of the renewal proposal:

1. An additional professional position should be added in the area of technology transfer. The existing project is stronger in technology development than in technology transfer. This recommendation is important for proper implementation of the information obtained from the project. The programs must be designed to benefit small farmers in developing countries. The responsibilities of this position should include both research on appropriate technology transfer procedure, and work with the international cooperators in implementation of procedures designed to reduce *Meloidogyne* losses in an economically, ecologically and sociologically compatible manner. This recommendation will require an additional \$225,000 during the first three-year period of the renewal. One of the two Research Associate positions should be revised to provide crop rotation system research support for this area (Table 4).
2. There is a distinct need to provide additional training for the international cooperators. A number of short-term and long-term models can be used. Various aspects of the additional training should take place at North Carolina State University, other institutions, and in developing countries. A total of \$150,000 is recommended for implementation of the activity.

3. A plant breeder should be obtained to serve as a consultant to IMP. This scientist should attend the international conferences. Local plant breeders should be invited to attend the conferences to interact with the international cooperators and consulting plant breeder. A budget increase of \$50,000 is needed for implementation of this recommendation. The second of the two Research Associate positions should be changed to provide additional support for this area (Table 4).
4. The project should acquire the services of a consultant in the area of ecology. This will very likely result in an increase in the value of the output from this objective.
5. Regional coordinators and cooperators should be appointed and terminated at the discretion of the principal investigator. In several cases the current regional coordinators are not effective. A minimal number of cooperators are inactive.
6. IMP should work as closely as possible with the USDA/SEA/CR Committee on Crop Loss Assessment Systems.

EXTERNAL FACTORS

There has been significant evolution of socio-economic factors during the past five years many of these make the current project and its renewal even more important than when it was approved in 1975. These factors include and increased awareness of the significance of the interactions among agricultural production systems, other production systems, social institutions (including host government priorities) and our natural

resources. These and a number of important constraints in the areas of nematicide development and energy availability, make it imperative that every possible effort be made to enhance knowledge about Meloidogyne problems in relation to small farmers in developing countries.

INPUTS

There have been no problems with resource inputs from U.S. AID or North Carolina State (Table 2). The inputs from the international cooperators have been far greater than expected (Table 1). Some cooperators, however, have inadequate resources. There have been some constraints in the areas of movement of plant germ plasm between countries, development of appropriate technology transfer schemes, and implementation of Meloidogyne-oriented plant protection programs for small farmers in developing countries.

OUTPUTS

All implementation plan outputs will have been provided to some extent by the end-of-project (EOP). The project renewal submitted by North Carolina State University is designed to build on existing outputs and contribute to the original and updated goals and objectives. Current output includes contributions in the following nine areas:

1. Developed a functional network of international scientists.
This has upgraded the crop protection capabilities of developing countries.
2. Identified the extent of the Meloidogyne problem (crop loss) in relation to the major food and fiber crops of developing countries.

3. Characterized the nature (species, races, distribution and ecology) of the Meloidogyne problem in developing countries.
4. Advanced knowledge about one of the world's most important groups of plant pathogens, especially in the areas of nematode taxonomy, morphology and cytogenetics.
5. Published 182 scientific contributions about Meloidogyne.
6. Initiated a program to determine the susceptibility or resistance of food and fiber crops in developing countries to Meloidogyne, and identified sources of resistant germ plasm.
7. Initiated discussion among the Research Center scientists and international cooperators about crop response information in relation to the development and implementation of effective rotation schemes for control of Meloidogyne by small farmers in developing countries.
8. Interacted in an appropriate manner with a number of the international agriculture development centers.
9. Constructed the basic foundation for future Meloidogyne control programs for small farmers in developing countries by enhancing the overall crop protection capabilities of developing nations.

PURPOSE

The root-knot nematode, Meloidogyne, is a major obstacle to the production of adequate food and fiber in developing nations. The purpose of this project is to increase production of economic food and fiber crops in developing nations by advancing knowledge about Meloidogyne and

upgrading the crop protection capabilities of developing nations. This is a very complex process and can only be achieved through completion of all project objectives. It was unrealistic to expect this during the first five years of the project. The Review Team and Project Manager rated the progress and excellence of the seven objectives on a scale of 0 - 10 (0 = poor and 10 = excellent). The following are the mean rating values for the seven objectives:

- | | |
|--|-----|
| 1. Development of an international network of cooperators. | 9.8 |
| 2. Global characterization of Meloidogyne. | 9.8 |
| 3. Biology of Meloidogyne. | 9.0 |
| 4. Evaluation of environmental parameters. | 5.9 |
| 5. Identification of resistant germ plasm. | 4.8 |
| 6. Development of crop response information for crop rotation schemes. | 2.2 |
| 7. Implementation of crop production systems | 3.0 |

Although some progress must occur simultaneously on all of the objectives, achievement of the project goals is a process that requires specific sequential development in relation to the objectives. The above listing of the objectives is one highly probable sequence. Outstanding progress has been made on the preliminary objectives and less on those which rely on the initial results. This means that a normal time lag could be responsible for some of the slower progress with the last four objectives. The scientific expertise at the Research Center is oriented more towards the first three than the last four objectives. The budget was also oriented

in this direction. In addition, there are numerous significant institutional constraints of a global nature that prevent rapid progress on the last four objectives. These are external to the science of nematology and are a major current challenge for agricultural production systems and their supporting institutions. Current project progress should be considered as excellent. The areas that need additional work are either emphasized in the renewal request or the review recommendations. In several cases (ecology, plant genetics and technology transfer) the Review Team has made specific recommendations that should enhance the probability of satisfactory completion of all updated goals and objectives in the proposed extension.

GOAL/SUBGOAL/OBJECTIVES

The Review Team recommends the following goal and subgoal, for the project extension:

Goal

Increase production of economic food and fiber crops
in developing nations.

Subgoals

Upgrade the crop protection capabilities of developing
countries.

Advance knowledge about Meloidogyne, one of the world's
most important groups of plant pathogens.

Although much progress has been made towards the accomplishment of the objectives of the current project, work has not progressed uniformly in all international regions. Thus, it is important that the original

objectives continue in the project extension. The current state of the project, however, dictates the need for the following updated objectives:

1. Continue the development and maintainance of a functional global network of cooperators.
2. Re-evaluate reported resistance against root-knot nematodes in various important crop species to determine the effectiveness of the sources of resistance against the newly discovered host cytogenetic races of Meloidogyne incognita, M. hapla and M. arenaria.
3. Begin screening at the Research Center and within the appropriate regions the vast germplasm collections of the mandate crop species of the various international agricultural centers (CIAT, CIT, ICRISAT, AVRDC, IRRI, IITA, ICARDA, INTSOY and CIMMYT) for sources of resistance to important root-knot species.
4. Use selected cooperators to evaluate the currently practiced cropping systems and new cropping systems with special emphasis on the effect of using root-knot resistant cultivars and of occasional, timely use of nematicides.
5. Evaluate the effects of various cropping systems, including intercropping, on the behavior of root-knot nematode populations, including the emergence of resistance breaking biotypes.
6. Publish (1985-86) a scholarly, yet practical, text on the biology, ecology and control of root-knot nematodes, using project funds. The book will incorporate the significant

findings generated by this project along with other important and relevant information, to be edited by project personnel with various chapters written by recognized authorities. The book will be sent to all cooperators.

7. Begin an advanced training program through which selected, cooperators (professional or technical) can be brought to the research center or advanced training in nematology or appropriate related disciplines to enable them to become familiar with the most up-to-date technology and philosophy. An opportunity will be given trainees to visit other laboratories noted for their excellence, both in the U.S. and Europe.
8. Incorporate the most up-to-date crop loss assessment technology and philosophy into the project. The international network of cooperators will be used for this objective.

BENEFICIARIES

The ultimate beneficiaries of this project are the small farmers of developing nations. During the process there has been a significant enhancement of the crop protection capabilities of developing nations and advancement of the science of nematology. This has had an indirect benefit on all countries. It was determined that many U.S. nematologists not involved in the project have received numerous indirect benefits. During the first five years of the project, North Carolina State University established itself as the Meloidogyne Research Center for the world. If the implementation and technology transfer goals of the project are

successfully completed during the renewal, the project should serve as a model for many unrelated international research and development programs.

UNPLANNED EFFECTS

The project has stimulated a significant amount of global interest outside the boundaries of the original six regions. Success in the nematology disciplinary components of the project dictate that additional interdisciplinary interaction is necessary for transfer of appropriate technology to small farmers in developing countries. The project had no unplanned detrimental environmental impact. On the contrary, it is designed to stimulate scientific activity that will result in outputs of economic, ecologic and sociologic compatibility.

LESSONS LEARNED

Several important lessons have been learned during the first five years of the project. It is highly probable that these could become part of future or existing principles for foreign assistance programs. The following are three areas that were readily identified by the Review Team:

1. It was best to allocate limited resources to local cooperators. This resulted in the development of dedication to the program because of scientific advantages and not financial reasons. It resulted in the generation of significant local resources for the program (Table 1). It is highly probable that the regional networks of nematologists and local resources will remain long after completion of the formal phases of the project.

2. The original program was limited to six regions. Additional cooperators and new regions were added because of the success of the program. This is a good feature of the project.
3. In most cases the regional coordinator concept did not work as well as expected. Coordinators were selected at the beginning of the project. If regional coordinators are necessary, they should be identified and appointed after the initial stages of the project. This is essential for proper identification of the most highly qualified and motivated scientists to provide regional leadership and interact formal basis with the Research Center.

SPECIAL CONSIDERATIONS

This section of the report contains additional information about the current project, items pertaining to the project renewal request (justification and Review Team recommendations) and several important attachments.

Current Project

The administration and IMP staff at the North Carolina State University Research Center are totally dedicated to the project. In addition to the direct influence of the program on scientists and small farmers in developing countries, the program appears to have a positive indirect influence on the Department of Plant Pathology, School of Agriculture, various components of North Carolina agriculture and nematologists throughout the U.S.

The Review Team evaluated all project statements related to the initial contract and subsequent PES, assessed the project goals and objectives in relation to their impact on small farmers in developing countries, reviewed the planned results of the project, evaluated the assumptions in relation to anticipated EOPS, and assessed the adequacy and correctness of the overall project design in relation to the research methodology. The results were very favorable and are outlined in this report.

The Review Team assessed the following five specific problems and issues related to the project:

1. The direction and scope of the proposed renewal were reviewed in detail in relation to the adequacy of the project design, budget and utilization of the results by regional centers and small farmers in developing countries. The recommendations of the Review Team were favorable and are outlined throughout the report and in the next part of the "Special Comments Section". Several budget changes and additions are recommended.
2. Progress has been made in the area of identification and development of Meloidogyne resistant cultivars suitable for use by small farmers in developing countries. A number of specific recommendations about this are made in the summary and in the next part of the "Special Comments Section".

3. The Review Team has made recommendations that will enhance the rate of development of crop rotation systems designed to reduce root-knot nematode losses in developing countries.
4. The Review Team found that satisfactory progress is being made on developing working relationships with other U.S. institutions and international agricultural research centers.
5. The fact that this project is limited to a single group of nematodes was determined to be an asset and not a problem.

The Review Team assessed the results of three requests by the Research Center for information from the international cooperators. There was good response from all regions. An average of 53.9 cooperators responded to each request (Table 7). The cooperators identified numerous aspects of the program of significance to their local responsibilities with *Meloidogyne* (Table 8). It is important to note that of the 21 mentions of the importance of information about nematode control, 20 pertained to crop resistance, crop rotation and biocontrol. The cooperators identified a broad array of areas for future program emphasis and recommended changes (Table 9). Of the eight individuals that requested additional components related to nematode control, there were nine mentions concerning host

Table 7. International Meloidogyne Project cooperator's response 1979
for information related to the program.

Region	Requests				
	Question No. 1	Question No. 2	Contributed resources	Vita	\bar{x}
I	6	5	5	6	5.5
II	8	8	8	7	7.8
III	4	3	3	3	3.3
IV	5	5	4	3	4.8
V	1	1	1	1	1.0
VI	9	9	11	13	10.5
VII	12	11	12	13	13.0
VIII	--	--	9	9	9.0
TOTAL	45	42	53	55	53.9

Table 8. Response of International Meloidogyne Project cooperators concerning the most significant components of the program.

Region	Interaction and communication	Technology	Information and literature	Comprehensive research	Meloidogyne identification	Nematode control	Moral and local support	Extension	Total
I	2	1	3	2	1	1	0	0	10
II	3	0	1	3	2	3	2	1	15
III	0	0	1	0	2	0	1	0	4
IV	2	0	1	1	2	4	0	0	10
V	1	0	0	0	0	1	0	0	2
VI	2	0	1	2	4	6	0	1	16
VII	7	4	4	2	5	6	3	1	32
TOTAL	16	5	11	10	16	21	6	3	89

Control components identified (Biocontrol, 3; Resistance, 12; Crop rotation, 5)

Table 9. Response of the International Meloidogyne Project cooperators concerning future program emphasis and recommended changes.

Region	None	Scientific digest	Technology	Formal training	Literature	Crop loss assessment	Greater resources	More meetings	More visits	Nematode ₁ control	Other species	Total
I	1	1	1	1	1	0	0	0	0	0	0	5
II	2	0	0	1	2	1	2	1	2	2	1	14
III	0	0	0		0	0	1	1	1	1	0	4
IV	0	0	0	1	0	0	2	0	2	2	0	7
V	1	0	0	1	0	0	5	1	1	3	0	12
VI	0	2	0	0	0	0	1	0	1	0	0	4
VII	0	0	0	3	1	0	2	1	6	0	0	13
TOTAL	4	3	1	7	4	1	13	4	13	8	1	59

Control components (Biocontrol, 1, Resistance, 5, Crop rotation, 3)

resistance, crop rotation and biocontrol information. Only one cooperator felt that it was necessary to broaden the scope of the project to cover nematodes other than Meloidogyne.

The importance of the initial crop loss assessment survey and characterization of the Meloidogyne problem on a global basis can not be over emphasized. The quality of the basic taxonomy, morphology and cytogenetics research conducted at the Research Center is excellent, and considered by many nematologists to be the best current program on a world-wide basis.

IMP Renewal Request

Justification for the project renewal in relation to the original objectives is adequately described in the original 1975 project proposal, the 1977 proposal for continued funding and this report. Justification for continuation of the project as outlined in the following outdated objectives:

1. Progress in understanding and controlling this important group of nematodes has been substantial. Advances in the future will be greater if we continue the network approach, each participant working as a member of the team whose goal is to collectively gain the knowledge necessary. The network approach provides access to a wide range of environmental conditions in which to study behavior.

2. Resistance to root-knot nematodes has been incorporated into several crop species important in the U.S.A. Many of these crop species are important food crops in the different regions and may be useful to regional cooperators. Unfortunately, host resistance in most instances was determined on the basis of host reaction to one or two local root-knot populations. Little is known concerning the effectiveness of these resistant varieties to recently identified host or cytogenetic races of the different root-knot species. A re-evaluation of these resistant varieties is needed to determine their effectiveness against the different races, and whether the resistance is likely to be useful in other parts of the world.
3. The various International Agricultural Research Institutes have a collective mandate for the genetic improvement of nearly 25 of the world's most important food crops. These institutes have vast collections of the germplasm of these crop species and closely related wild species. With a few exceptions, these germplasm collections have not been screened for resistance against important root-knot species. As many of these crops are known to suffer major yield reductions due to root-knot nematodes, it is imperative

that a major, coordinated effort be initiated to identify sources of resistance within these readily available germplasm collections.

4. It is now recognized that considerable or significant increases in agricultural productivity can be accomplished through the development of specialized cropping systems, especially through intercropping. The incorporation of root-knot resistant varieties into a cropping system will significantly increase its overall productivity and also reduce the root-knot nematode population. Although the average farmer in developing countries cannot afford the extensive use of nematicides, occasional, limited and timely application of nematicides are also likely to increase the productivity of various cropping systems. These areas of research need immediate attention.
5. Although the behavior of a given root-knot population is relatively stable with ordinary farming practices, the repeated use of a resistant crop can result in the selection of resistance-breaking biotypes of the nematode. With the anticipated increase use of host-resistance as a means of controlling root-knot nematodes. It is important to determine the frequency with which a resistant variety can be cultivated without the danger of selecting a resistance breaking biotype.

6. The ultimate success of any research program can only be achieved through the wide dissemination of the findings of that program. Although this program has an extensive international network of cooperating scientists who will publish their important findings, many potentially interested agricultural scientists are likely to remain unaware of the achievements of the project. Thus, the compilation of this information, along with other relevant information on the biology, ecology and control of root-knot nematodes in a single volume will be of immense value. Current project personnel are in a unique position to prepare such a volume.
7. Although most regional cooperators have increased their level of expertise through association with this project, and have gained access to otherwise unavailable information, many would benefit greatly from brief periods of intensive study outside of their respective countries. Upon completion of such study leaves, these persons would be better able to continue and complete work begun under this project. Additionally, they would be more competent in the training of future agricultural scientists.
8. This is the only international program devoted exclusively to the control of root-knot nematodes. Two of the international centers (IITA and CIP) have

nematologists on their staffs, but the others concerned with crop production (CIAT, CIMMYT, IRRI, ICRISAT, AVRDC) do not. The International Meloidogyne Project is already cooperating with CIAT, IITA, CIP and INTSOY and hopes to extend this cooperation to the other centers. Such collaboration should be mutually beneficial.

It is the recommendation of the review team that favorable action be taken in a timely manner of the request for renewal of the project and funding be allocated for the period of June 30, 1980 through June 29, 1983 for \$1,774,723 (Table 4). At the end of this period the project should be reviewed and funding recommendations made for the final two years.