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CGIAR. — D3 UNDP - Documents 78/80 vol. I cc: Mr. Lejeune (CGIAR)

UNITED NATIONS
DEVELOPMENT PROGRAMME

PROGRAMME DES NATIONS UNIES
POUR LE DEVELOPPEMENT

ONE UNITED NATIONS PLAZA
NEW YORK, N.Y. 10017

TELEPHONE: 754-1234

CABLE ADDRESS: UNDEVPRO • NEW YORK

REFERENCE: GLO/79L013

10 September 1980

Dear Dr. Nickel,

Subject: Technology Transfer on Root and Tuber Crops

We are pleased to send you herewith, for your records, three conformed copies of the Contract between UNDP and CIAT covering the above-mentioned project. One copy of the contract is being sent to CIP, IITA, FAO, CGIAR and to our Resident Representatives in Colombia, Peru and Nigeria, along with a copy of this letter, for their information and records.

Yours sincerely,

William T. Mashler
Senior Director
Division for Global and Interregional Projects

Dr. John L. Nickel
Director-General
Centro Internacional de Agricultura
Tropical
Apartado Aéreo 6713
Cali, Colombia

CONTRACT

BETWEEN THE

UNITED NATIONS DEVELOPMENT PROGRAMME

(UNDP)

AND THE

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

(CIAT)

The Contract entered into by and between the United Nations Development Programme (hereinafter called the "UNDP") and the Centro Internacional de Agricultura Tropical (hereinafter called "CIAT"), an organization with legal capacity recognized by the Government of Colombia and with its principal office located at Palmira, Colombia;

WITNESSETH

WHEREAS, CIAT, the Centro Internacional de la Papa (CIP) in Lima, Peru, and the International Institute of Tropical Agriculture (IITA) at Ibadan, Nigeria, are unique research institutes dedicated to scientific endeavours aimed at increasing the yield and quality of several agricultural species including root and tuber crops, namely: cassava (CIAT, IITA), white potato (CIP) and sweet potato (IITA), and through major research and training networks has cooperated with scientists from major root and tuber crop-growing regions of the world with the objective of testing and evaluating the adaptability of improved varieties and breeding lines in a variety of climatic, hydrological and biological conditions around the world.

WHEREAS, the UNDP seeks to promote research and training directed towards increased production of root and tuber crops by (1) development of high-yielding varieties and the prompt testing and dissemination of such materials and knowledge among appropriate research and action institutions and agencies throughout the world and (2) by developing technology for improving the efficiency of production inputs especially suited to the smaller and poorer farmers of the world.

WHEREAS CIAT, CIP and IITA are competent and prepared to participate in the Project described in this Contract;

WHEREAS the CIAT is competent and prepared, for that purpose, to enter into the present Contract with UNDP and to arrange for the participation of the CIP and IITA in the Project;

NOW, therefore, UNDP and the CIAT, being parties to this Contract, agree as follows:

ARTICLE I

The CIAT, CIP and IITA shall, pursuant to this Contract and as provided for in the project described in this Contract, hereby agree to conduct training and conference activities designed to help transfer technology on root crops from the centers to national programs and to help strengthen the research and extension capabilities of those programs in order for them to make the best use of the new technologies being made available.

For these purposes the CIAT, CIP and IITA shall make the following services and facilities available for the project:

a) The services, on a part-time basis, of its training and administrative staff and of its senior scientists to provide training inputs and follow-up.

b) Necessary general administrative and support personnel.

c) Necessary facilities including classrooms, laboratories, fields, greenhouses and services at their respective facilities and/or outreach stations.

ARTICLE II

CIAT as the lead institution and CIP and IITA as part of this Project shall carry out the Project and all activities under this Contract in accordance with the work planned attached as annex II of this Contract and such changes in Work Plan as the parties may mutually agree upon from time to time.

ARTICLE III

The selection of personnel to work on the Project shall be the responsibility of CIAT, CIP and IITA for their respective parts of the Project, provided that UNDP shall be furnished by CIAT with curriculum vitae of senior scientists who are to work full time on the Project and whose compensation shall be provided in full by UNDP under this Contract. UNDP shall have the right to approve any individual proposed to work full time on the Project either at its onset or at any later stage (whether for initial assignment thereto or as replacement for any individual removed therefrom).

ARTICLE IV

UNDP shall have the right to observe at all reasonable time the progress of work carried out under this Contract and to consult directly with personnel of the centers on work by them.

ARTICLE V

1. As complete consideration for the performance of the Contract and the Project, UNDP shall pay CIAT the costs of carrying out the Project in the amounts approved by UNDP, which costs shall be limited to those itemized in the Budget, Annex III (hereinafter called the "Budget").

2. Equipment required by the Project will normally be purchased directly by CIAT, CIP or IITA, however, the UNDP will, on request from CIAT, purchase and arrange shipment to the Project site any of the items required for the execution of the Project in accordance with specifications for the classes of equipment as submitted by CIAT.

3. Anything in this Contract to the contrary notwithstanding, UNDP shall not be obligated to make payments hereunder in excess of the

amount of $600,000 and CIAT shall not be obligated to continue performance hereunder where continuation would otherwise entail payments by UNDP in excess of such amount.

4. UNDP hereby approves the work plan and budget submitted by CIAT on its own account and also representing CIP and IITA for the two years of this Contract[1/]. CIAT agrees to submit a consolidated work plan and budget 60 days prior to the end of each of the remaining years of this Contract. Each work plan and budget shall become effective only upon written approval of UNDP.

ARTICLE VI

1. On the date this Contract enters into force, UNDP will advance to CIAT, as the lead organization, an amount equal to the estimated costs for the first quarter of the first year of this Contract. Subsequent quarterly advances shall be made by UNDP to CIAT within one week of the beginning of each quarter based on the estimated costs detailed in the budget and the annual work plan and budget to be prepared under Article V. Payments will be made in U.S. Dollars to bank accounts in the United States designated by CIAT.

2. It is understood that the advances payable to CIAT under paragraph 1 of this Article are intended to cover only estimated costs detailed in the budget. CIAT shall inform UNDP of any significant departures from the budget. Any advance under paragraph 1 of this Article shall be reduced in the next quarter to the extent that the sums actually expanded by CIAT in the previous quarter fall short of the total amount estimated. CIAT shall submit quarterly financial reports detailing expenditures made in the quarter to which the report relates, which reports shall be corroborated annually by CIAT,

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1/ Towards the end of the first year, CIAT will submit for UNDP's approval an up-dated work plan for the second year of the Contract with such revisions as may be deemed necessary.

CIP and IITA's financial statements certified by their respective auditors as to the correctness of the totals given in the financial reports.

3. CIAT shall submit to UNDP an annual report in respect of each year of the Project and a final report on the conclusion of the Project. The reports shall provide information on all expenditures made on the Project and shall be accompanied by CIAT's annual financial statements which include a certificate from CIAT's external auditors certifying to the correctness of such information. The final report shall be due within 180 days of the expiration of this Contract. Any difference between the disbursements made by UNDP under paragraphs 1 and 2 of the Article and total expenditures made by CIAT on the Project shall be reconciled within the next calendar month following that in which the relevant report is presented to the UNDP, provided that the total disbursements by UNDP under this Contract shall not exceed the costs referred to in paragraph 1 of Article V.

ARTICLE VII

With respect to Annex IV, General Conditions, hereof:

1. The term "Contractor" shall be understood to mean the Centro Internacional de Agricultura Tropical - CIAT.
2. The term "Government" shall be understood to mean the Governments of Colombia, Perú and Nigeria or any other country or countries in which the Project or any aspect of the Project is being carried out.
3. Section 03, Confidential Nature of Documents, is amended by deleting everything following "UNDP" where it first appears in said Section, ending the first sentence at said "UNDP", and adding the following sentence:

"With reference to the Agreement(s) between UNDP and the Government(s), on the request of the Government, Contractor will hold confidential any documents or data received from the Government under this Contract."

4. Section 06, Assignment of Personnel, is deleted in its entirety.

5. Section 14, Termination, is amended by adding the following sentence: "Under no circumstances shall payments under this section be understood to include costs other than those provided for in Article V, paragraph 1."

6. Section 18, Conflict of Interest, is amended by adding the following sentence: "This provision shall apply only if an activity or association described above would interfere with employee's ability to perform on the Project or if it would be possible for him to benefit from any such association, loan, or investment by reason of his employment on the Project. The mere holding of shares in a company shall not constitute an investment within the meaning of this section unless such holding constitutes a substantial control".

7. Section 20, Title of Equipment, is amended by adding the following sentences: "CIAT, CIP and IITA shall maintain records of all equipment purchased under this Contract and shall purchase insurance to cover casualty and other loss of such equipment. The cost of such insurance shall be an allowable cost under this Contract. Equipment shall be defined to include those items costing more than two hundred dollars and having a service life of more than five years. At the conclusion of the Project, UNDP shall consult the Parties involved regarding the disposition of the equipment provided

by the UNDP. Such consultation shall not prejudice the right of the UNDP to retain title to that part of the equipment which is not needed for the continued operation of the Project, or for activities directly arising therefrom, or which is more urgently needed by other UNDP-assisted projects. Any disposition of equipment shall be done in accordance with existing UNDP rules and regulations.

8. The Contractor agrees that he will forthwith disclose to UNDP all discoveries, processes, or inventions, made or conceived in whole or in part by him alone or in conjunction with others relating to and arising out of the work and that said discoveries, processes or inventions shall be registered or patented by the Contractor or shall be dedicated to the public domain. Such discoveries, processes or inventions, whether patented or not, will be shared or licensed on a non-exclusive basis and at no cost to the user or licenser in the developing countries.

Article VIII

Any notice required to be given by any of the Parties hereunder shall be sent in writing addressed as follows:

to UNITED NATIONS DEVELOPMENT PROGRAMME:

Mr. William T. Mashler
Senior Director
Division for Global and Interregional Projects
United Nations Development Programme
One United Nations Plaza
New York, N.Y. 10017
U.S.A.

with copy to:

Resident Representative of the
United Nations Development Programme In Colombia
Carrera 11 No. 84-51
Apartado Aéreo No. 091369
Bogotá D. E., Colombia

to CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

Dr. John L. Nickel
Director General
Centro Internacional de Agricultura Tropical
Apartado Aéreo No. 67-13
Cali, Colombia

or such other address of any such addressees as shall be designated by notice given as herein required. Notices hereunder shall be effective when received.

ARTICLE IX

This Contract shall become effective on July 1. 1980 and shall remain in effect for a period of two years unless terminated in accordance with its terms.

ARTICLE X

This Contract shall consist of the provisions contained in Articles I - X inclusive, Annex I (Project Proposal), Annex II (Work Plan), Annex III (Budget), and Annex IV (General Conditions) as amended. Any reference herein to "Contract" shall be deemed to include all of the aforementioned.

In WITNESS WHEREOF, the Parties hereto have signed this Contract on the dates indicated beneath their respective signatures.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL	UNITED NATIONS DEVELOPMENT PROGRAMME
John L. Nickel	John B. Cella
John L. Nickel Director General	John B. Cella Senior Director Office for Projects Execution
- 1 AUG 1980	31/8/80
Date	Date

AWARD RECOMMENDED BY
UNDP CONTRACTS COMMITTEE
Mtg. No. 131 of 3 July 1980 DATE
C.H. Jones SECY
for D.P.H. Richards

Annex I

INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE (CIAT),
INTERNATIONAL INSTITUTE FOR TROPICAL AGRICULTURE (IITA) AND
INTERNATIONAL POTATO CENTER (CIP)

PROJECT PROPOSAL

Submitted to the

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)

June 1980

TECHNOLOGY TRANSFER ON ROOT AND TUBER CROPS

Estimated UNDP contribution requested:	$600,000
Duration:	Two years
Executing Agency:	UNDP

Technology Transfer on Root and Tuber Crops

I. Introduction

1. Edible roots and tubers have always been a basic component of the staple diets of many people throughout the world. In fact, potatoes, cassava and sweet potatoes singly outrank the average production of energy per hectare per day produced by each of the most popular foods in tropical developing countries, including dry beans, chick-peas, rice and maize. Cassava, with a total of 13.1 million hectares of production, is almost exclusively produced and consumed in developing countries, and 98 per cent of the world's 15 million hectares of sweet potatoes is grown in developing countries.

2. Forty-six per cent of the world's 18.2 hectares in potato production are in developing countries. Recognizing these facts and the three crops' potential for alleviating world hunger, the international research centers - International Center for Tropical Agriculture (CIAT), International Potato Center (CIP) and International Institute of Tropical Agriculture (IITA) - have been mandated by the Consultative Group on International Agricultural Research (CGIAR) to conduct research on these crops with the objective of assisting national programs to adapt and generate new technologies for increased production. With this mandate, the three centers, with CIAT as the lead organization, intend to launch a co-ordinated effort to transfer technology on three economically important crops, namely, potatoes, sweet potatoes and cassava to interested developing countries. This effort would emphasize training for developing country national program personnel and would seek to facilitate the exchange of information, knowledge and experiences.

3. Because of the uniqueness of each center in regard to certain aspects of their respective commodities, priority geographical areas of responsibility and program structure, most of the activities in this project are to be conducted separately. Some aspects of research and technology transfer may be common to all root and tuber crops. In such programs, the centers intend to mount co-operative training programs, taking into account the fact that diseases and indexing of diseases (virus), tissue culture medium, etc., may be different with the crops concerned. These are 1) tissue culture techniques and 2) the problems associated with the transfer of germplasm across national boundaries.

4. The International Center for Tropical Agriculture (CIAT) at Palmira, Colombia, devotes its efforts to generate and deliver, in co-operation with national programs, improved technologies aimed to increase production of cassava, field beans, tropical pastures and rice. The Cassava Program started in 1972; its actions concentrated on the evaluation, selection and improvement of cassava germplasm breeding for high yield, resistance to major pests and diseases and the development of simple technology based on improved agronomic practices. Selection and hybrids are now available from the program that in regional trials have yielded 30-35 T/ha, that is 2 to 3 times the average national yields in developing countries. Attendant yield-increasing technologies have been developed, such as improved cultural practices, fertilization and disease, insect and weed control methods. Complementary techniques and technologies have also been generated in meristem culture for pathogen-free germplasm exchange, rapid propagation, sun-drying, root storage and protein enrichment.

5. A growing network of cassava research workers is developing mostly

through training at the center. A total of 249 professionals have received training since 1972. Additional trained personnel is needed to expand the network and strengthen the collaborative and independent capabilities of cassava research programs in developing countries, especially in Latin America but also in South Asia. In this region, with funding from the International Development Research Centre (IDRC) of Canada, CIAT has co-ordinated outreach efforts, including testing of cultivars and training. CIAT's Cassava Program is now planning to expand its training activities to include short-term multidisciplinary intensive courses on cassava production to be conducted in interested countries. These courses will assist national research programs to integrate with extension services and the diffusion of new technologies, resulting in yield increases.

6. Parallel to its research and training activities, CIAT's Cassava Program brings together each year scientists from national programs on cassava to participate in workshops on specific subjects with the purpose of exchanging updated information on research methodologies and on new technologies and to agree on future research strategies and plans. Outreach scientists with responsibility for certain geographic areas (i.e., South Aemrica, Central America, Caribbean and South Asia) help to keep network researchers well-informed and supplied with germplasm and trial materials. Some of the countries involved are: Brazil, Colombia, Mexico, Costa Rica, Dominican Republic, Ecuador, Venezuela and Guyana in South America, Central America and the Caribbean.

Note: Because of financial constraints, this proposal does not include yams and cocoyams which are mainly grown in the developing countries and are important food crops in many countries of the tropics. Training on these crops has been covered by IITA in a limited way as part of its root and tuber crops production training course.

In Asia, where CIAT's co-operative program is relatively recent, the following countries have been involved: India, Indonesia, Malaysia, the Philippines and Thailand. The present project seeks to expand the above activities, especially with regard to training, with the purpose of strengthening research capabilities of national programs and transferring technology.

7. The International Potato Center (CIP) at Lima, Perú, conducts research into all aspects of the improvement and production of the potato. At its headquarters in Lima, Perú, and elsewhere, the Center conducts basic research which includes the utilization of the international germplasm collection in breeding programs, pathology, physiology, entomology, nematology and social sciences.

8. From the initiation of the center, an equal amount of core funds were allocated to the development of a world-wide network of scientists whose principal role was to evaluate improved technology at the regional level and train national scientists for research on improved methodology. This regional program also evaluates and distributes improved germplasm emerging from the various breeding programs. Seven regional locations[1] have been established and 75 per cent of CIP training is carried out at these or in countries within the regions. Already, through the regional research programs, large numbers of competent national scientists have been trained. In addition,

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1/ The countries presently covered in the seven regions are as follows: Region I - Brazil, Argentina, Uruguay and Chile; Region II - Mexico, Guatemala, Honduras, Costa Rica, Panamá and Dominican Republic; Region III - Kenya, Rwanda and Burundi; Region IV - Turkey, Egypt, Jordan, Syria, Algeria, Morocco and Tunisia; Region V - Pakistan; Region VI - India, Bangladesh, Nepal and Bhutan; and Region VII - the Philippines.

the regional scientists have identified several cells of expertise within national institutions which are capable of training scientists in neighbouring programs. It is CIP's stated policy in its long-term profile that, as early as possible, it will try to catalyse the process of horizontal transfer of existing technology between national programs using national capabilities. It is the intention to use the majority of the UNDP grant for this purpose. Thus, the proposed training will be additional to the ongoing training program financed from core funds.

9. For this reason, the following three principal areas have been identified for consideration:

a. Seed technology;

b. Improved agronomic methods which are economically acceptable:

c. Post harvest technology and, in particular, low cost storage.

10. Within the international network of agricultural research and training centers, the International Institute of Tropical Agriculture (IITA) established the Root and Tuber Improvement Program in 1971 with the responsibility of improving cassava, sweet potatoes, yams and aroids. It has been assigned world-wide responsibility for sweet potato, yams and aroids, and regional responsibility for cassava in Africa. It has since conducted research leading to improvement in both yield and quality, to distribute improved plant materials to national research centers where they can be of significant value to breeding or improvement programs and to conduct training programs to increase the capability of developing nations to solve their food production problems with their own expertise. The staff of the Institute's Root and Tuber Improvement Program, including breeders, pathologists, agronomists, entomologists, biochemist/food technologist, tissue culture scientists and

farming systems scientists, nematologist and co-operating virologists, have since the early days of the Institute worked with some success to provide national programs and farmers with high-yielding planting materials with resistance to such diseases as the cassava mosaic disease, cassava bacterial blight and sweet potato virus and, through both resistance breeding and biological control, to limit the losses caused by such insect pests as the sweet potato weevil, cassava mealybug and green spider mite. The program also conducts research in the area of tissue culture and has facilities to assess starch quality, the content of hydrocyanic acid which is toxic, and other consumer-related attributes of the lines that are considered by the breeders to be promising. Seeds of promising lines of cassava identified by IITA have been sent by IITA for evaluation by national programs in Burundi, Cameroon, Congo, Ghana, Liberia, Sierra Leone, Seychelles, Tanzania, Togo, Zaire and Zambia in Africa and to India. IITA has also developed good collaboration with Indonesia on sweet potato.

11. IITA has conducted a root and tuber production training course for 20-30 trainees every year since 1974. In addition, the Institute also has accommodated five technical trainees in the field of root and tuber improvement every year. The Institute currently has 14 degree-related trainees working on roots and tubers.

12. The ultimate goal of the Root and Tuber Improvement Program is to develop a package of improved technology in terms of cultivars and improve cultural methods for high stable yields, high economic returns and high consumer acceptance of cassava and sweet potato and to transfer the package of technology to farmers by training scientists of national root and tuber improvement programs and by close co-operation with these programs in the tropics.

13. The UNDP grant solicited by the present proposal would enable the Institute to augment its activities leading to technology transfer and to the reinforcement of national programs. It proposes to use the funds for research fellowships and to provide requisite financial support for research and extension personnel and for research support personnel for whom group courses or indididualized training programs would be indicated.

14. The intent of the fellowships is to strengthen collaborative ties with interested developing nations and to afford scientists of these nations the opportunity to become familiar with new and emerging technologies related to cassava and sweet potatoes.

15. Group courses and individualized training programs are organized for research support personnel who require additional knowledge or expertise to adequately fulfill their responsibilities. Courses and programs may be for periods as brief as one week or as long as six months, depending on the subject matter area and the nature of the participant's training deficiency.

II. Objectives

16. This project has two goals:

a. To strengthen the root and tuber crop research and extension capabilities of selected national programs concerned with cassava, sweet potatoes and potatoes which are economically significant crops; and

b. To promote the transfer of technology emerging from international centers conducting research on the above-mentioned crops.

17. To reach these goals, the following operational objectives for this project have been established:

a. Strengthening through training, the existing network of national programs that conduct adaptive research and evaluation of emerging technologies;

b. Catalysing a horizontal exchange process of existing knowledge and technologies between national programs within certain geographical spheres;

c. Facilitating an effective distribution of new germplasm emerging from research.

IV. Project Activities

18. All the training and information exchange activities envisaged by this project, involving CIAT, CIP and IITA, can be categorized in one of the action-oriented project thrusts listed below. These are designed to focus all training efforts on the accomplishment of the objectives. Because of the different strategies and existent programs of the centers, each center will exert varying amounts of energy for each of the thrusts while utilizing funds from this project. The respective budget for each center and the integrated total budget for these activities are given in table 1 to 4. Preliminary information on countries likely to be involved in the various training programs under this project is presented in Annexes A, B and C.

a. Training for Adaptive Research. The training activities under this heading are directed towards improving the national programs' competencies to conduct co-operative and independent research on specific root and tuber crops and evaluate technology and germplasm development by international centers and associated institutions for suitability for their respective sociological and ecological conditions.

(i) In this regard, CIAT plans to conduct an internship program on disciplinary research for cassava for up to 20 man-months. Disciplines available for breeding, pathology, entomology, physiology and agronomy. Additionally, CIAT would offer a 4-week training course on biological pest control for cassava, with ten participants.

(ii) CIP intends to conduct four regional short courses on low-cost storages for potatoes in the most appropriate geographical areas.

(iii) IITA requests funds for research fellowships to permit agricultural scientists from developing nations to conduct at the Institute, research on cassava and sweet potatoes, to become familiar with new and emerging technologies related to their crops and to strengthen the basis for collaboration between IITA and the national programs they represent.

b. Training for Validative Research and Extension. This training is directed at improving the national programs' competencies to evaluate technology and germplasm for economic acceptability under farm conditions.

(i) In this regard, CIAT plans to assist a limited number of national programs in the conduct of up to four in-country short courses on cassava production aimed primarily at extension personnel for purposes of bridging research and extension and helping to disseminate new technologies for increasing yields.

(ii) CIP intends to conduct two regional short courses on agro-economic methodologies for potato research and three regional short courses on potato seed production technology in the most appropriate geographical areas.

(iii) IITA requests scholarships to: 1) permit research workers and extension personnel from national programs to participate in the 1981 and 1982 training courses on tropical root crop production technology and extension and 2) to organize individual programs to meet the training needs of research and technical personnel of national cassava and sweet potato improvement programs.

c. Training for Specialized Research Support Functions. This training is directed at improving the national programs' competencies to perform specific and specialized research techniques unutilized in direct support of comprehensive research efforts. In this regard, CIAT, CIP and IITA intend to collaborate in the planning, conduct and evaluation of two regional workshops on root and tuber crops tissue culture techniques.

d. Interaction with National Programs for Information Exchange and Strategies for Solution of Common Problem Areas. This activity is directed at providing national programs and international centers an opportunity to exchange scientific information and to discuss major problem areas related to the execution of research programs and the transfer of technology, with the intent of formulating possible strategies for their solution.

(i) In this regard, CIAT, CIP and IITA intend to collaborate in the planning, conduct and evaluation of a workshop on root and tuber crops germplasm distribution and quarantine considerations.

(ii) In addition, all three centers will provide follow-up support to the scientific personnel trained under the project, including the channeling of information on research progress, supplying of germplasm and technical advice on the conduct of adaptive research. Two regional workshops, one in Latin America and the other in the Far East are envisaged.

Note: Tentative programs involving training, workshops, etc. under this project are shown in Annexes A, B and C. Detailed programs and work plans will be prepared and submitted to UNDP in due course after consulations between CIAT, IITA and CIP and selected countries.

Annex II

TECHNOLOGY TRANSFER IN ROOT AND TUBER CROPS

WORK PLAN

CIAT

As part of the project and concentrating on cassava CIAT individually will conduct the following:

	Dates/location
1. A training internship program of up to 20 man-months for research scientists from national programs in - selected disciplines among: breeding, pathology, - entomology, physiology, agronomy or utilization.	July 80 to June 82 CIAT
2. A four-week course on biological pests control of cassava for ten participants.	October 1981 CIAT
3. Four in-country courses on cassava production for extension-development professionals of national programs in selected interested countries most - likely Mexico, Brasil, Dominican Republic and Haiti. Project funds will cover organization, internatio nal instructors and materials support of partici- pants will be provided by the host institution(s)	August 1980 November 1980 July 1981 October 1981

CIAT, CIP will jointly conduct:

4. A regional five-day workshop for Latin American

countries on germplasm distribution and quarantine up to 14 participants. June 1981 CIAT

5. A regional training course of two weeks duration on root and tuber crops tissue culture techniques; for Latin American Countries up to 8 participants. June 1982 CIAT

CIAT and IITA will jointly conduct:

6. A workshop on germplasm distribution and quarentine considerations for African countries, up to 18 - participants, 5 days 1982 IITA

WORK PLAN

CIP

As part of the project CIP individually will conduct the following:

1.	A course on potato storage for 10 participants 21 days.	Nov. 1980 Colombia
	A course on potato storage for 10 participants 21 days.	July 1981 Sri Lanka
	A course on potato storage for 10 participants 21 days.	Nov. 1981 Bolivia
	A course on potato storage for 10 participants 21 days.	Sept. 1982 Nepal
2.	A course on Agro-economic methodologies for 8 participants, 30 days	May 1981 Rwanda
	A course on Agro-economic methodologies for 10 participants, 21 days	April 1982 Philippines
3.	A course on potato seed production for 8 participants, 30 days	July 1981 Turkey
	A course on potato seed production for 8 participants, 30 days	Feb. 1981 Bangladesh
	A course on potato seed storage for 10 participants	April 1982 Tunisia

4. Workshop on potato germplasm distribution and quarentine considerations, 1 week, 10 participants — March 1982, Far East

CIP and IITA will jointly conduct:

5. A course on root and tuber crops tissue culture techniques for up to 14 participants, 30 days — 1981, IITA

WORK PLAN

IITA

As part of the Project IITA individually will conduct the following:

		Dates/location
1.	A training internship program of 10 participants 6-month training associateships on cassava and sweet potato improvement.	July-Dec.1980 IITA
2.	A 2-week training course of cassava and sweet potato improvement for 19 participants with a 3-month extension for 7 participants in - specialized training.	May-June 1981 IITA
3.	Three 4 month research associateships cassava and sweet potato improvement.	1981 IITA
4.	A 9-week training course on cassava and sweet potato improvement for 11 participants.	May-June 1982 IITA
5.	A 3-4/month research associateships in cassava and sweet potato improvement	1982 IITA

Organization and Planning and Implementation

Overall responsibility for the organization and execution of the project rests with the Contractor, CIAT, which will implement the project in close collaboration with IITA and CIP. Advice will be sought from FAO and the Policy Advisory Committee established below.

CIAT shall:

(a) Be responsible for the detailed planning, administration and execution of the project including timing and budgeting of the various elements, and the preparation of technical reports;

(b) Be responsible directly to the UNDP for all materials, equipment and transport furnished to the project by the UNDP;

(c) Coordinate as appropriate, the efforts of the project personnel with that of other agencies and programs whose activities have a bearing on this project;

(d) Convene a Policy Advisory Committee which will be made up of scientists or science administrators from cooperating countries together with a respresentative from the Food and Agriculture Organization, United Nations Development Programme and IITA and CIP, to advise on policies and programs of work, particularly as to the emphasis to be given to research, training and demonstration activities during the life of this Contract. It is emphasized that this Committee shall advise on policy and planning activities as requested by CIAT. It shall not involve itself in operational or supervisory aspects of the project. It shall meet periodically as determined by the Director General of CIAT, but at least once a year during the life of the project, at such times and places as CIAT shall determine.

Reports

In addition to the reports required under Article VI, paragraphs 2 and 3, CIAT will submit to UNDP the following:

(a) Annual reports indicating:

(i) progress of the Project;

(ii) an inventory of Project equipment purchased with UNDP funds, and for which title remains with UNDP.

(b) A Final Report indicating:

(i) satisfactory completion of the Project; and

(ii) an inventory of Project equipment pruchased with UNDP funds, and for which title remains with UNDP.

Items (a) (ii) and (b) (ii) shall be accompanied by a certificate from CIAT's External Auditor certifying to the correctness of such statement. CIAT will also provide UNDP with certified expenditure statements from the External Auditors of IITA and CIP certifying to the correctness of these statements covering the sums of UNDP funds being allocated to IITA and CIP on this project.

Reports shall be written in English.

Toward the end of the Project, UNDP will, in consultation with CIAT, undertake a review of the accomplishments of the Project to be carried out by a team of independent consultants.

ANNEX III

TRAINING AND TECHNOLGY TRANSFER ON ROOT AND TUBER CROPS: CIAT, CIP, IITA

Table 1

Proposed CIAT Budget in US Dollars

		1980		1981		1982		Total	
		MY	$	MY	$	MY	$	MY	$
1.	Salaries and benefits. One training expert	1/2	12500	1	27500	1/2	15000	2	55000
2.	Equipment		3000		-		-		3000
3.	Supplies		2000		3000		1000		6000
4.	Training materials		7500		5000		-		12500
5.	Travel		-		15000		3000		18000
6.	Training fellowships		12500		18000		29200		59700
7.	Consultants		-		5000		-		5000
8.	Conferences / workshops		-		16000		-		16000
9.	Central services		5500		13500		5800		24800
10.	Conctract management (lead institution)		2500		5000		2500		10000
	TOTAL		45500		108000		56500		210000

TRAINING AND TECHNOLOGY TRANSFER
ON ROOT AND TUBER CROPS: CIAT, CIP, IITA

Table 2 — Proposed CIP Budget in US Dollars

		1980	1981	1982	TOTAL
1.	Salaries and benefits	-	-	-	-
2.	Equipment	-	-	-	-
3.	Supplies	1500	2100	1500	5100
4.	Training Materials	1000	3500	2500	7000
5.	Travel	-	-	-	-
6.	Training Fellowships	24200	47700	40300	112200
7.	Consultants	5500	21000	9000	35500
8.	Conferences; Workshops	-	12000	6800	18800
9.	Central Services	4200	8000	4200	16400
	TOTAL	36400	94300	64300	195000

TRAINING AND TECHNOLOGY TRANSFER ON ROOT AND TUBER CROPS: CIAT, CIP, IITA

Table 3 - Proposed IITA Budget in US Dollars

	1980	1981	1982	TOTAL
1. Salaries and Benefits	-	-	-	-
2. Equipment	-	-	-	-
3. Supplies	2000	4000	2000	8000
4. Training materials	-	-	-	-
5. Travel	3000	2500	1500	7000
6. Training Fellowships	13000	100000	48000	163000
7. Consultants	-	4000	3000	7000
8. Conferences - workshops	-	10000	-	10000
9. Central Services	-	-	-	-
TOTAL	20000	120500	54500	195000

TRAINING AND TECHNOLOGY TRANSFER
ON ROOT AND TUBER CROPS; CIAT, CIP, IITA

Table 4 Proposed total Budget in US Dollars

	1980	1981	1982	TOTAL
1. Salaries and benefits	12500	27500	15000	55000
2. Equipment	3000	-	-	3000
3. Supplies	5500	9100	4500	19100
4. Training Materials	8500	8500	2500	19500
5. Travel	3000	17500	4500	25000
6. Training Fellowships	51700	165700	111500	334000
7. Consultants	5500	30000	12000	47500
8. Conferences and Workshops	-	38000	6800	44800
9. Central Services	9700	21500	10000	41200
10. Conctract Management (CIAT lead institution)	2500	5000	2500	10000
TOTAL	101900	322800	175300	600000

GENERAL CONDITIONS

01 - Privileges and Immunities of Contractor and Contractor's Personnel

The UNDP will obtain for the Contractor exemption from or reimbursement for the cost of any taxes, duties, fees or levies which may be imposed in the country on salaries or wages earned by the Contractor's foreign personnel in the execution of the Project and on any equipment, materials and supplies which the Contractor may bring into the country in connexion with this Project or which after having been brought into the country may be subsequently withdrawn therefrom. It is agreed that the UNDP shall not be liable beyond the amount of said taxes, duties, fees and levies for any failure or delay in obtaining exemption or reimbursement for the Contractor or his foreign personnel.

The UNDP agrees to use its best efforts to obtain for the Contractor and his personnel (except Government nationals employed locally), to the extent granted by the Government to UNDP staff members, such facilities and immunities as the Government has agreed to grant to contractors performing services for the United Nations Development Programme within the country and to their personnel. A copy of the provision relating hereto in the Project Document concerning this Project is herewith transmitted to the Contractor for his information as Annex A to this Contract.

02 - Waiver of Privileges and Immunities

Any provision, whether in an Agreement, Project Document, or any other instrument, to which the recipient Government is a party, by which the recipient Government confers benefits upon the Contractor and his personnel in the form of facilities, privileges, immunities, or exemptions by reason of his performance of services for the UNDP on this Project, may be waived by the UNDP where, in its opinion, the immunity would impede the course of justice and can be waived without prejudice to the successful completion of the Project or to the interests of the United Nations Development Programme.

03 - Confidential Nature of Documents

All maps, drawings, photographs, mosaics, plans, reports, recommendations, estimates, documents and all other data compiled by or received by the Contractor under this Contract shall be the property of the UNDP, shall be treated as confidential and shall be delivered only to the UNDP Project Manager or other authorized officials on completion of work under this Contract; their contents shall not be made known by the Contractor to any person other than personnel of the Contractor performing services under this Contract without written consent of the UNDP.

04 - Independent Contractor

(1) The Contractor shall have the legal status of an independent Contractor vis-à-vis the UNDP.

(2) Neither the Contractor nor his personnel shall be considered an employee or agent of the UNDP.

(3) Unless otherwise provided for in this Contract, the UNDP shall not be liable for claims of any kind arising in connexion with the performance of this Contract.

05 - Contractor's Responsibility for Employees

The Contractor shall be responsible for the professional and technical competence of his employees and will select for work under this Contract reliable individuals who will perform effectively in the implementation of the Contract, respect the local customs and conform to a high standard of moral and ethical conduct. The Contractor and his employees shall conform to all applicable laws, regulations and ordinances promulgated by legally constituted authorities of the Government.

06 - Assignment of Personnel

The Contractor shall not assign any personnel other than that referred to in this Contract for the performance of work in the field without the prior written approval of the UNDP. Prior to assigning any other personnel for the performance of work in the field, the Contractor shall submit to the UNDP for its consideration the curriculum vitae of any person the Contractor proposes to assign for such service.

07 - Removal of Personnel

(1) Upon written request by the UNDP, the Contractor shall withdraw from the field any personnel provided under this Contract and shall replace such personnel by others acceptable to the UNDP if the UNDP so requests.

(2) Such request for withdrawal or replacement shall not be considered as termination in part or in whole of this Contract under the provisions of Article 14 of the General Conditions.

(3) All costs and additional expenses resulting from any withdrawal or replacement for whatever reason of any of the Contractor's personnel shall be at the Contractor's expense.

08 - Assignment

The Contractor shall not assign, transfer, pledge or make other disposition of this Contract or any part thereof or of any of the Contractor's rights, claims or obligations under this Contract, except with the prior written consent of the UNDP.

09 - Sub-Contracting

In the event the Contractor requires the services of sub-contractors, the Contractor shall obtain the prior written approval and clearance of the UNDP for all sub-contractors. The approval of the UNDP of a sub-contractor shall not relieve the Contractor of any of his obligations under this Contract, and the terms of any sub-contract shall be subject to and be in conformity with the provisions of this Contract.

10 - UNDP Privileges and Immunities

Nothing in or relating to this Contract shall be deemed a waiver of any of the privileges and immunities of the UNDP.

11 - Officials not to Benefit

The Contractor warrants that no official of the United Nations Programme or the Government has been or shall be admitted by the Contractor to any direct or indirect benefit arising from this Contract or the award thereof.

12 - Language, Weights and Measures

Except as may be otherwise specified in the Contract, the English language shall be used by the Contractor in all written communications to the UNDP with respect to the services to be rendered and with respect to all documents procured or prepared by the Contractor pertaining to the work. The project surveys shall be based on the metric system of weights and measures, and estimates of quantities involved shall be made and recorded in metric units except as otherwise specified in the Contract.

13 - Force majeure; Other Changes in Conditions

(1) Force Majeure as used herein shall mean acts of God, laws or regulations, industrial disturbances, acts of the public enemy, civil disturbances, explosions and any other similar cause of equivalent force not caused by nor within the control of either party and which neither party is able to overcome. As soon as possible after the occurrence of any cause constituting force majeure, the Contractor shall give notice and full particulars in writing to the UNDP of such force majeure if the Contractor is thereby rendered unable, wholly or in part, to perform his obligations and meet his responsibilities under this Contract. Subject to acceptance by the UNDP of the existence of such force majeure, the following provisions shall apply:

(a) The obligations and responsibilities of the Contractor under this Contract shall be suspended to the extent of his inability of to perform them and for as long as such inability continues. During such suspension and in respect of work suspended, the Contractor shall be entitled only to reimbursement by the UNDP against appropriate vouchers of the essential costs of maintenance of any of the Contractor's equipment and of per diem of the Contractor's personnel rendered idle by such suspension.

(b) The Contractor shall within fifteen (15) days of the occurrence of the force majeure submit a statement to the UNDP of estimated expenditures for the duration of the period of suspension.

(c) The term of this Contract shall be extended for a period equal to the period of suspension taking, however, into account any special conditions which may cause the time for completion of the work to be different from the period of suspension.

(d) If the Contractor is rendered permanently unable, wholly, or in part, by reason of force majeure, to perform his obligations and meet his responsibilities under this Contract, the UNDP shall have the right to terminate this Contract on the same terms and conditions as are provided for in Article 0.14 "Termination", except that the period of notice may be seven (7) days instead of thirty (30) days.

(e) For the purpose of the preceding sub-section, the UNDP may consider the Contractor permanently unable to perform in case of any period of suspension in excess of ninety (90) days. Any such period of ninety (90) days or less shall be deemed temporary inability to perform.

(2) The Contractor shall notify the UNDP of any other changes in conditions or the occurrence of any event which interferes or threatens to interfere with his performance of the Contract. On receipt of such notice, the UNDP shall take such action as in its sole discretion considered to be appropriate or necessary in the circumstances.

14 - Termination

The UNDP may terminate this Contract, in whole or in part, upon thirty (30) days notice to the Contractor. Upon receipt of notice of termination, the Contractor shall take immediate steps to bring the work and services to a close in a prompt and orderly manner, shall reduce expenses to a minimum and shall not undertake any forward commitment from the date of receipt of notice of termination. In the event such termination is not caused by the Contractor's negligence or fault, no payment shall be due from the UNDP to the Contractor except for work and service satisfactorily performed, for the cost of repatriation of the Contractor's personnel, for expenses necessary for the prompt and orderly termination of the work, and for the cost of such urgent work as is essential as the Contractor is asked by the UNDP to complete.

15 - Workmen's compensation and other Insurance

(1) The Contractor shall provide and thereafter maintain appropriate workmen's compensation and liability insurance, with respect to and prior to the departure for overseas employment under this Contract of all employees who are hired outside the country of the Government and who are not citizens of the said country.

(2) The Contractor shall provide and thereafter maintain insurance in an appropriate amount against public liability for death, bodily injury or damage to property arising from the operation in the country in which the contract is to be performed of motor vehicles, boats or airplanes owned or leased by the Contractor. The Contractor warrants that similar insurance shall be provided and maintained in respect of all vehicles or boats owned or leased by foreign personnel of the Contractor and used by them in the country in which the Contract is to be performed.

(3) The Contractor shall comply with the labour laws of the Government providing for benefits covering injury of death in the course of employment.

(4) The Contractor shall arrange that all insurance policies other than that for workmen's compensation, referred to in the preceding paragraphs of this Article, shall include the UNDP, and where appropriate, the sub-contractor concerned, together with the Contractor as the Insured.

16 - Indemnification

The Contractor shall indemnify, hold and save harmless and defend at his own expense the UNDP, its officers, agents, servants and employees from and against all suits, claims, demands, and liability of any nature or kind, including costs and expenses arising out of acts of omissions of the Contractor or his employees or sub-contractors in the performance of this Contract. This clause shall extend to claims or liability in the nature of workmen's compensation claims or liability or those arising out of the use of patented inventions or devices.

17 - Disputes - Arbitration

Any dispute arising out of the interpretation or application of the terms of this Contract shall, unless it is settled by direct negotiations, be referred to arbitration in accordance with the rules then obtaining of the International Chamber of Commerce. The UNDP and the Contractor agree to be bound by any arbitration award rendered in accordance with this section as the final adjudication of any dispute.

A

D-3-Document w/c/d June 16, 78

UNITED NATIONS DEVELOPMENT PROGRAMME

GLOBAL PROJECT

Project Document

Title: International Institute of Tropical Agriculture (IITA). "Maximizing Nitrogen Fixation by Cowpeas and Soybeans in Farming Systems in the Humid Tropics"

Project No. GLO/77/013

Duration: Five years

Sector: Agriculture, forestry, and fisheries (05)

Starting date: 1 Feb. 1979

Sub-sector: Agricultural institutions, services, and rural training (0560)

Executing Agency: UNDP

Government contribution: n. a.

UNDP contribution: US$2,554,000

Approved: ____________________
(on behalf of UNDP)

Date: ____________________

Approved: ____________________
(on behalf of Office for Projects Execution, UNDP)

Date: ____________________

PROJECT IDENTIFICATION A

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ATTACHMENT A

Background on the International Institute of Tropical Agriculture (IITA), P.M.B. 5320, Ibadan, Nigeria.

The International Institute of Tropical Agriculture (IITA) was established in 1967 through an agreement with Nigeria. The host government provided 1,000 hectares of land for site near the University of Ibadan, one of Africa's leading educational centers.

The primary objective of all IITA research is to improve the quality and quantity of food crops in the humid lowland tropics. Many crops are important sources of food in this agroclimatic region, and IITA has sharpened its focus to concentrate on those considered of major importance. Among other things, the Institute seeks to deal with the problems that arise when the prevailing system of cultivation is forced to give way. In much of the tropics, agriculture traditionally has been a subsistence-level, low-input, labor-intensive endeavor. Except in lowland rice-growing areas, the predominant system has been shifting cultivation. A short cropping period is followed by a longer period during which the soil rests under natural ("bush") fallow. During the fallow period, nutrients removed by the crops are replenished by recycling nutrients through the fallow vegetation. By and large, the shifting system is a stable one, in balance with nature, and providing a limited number of people living on sufficient land with adequate food.

As populations of tropical countries increase and land-use pressures intensify, however, the natural balance of shifting cultivation is upset. To meet the increased demand for food the farmer is forced to cultivate more of his land more of the time and to shorten the restorative fallow period or eliminate it altogether. The net result is less -- not more -- food produced from each unit of land and serious long-term deterioration of irreplaceable natural resources.

Increasing the quality and quantity of food crops in the tropics thus involves more than developing new varieties and introducing new agronomic practices. IITA has accepted the challenge of finding solutions to the problems associated with replacing shifting cultivation with more productive land-use systems. Such systems are needed to increase tropical food production and, thereby, to improve living conditions for millions.

To meet the challenge IITA has adopted a three-pronged approach. The first is research conducted both on the IITA site near Ibadan and at other locations -- mainly, but not exclusively, in Africa south of the Sahara -- and through cooperative efforts with national programs, institutions and agencies. Second is training in research and production skills to increase the numbers and competencies of those who work or will work to solve the problems of tropical food production. The third approach is dissemination of information through distribution of written documents and through conferences, workshops and seminars to share research results and new production technologies with scientists throughout the world.

IITA's research efforts are concentrated in four research programs. Three of the programs are crop-centered: The cereal, grain legume, and root and tuber improvement programs. The fourth program -- the farming systems program -- is designed to synthesize all IITA research activities and develop viable alternatives to traditional agricultural practices in the tropics. The materials and methods developed in the crop programs are used by farming-systems program researchers to determine the most efficient uses of available resources. The results of this research are fed back into the crop programs to guide researchers in the development of improved varieties and agronomic practices. The needs of the small farmer are considered paramount. The integrated research efforts of all programs are aimed at developing materials, crop combinations and farm-management systems within his economic and ecological range.

1.1 ABSTRACT

Cowpeas (Vigna unguiculata (L.) Walp.) fulfill a very important role in the cropping systems and diets in the subhumid tropics. Their capability to nodulate with soil rhizobia and fix atmospheric nitrogen enables the subsistence farmer to produce a protein rich food with minimal inputs. In addition, when employed in a cropping system or rotation, they may enhance the fertility of the soil for subsequent production of cereal grain crops. This project is designed to further develop the exploitation of cowpeas in the humid tropics with the ultimate objective of increasing the total food production of the cropping system. Emphasis will be placed on identifying cowpea/rhizobia combinations for maximum nitrogen fixation under humid tropical conditions. This will entail collection and evaluation of indigenous cowpea rhizobia, identifying elite strains, production of rhizobial mutants which are competitive under adverse conditions, extensive field testing of legume cultivar/Rhizobium strain combinations, and developing simple, inexpensive screening procedures for field use in detecting cultivars that have a high potential for nitrogen fixation.

Because of the great interest in developing the production of soybeans (Glycine max (L.) Merr.) in the humid tropics and in Africa in particular, they are also included in this study.

A training component is included to assist in developing technical competence in legume technology in the tropics. In addition, certain portions of the research will be executed in cooperation with scientists in Sri Lanka, Sweden, Philippines, Brazil, Australia, United States and several countries in Africa including Kenya and Senegal.

1.2 INTRODUCTION

In the least productive areas of the humid tropics the inputs required to improve crop productivity are beyond the means of the impoverished farmer, who is dependent upon natural fallow to provide nutrients to support plant growth. Yields are extremely low with this system but improvements can be made by maximizing the nitrogen contribution from the grain legume/*Rhizobium* symbiosis.

Traditionally, soil fertility in the humid tropics has been maintained by the system of shifting cultivation. In this system soil fertility is restored by leaving the soil under natural vegetation for several years when nutrients are re-cycled through the vegetation to the surface soil, and organic matter is restored by addition from the vegetation. An essential part of the process is the fixation of nitrogen by symbiotic and non-symbiotic bacteria associated with soil and vegetation. Nitrogen accumulates in the soil as part of the soil organic matter, and is mineralized and available to crops during a subsequent cultivation period. However, this system is breaking down because increasing population densities do not allow the natural fallow vegetation for a sufficiently long period for soil fertility to be restored. A cycle commences in which each successive fallow and cropping sequence leads to lower and lower soil productivity.

The inability of the farmer to continue with the traditional system combined with the increasing demands for more food production dictate that a new, improved farming system be sought. The more productive farming must include improved cultivars, good agronomic practices, and an adequate supply of nutrients to support high yields. Microorganisms alone cannot provide sufficient nutrients to meet the requirements of a high yielding cultivar. However, they can be an integral part of the improved package by supplementing industrial fertilizers. The use of plant/microorganism associations to complement chemical fertilizers is a practical alternative to the extremes of total dependence upon inorganic fertilizers and the slow recycling process by natural bush fallow.

Improved agricultural systems are already being adopted in many areas of the developing world and large increases in productivity are evidence of their success. With both the improved and the traditional systems the most common limiting nutrient is nitrogen. Grain legumes occupy an important role in both types of farming system due to their ability to form a root nodule symbiosis with Rhizobium spp. and convert atmospheric nitrogen to a utilizable form, enabling them to grow in low fertility soils without the addition of nitrogenous fertilizers. The subsistence farmer can thus produce a high protein food staple with minimal inputs.

Grain legumes have an added importance as part of the improved farming system; when grown in a rotational or relay cropping program they can enhance the fertility status of the soil for subsequent production of cereal crops. Legume nitrogen residual in the soil is in a slowly mineralizable, organic form, and is less subject to leaching than chemical fertilizers. A well constructed rotation also makes better use of land as many legumes are short duration crops with high degree of drought resistance, enabling them to be grown during a short rainy season or at the end of the rains after the removal of a cereal crop.

The extension of improved practices to the farm level is an essential ingredient of agricultural development. At IITA, training is given equal priority to research. Training programs are offered in production and research for most major tropical food crops. A course covering microbiological methods will be conducted and a network of collaborators established throughout the tropics. Research as proposed in this project requires cooperation with other institutes thereby facilitating the transfer of information.

1.3 RELEVANT COWPEA AND SOYBEAN RESEARCH AT IITA

Research on grain legumes at IITA has been mainly on cowpeas because of their importance in Africa and Brazil. Indigenous to soils of West Africa are rhizobia capable of nodulating cowpeas, and preliminary work at IITA has shown little or no positive response to field inoculation with cowpea rhizobia. However pot trials have shown that the cowpea cultivar/Rhizobium strain effectivity can vary over a wide range. There is little information available on the variation of "cowpea" rhizobia from location to location, and so at present there is no basis for an accurate assessment of the potential benefits of Rhizobium inoculation of cowpea crops. Certainly under "problem soil" conditions, benefit may accrue from cowpea seed inoculation, as has been shown in field trials at the IITA site at Onne which is typical of the acid soils of tropical West Africa. Rhizobium strain CIAT 79 gave a 3-fold increase in nodule number and a 5-fold increase in nodule mass compared with uninoculated plants. A full study of the cowpea/Rhizobium interaction on problem soils (i.e. low Ca, acid conditions, low P, low N) is required in order that the best host/symbiont combinations may be recommended for maximum yields in particular localities.

In West African soils where they have not been previously grown, the high yielding U.S. cultivars of soybean nodulate only very poorly and are found to show a strong positive response to inoculation. Where they have been introduced into the soil as inoculant, Rhizobium japonicum strains were found to persist over several seasons in neutral soils, while in acid soils preliminary work has indicated poor persistence and a need for continual reinoculation.

The lack of R. japonicum represents a unique opportunity to introduce highly effective strains without competition from less effective indigenous rhizobia. It is essential that R. japonicum strains which will in the future be recommended by IITA for inoculant use be fully characterized for survival ability, low mutation propensity, and for effectivity with the appropriate cultivars under field conditions. Characterization of a wide range of strains from various origins with different host cultivars in glasshouse and field trials is required. Problems peculiar to growing soybean in acid soils, low P soils etc. also require investigation.

Some cultivars of soybean which originate in the Far East have been found to nodulate well in African soils with no history of soybean field inoculation (unlike the U.S. cultivars as stated above, which nodulate poorly if at all). This phenomenon requires investigation. If the nodulating ability of Asian cultivars can be combined with the desirable characteristics of the U.S. cultivars, high soybean yields without the problems of the development and use of inoculants may be possible.

1.4 RESEARCH GOALS

A. Investigate and compare the diversity and population sizes of rhizobia in soils from various locations in Nigeria, with particular emphasis on cowpea rhizobia. Rhizobium strains will be purified and tested on plants for effectivity, and elite strains identified for further field inoculation studies. Highly efficient cowpea host/strain combinations will be identified as a possible aid in developing superior cultivars for locations where the particular strains are dominant.

B. Identify lines of cowpea and soybean and appropriate Rhizobium strains most capable of forming early and efficient symbiosis in soils where there are problems of acidity and/or phosphorus deficiency and/or nitrogen deficiency. There are very large areas of these soils in the tropics and they therefore warrant special attention.

C. Assess the potential benefits from the use of Rhizobium inoculants with field grown cowpea and soybean in extensive trials, using promising strains from A and B. Problems associated with use of inoculants in the tropics will be identified for possible future study.

D. Identify and evaluate soybean lines capable of nodulating with indigenous strains of Rhizobium in Nigerian soils perhaps obviating the need of inoculants. The nodulating strains will be characterized and effectivity of the symbioses appraised for possible use of these lines in breeding with agronomically superior lines which are unable to utilize indigenous strains.

E. Investigate the factors controlling survival of cowpea and soybean rhizobia in tropical soils. The strains of rhizobia which are most effective in fixing nitrogen do not always survive in the field. Rhizobium strains adapted to tropical stress conditions will be employed in developing mutants resistant to the environmental stresses; the mutants will be tested in tropical soils and explanations for the superiority of the resistant mutants will be sought. Methods will be sought to make active nitrogen-fixing strains more competitive in nodulation under field conditions.

F. Develop and test inexpensive techniques for screening and evaluating large numbers of cowpea and soybean genotypes in the field at various stages of growth for highly efficient symbiotic nitrogen fixation. It is anticipated that these methods will be particularly valuable for use in the developing countries.

G. Training Program. Regional competence in handling Rhizobium is necessary. IITA will conduct a five week training course on nitrogen fixation in legumes. The training course will also serve as a forum for formulating coordination of symbiotic nitrogen fixation work in the various regions represented. In addition, portions of the proposed research will be coordinated with scientists in the Philippines, Sri Lanka, Sweden, Brazil, Australia, USA, and several African nations that are currently working with IITA. Predoctoral and postdoctoral fellowships between Universities in many of these countries and IITA will be one means of establishing and maintaining effective collaboration.

2.1 PROPOSED RESEARCH

(Please refer to "Attachment A" for a more complete literature review and detailed description of the experimental methodology and protocol).

2.1.A. To study environmental diversity of cowpea rhizobia in order to identify the most effective host/strain combinations.

In legumes/Rhizobium symbiotic associations, several successful steps of interaction between the bacterium and the host root eventually lead to nodulation. Several physical and environmental factors may obstruct this process and prevent root infection, nodule formation or nitrogen fixation. Particularly moisture, soil acidity, fertility and temperature may adversely affect Rhizobium survival, nodulation and nitrogenase activity (Nutman, 1965). Therefore, to optimize the symbiotic efficiency of a particular legume in any given region, the host, the rhizobia and the environmental variables have to be taken into consideration.

In tropical regions, soils are generally acidic, infertile and deficient in plant nutrients, particularly in calcium and phosphorus. The small farmer has few resources to invest in fertilizers, if they are available, and consequently fertility levels are generally low (Okigbo, 1977). Legumes are valuable to the farmer under these circumstances because of their ability to fix atmospheric nitrogen and consequently are able to grow without the addition of fertilizer nitrogen. However there is little information on the effects of soil or environmental factors influencing native rhizobial populations or the cowpea/microsymbiont relationship. Preliminary investigations in Nigeria indicate a widespread occurrence of cowpea rhizobia (Ezedinma, 1964; Ayanaba, 1977) but the distribution of the populations with soil depth and season has been little studied. Where the native rhizobial populations exist in abundance they must be well adapted to the conditions, and from these the most efficient strains for high symbiotic nitrogen fixing rates should be identified.

There may be intense competition among effective and ineffective strains of native rhizobia, which may result in the domination of either type, depending on their saprophytic competence. Where the dominant population is of ineffective rhizobia, effective nodulation may be obtained by the introduction of a population of a more competitive strain in the form of an inoculant applied to seed or directly to soil (Date and Roughley, 1977).

The Grain Legume Improvement Program at IITA has cowpea trials planted in various regions of Nigeria. The diversity of rhizobia within these soils will be studied initially. The abundance of effective and ineffective cowpea rhizobia as well as those of other Rhizobium species will be estimated and correlated with cropping history, soil and environmental conditions etc. Strains nodulating the same cultivar from different localities will be typed serologically (Vincent, 1970) for comparison purposes. The effectiveness of the cultivar/strain combinations will be assessed in pot trials under glasshouse or controlled environment conditions.

The most promising host/strain combinations will be subjected to further trials at IITA in pots containing field soils. This will enable the study of the performance of host/strain combinations faced with microbial competition, including indigenous rhizobia, and varying soil nutrient factors (Roughley, 1970).

2.1.B. To identify cowpea and soybean cultivars capable of forming efficient symbioses with rhizobia in "problem soils".

Soils which are considered the "problem soils" of the tropics have two characteristic features which are difficult to rectify -- soil acidity and phosphorus deficiency (Uehara, 1977). Such soils exist in large areas of Africa, Asia, and Latin America. According to Munns (1977) there is a correlation between acidity, calcium deficiency, manganese toxicity, and aluminum toxicity, and these can be grouped as "soil acidity factors." Of these factors calcium and pH affect nitrogen fixation directly, whereas aluminum and manganese are likely to influence nitrogen fixation indirectly by their detrimental effects on legume growth (Munns, 1977).

Legumes with high symbiotic nitrogen fixing capacity have a high requirement of phosphorus for nodulation as well as for nitrogenase activity (Franco, 1977) and so legumes are particularly affected by conditions of phosphorus deficiency (Russell, 1968).

Another soil fertility problem typical of tropical farming is nitrogen deficiency. Legumes are generally grown late in farming rotations and commonly are exposed to low soil nitrogen levels e.g. cowpeas are generally grown after the cereals which deplete the soil of nitrogen. There are several reports demonstrating better nodulation and yield of legumes when small amounts of nitrogen are applied (Summerfield et al., 1977; Franco, 1977; Dart and Mercer, 1965). The more vigorous plant has a greater leaf area, produces more photosynthate and thus fixes more nitrogen in the long term. Under low soil nitrogen conditions the time to nodulation and inception of nitrogen fixation is, therefore, important and an early nodulation characteristic would favor more rapid cowpea seedling establishment and better yield.

Thus, acid, phosphorus deficient, and low nitrogen soils may have adverse effects on nodulation and nitrogen fixing ability of the legumes. Farmers in many tropical countries with their small holdings cannot commit their meager resources to buying lime, phosphate or nitrogen to significantly affect their crop yields. For this reason it is desirable to identify the best legume host/strain combinations that are tolerant to these adverse conditions.

Cowpea and soybean cultivars will be grown in pots containing problem soils (acid or phosphorus deficient) of various origins. Where nodulation is found, infecting strains will be typed serologically to examine for variation of nodulating strains from different localities. Further trials will be carried out in pots with tolerant cultivars which do not nodulate in particular soils. Host/strain combinations which yield well in pots will be tested in field trials at various locations where there is a soil problem, using the methods described in Section C.

Field trials will be carried out at IITA on a soil contour low in nitrogen. A range of different cultivars of cowpea and soybean will be planted, with and without inoculation (see Section C) with different strains of Rhizobium including the best host/strain combinations from Section A. Correlations between early nodulation and yield will be appraised, and, if applicable, promising cultivars or cultivar/strain combinations will be further tested on nitrogen deficient soils in other localities.

2.1.C. To evaluate promising host-strain combinations with superior nitrogen fixing abilities under field conditions.

In recent years great advancements in inoculation technology leading to significant increases in nitrogen fixing performance of Rhizobium/host cultivar combinations under field conditions have been made in several countries, prominent among which are Australia, USA, Brazil and several European and Asian countries where legumes are important food and fodder crops (Date and Roughley, 1977).

Strains selected from Projects A and B will be used to prepare inoculum broth. Several locations will be selected for these field trials. Nodulation will be assessed at several stages of plant growth. Comparative nitrogen fixing abilities of different host/strain combinations will be screened weekly by the acetylene reduction technique (Dart et al., 1972; Hardy and Holsten, 1977). Total plant and seed dry weight will be measured and total nitrogen content of plants will be determined by Kjeldahl technique at each harvest (Vincent, 1970).

It is anticipated that problems of Rhizobium survival in the inoculant will be encountered e.g. survival during storage and during the dissemination of inocula from IITA to other Centers. Appropriate methods will be adopted in an attempt to alleviate these problems.

2.1.D. Identification and evaluation of soybeans either capable of using indigenous strains of Rhizobium japonicum or strains belonging to the cowpea cross-inoculation group. Selection of soybean lines with high nitrogen fixing abilities for further breeding programs.

Soybean is recognized as a major source of plant protein (38-45% in seed), as well as a vegetable oil source (17-22%). It is extensively grown in U.S.A., China, Brazil and USSR and has been introduced in several African countries. According to Okigbo (1977) soybeans are being introduced on an experimental basis in large scale farms and plantations in tropical Africa and may indeed become an important commercial crop in the near future. Preliminary studies at IITA have revealed better nodulation and increased nitrogen fixation rates in plants inoculated with exotic strains (Annual Report, IITA, 1974, 1975). However, we do not have sufficient knowledge of the abundance in the soil and the nodulation potential of indigenous soybean rhizobia. If native strains do exist, they must be well adapted and need to be isolated and studied for symbiotic efficiency. Cross infectivity has been reported among the soybean, lupin and cowpea cross-inoculation groups (Graham, 1976; Lange, 1961). Experiments from Tanzania and from Yandev in Nigeria have shown that certain cultivars of soybeans of Asian origin nodulate without any inoculation whereas high yielding U.S. cultivars require inoculum (Annual Report, IITA, 1974, 1975). Nodulation of the Asian cultivars occurred even in soils with no history of soybean cultivation (Pulver, 1977). A contributory factor in Tanzania and Yandev may be that the repeated cultivation of the same soybean cultivar in the same locality over a period of time leads to an abundance of native rhizobia, giving effective nodulation only of these cultivars. If this is so, growing of desirable high yielding cultivars (as intercrops) with initially poor or no nodulating ability for several seasons may build up an adapted population of effective rhizobia, without the need for inoculant.

Soybeans of diverse origin will be used at selected localities in Nigeria. Nodulation profiles with indigenous rhizobia will be studied. Soybean lines with high nitrogen fixing qualities will be selected for breeding with lines with other desirable traits. The relatedness of authenticated rhizobia to cowpea rhizobia will be determined by plant tests and if necessary by using serological procedures (Vincent, 1970). If nodulation does not occur in any one or all of the cultivars, replanting of the cultivars in the same plot will be continued for several seasons and plants will be examined for nodulation from time to time.

2.1.E. Identification and production of improved strains of cowpea and soybean rhizobia which are tolerant of adverse tropical soil conditions and competitive with indigenous rhizobia.

2.1.E.1. To assess the population changes of Rhizobium in soil as affected by drought, temperature, pH and water tension.

It is proposed that the influence of several possible physical and chemical stress conditions or environmental variables will be tested on the population of Rhizobium in soil. On the basis of the published literature and some of our investigations, it seems that drought, temperature, salinity, pH and water tension may have the greatest impact, and these variables will thus be included. The method developed by Obaton (1971) and extended in this laboratory (Danso et al., 1973) will be employed. The method is simple and rapid so that several soil variables and Rhizobium strains can be studied in short periods of time.

2.1.E.2. The decline of rhizobia as caused by protozoa and other biological agents

The limited data that currently exist indicate that protozoa are the major agents causing the decline of individual species of Rhizobium in the very few soils that have been examined (Danso and Alexander, 1975; Danso et al., 1975; Habte and Alexander, 1977, and submitted for publication). This biologically induced decline is particularly striking when significant physical and chemical stresses are absent. However, the protozoa themselves are subject to suppression by these physical and chemical stresses. On the other hand, bacteriophages, Bdellovibrio, competition, lysis, toxin production and myxobacteria are not known to be of importance in the decline, but the potential role of such organisms or phenomena has not been well studied. For these reasons and because of the few Rhizobium species or strains and few soils examined, the role of protozoa, other predators, and parasites in the decline of root-nodule bacteria will be established more thorougly. The methods will involve counting of the changes in cell density of the introduced Rhizobium (by the procedure described above) and the fluctuations in populations of antibiotic producers, lytic microorganisms, Bdellovibrio, bacteriophages and protozoa as well as levels of soil toxins.

2.1.E.3. Identification of strains able to withstand stresses.

Attempts will be made to identify the properties which make some strains of Rhizobium more able than others to withstand the chief physical, chemical or microbial stress of importance in tropical soil. Rhizobia from Project C will be employed. It is expected that only two or three stresses will be examined in this way because of restrictions of time. It is not now possible to state which are the major stresses in nature, but our preliminary data point most strongly to the importance of protozoan predation and drought. In these investigations, spontaneous mutants will be sought as well as mutants that appear after exposure of cultures to a chemical mutagen (e.g. nitrosoguanidine).

2.1.E.4. Making efficient nitrogen fixing strains of Rhizobium more competitive in nodulation.

Means will be devised to make active nitrogen-fixing strains of Rhizobium more competitive in nodulation. Although methods are available from our laboratory on the use of fungicides to achieve this objective (Odeyemi and Alexander, 1977a, 1977b), the introduction of agricultural chemicals into tropical soil is inadvisable at this time because of likely environmental risks and added costs to the farmer. Consequently, the use of chemical mutagens (if necessary) will be confined to laboratory studies in which competitively superior strains will be identified and stable mutants will be developed from these. The stages in the development and testing will be as follows:

(1) Rhizobium strains identified from Project C as being highly effective in nitrogen fixation will be screened and rated with regard to both effectiveness and competitive ability. Mutants will be developed from effective but poor competitors using chemical and physical mutagens.

(2) Establish the competitive ability in model laboratory and greenhouse systems using mixtures of strains first in Leonard jars and then under pot conditions.

(3) Introduce the most competitive strains (suitably marked with antibiotic markers) into tropical field soil and confirm their competitive superiority.

2.1.F. Develop and test simple, inexpensive methods which can be used to identify cultivars with high potential for symbiotic nitrogen fixation.

Symbiotic nitrogen fixation depends on the cooperation of both the plant and the microbe. It is now known that plant genetic factors influence the initiation, amount, and termination of fixation. It is the identification of this plant genetic material that we should now investigate. There is an obvious need to develop screening methods for rapid evaluation of host genotype/Rhizobium strain combinations for desirable characteristics. However, established methods require apparatus or techniques which are expensive, time consuming or inconvenient under field conditions. In addition, workers in developing countries often lack analytical equipment. For this reason, we propose to develop and test simple inexpensive methods which can be applied to legumes for easy assays of activity and efficiency of symbiotic nitrogen fixation in the field. This will involve modification of existing techniques and/or development of novel procedures.

2.1.F.1. Assay of nitrogen fixing activity by non-destructive methods.

There are several methods of estimating nitrogen fixation in the field. However, these analyses are of senesced plants at harvest or estimations of nitrogenase activity in excised roots. In order to avoid destruction of the plant, acetylene reduction assays can be done "in situ" with plants grown in special containers, but these are too expensive, inconvenient, and interpretation is not always simple. It would be desirable to estimate nitrogen fixation by plants in a non-destructive manner, and especially useful if the assay could be done before flowering, so that individual plants with desirable characteristics could be identified for crossing and/or seed collection. Such an assay would require that some measurable characteristic of the plant would vary in a dependable way with the amount of nitrogen fixation.

Legumes have long been known to contain uric acid, allantoin, allantoic acid, and urea, as well as the related enzymes xanthine oxidase, uricase, allantoinase, allantoicase and urease. Recently Yamamoto and co-workers (Matsumoto et al., 1977a, 1977b) found by N_2-15 studies that allantoin and allantoic acid were products of nitrogen fixation in soybean nodules. Significantly, the concentration of these compounds was higher in nodulated than in non-nodulated plants. The amount of allantoin in plant tops was related to nodule mass.

These results have been confirmed for soybean, and extended to other legumes (Child and LaRue, unpublished). Cowpeas behave like soybeans in having a higher ureide concentration in nodulated plants.

We will examine the concentration of ureides in plant top parts, over the growing season, under different regimes of nitrogen fertilizer and with different rhizobial strains. Cowpeas and nodulating and non-nodulating isolines of soybeans will be investigated. If it is established that ureides (or the enzymes acting on them) are an indication of nitrogen fixing ability, we will attempt to develop rapid simple assays for them.

2.1.F.2. Assay of hydrogen evolution as indicative of nitrogen fixing efficiency.

In the legume/rhizobia symbiosis, the energy needed for nitrogen fixation is derived from the oxidation of the products of plant photosynthesis. Considerable evidence suggests that it is the supply of energy which often limits the nitrogen fixing capability of symbiotic systems. The nodule enzyme nitrogenase evolves hydrogen. This production of hydrogen requires energy (4 moles of ATP per mole hydrogen) and it is not reversible. It apparently represents a waste of valuable energy and clearly reduces the efficiency of nitrogen fixation.

Schubert and Evans (1976) found that legume nodules evolved a great deal of hydrogen. Some legumes were very efficient e.g. soybean and cowpea in certain cultivar/strain combinations lost very little hydrogen (Schubert et al., 1977). The host plant may have some effect on the hydrogenase in the bacteroid. They noted that plant age had an effect on hydrogen evolution. Earlier, Dixon (1972) had shown that the amount of hydrogenase produced by bacteroids of a strain of Rhizobium leguminosarum depended on the host plant.

We will design a simple chamber for growing and testing undisturbed plants so that they can be assayed several times during growth for hydrogen evolution. If variation is found between different cultivars and/or different host/strain combinations, high and low hydrogen evolving cultivars/Rhizobium strains will be identified. These will be tested to determine if low hydrogen evolution is associated with increased nitrogen fixation and increased yield. If such a negative correlation is found, we will attempt to design an inexpensive, simple apparatus for measuring hydrogen in the field.

2.1.G. Training of agricultural researchers from the tropics on methods of study of nitrogen fixation in legumes.

IITA will conduct a training course (for 5 weeks) on Rhizobium isolation and maintenance, plant testing and inoculant use. The training course would also serve as a forum for discussing and formulating coordination of research in nitrogen fixation in this region as well as other regions. The training will also facilitate the research on regional testing of cultivars and rhizobia. In addition, a Predoctoral Training Program in collaboration with several universities around the world is proposed (see section on Research Management and Coordination).

2.2 IMPORTANCE OF THE PROPOSED RESEARCH ON COWPEA AND SOYBEAN PRODUCTION IN THE HUMID TROPICS

Cowpeas are very important in terms of total production and protein source in West Africa. They are particularly important to the subsistence farmer because of their ability to grow under low fertility conditions. Thus, any progress that can be made in enhancing their yields will be of special significance to small, less affluent farmers. Likewise, any increase in the general fertility level of a cropping system that might accrue as a result of improved cowpea production would have an immediate impact on food production and the nutritional status of a sizeable portion of the population in this region. In the case of soybeans, there is a very large potential for development of production in this area, and many national governments are very interested in developing this potential. If the increased soybean production is accompanied by the processing facilities necessary to extract oil, produce meal, etc., it could have an important effect on livestock production, and offer attractive export possibilities.

IITA has a mandate to assist in developing cowpea and soybean production in the humid tropics. However, any development at the research level must be extended to the farmer. IITA has a network of cooperating agencies in many parts of the humid tropics. Furthermore, the institute has established several outreach programs and it is planned that some of the field testing and isolation of rhizobia discussed in this proposal will be conducted by outreach personnel. These cooperating programs combined with the training will, of course, facilitate the transfer of information gained from the research.

In summary, IITA has a strong delivery system available to translate promising research results into increased crop production.

3.1 RESEARCH MANAGEMENT AND COORDINATION

Preliminary work initiated by IITA with its own funding and with supplemental support from UNEP has shown potential high payoff from a concentrated collaborative effort in nitrogen fixation studies on cowpeas and soybean. The present proposal is for a fixed term project which if given substantial support at this time could bring together facilities and outstanding resources to achieve stated objectives. The Boyce Thompson Institute and Cornell University have both staff and physical facilities which are highly complementary to those of IITA which if provided special support can be allocated for a limited time for research on this priority topic. Since solutions are expected within a reasonable time period, IITA would not be justified to seek core support for the facilities or to staff up to fully carry out the program. Therefore, the proposal to seek special funding and to collaborate with institutions and staff well recognized in this field of research for a limited time appears to be the appropriate approach. This collaboration will result in a more efficient use of funds, quicker attainment of research goals and also allow IITA staff to concentrate on work best done on location in the tropics.

Of Sections A, B, C and D, soil characterization of Rhizobium species, isolation and purification of rhizobia, pot trials with soil and field trials will be assigned to Dr. A. Ayanaba and Dr. E. Pulver at IITA.* Screening of Rhizobium strains for host specificity, effectivity with host cultivars and serological typing will be assigned to Dr. A. Eaglesham at Boyce Thompson Institute. Cultivar/strain screening is work best done in a suitable glasshouse in a temperate region where airborne contamination of tropical rhizobia is minimal and there is less problem in controlling the temperature of pot-grown plants. Dr. Eaglesham has experience in this work. Serological work requires rabbits, which mitigates against it being done at IITA. Thus soils work will be done at IITA (to obviate importation to the U.S.) and Rhizobium strains will be transported in freeze dried form to the U.S. for further characterization.

Section E will be assigned to Dr. M. Alexander at Cornell University. Dr. Alexander has a wide experience of many aspects of soil microbiology, including the ecology of rhizobia. Within his group, methods have been developed specifically for the study of Rhizobium survival in soil.

Section F will be assigned to Dr. T. LaRue at Boyce Thompson Institute. Dr. LaRue has a wide and varied experience of Rhizobium and legume research as well as in developing chemical methods and hardware for biological assay work.

(*At present, Dr. V. Ranga Rao, a postdoctoral fellow of Boyce Thompson Institute is at IITA working on collaboration with Dr. Ayanaba on a UNEP project. Dr. Rao has considerable experience in Rhizobium research and has contributed to this research proposal, particularly Sections A, B, C, and D. At the termination of the UNEP project it is anticipated that he will stay at IITA and collaborate in achieving the research goals set out herein).

The research program of Prof. C.A. Parker and his group at the University of Western Australia on "inoculum potential" and on the survival of rhizobia on seed and in soil has direct relevance to Section C of this proposal. Consultations will be held with individuals in this group, and it is hoped to link one of the predoctoral traineeships with the University of Western Australia. Likewise, Dr. Hans Ljunggren, Royal Agricultural College, Uppsala, Sweden, has an active interest in this area and will be consulted and a predoctoral exchange proposed with the Royal Agricultural College.

Physiological studies of cowpea including investigation of ureide synthesis are in progress also at the University of Western Australia, in Dr. J. Pates' group. It is hoped that consultations will be held with Dr. C. Atkins of this group.

It is envisioned that a predoctoral student at the University of the Philippines, Los Banos, will be linked to this project research program. Specifically, Drs. S.N. Tilo and I. Manguiat, Soil Science Department, Microbiology Section are concerned with nitrogen fixation in tropical legumes, and their involvement would clearly be beneficial to Sections C and D. We also hope that a similar arrangement can be consummated with the UNDP financed program on soybeans (in cooperation with INTSOY) in Sri Lanka, and with one or more of the following scientists and institutions in Brazil: CENA (University of Sao Paulo, Campinas), Dr. Dobereiner (EMBRAPA, Federal University of Rio de Janeiro), Dr. Freire (Federal University of Rio Grande). Note that where the University is located in the humid tropics, the students research may be performed in that country. The research will be planned in cooperation with IITA, and will assist in extending the scope of the proposed research and facilitate the exchange of information. Finally, IITA already has a cooperative arrangement with INTSOY and this will no doubt assume greater importance as a direct result of this proposed research. IITA already has established cooperative programs for nitrogen fixation research with Kenya, Senegal, Ivory Coast, Zaire, Ghana, Tanzania and Zambia. In the same light, we anticipate meaningful contact with the NIFTAL project at the University of Hawaii and exchange of cultures, techniques, etc.

The general management of the research program will be the responsibility of IITA. Dr. Ayanaba will be project coordinator and he will integrate the various research projects for the best progress of the program.

3.2 ADVISORY COMMITTEE

It is proposed that an Advisory Committee composed of six to ten renowned scientists currently engaged in legume/Rhizobium research will be invited to meet with collaborators at IITA each year. They will appraise the on going research objectives and advise on its future direction. A representative from IRRI, ICARDA, CIAT and ICRISAT will be invited to serve on this committee. The committee reports will be submitted to IITA and made available to UNDP.

It is hoped that the contacts established between committee members and collaborators will lead to informal exchanges during the course of the project, thus advancing the programs of the research.

4.1 PROJECT BUDGET
(U.S. $'000)

4.1.1 International Institute of Tropical Agriculture (Projects A, B, C, D.)

	1979/80 UNDP	1980/81 UNDP	1981/82 UNDP	1982/83 UNDP	1983/84 UNDP	Total
Project Personnel						
Senior Physiologist (20% of time)						
Senior Microbiologist (25% of time)						
Two Postdoctoral Fellows	38.0	38.0	38.0	38.0	38.0	190.0
Consultants Visits	20.0	20.0	20.0	20.0	20.0	100.0
One Senior Research Assistant	9.4	9.4	9.4	9.4	9.4	47.0
Two Junior Research Assistants	6.0	6.0	6.0	6.0	6.0	30.0
One Secretary	8.0	8.0	8.0	8.0	8.0	40.0
Component Total	81.4	81.4	81.4	81.4	81.4	407.0
Advisory Committee Expenses	20.0	20.0	20.0	20.0	20.0	100.0
Offsite Cooperative Projects and Fellowships	60.0	60.0	60.0	60.0	60.0	300.0
Training Course					30.0	30.0
	60.0	60.0	60.0	60.0	90.0	330.0
Equipment: Expendable	5.0	7.0	8.0	8.0	8.0	36.0
Non-expendable	39.0	40.0	8.0	8.0	8.0	103.0
Component Total	44.0	47.0	16.0	16.0	16.0	139.0
Travel	10.0	10.0	10.0	10.0	10.0	50.0
IITA Support Services	38.8	39.3	33.7	33.7	39.1	184.6
Subtotal	254.2	257.7	221.1	221.1	256.5	1,210.6
Allowance for price increase (10%)		25.8	46.4	73.2	119.0	264.4
Total	254.2	283.5	267.5	294.3	375.5	1,475.0

4.1.2 Boyce Thompson Institute (Projects A, B, C, D.)

	1979/80 UNDP	1980/81 UNDP	1981/82 UNDP	1982/83 UNDP	1983/84 UNDP	Total
Project Personnel						
One Postdoctoral Fellow	13.2	13.2	13.2	13.2	13.2	66.0
One Senior Technician	14.0	14.0	14.0	14.0	14.0	70.0
One Junior Technician	9.0	9.0	9.0	9.0	9.0	45.0
Component Total	36.2	36.2	36.2	36.2	36.2	181.0
Expendable Supplies	6.0	6.0	6.0	6.0	6.0	30.0
Component Total	6.0	6.0	6.0	6.0	6.0	30.0
Travel	5.6	5.0	5.0	5.0	5.0	25.6
BTI Support Services	18.1	18.1	18.1	18.1	18.1	90.5
Subtotal	65.9	65.3	65.3	65.3	65.3	327.1
Allowance for price increase (10%)		6.5	13.7	21.6	30.3	72.1
Total	65.9	71.8	79.0	86.9	95.6	399.2

4.1.4 Boyce Thompson Institute (Project F).

	1979/80 UNDP	1980/81 UNDP	1981/82 UNDP	1982/83 UNDP	1983/84 UNDP	Total
<u>Project Personnel</u>						
One Postdoctoral Fellow	13.2	13.2	13.2	13.2	13.2	66.0
One Senior Technician	14.0	14.0	14.0	14.0	14.0	70.0
One Junior Technician	9.0	9.0	9.0	9.0	9.0	45.0
Component Total	36.2	36.2	36.2	36.2	36.2	181.0
Expendable Supplies (including N-15)	10.0	10.0	10.0	10.0	10.0	50.0
Component Total	10.0	10.0	10.0	10.0	10.0	50.0
Travel	4.0	4.0	4.0	4.0	4.0	20.0
BTI Support Services	18.1	18.1	18.1	18.1	18.1	90.5
Subtotal	68.3	68.3	68.3	68.3	68.3	341.5
Allowance for price increase (10%)		6.8	14.4	22.6	31.7	75.5
Total	68.3	75.1	82.7	90.9	100.0	417.0

4.2 JUSTIFICATION OF NON-EXPENDABLE EQUIPMENT

4.2.1 IITA

Year 1979/80

Research Microscope:	$ 18,000

A research microscope with phase contrast and fluorescent attachment and camera for ecological studies, strain identification, etc.

Four-wheel drive vehicle, 2 automobiles:	20,000

For off-site use for nodule and soil collection and for general use by project personnel.

Two mobylettes:	1,000

For on-site use by project personnel.

Year 1980/81

Autoanalyzer:	40,000

Technicon instrument for nitrogen analysis.

The proposed research will generate many samples for nitrogen analysis, and this instrument would materially increase the number of samples that may be analyzed at IITA. Samples from both IITA and their cooperators may be analyzed.

Year 1981/82

Gas chromatograph:

With flame ionization detector for acetylene-ethylene assays.	6,300
Laminar flow sterile workstation:	1,700

For pure culture Rhizobium work

5.1 ENDORSEMENTS

5.1.1 International Institute of Tropical Agriculture

Title: Maximizing Nitrogen Fixation by Cowpeas and Soybeans in Farming Systems in the Humid Tropics

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

Cost to UNDP: 1,475,000

Endorsement :

William K. Gamble
William K. Gamble
Director General
IITA

29 May 1978
Date

5.1.2 Cornell University

Title: Maximizing Nitrogen Fixation by Cowpeas and Soybean in Farming Systems in the Humid Tropics

Subtitle: Identification and production of improved strains of cowpea and soybean rhizobia which are tolerant of adverse tropical soil conditions and competitive with indigenous rhizobia

Institution: Department of Agronomy
Cornell University
Ithaca, N. Y. 14853, U.S.A.

Cost to UNDP: 262,800

Endorsements:

Martin Alexander Principal Investigator	Date
Robert F. Lucey Department Chairman	Date
N. L. VanDemark Director of Research	Date
J. A. Youngers Office of Academic Funding	Date

5.1.3 Boyce Thompson Institute

Title: Maximizing Nitrogen Fixation by Cowpeas and Soybeans in Farming Systems in the Humid Tropics

Institution: Boyce Thompson Institute for Plant Research, Inc.
1086 North Broadway, Yonkers, N.Y. 10701, U.S.A.

Cost to UNDP: 816,200

Endorsements:

T La Rue
Thomas LaRue
Principal Investigator

30 May '78
Date

Allan R J Eaglesham
Allan R. J. Eaglesham
Co-Principal Investigator

25 May 1978
Date

R H Wellman
R. H. Wellman
Managing Director
Boyce Thompson Institute

30 May 1978
Date

ATTACHMENT A

MAXIMIZING NITROGEN FIXATION BY COWPEAS AND SOYBEANS IN FARMING SYSTEMS IN THE HUMID TROPICS

2.1. PROPOSED RESEARCH

2.1.A. To study environmental diversity of cowpea rhizobia in order to identify the most effective host/strain combinations.

In legume/*Rhizobium* symbiotic associations several successful steps of interaction between the bacterium and the host root eventually lead to nodulation. Several physical and environmental factors may obstruct the symbiotic process, preventing root infection, nodule formation or nitrogen fixation. Particularly moisture, soil acidity, fertility and temperature may adversely affect *Rhizobium* survival, nodulation or nitrogenase activity (Nutman, 1965). For example a *Rhizobium leguminosarum* population added to a sterile soil was greatly reduced in numbers after two weeks of flooding (Date and Roughley, 1977). Soil acidity causes a selection of slow growing rhizobia i.e. *R. japonicum*, *R. lupini* and rhizobia of the cowpea group while fast growers like *R. meliloti* and *R. trifolii* dominate in less acidic soils (Fred et al., 1932; Norris, 1965). High soil fertility levels favour the build-up of rhizobial populations (Parker et al., 1977). Soil temperature influences the infection process, nodule formation and nitrogen fixing activity. *Lotus* the largely temperate and sub-tropical genus requires relatively low root temperature (10-25^{o}C), with 15^{o}C being optimum for the infection process and 20-25^{o}C for nodulation and nitrogen fixation, while *Stylosanthes*, a tropical forage legume requires 27-30^{o}C for maximum nodulation and nitrogen fixation (Ranga Rao, 1977a and 1977b). Preliminary work with cowpea has shown its ability to nodulate and fix nitrogen at 36^{o}C (Eaglesham and Dart, 1975). Therefore to optimise the symbiotic efficiency of a particular legume in any given region, the host, the rhizobia and the environmental variables have to be taken into consideration.

In tropical Africa, soils are generally acidic, infertile and deficient in plant nutrients, particularly in calcium and phosphorus. The small farmer has few resources to invest in fertilizers, if they are available, and consequently fertility levels are generally low (Okigbo, 1977). Legumes are valuable to the farmer under these circumstances because of their ability to fix atmospheric nitrogen and consequently are able to grow without the addition of fertilizer nitrogen. In addition, grain legumes are protein rich and constitute a necessary and important part of the human diet in Africa. In West Africa cowpea is of prime importance. Africa accounts for 50% of the world production and of this, Nigeria produces 60% (Dart and Krantz, 1977). Thus any improvement of the symbiotic nitrogen fixing efficiency of cowpea at the farmers level will help alleviate both soil fertility as well as human nutrition problems in Africa. However there is little information on the effects of soil or environmental factors influencing native rhizobial populations or the cowpea/microsymbiont relationship. The aforesaid considerations make the study of the diversity of cowpea rhizobial strains within Nigerian soils very important. Preliminary investigations in Nigeria indicate a widespread occurrence of cowpea rhizobia (Ezedinma 1964, Ayanaba, 1977), but the distribution of the populations with soil depth and season has been little studied. Crown nodulation is rarely reported suggesting now Rhizobium numbers in soil surface layers. Where the native rhizobial populations exist in abundance they must be well adapted to the conditions, and from these the most efficient strains for high symbiotic nitrogen fixing rates should be identified.

Symbiotic promiscuity (nodulation of species of different infection groups by a single Rhizobium strain) has been found among the soybean, cowpea and lupin cross inoculation groups in Australia (Lange, 1961; Graham, 1976) and its relevance needs to be assessed in other tropical soils. There may be intense competition among effective and ineffective strains of native rhizobia, which may result in the domination of either type, depending on their saprophytic competence. Where the dominant population is of ineffective rhizobia, effective nodulation may be obtained by the introduction of a population of a more competitive strain in the form of an inoculant applied to seed or directly to soil (Date and Roughley, 1977).

Methods

The Grain Legume Improvement Program at IITA has cowpea trials planted in various regions of Nigeria. The diversity of rhizobia within these soils will be studied initially. Soil samples from different depths will be collected and suspensions in sterile water prepared. Surface sterilised seeds of species of different cross inoculation groups will be coated with one of the suspensions and sown in Leonard jar assemblies. Population sizes will then be evaluated by the most probable number method using the appropriate plant hosts. Thus the abundance of effective and ineffective cowpea rhizobia as well as those of other Rhizobium species will be estimated and correlated with cropping history, soil and environmental conditions etc. Strains nodulating the same cultivar from different localities will be typed serologically (Vincent, 1970) for comparison purposes.

It will be borne in mind that symbiotic promiscuity may hinder the accuracy of estimates of relative abundance, and where applicable, allowances will be made.

Rhizobial strains will be isolated from the nodules and maintained in pure culture. Preliminary screening of the cowpea rhizobia by the Leonard jar technique will follow, using different cowpea lines with scoring for nodulation and acetylene reduction activities (Hardy and Holsten, 1977; Dart et al., 1972). Where nodulation and acetylene reduction activity are exceedingly high, the effectiveness of the cultivar/strain combination will be assessed in pot trials under glasshouse or controlled environment conditions. Uninoculated plants will be grown simultaneously as check against cross-contamination. Plants will be grown to maturity and vegetative dry weight, fruit dry weight and total Kjeldahl nitrogen determined (Vincent, 1970).

The most promising host/strain combinations will be subjected to further trials at IITA in pots containing field soils. This will enable the study of the performance of host/strain combinations faced with microbial competition, including indigenous rhizobia, and varying soil nutrient factors (Roughley, 1970). Host/strain combinations performing well as determined by final yield and total Kjeldahl nitrogen will be tested in field trials using the methods described in Section C.

2.1.B. To identify cowpea and soybean cultivars capable of forming efficient symbioses with rhizobia in "problem soils".

Soils which are considered the "problem soils" of the tropics have two characteristic features which are difficult to rectify - soil acidity and phosphorus deficiency (Uehara, 1977). Such soils exist in large areas of Africa, Asia and Latin America. According to Munns (1977) there is a correlation between acidity, calcium deficiency, manganese toxicity, and aluminium toxicity, and these can be grouped as "soil acidity factors". Of these factors calcium and pH affect nitrogen fixation directly, whereas aluminium and manganese are likely to influence nitrogen fixation indirectly by their detrimental effects on legume growth (Munns, 1977). In general, extremely acid conditions are unsatisfactory for the survival and growth of all rhizobia. Fast growing rhizobia thrive only in neutral soils and can tolerate very little acidity although slow growers are found in acid as well as neutral soils (Holding and Lowe, 1971; Chatel et al., 1968). The action of calcium may be dual, as a direct effect on the symbiotic process, prominently the root hair infection (Norris, 1958) and also as a soil neutralising agent affecting plant growth and the symbiotic process indirectly (Franco, 1977).

Legumes with high symbiotic nitrogen fixing capacity have a high requirement of phosphorus for nodulation as well as for nitrogenase activity (Franco, 1977) and so legumes are particularly affected by conditions of phosphorus deficiency (Russel, 1968). A complicating factor is the adsorption of phosphorus by acid soils in the presence of aluminium oxide and clay particles, making it unavailable to plants. Under these conditions the task of increasing available phosphorus is a difficult one, and massive applications of phosphate fertilizer may exhibit only small increases in yields with time, the major portion reverting to fixed forms, making phosphate treatment uneconomical.

Another soil fertility problem typical of tropical farming is nitrogen deficiency. Legumes are generally grown late in farming rotations and commonly are exposed to low soil nitrogen levels e.g. cowpeas are generally grown after the cereals which deplete the soil of nitrogen. There are several reports demonstrating better nodulation and yield of legumes when small amounts of nitrogen are applied (Summerfield et al., 1977; Franco, 1977; Dart and Mercer, 1965). These so called "starter" nitrogen applications give a positive growth response by providing the legume with nitrogen at the stage when the seed reserves are consumed and before nodule fixation is established; otherwise the seedling goes through a nitrogen "hunger" stage. The more vigorous plant has a greater leaf area, produces more photosynthate and thus fixes more nitrogen in the long term. Under low soil nitrogen conditions the time to nodulation and inception of nitrogen fixation is, therefore, important and an early nodulation characteristic would favour more rapid cowpea seedling establishment and better yield.

Thus, acid, phosphorus deficient, and low nitrogen soils may have adverse effects on nodulation and nitrogen fixing ability of the legumes. Farmers in many tropical countries with their small holdings cannot commit their meagre resources to buying lime, phosphate or nitrogen to significantly affect their crop yields. For this reason it is desirable to identify the best legume host/

strain combinations that are tolerant to these adverse conditions.

Methods

Acidic soils: Cowpea and soybean cultivars will be grown in pots containing acidic soils of various origins with two treatments (a) with sufficient fertilizer nitrogen to support a good yield (e.g. 200 kg N/ha equivalent). (b) without nitrogen applied, to permit nodulation. Treatment (a) will identify cultivars which are tolerant to low pH while treatment (b) will identify cultivars which both nodulate effectively with indigenous *Rhizobium* strains and tolerate low pH. Where nodulation is found, infecting strains will be typed serologically (Vincent, 1970) to examine for variation of nodulating strains from different localities. Further trials will be carried out in pots with acid tolerant cultivars which do not nodulate in particular soils. These plants will be inoculated with rhizobia, the sources of strains may be elite strains identified in Section A, strains isolated from other acidic soils or obtained from other culture collections around the world. Host/strain combinations which yield well in pots will be tested in field trials at various locations where there is an acid soil problem, using the methods described in Section C.

Phosphorus deficient soils: The general protocol described for acidic soils will be adopted for phosphorus deficient soils.

Nitrogen deficient soils: Field trials will be carried out at IITA on a soil contour low in nitrogen. To obtain this the site will be cropped two or three times to closely sown maize. A range of different cultivars of cowpea and soybean will be planted, with and without inoculation (see Section C) with different strains of *Rhizobium* including the best host/strain combinations from Section A. There will be sequential harvesting to examine for time to nodulation and inception of nitrogen fixing activity (Dart et al., 1972)as well as the pattern of accumulation of nitrogen, particularly over the early weeks of growth. Correlations between early nodulation and yield will be appraised, and, if applicable, promising cultivars or cultivar/strain combinations will be further tested on nitrogen deficient soils in other localities.

2.1.C. To evaluate promising host-strain combinations with superior nitrogen fixing abilities under field conditions.

In recent years great advancements in inoculation technology leading to significant increases in nitrogen fixing performance of Rhizobium/host cultivar combinations under field conditions have been made in several countries, prominent among which are Australia, USA, Brazil and several European and Asian countries where legumes are important food and fodder crops (Date and Roughley, 1977). Based on the experiences in these countries several authors have suggested the following criteria for a rhizobial strain to be regarded as a successful field inoculant (Date and Roughley, 1977; Burton, 1976; Brockwell, 1977) These are: (a) the Rhizobium strain should be able to grow well on defined or partially defined culture media. (b) it should be able to survive, multiply and persist in the carrier substrate and on the seed coat along with the carrier prior to germination of the seed and in the rhizosphere and rhizoplane during the course of plant growth. (c) it should be able to withstand adverse environmental conditions prevailing in the soil and be able to compete with native microorganisms and other rhizobia until the symbiosis is established with the plant root. (d) it should exhibit pH and pesticide tolerance and show an ability to nodulate in the presence of combined nitrogen. (e) and the strain should form effective nodules with high nitrogen fixing ability under a range of field conditions.

Methods

Strains selected from projects A and B will be used to prepare inoculum broth in YEM (Vincent, 1970). Peat and the broth along with adhesive such as gum arabic or cellulose derivatives such a cellofas 'A'(methyl ethyl cellulose) will be mixed and the seeds will be coated with this mixture, prior to sowing (Date and Roughley, 1977; Brockwell, 1977). Rhizobial survival on the seed before and after sowing will be determined by plate counting or the "most probable number" method. (Date and Vincent, 1962; Weaver and Frederick, 1972; Davis and Eaglesham, 1975). Estimates will also be made of rhizobia in the rhizosphere of the seedling by plate counts. The medium used for such counts will be supplemented with antibiotics to suppress the growth of fungi and actinomycetes present in the soil (Vincent, 1970; Burton, 1976). Three or four locations will be selected for these field trials. The proper design of field experiments is important for successful results. Consequently, a split plot design with inoculated plants as the main treatment will be adopted. Lime, phosphorus and nitrogen may be secondary treatments as subplots. Nodulation will be assessed at several stages of plant growth. Comparative nitrogen fixing abilities of different host/strain combinations will be screened weekly by the acetylene reduction technique (Dart et al., 1972; Hardy and Holsten, 1977). Total plant and seed dry weight will be measured and total nitrogen content of plants will be determined by Kjeldahl's technique at each harvest (Vincent, 1970).

It is anticipated that problems of <u>Rhizobium</u> survival in the inoculant will be encountered e.g. survival during storage and during the dissemination of inocula from IITA to other Centers.
Appropriate methods will be adopted to alleviate these problems.

2.1.D. Identification and evaluation of soybeans either capable of using indigenous strains of <u>Rhizobium japonicum</u> or strains belonging to the cowpea cross-inoculation group. Selection of soybean lines with high nitrogen fixing abilities for further breeding programs.

Soybean is recognized as a major source of plant protein (38-45% in seed), as well as a vegetable oil source (17-22%) . It is extensively grown in USA, China, Brazil and USSR and has been recently introduced in several African countries. According to Okigbo (1977) soybeans are being introduced on an experimental basis in large scale farms and plantations in tropical Africa and may indeed become an important commercial crop in the near future. Preliminary studies at IITA have revealed better nodulation and increased nitrogen fixation rates in plants inoculated with exotic strains (Annual Report, IITA , 1974,75). However we do not have sufficient knowledge of the abundance in the soil and the nodulation potential of indigenous soybean rhizobia. If native strains do exist, they must be well adapted and need to be isolated and studied for symbiotic efficiency. Cross infectivity has been reported among the soybean, lupin and cowpea cross-inoculation groups (Graham, 1976; Lange, 1961). Experiments from Tanzania and from Yandev in Nigeria have shown that certain cultivars of soybeans of Asian origin nodulate without any inoculation whereas high yielding U.S cultivars require inoculum (Annual Report, IITA, 1974, 75). Nodulation of the Asian cultivars occurred even in soils with no history of soybean cultivation (Pulver, 1977). A contributory factor in Tanzania and Yandev may be that the repeated cultivation of the same soybean cultivar in the same locality over a period of time leads to an abundance of native rhizobia, giving effective nodulation only of these cultivars. If this is so, growing of desirable high yielding cultivars (as intercrops) with initially poor or no nodulating ability for several seasons may build up an adapted population of effective rhizobia, without the need for inoculant.

Methods

Soybeans of diverse origin will be used at selected localities in Nigeria. Nodulation profiles with indigenous rhizobia will be studied. Acetylene reduction activities, plant dry weight and nitrogen content of the nodulated cultivars will be determined. Soybean lines with high nitrogen fixing qualities will be selected for breeding with lines with other desirable traits. In situations where nodulation is sparse, rhizobia will be isolated from the nodules, purified, and the hosts will be reinoculated with the rhizobia in further field trials. The relatedness of authenticated rhizobia to cowpea rhizobia will be determined by plant tests and if necessary by using serological procedures (Vincent, 1970). If nodulation does not occur in any one or all of the cultivars, replanting of the cultivars in the same plot will be continued for several seasons and plants will be examined for nodulation from time to time.

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2.1.E. Identification and production of improved strains of cowpea and soybean rhizobia which are tolerant of adverse tropical soil conditions and competitive with indigenous rhizobia.

2.1.E.1. To assess the population changes of Rhizobium in soil as affected by drought, temperature, pH and water tension.

Methods

The method developed by Obaton (1971) and extended in this laboratory (Danso et al., 1973) will be employed. This procedure allows population changes of four or five or more logarithmic orders of magnitude to be determined simply and with accuracy, and it has been used in investigations of several Rhizobium species and in dissimilar soils (Danso et al., 1973; Danso et al., 1975; Keya and Alexander, 1975; Obaton, 1971; Habte and Alexander, 1977, and submitted for publication). In this method, mutants of the organisms resistant to high concentrations of the antibiotic are obtained, they are introduced into soil, and samples of the soil are taken at regular intervals and plated on an agar medium containing that antibiotic as well as actidione, the latter serving to inhibit fungi. The inhibitors in the agar are at sufficiently high concentration that few bacteria, actinomycetes or fungi appear on the plates; hence, the population decline of Rhizobium is easily characterized. The method is also quite simple and rapid so that several soil variables and Rhizobium strains can be studied in short periods of time.

It is proposed that the influence of several possible physical and chemical stress conditions or environmental variables will be tested by this method. On the basis of the published literature and some of our investigations, it seems that drought, temperature, salinity, pH and water tension may have the greatest impact, and these variables will thus be included.

2.1.E.2. The decline of rhizobia as caused by protozoa and other biological agents.

The limited data that currently exist indicate that protozoa are the major agents causing the decline of individual species of Rhizobium in the very few soils that have been examined (Danso and Alexander, 1975; Danso et al., 1975; Habte and Alexander, 1977, and submitted for publication). This biologically induced decline is particularly striking when significant physical and chemical stresses are absent. However, the protozoa themselves are subject to suppression by these physical and chemical stresses. On the other hand, bacteriophages, Bdellovibrio, competition, lysis, toxin production and myxobacteria are not known to be of importance in the decline, but the potential role of such organisms or phenomena has not been well studied. For these reasons and because of the few Rhizobium species or strains and few soils examined, the role of protozoa, other predators, and parasites in the decline of root-nodule bacteria will be established more thoroughly.

Methods

The methods will involve counting of the changes in cell density of the introduced Rhizobium (by the procedure described above) and the fluctuations in populations of antibiotic producers, lytic microorganisms, Bdellovibrio, bacteriophages and protozoa as well as levels of soil toxins. The requisite methods for the latter populations and inhibitors have been described (Habte and Alexander, 1975; Keya and Alexander, 1975; Danso et al., 1975). These studies, moreover, have provided a basis for predicting the number of protozoa or Bdellovibrio that should appear per rhizobial cell destroyed: 10^3 to 10^4 rhizobia per protozoan cell division and 3 Bdellovibrio cells per Rhizobium destroyed.

These values have been obtained from studies in culture media, sterile soil and in natural soil. Data for the requisite number of bacteriophages to decimate a given Rhizobium population, in media at least, have been published by others (e.g., Kleczkowska, 1945).

2.1.E.3. Identification of strains able to withstand stresses.

Methods

Attempts will be made to identify the properties which make some strains of Rhizobium more able than others to withstand the chief physical, chemical or microbial stresses of importance in tropical soil. Rhizobia from Project C will be employed. It is expected that only two or three stresses will be examined in this way because of restrictions of time. It is not now possible to state which are the major stresses in nature, but our preliminary data point most strongly to the importance of protozoan predation and drought. In these investigations, spontaneous mutants will be sought as well as mutants that appear after exposure of cultures to a chemical mutagen (e.g., nitrosoguanidine). Such methods have permitted us to obtain mutants resistant to antibiotics (Danso and Alexander, 1975) and also to a number of different fungicides (Odeyemi and Alexander, 1977a, 1977b). Another technique that may be employed involves isolating strains that survive increasing levels of the stress factor, presumably by some undefined mechanism of acclimation; we have by such means obtained Rhizobium strains far more resistant to high salt concentrations in liquid than the parent cultures (Mendez-Castro and Alexander, 1976). Furthermore, a report exists in the patent literature (U.S. Patent 3,6.6,236 issued to P.S. Delin) that strains can be developed, by an analogous technique, that resist drying, on seeds at least.

2.1.E.4. Making efficient nitrogen fixing strains of Rhizobium more competitive in nodulation.

Methods

Means will be devised to make active nitrogen-fixing strains of Rhizobium more competitive in nodulation.

Although methods are available from our laboratory on the use of fungicides to achieve this objective (Odeyemi and Alexander, 1977a, 1977b), the introduction of agricultural chemicals into tropical soil is inadvisable because of likely environmental risks and added costs to the farmer. Consequently, the use of chemical mutagens (if necessary) will be confined to laboratory studies in which competitively superior strains will be identified and stable mutants will be developed from these. The stages in the development and testing will be as follows:

(1) Rhizobium strains identified from Project C as being highly effective in nitrogen fixation will be screened and rated with regard to both effectiveness and competitive ability. Mutants will be developed from effective but poor competitors using chemical and physical mutagens;

(2) Establish the competitive ability in model laboratory and greenhouse systems using mixtures of strains first in Leonard jars and then under pot conditions;

(3) Introduce the most competitive strains (suitably marked with antibiotic markers) into tropical field soil and confirm their competitive superiority.

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2.1.F. Develop and test simple, inexpensive methods which can be used to identify cultivars with high potential for symbiotic nitrogen fixation.

Symbiotic nitrogen fixation depends on the cooperation of both the plant and the microbe. It is now known that plant genetic factors influence the initiation, amount, and termination of fixation. It is the identification of this plant genetic material that we should now investigate. In considering this problem, Evans (1975) and Milner (1977) have emphasised the need of a better understanding of the genetics of both host and endophyte in relation to the nitrogen fixing symbiosis as well as the need to develop screening methods for rapid evaluation of host genotype/Rhizobium strain combinations for desirable characteristics. However, established methods require apparatus or techniques which are expensive, time consuming or inconvenient under field conditions. In addition, workers in developing countries often lack analytical equipment. For this reason we propose to develop and test simple inexpensive methods which can be applied to legumes for easy assays of activity and efficiency of symbiotic nitrogen fixation in the field. This will involve modification of existing techniques and/or development of novel procedures.

2.1.F.1. Assay of nitrogen fixing activity by non-destructive methods.

There are several methods of estimating nitrogen fixation in the field viz. total nitrogen analysis, by the use of N-15 labelled nitrogen fertilizers, by yield comparison with a non-fixing control and by acetylene reduction. These analyses are of senesced plants at harvest or estimations of nitrogenase activity in excised roots. In order to avoid destruction of the plant, acetylene reduction assays can be done "in situ" with plants grown in special containers, but these are too expensive, inconvenient, and interpretation is not always simple. It would be desirable to estimate nitrogen fixation by plants in a non-destructive manner, and especially useful if the assay could be done before flowering, so that individual plants with desirable characteristics could be identified for crossing and/or seed collection. Such an assay would require that some measurable characteristic of the plant would vary in a dependable way with the amount of nitrogen fixation.

Legumes have long been known to contain uric acid, allantoin, allantoic acid, and urea, as well as the related enzymes xanthine oxidase, uricase, allantoinase, allantoicase and urease. Their function in plant metabolism is scarcely known, and the last reviews on the subject were written two decades ago (Bollard, 1959; Reinbothe and Mothes, 1961). Recently Yamamoto and co-workers (Matsumoto et al., 1977a, 1977b) found by N_2-15 studies that allantoin and allantoic acid were products of nitrogen fixation in soybean nodules. In soybeans, these acids are a major form of transport of newly fixed nitrogen from root nodules to the plant top. Significantly, the concentration of these compounds was higher in nodulated than non-nodulated plants. For example, the ureide concentration in trifoliate leaves was 2.2 mg/leaf vs. 0.3 mg/leaf. In the stem, nodulated plants had 400-1100 mg/100 g fresh weight, while non-nodulated plants contained less than 20 mg. The amount of allantoin in plant tops was related to nodule mass.

These results have been confirmed for soybean, and extended to other legumes (Child and LaRue, unpublished). The relation of ureides to nodulation is not universal; nodulated peas and broad beans for example are low in ureides. However cowpeas behave like soybeans in having a higher ureide concentration in nodulated plants.

Doubtless the concentration of other plant components may reflect nodule activity. However, at this time, ureides are the only compounds known to have this property.

Methods

We will examine the concentration of ureides in plant top parts, over the growing season, under different regimes of nitrogen fertilizer and with different rhizobial strains. Cowpeas and nodulating and non-nodulating isolines of soybeans will be investigated. Nitrogenase will be estimated with acetylene reduction and seasonal fixation estimated with N-15. If it is established that ureides (or the enzymes acting on them) are an indication of nitrogen fixing ability, we will develop rapid simple assays for them.

2.1.F.2. Assay of hydrogen evolution as indicative of nitrogen fixing efficiency.

The conversion of nitrogen to ammonia, by whatever means, requires energy. In the legume/rhizobia symbiosis this energy is derived from the oxidation in the nodule of the products of host plant photosynthesis. Considerable evidence suggests that it is the supply of energy which often limits the nitrogen fixing capability of symbiotic systems. The "cost" of fixing 1.0 g of nitrogen has been estimated (using different experimental approaches) as 6.8 g of carbohydrate in cowpea (Herridge and Pate, 1977) and 17 g in field peas (Mahon, 1978). This energy requirement includes not only

12 moles of ATP per mole nitrogen reduced, but the energy for forming and maintaining nodules, transporting carbon compounds to the nodules, incorporating ammonia into organic compounds and transporting the amines up to the stem, leaves or pods. It is still impossible to measure the energy requirement for these processes individually. However, there is one significant factor related to energy use which can be estimated - that is hydrogen evolution from the nodule.

The enzyme nitrogenase evolves hydrogen. This production of hydrogen differs from that of hydrogenase in two ways. It requires energy (4 moles of ATP per mole hydrogen) and it is not reversible. The free living nitrogen fixer Clostridium pasteurianum evolves appreciable amounts of hydrogen. However Azotobacter vinelandii does not evolve hydrogen, even when fixing nitrogen in the presence of excess carbohydrate. Nitrogen fixing A. vinelandii contains a very active hydrogenase. It is likely that this enzyme, probably located in the vicinity of nitrogenase, is able to "recycle" the hydrogen, and regain some of the energy otherwise dissipated.

Schubert and Evans (1976) found that legume nodules evolved a great deal of hydrogen. In some cases, they calculated that over a third of the energy directed to nitrogenase was lost as hydrogen. However some legumes were very efficient e.g. soybean and cowpea in some cultivar/strain combinations lost very little hydrogen (Schubert et al., 1977). They suggested this was due to hydrogenase in the rhizobia. However, the host plant may have some effect on the hydrogenase in the bacteroid. They noted that plant age had an effect on hydrogen evolution. Earlier, Dixon (1972) had shown that the amount of hydrogenase produced by bacteroids of a strain of Rhizobium leguminosarum depended on the host plant.

The studies referred to above were conducted with decapitated roots on excised nodules. Hydrogen was measured amperometrically or with a gas chromatograph fitted with a flame ionization detector.

Methods

We will design a simple chamber for growing and testing undisturbed plants so that they can be assayed several times during growth for hydrogen evolution. If variation is found between different cultivars and/or different host/strain combinations, high and low hydrogen evolving cultivars/Rhizobium strains will be identified. These will be tested to determine if low hydrogen evolution is associated with increased nitrogen fixation and increased yield. If such a negative correlation is found, we will design an inexpensive, simple apparatus for measuring hydrogen in the field. We have experience (Mallard et al., 1977) in developing a simple, portable, inexpensive gas chromatograph for the estimation of ethylene in determining nitrogenase activity by the acetylene reduction assay. Appropriate modifications in circuitry and column packing should provide a detector suitable for measuring hydrogen.

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Milner, M., N.S. Scrimshaw and D.I.C. Wang (1977). In: "Exploiting the Legume-Rhizobium Symbiosis in Tropical Agriculture". (Eds. J.M. Vincent, A.S. Whitney and J. Bose). College of Trop. Agr. Pub. 145. Univ. of Hawaii. pp. 1-20.

Reinbothe, H. and K. Mothes (1961). Ann. Rev. Plant Physiol. 22: 129-150.

Schubert, K.R., J.A. Engelke, S.A. Russell and H.J. Evans (1977). Plant Physiol. 60: 651-659.

Schubert, K.R. and H.J. Evans (1976). Proc. Nat'l. Acad. Sci. USA. 73: 1207-1211.

2.1.G. Training of agricultural researchers from the tropics on methods of study of nitrogen fixation in legumes.

IITA will conduct a training course (for 5 weeks) on Rhizobium isolation and maintenance, plant testing and inoculant use. The training course would also serve as a forum for discussing and formulating coordination of research in nitrogen fixation in this region as well as other regions. The training will also facilitate the research on regional testing of cultivars and rhizobia. In addition, a Predoctoral Training Program in collaboration with several universities around the world is proposed.

MAXIMIZING NITROGEN FIXATION BY COWPEAS AND SOYBEANS
IN FARMING SYSTEMS IN THE HUMID TROPICS

A P P E N D I X

CURRICULA VITAE

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Subject / Title
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Sherrine M. Thompson	April 12, 2021

D3

UNITED NATIONS
DEVELOPMENT PROGRAMME

PROGRAMME DES NATIONS UNIES
POUR LE DEVELOPPEMENT

ONE UNITED NATIONS PLAZA
NEW YORK, N.Y. 10017

TELEPHONE: 754-1234

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REFERENCE: GLO/77/008
GLO/77/005
GLO/77/002

25 January 1978

Dear Mike,

Our Governing Council has now approved a number of support programmes to ICRISAT and to ILRAD. I take pleasure in enclosing for your records one conformed copy of a contract signed between ILRAD and UNDP on 20 January 1978 which came into effect on 20 January. I will in due course send you conformed copies of the contracts between UNDP and ICRISAT.

acknowledged 1/26/78

With best personal regards,

Yours sincerely,

William T. Mashler
Senior Director
Division for Global and Interregional Projects

Mr. Michael L. Lejeune
Executive Secretary
Consultative Group on International
Agricultural Research
1818 H Street, N.W.
Washington, D.C. 20433

The United Nations Conference on Technical Co-operation among Developing Countries (TCDC) will take place in August/September 1978 in Buenos Aires
"An opportunity for the world community to help release the latent creativity of two billion people"
(from the Kuwait Declaration on TCDC, 5 June 1977)

CONFORMED COPY

CONTRACT

BETWEEN

THE UNITED NATIONS DEVELOPMENT PROGRAMME

AND THE

INTERNATIONAL LABORATORY FOR RESEARCH ON ANIMAL DISEASES

(ILRAD)

This Contract entered into by and between the United Nations Development Programme (hereinafter called the UNDP) and the International Laboratory for Research on Animal Diseases (hereinafter called ILRAD), a general copartnership with legal capacity organized under the laws of Kenya and with its principal offices at Nairobi, Kenya.

WITNESSETH

WHEREAS, the UNDP seeks to promote research directed towards increasing animal production and improving human health and well being by the control of trypanosomiasis and also seeks to promote the training of scientists to carry out national programmes of animal and human disease research and control, in order to assist peoples of developing countries in improving food production, availability of animals for draft and for other purposes including the improvement of human health, and

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WHEREAS, ILRAD is staffed and equipped to carry out such research and training, having been established for the purpose of carrying out research into such matters.

NOW THEREFORE the Parties hereto hereby agree as follows:

ARTICLE I

1. ILRAD hereby agrees to undertake a programme of research on trypanosomiasis and training of scientists from developing countries directed towards the development of additional required information about and procedures for the control of trypanosomiasis, a disease of immense importance in both man and animals in vast areas of Africa and Central and South America. Included will be research on the trypanosome including in vitro propagation, antigenic variation and the molecular and antigenic make-up of the surface coat; the host immune response including the effectiveness and composition of the host defense mechanisms and methods for increasing the efficiency of the immune response for producing resistance to infection; and define and develop procedures and materials for vaccination against the disease. A multi-disciplinary, co-ordinated approach to the Project involving the participation, interaction and collaboration of immunologists, parasitologists, biochemists, cell biologists, and other specialists who are available to ILRAD will be conducted.

2. For the purpose of carrying out the Project, ILRAD will provide the following:

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(a) technical personnel, including personnel in the disciplines mentioned above;

(b) other necessary personnel, including administrative personnel and supporting personnel for those mentioned in sub-paragraph (a) above;

(c) necessary facilities, including buildings, laboratories, equipment and services at its headquarters in Kenya;

(d) training facilities for approximately 10 persons per year from Africa, the Middle East, Central and South America and other regions of the world;

(e) such other facilities as may be necessary or appropriate to the carrying out of the Project.

ARTICLE II

ILRAD shall carry out the Project and all activities under this Contract in accordance with the Work Plan, Annex I, to this Contract and such changes in the Work Plan as the parties may mutually agree upon from time to time.

ARTICLE III

ILRAD shall, in carrying out the Project, consult the Food and Agriculture and World Health Organizations of the United Nations where appropriate for a continuing liaison and communication regarding the activities carried out under the auspices of this Project. A Policy Advisory Committee established in Part 2.2d of the Work Plan, Annex I, shall meet and function as described therein. ILRAD shall also consult other organizations possessing technical competence on the Project or any part thereof if requested to do so by UNDP.

ARTICLE IV

(a) The staff to be provided by ILRAD for work on the Project shall include the services of the following Scientific Staff:

1. Dr. H. Hirumi - Cell Culture
2. Dr. G. Roelants - Immunology
3. Dr. R. Williams - Biochemistry
4. Training Officer - Training
5. Dr. J. Doyle - Parasitology
6. Post-doctorals - Various of above

(b) ILRAD shall also provide such executive, administrative and other supporting or back-stopping services from its permanent establishment as the efficient execution of the Project may require. This will include the services of the following individuals:

1. To be named - Associate Director
2. Mr. M. Mitoko - Controller
3. Dr. R. Cook - Clinical Veterinarian
4. Mr. J. Paris - Supervisor, Stabilate Bank

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ARTICLE VI

The selection of ILRAD's personnel to work on the Project shall be the responsibility of ILRAD, provided that UNDP shall be furnished by ILRAD with the curriculum vitae of scientific personnel, and shall have the right to approve any individual proposed by ILRAD for work on the Project at its onset or at any later stage (whether for initial assignment thereto or as a replacement for any individual removed therefrom). The UNDP shall have the right to require that ILRAD withdraw or replace any individual assigned by it to the Project. The UNDP may exercise its rights under this paragraph for any reason it may deem sufficient.

ARTICLE VI

UNDP shall have the right to observe at all reasonable times the progress of work carried out under this Contract and to consult directly with personnel of ILRAD on work being performed by them.

ARTICLE VII

1. As complete consideration for the performance by ILRAD of its obligations under this Contract, UNDP shall pay the costs of carrying out the Project, in the amounts approved by UNDP, which costs shall be limited to those itemized in the Budget, Tables I and II, of the Work Plan, Annex I (hereinafter called the "Budget").

2. ILRAD will normally purchase the equipment required for the Project directly. However, the UNDP will on request from ILRAD purchase and arrange shipment to the Project site of any of the items required for

the execution of the Project in accordance with the detailed specifications for the classes of equipment as per the attached lists submitted by ILRAD.

3. Anything in this Contract to the contrary notwithstanding, UNDP shall not be obligated to make payments hereunder in excess of the amount of $3,390,170, and ILRAD shall not be obligated to continue performance hereunder where continuation would otherwise entail payments by UNDP in excess of such amount.

4. UNDP hereby approves the work plan and budget submitted by ILRAD for the first year of this Contract. ILRAD agrees to submit a work plan and budget 60 days prior to the end of each of the remaining years of this Contract. Each work plan and budget shall become effective only upon the written approval of UNDP.

ARTICLE VIII

1. On the date this Contract enters into force, UNDP will advance to ILRAD an amount equal to the estimated costs for the first quarter. Subsequent quarterly advances shall be made by UNDP to ILRAD within one week of the beginning of each quarter based on the estimated costs detailed in the Budget and the annual work plan and budget to be prepared under Article VII, paragraph 4. Payments will be made in U.S. dollars or Kenyan Shillings as required by ILRAD and approved by UNDP to bank accounts in the United States or Kenya as designated by ILRAD.

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2. It is understood that the advances payable to ILRAD under paragraph one of this Article are intended to cover only estimated costs detailed in the Budget. ILRAD shall inform UNDP of any significant departures from the Budget. Any advance under paragraph one of this Article shall be reduced in the next quarter to the extent that the sums actually expended by ILRAD in the previous quarter fall short of the total amount estimated. ILRAD shall submit quarterly financial reports detailing expenditures made in the quarter to which the report relates, which reports shall be accompanied by a certificate from ILRAD's external auditors certifying to the correctness of the statement.

3. ILRAD shall submit to UNDP annual and final reports which shall state the total expenditures on the Project, and shall be accompanied by a certificate from ILRAD's external auditors certifying to the correctness of such statement. Each annual report shall be due within 30 days of the end of each fiscal year. Any difference between the disbursements made by UNDP under paragraphs one and two of this Article and the total expenditure made by ILRAD on the Project as certified by its external auditor shall be reconciled within the next calendar month following that in which the statement is presented to the UNDP.

ARTICLE IX

With respect to Annex III, General Conditions, hereof:

1. The term "Contractor" shall be understood to mean the International Laboratory for Research on Animal Diseases (ILRAD).

2. The term "Government" shall be understood to mean the Government of Kenya or any other country or countries in which the Project or any aspect of the Project is being carried out.

3. Section 03, Confidential Nature of Documents, is amended by deleting everything following "UNDP" where it first appears in said Section, ending the first sentence at said "UNDP", and adding the following sentence: "With reference to the Agreement(s) between UNDP and the Government(s), on the request of the Government, Contractor will hold confidential any documents or data received from the Government under this Contract."

4. Section 06, Assignment of Personnel, is deleted in its entirety.

5. Section 14, Termination, is amended by adding the following sentence: "Under no circumstances shall payments under this section be understood to include costs other than those provided for in Article VII, paragraph 1."

6. Section 18, Conflict of Interest, is amended by adding the following sentence: "This provision shall apply only if an activity or association described above would interfere with employee's ability to perform on the Project or if it would be possible for him to benefit from any such association, loan, or investment by reason of his employment on the Project. The mere holding of shares in a company shall not constitute an investment within the meaning of this section unless such holding constitutes a substantial control."

7. Section 20, Title to Equipment, is amended by adding the following sentences: "ILRAD shall maintain records of all equipment purchased under this Contract and shall purchase insurance to cover casualty and other loss of such equipment. The cost of such insurance shall be an allowable cost

under this Contract. Equipment shall be defined to include those items costing more than two hundred dollars and having a service life of more than five years."

ARTICLE X

Any notice required to be given by any of the parties hereunder shall be sent in writing addressed as follows:

To UNITED NATIONS DEVELOPMENT PROGRAMME:

Mr. William T. Mashler
Senior Director
Division for Global and Interregional Projects
United Nations Development Programme
One United Nations Plaza
New York, New York 10017
USA

With copy to:

Resident Representative of the
United Nations Development Programme in Kenya

To ILRAD:

The Director
International Laboratory for Research on Animal Diseases
P.O. Box 30709
Nairobi, Kenya

or such other address or addressees as shall be designated by notice given as herein required. Notices hereunder shall be effective when received.

ARTICLE XI

This Contract shall become effective on 20 January 1978, and shall remain in effect for a period of five years unless terminated in accordance with its terms.

ARTICLE XII

This Contract shall consist of the provisions contained in Articles I-XII inclusive, Annex I (Work Plan), Annex II (Sequence of Operations), and Annex III (General Conditions) as amended. Any reference herein to "Contract" shall be deemed to include all of the aforementioned.

IN WITNESS WHEREOF, the Parties hereto have signed this Contract on the dates indicated beneath their respective signatures:

INTERNATIONAL LABORATORY FOR RESEARCH ON ANIMAL DISEASES:	UNITED NATIONS DEVELOPMENT PROGRAMME:
John A. Pino Chairman Board of Trustees ILRAD	William T. Mashler Senior Director Division for Global and Interregional Projects UNDP
20 JAN 1978 date	20 JAN 1978 date

ANNEX I

WORK PLAN

RESEARCH AND TRAINING ON ANIMAL TRYPANOSOMIASIS

This project will be carried out by the UNDP through the International Laboratory for Research on Animal Diseases, Nairobi, Kenya, in co-ordination with other ongoing projects in this general area being carried out by the Food and Agriculture Organization and the World Health Organization of the United Nations.

(1.) Preamble:

As contractor for the UNDP, the International Laboratory for Research on Animal Diseases (ILRAD) will conduct research and training activities on trypanosomiasis. The objectives of this project are set out in the Governing Council Document. Generally the objectives are to elucidate additional information concerning the parasite, the host response directed against the trypanosome and devise and define methods for the immunologic control of the disease. The information that will be developed will have a potential in both human and animal trypanosomiasis.

(2.1) Description of Project:

The project work plan can be divided into two areas which are research and training. Also a part of the activity will be the inter-relation of this project with others when and where appropriate.

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ANNEX I

WORK PLAN

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(2.1) Description of Project:

The project work plan can be divided into two areas which are research and training. Also a part of the activity will be the interrelation of this project with others when and where appropriate.

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(a) Research:

Research to be carried out includes further definition and development of the in vitro propagation system for trypanosomiasis recently reported from ILRAD; studies on the surface antigens and membrane of trypanosomes, their characterization and role in the prevention of the disease; antigenic variation and the identification of commonly occurring antigens and a study of the metacyclic antigens; investigations of the immune response of infected animals and of mechanisms by which this host defense system can be made optimally effective and protective; and to define methods for immunologic protection of animals and man against trypanosomiasis infection based upon the information obtained from the foregoing, research accruing from other ILRAD activities and the activities of other individuals and institutions.

The in vitro propagation technique recently developed at ILRAD has made possible research approaches which were not previously available because of the inability to manipulate the organism in the laboratory separate from the infected animal or man. This research will also have wide spread application in both the study of trypanosomiasis as outlined here, but other important areas including drug evaluation, etc. The research on the in vitro system will be directed to the further development of this important break-through and standardization of the procedures so that they can readily be carried out in other laboratories throughout the world. Also, the technique will make available research approaches and provide material for other aspects of the research proposed in this project. The research will be directed towards defining and standardizing the nutritional and other factors which enable or inhibit the propagation of trypanosomes in culture. In addition, the completion of the life cycle in vitro will be carried out as will be the utilization of the system for studying antigenic variation. All three species of animal pathogenic trypanosomes will be established in culture.

The surface of the trypanosome including its variant antigen and membrane form the interface between the parasite and the infected host and thereby serves as a focal point where the host defense mechanisms can be brought to bear to eliminate the parasite from the infected animal or man. Also, the definition of these important components will make it possible to identify potential immunogens that can be utilized in both serelogic, diagnostic and immunization procedures. Therefore, the surface antigens of the three important animal trypanosome pathogens which are T. brucei, T. congolense and T. vivax will be studied to determine their make up. The possibility of commonly occurring antigens will be investigated and their potential utilization in protection examined. The membrane of the trypanosome will be investigated in these studies with the orientation directed to the defining methods by which this membrane can be attacked and the surface antigens and/or membrane destroyed in the infected animal.

Antigenic variation is a process by which the surface "antigens" of the trypanosome can change during the course of the infection. This mechanism has undoubtedly evolved as a self-preservation process on the part of the parasite to circumvent the effectiveness of the host defense mechanisms. In order to combat this capability on the part of the parasite and to make it optimally susceptible to destruction by the host, an understanding of the mechanisms of antigenic variation and the spectrum and frequency of occurrence of the surface antigens in the metacyclic as well as the animal infective forms is important. The research will be directed to studying this aspect of antigenic variation with the emphasis in 1978 on the metacyclic antigens of T. congolense, mechanisms by which antigenic variation is induced utilizing the in vitro cell culture propagation system, and to utilize molecular biological approaches to define the potential spectrum of antigens and the genetics of its occurrence.

The immune system of the host will be studied to determine the cellular and humoral immune responses, their effectiveness and to define methods whereby this effectiveness can be increased. The research will involve both domesticated and laboratory animal species and will be based upon significant recent ILRAD research findings which provide model systems for carrying out such research activities. The research will involve a determination of the cell kinetics of the lymphoid system, the humoral responses including antibody class and subclass responses and their killing effectiveness, and methods by which the effective components can be augmented or adverse influence on the immune system eliminated.

All the above investigations will indicate possible methods for immunologic protection of man and animal against trypanosomiasis infection. The information accruing from these research activities as well as immunization regimes, incorporation of various antigens or antigen mixtures, etc., will be utilized to develop methods for protection against laboratory and field challenge.

(b) Training:

Training will be an important component of this project and will take a form of specific courses as well as individual instruction. The training activities will be directed towards scientific, professional and technical personnel from African and Latin American countries. Group courses will be given in the use of radioisotopes, in vitro propagation of trypanosomes, diagnostic techniques, trypanosome identification and stabilate production and others. Participants will number from 10-15 with the courses repeated in subsequent years. In addition to the group training, individual in-service training will be carried out for scientists, professionals and technicians who will come to ILRAD to learn specific techniques and work for short periods of time with ILRAD scientists.

(c) Meetings, Conferences and Publications:

The information obtained from the project will be made available to other institutions and individuals where appropriate throughout the world. In addition, ILRAD will maintain a close liaison with both WHO and FAO as well as other institutions with similar or related activities. The results of the research will be published in scientific journals and in ILRAD reports.

(2.2) Organization:

Overall responsibility for the organization and execution of the project rests with the Contractor (ILRAD).

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ILRAD shall:

(a) Be responsible for the detailed planning, administration and execution of the project including timing and budgeting of the various elements, and the preparation of technical reports;

(b) Be responsible directly to the UNDP for all material, equipment and transport furnished to the project by UNDP;

(c) Co-ordinate, as judgement indicates desirable, the efforts of project personnel with that of other agencies and programmes whose activities have a bearing on this project;

(d) Convene a Policy Advisory Committee which will include representatives from developing countries and one each from WHO, FAO, UNEP, and UNDP to advise ILRAD on policies and programme of work, particularly as to emphasis to be given to research and training activities during the life of this Contract. It is emphasized that this Committee shall advise on policy and planning activities as requested by the ILRAD officer who will serve as chairman. It shall not involve itself in operational or supervisory aspects of the project. It shall meet periodically as determined by ILRAD, but at least once a year during the life of the project, at such time and place as ILRAD shall determine. ILRAD will select the Committee members except those from UNDP, FAO, WHO and UNEP.

(2.3) Sequence of Operations:

ILRAD shall commence execution of the project upon receipt of written authorization to do so from the UNDP.

The project shall commence in January 1978, and continue for five years thereafter. The project may be renewed for a further period on agreement of both parties.

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(2.4) Budget:

The estimated cost of the services and facilities to be provided by ILRAD is summarized in the Budget Tables I and II of this Annex. Funds will be provided by the UNDP to the extent of the equivalent of US$3,390,170 to meet these costs in accordance with the provisions of Articles VII and VIII of this Contract.

(2.5) Reports:

In addition to the reports required under Article VIII, paragraphs 2 and 3, ILRAD will submit to UNDP the following:

(a) Annual reports indicating:

(i) progress of the project

(ii) an inventory of project equipment purchased with UNDP funds, and for which title remains with UNDP.

(b) A Final Report indicating:

(i) satisfactory completion of the project; and

(ii) an inventory of project equipment purchased with UNDP funds, and for which title remains with UNDP.

Items 2.5 (a)(ii) and 2.5 (b)(ii) shall be accompanied by a certificate from ILRAD's External Auditors certifying to the correctness of such statement.

Reports will be written in English.

(2.6) Changes in Work Plan:

On the basis of periodic reviews of project activities, the two parties to the project shall as appropriate, confer to determine if any modification to the Work Plan is required. All agreed modifications shall be reflected in amendments to the Work Plan.

(2.7) Steps to be taken at the completion of UNDP assistance to the project:

At the conclusion of the project, UNDP shall consult the Parties involved regarding the disposition of the equipment provided by the UNDP. Such consultation shall not prejudice the right of the UNDP to retain title to that part of the equipment which is not needed for the continued operation of the project, or for activities following directly therefrom, or which is more urgently needed by other UNDP assisted projects.

ANNEX I - WORK PLAN

Table I

BUDGET

RESEARCH AND TRAINING ON TRYPANOSOMIASIS

	1978	1979	1980	1981	1982	Grand Total
A. Research						
1. Salaries and Allowance	410,000	450,450	495,495	545,040	589,555	2,490,540
2. Field, Laboratory and Office Expenses and Supplies	78,000	85,800	94,380	103,818	114,199	476,197
3. Travel	12,000	13,200	14,520	15,972	17,562	73,254
4. Equipment	25,000	28,050	30,855	33,940	37,334	155,179
	525,000	577,500	635,250	698,770	758,650	3,195,170
B. Training and Conferences						
1. Meetings and Conferences	30,000	31,000	30,000	30,000	30,000	151,000
2. Training	8,000	10,000	8,000	8,000	10,000	44,000
	38,000	41,000	38,000	38,000	40,000	195,000
Grand Total	563,000	618,500	673,250	736,770	798,650	3,390,170

Table II

ANNEX I - WORK PLAN

Detailed Budget for 1978

A. Research		
1. Personnel		
	Scientific Staff	$230,000
	Technical Staff	130,000
	Trypanosomiasis Bank Staff	24,000
	Support Staff	26,000
	Sub-total	410,000
2. Operations		
	Consumable laboratory supplies	60,000
	Animals, feeds and drugs	13,000
	General support supplies	5,000
	Sub-total	78,000
3. Travel		12,000
4. Equipment		25,000
	Sub-total Research	525,000
B. Training		
1. Courses and Conferences		30,000
2. Training		8,000
	Sub-total Training and Conferences	38,000
	GRAND TOTAL	563,000

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ANNEX II

SEQUENCE OF OPERATIONS

During the first year of this Contract the following activities will be undertaken:

A) RESEARCH:

(i) In vitro Propagation - The ability to propagate in trypanosome in culture makes available heretofore unapproachable areas for research on the trypanosomes causing the disease in both animals and men. This technique was first reported from ILRAD in 1977 and has been utilized for the propagation of T. brucei. The technique must be further studied, standardized and defined for its use in the research programme and the other species of trypanosomes must be adopted for growth in the culture system.

In 1978 investigations will be carried out to define and standardize the nutritional and other requirements for successful propagation of trypanosomes in culture. Included in the investigations will be the determination of the role that the feeder cell layer plays in supplying the undefined nutritional requirements that enable the trypanosomes to grow. The culture media itself will be examined in depth to determine the media make-up required for optimal propagation of T. brucei and for the establishment of T. congolense and T. vivax in this system. Analysis of such factors as oxygen requirements, glucose, various amino acids, etc., will be carried out utilizing biochemical approaches on newly established cultures as well as cultures that have been maintained for a long period of time. The results of these investigations should make it possible for other laboratories in the world to utilize a standardized procedure for growing trypanosomes in culture so that this important technique can be used in research at other institutions. In addition, this will form the basis for attempts to establish *T. vivax* and *T. congolense* in culture. The findings will also relate directly to the possible establishment of the human pathogens, *T. gambiense* and *T. rhodesiense* in culture.

As indicated above, efforts in 1978 will be made to establish *T. vivax* and *T. congolense* in culture. The same general procedures will be utilized as were carried out for *T. brucei* but initial efforts have indicated that these two pathogens will be more difficult to establish than was *T. brucei*. Results accruing from the study of nutritional and media requirements for propagation will influence the establishment of these two species in culture.

Research will be continued to complete the life cycle of the trypanosome *in vitro*. The present culture system enables the propagation of the animal infective forms with the research to be carried out directed to completing the cycle through the fly forms and back to the blood stream, animal infective forms. When this can be done, one can begin to study a number of parameters relating to the various stages of the organism.

The investigations in 1978 will form the base line for studying relevant aspects of the various trypanosome forms that occur in both the vertebrate and invertebrate hosts.

A part of the research relating to the in vitro propagation and also to antigenic variation, which is described above, will be the utilization of in vitro propagated trypanosomes to study the mechanism(s) of antigenic variation. Utilizing defined cultures of trypanosomes, the influence of a variety of potential inducers for antigenic variation will be carried out. Included will be antibody, media changes, temperature, etc. In addition, the dynamics of specifically identified trypanosomes bearing specific antigenic antigens on their surface will be utilized to determine the growth and cellular kinetics of these various antigenic types in culture.

(ii) Variant Antigens and Membrane:

The surface of the trypanosome is that part of the organism most exposed to the host and the logical site for destruction of the parasite by the host defence mechanisms. One important aspect of the surface antigens is antigenic variation which will be discussed in the following sub-heading. The composition of the surface antigens, their characterization, demonstration of common surface components and use of these components as immunogens in the potential protection of animals against trypanosomiasis for the basis of vaccination. Also important is the identification and utilization of antigens for serologic and diagnostic procedures.

The presently available ones are not specific and pose constraints to optimal study of the epidemiology and other aspects of both the human and animal disease. In 1978, the surface antigens of the three animal infective species of trypanosomes will be further characterized. In addition, efforts will be made to identify common antigens that occur within a given species as well as ones that might cross react among the different species. When identified, such common or possibly unexpressed antigens will be utilized in serologic and diagnostic test procedures and incorporated into experimental vaccines. Included in this study will be the development of appropriate technology for identifying and characterizing the surface antigens.

Little information is available on the make up of the membrane of the trypanosome, which constrains the development of potential methods of damaging the membrane and destroying the trypanosome in the host. The research in 1978 will be directed to development of techniques for labelling, isolating and characterizing the membrane components of the trypanosomes. Such techniques must be specific in their labelling capabilities as well as sufficiently gentle to prevent damage to the membrane components while they are being isolated without distortion of their true characteristics.

T. brucei will be used as the model system for developing the technology with techniques being applied to *T. congolense* and *T. vivax* as well when the procedures have been worked out. It will then be possible to carry out a comparison of the membrane of all three species. In addition, efforts will be made to identify methods by which the membrane might be damaged by the host immune system.

(iii) Antigenic Variation:

Antigenic variation is one of the prime considerations in the inability of the infected host to rid its body trypanosomes. It has been recognized for many years that antigenic variation occurs with the surface glycoprotein changing periodically within the body of a given infected host. Although the phenomenon has been recognized, there is little information regarding the mechanisms of antigenic variation. Therefore, the research to be carried out in 1978 will be directed to studying antigenic variation in terms of the mechanisms responsible for its induction, the genetics of variation and the antigenic composition of metacyclic trypanosomes as they come from infected flies. Relevant to these investigations is the determination of the occurrence of common or frequently occurring antigens.

The initial contact between the animal or man and the trypanosome is when the animal is bitten by an infected tsetse fly or biting fly and the trypanosome introduced into the tissues. Therefore, if one could demonstrate a specific component or components on the surface of metacyclic trypanosomes as they come from the infected fly, such could potentially be useful in protecting animals. The research to be carried out in 1978 will be directed to the elucidation of the surface antigen composition and the stability of surface antigens on metacyclically transmitted *T. congolense*. This will be carried out in co-operation with the Swiss Tropical Institute. In addition to determining the surface composition of the metacyclics, the reversion of trypanosomes of a given antigenic type from infected animals to a common antigenic type or types in the fly will be carried out.

As indicated under the section on *in vitro* propagation above, trypanosomes grown in the laboratory will be studied to determine some of the potential mechanisms causing variation. This will utilize *in vitro* propagated trypanosomes exposed to a number of influences including antibody and others.

To be reported soon from ILRAD will be the isolation of messenger RNA from the cytoplasm of trypanosomes. This mRNA is the message responsible for the production of the surface antigen on the trypanosome. The mRNA isolated can be used to prepare DNA probes that can be utilized for investigating the genetics of antigenic variation. Questions relating to whether the spectrum of variants is coded and transmitted in the germ line or whether it is mutational are important considerations to be investigated. The research in 1978 will be directed to applying the recent findings on mRNA to develop DNA probes for investigating the genetics of antigenic variations. In later years, this approach will be further utilized to determine the occurrence of common or frequently occurring antigens within a given trypanosome population and will ultimately be applied to epidemiologic investigations. In this regard, ILRAD will begin shortly long term epidemiologic investigations for developing baseline information useful for this research as well as other research carried out at the institution. The molecular biological approach to research on the disease will apply very powerful tools for obtaining answers that are difficult or impossible to otherwise obtain.

(iv) <u>The Immune System</u>:

In controlling trypanosomiasis, the immune system of the host is either circumvented or is ineffectual in destroying trypanosomes. Research to be carried out at the ILRAD on this project will be directed to determining the cellular and humoral immune responses in infected mice and cattle. The responses will be investigated and the effectiveness of both the antibody and the cell mediated arms of the immune system will be examined. The results obtained in 1978 from such investigations will lead in later years to the potential augmentation of the effective portions of the immune system or prevention of the immunosuppressive influence of the trypanosome and/or its products.

The research in 1978 will involve the determination of the cellular responses in tolerant and non-tolerant animals. In addition, the antibody responses including antibody class and sub-classes will be examined. The effectiveness of both the cells and the antibodies to destroy trypanosomes will be investigated in a variety of test situations. This research will use mice as well as cattle for investigation. The latter will be carried out on tolerant and non-tolerant cattle which ILRAD has under investigation in West Africa.

(v) Immunologic Protection:

Various procedures will be examined for potential immunologic protection of animals against trypanosomiasis challenge. The antigens which have been discussed in earlier sections of this annex will be utilized in immunization trials. In addition, various components of trypanosomes will be isolated and incorporated into experimental vaccination regimes to determine the potential effectiveness of such on preventing experimental infection.

This particular aspect of the research project will not receive a great deal of attention in 1978 since the identification of the material to be utilized as well as the host defence mechanisms that should be stimulated for protection will accrue from the investigations described above.

Continuation:

The general research approaches are described in annex I with more detailed descriptions for 1978 given above. The research will continue in the general areas indicated for following years of the project with the specific research to be carried out dictated to a considerable degree by the results obtained, other research at ILRAD and the results of others. Emphasis will be given throughout the project period to the effective protection of men and animals against trypanosome challenges as well as the evolution of materials and information that have relevance to other methods of trypanosomiasis control and investigation.

B) TRAINING:

The training to be carried out under this project involves both group training as well as individual instruction. A number of courses will be offered during the course of the project with the subject matter relating to specific essential components of trypanosomiasis and its control. The trainees will come from the developing countries in Africa and Latin America and will be given intensive training in specific areas.

In 1978 a course will be offered on the utilization of radioisotopes in trypanosomiasis research. The utilization of radioisotopes offer powerful techniques for answering relevant questions relating to both the human and animal disease. The course will be directed to training scientists in the potential application of radioisotopic techniques, methods for handling isotopes including safety considerations and specific training in techniques that can be applied to a variety of approaches to investigations that can be carried out in developing countries including immunology, biochemistry, etc.

In addition to courses offered over the project period, individual instruction will be carried out for individual scientists, technicians or professional persons from the developing countries. The individuals will come to ILRAD for varying periods of time up to several months to work with ILRAD scientific staff and learn specific techniques and research approaches appropriate to their needs in their home countries. Utilized in this portion of the training will be the various physical facilities, equipment and the broad range of staff at the institution.

Continuation:

The training activities will be continued over the course of the project. Other courses including diagnostic techniques and their application in the field, in vitro propagation of trypanosomes, trypanosome identification, storage and stabilate production, etc., will be the subject for other courses. Additional training needs and potential will be developed as appropriate to the requirements of the developing countries. In addition, the individual instruction for scientists and professionals from the developing countries will be continued through the course of this project. The subjects to be covered will be tailored to meet the requirements of their home countries.

C) PUBLICATION:

The results of the research will be made available to all the interested persons in the form of scientific journal publications, ILRAD reports and forums and meetings for discussions with individuals from other institutions.

ANNEX III

GENERAL CONDITIONS

01 Privileges and Immunities of Contractor and Contractor's Personnel

The UNDP will obtain for the Contractor exemption from or reimbursement for the cost of any taxes, duties, fees or levies which may be imposed in the country on salaries or wages earned by the Contractor's foreign personnel in the execution of the Project and on any equipment, materials and supplies which the Contractor may bring into the country in connexion with this Project or which after having been brought into the country may be subsequently withdrawn therefrom. It is agreed that the UNDP shall not be liable beyond the amount of said taxes, duties, fees and levies for any failure or delay in obtaining exemption or reimbursement for the Contractor or his foreign personnel.

The UNDP agrees to use its best efforts to obtain for the Contractor and his personnel (except Government nationals employed locally), to the extent granted by the Government to UNDP staff members, such facilities and immunities as the Government has agreed to grant to contractors performing services for the UNDP within the country and to their personnel. A copy of the provision relating hereto in the Project Document concerning this Project is herewith transmitted to the Contractor for his information as Annex A to this Contract.

02 Waiver of Privileges and Immunities

Any provision, whether in an Agreement, Project Document, or any other instrument, to which the recipient Government is a party, by which the recipient Government confers benefits upon the Contractor and his personnel in the form of facilities, privileges, immunities, or exemptions by reason of his performance of services for the UNDP on this Project, may be waived by the UNDP where, in its opinion, the immunity would impede the course of justice and can be waived without prejudice to the successful completion of the Project or to the interests of the UNDP.

03 Confidential Nature of Documents

All maps, drawings, photographs, mosaics, plans, reports, recommendations, estimates, documents and all other data compiled by or received by the Contractor under this Contract shall be the property of the UNDP, shall be treated as confidential and shall be delivered only to the UNDP Project Manager or other authorized officials on completion of work under this Contract; their contents shall not be made known by the Contractor to any person other than personnel of the Contractor performing services under this Contract without written consent of the UNDP.

04 Independent Contractor

(1) The Contractor shall have the legal status of an independent Contractor vis-à-vis the UNDP.
(2) Neither the Contractor nor his personnel shall be considered an employee or agent of the UNDP.
(3) Unless otherwise provided for in this Contract, the UNDP shall not be liable for claims of any kind arising in connexion with the performance of this Contract.

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05 Contractor's Responsibility for Employees

The Contractor shall be responsible for the professional and technical competence of his employees and will select for work under this Contract, reliable individuals who will perform effectively in the implementation of the Contract, respect the local customs and conform to a high standard of moral and ethical conduct. The Contractor and his employees shall conform to all applicable laws, regulations and ordinances promulgated by legally constituted authorities of the Government.

06 Assignment of Personnel

The Contractor shall not assign any personnel other than that referred to in this Contract for the performance of work in the field without the prior written approval of the UNDP. Prior to assigning any other personnel for the performance of work in the field, the Contractor shall submit to the UNDP for its consideration the curriculum vitae of any person the Contractor proposes to assign for such service.

07 Removal of Personnel

(1) Upon written request by the UNDP, the Contractor shall withdraw from the field any personnel provided under this Contract and shall replace such personnel by others acceptable to the UNDP if the UNDP so requests.
(2) Such request for withdrawal or replacement shall not be considered as termination in part or in whole of this Contract under the provisions of Section 14 of the General Conditions.
(3) All costs and additional expenses resulting from any withdrawal or replacement for whatever reason of any of the Contractor's personnel shall be at the Contractor's expense.

08 Assignment

The Contractor shall not assign, transfer, pledge or make other disposition of this Contract or any part thereof or of any of the Contractor's rights, claims or obligations under this Contract except with the prior written consent of the UNDP.

09 Sub-Contracting

In the event the Contractor requires the services of sub-contractors, the Contractor shall obtain the prior written approval and clearance of the UNDP for all sub-contractors. The approval of the UNDP of a sub-contractor shall not relieve the Contractor of any of his obligations under this Contract, and the terms of any sub-contract shall be subject to and be in conformity with the provisions of this Contract.

10 UNDP Privileges and Immunities

Nothing in or relating to this Contract shall be deemed a waiver of any of the privileges and immunities of the UNDP.

11 Officials not to Benefit

The Contractor warrants that no official of the United Nations Development Programme or the Government has been or shall be admitted by the Contractor to any direct or indirect benefit arising from this Contract or the award thereof.

12 Language, Weights and Measures

Except as may be otherwise specified in the Contract, the English language shall be used by the Contractor in all written communications to the UNDP with respect to the services to be rendered and with respect to all documents procured or prepared by the Contractor pertaining to the work. The project surveys shall be based on the metric system of weights and measures, and estimates of quantities involved shall be made and recorded in metric units except as otherwise specified in the Contract.

13 Force Majeure; Other Changes in Conditions

(1) Force Majeure as used herein shall mean acts of God, laws or regulations, industrial disturbances, acts of the public enemy, civil disturbances, explosions and any other similar cause of equivalent force not caused by nor within the control of either party and which neither party is able to overcome. As soon as possible after the occurrence of any cause constituting force majeure, the Contractor shall give notice and full particulars in writing to the UNDP of such force majeure if the Contractor is thereby rendered unable, wholly or in part, to perform his obligations and meet his responsibilities under this Contract. Subject to acceptance by the UNDP of the existence of such force majeure, the following provisions shall apply:

(a) The obligations and responsibilities of the Contractor under this Contract shall be suspended to the extent of his inability to perform them and for as long as such inability continues. During such suspension and in respect of work suspended, the Contractor shall be entitled only to reimbursement by the UNDP against appropriate vouchers of the essential costs of maintenance of any of the Contractor's equipment and of per diem of the Contractor's personnel rendered idle by such suspension.

(b) The Contractor shall within fifteen (15) days of the occurrence of the force majeure submit a statement to the UNDP of estimated expenditures for the duration of the period of suspension.

(c) The term of this Contract shall be extended for a period equal to the period of suspension taking, however, into account any special conditions which may cause the time for completion of the work to be different from the period of suspension.

(d) If the Contractor is rendered permanently unable, wholly, or in part, by reason of force majeure to perform his obligations and meet his responsibilities under this Contract, the UNDP shall have the right to terminate this Contract on the same terms and conditions as are provided for in Section 14, "Termination," except that the period of notice may be seven (7) days instead of thirty (30) days.

(e) For the purpose of the preceding sub-section, the UNDP may consider the Contractor permanently unable to perform in case of any period of suspension in excess of ninety (90) days. Any such period of ninety (90) days or less shall be deemed temporary inability to perform.

(2) The Contractor shall notify the UNDP of any other changes in conditions or the occurrence of any event which interferes or threatens to interfere with his performance of the Contract. On receipt of such notice, the UNDP shall take such action as in its sole discretion it considers to be appropriate or necessary in the circumstances.

14 Termination

The UNDP may terminate this Contract, in whole or in part upon thirty (30) days notice to the Contractor. Upon receipt of notice of termination, the Contractor shall take immediate steps to bring the work and services to a close in a prompt and orderly manner, shall reduce expenses to a minimum and shall not undertake any forward commitment from the date of receipt of notice of termination. In the event such termination is not caused by the Contractor's negligence or fault, no payment shall be due from the UNDP to the Contractor except for work and service satisfactorily performed, for the cost of repatriation of the Contractor's personnel, for expenses necessary for the prompt and orderly termination of the work, and for the cost of such urgent work as is essential and as the Contractor is asked by the UNDP to complete.

15 Workmen's Compensation and other Insurance

(1) The Contractor shall provide and thereafter maintain appropriate workmen's compensation and liability insurance, with respect to and prior to the departure for overseas employment under this Contract of all employees who are hired outside the country of the Government and who are not citizens of the said country.

(2) The Contractor shall provide and thereafter maintain insurance in an appropriate amount against public liability for death, bodily injury or damage to property arising from the operation in the country in which the contract is to be performed of motor vehicles, boats or airplanes owned or leased by the Contractor. The Contractor warrants that similar insurance shall be provided and maintained in respect of all vehicles or boats owned or leased by foreign personnel of the Contractor and used by them in the country in which the Contract is to be performed.

(3) The Contractor shall comply with the labour laws of the Government providing for benefits covering injury or death in the course of employment.

(4) The Contractor shall arrange that all insurance policies other than that for workmen's compensation, referred to in the preceding paragraphs of this Section, shall include the UNDP, and where appropriate, the sub-contractor concerned, together with the Contractor as the insured.

16 Indemnification

The Contractor shall indemnify, hold and save harmless and defend at his own expense the UNDP, its officers, agents, servants and employees from and against all suits, claims, demands, and liability of any nature or kind, including costs and expenses arising out of acts or omissions of the Contractor or his employees or sub-contractors in the performance of this Contract. This clause shall extend to claims or liability in the nature of workmen's compensation claims or liability or those arising out of the use of patented inventions or devices.

17 Disputes - Arbitration

Any dispute arising out of the interpretation or application of the terms of this Contract shall, unless it is settled by direct negotiations, be referred to arbitration in accordance with the rules then obtaining of the International Chamber of Commerce. The UNDP and the Contractor agree to be bound by any arbitration award rendered in accordance with this section as the final adjudication of any dispute.

18 Conflict of Interest

No employee of the Contractor assigned to perform work under this Contract shall engage, directly or indirectly, either in his own name or through the agency of another person, in any business, profession, or occupation in the country of the Government; nor shall he make loans or investments to or in any business, profession, or occupation in said country.

19 Source of Instruction

The Contractor shall neither seek nor accept instructions from any authority external to the UNDP in connexion with the performance of services under this Contract. The Contractor shall refrain from any action which may adversely affect the UNDP and shall fulfill his commitments with fullest regard for the interest of the UNDP.

20 Title to Equipment

Title to any equipment and supplies which may be furnished by the UNDP shall rest with the UNDP and any such equipment shall be returned to the UNDP at the conclusion of this Contract or when no longer needed by the Contractor. Such equipment, when returned to the UNDP, shall be in the same condition as when delivered to the Contractor, subject to normal wear and tear.

21 Copyright, Patents and Other Proprietary Rights

(1) The copyright in all countries and all proprietary rights in the manuscripts, records, reports and other materials, except pre-existing materials, publicly or privately owned, collected or prepared in the course of the execution of this Contract, shall become the sole property of UNDP, which shall have the sole right to publish the same in whole or in part and to adapt and use them as may seem desirable, and to authorize all translations and extensive quotations therefrom. If the Contractor desires to incorporate any previously published or unpublished manuscript(s) or other materials, he shall obtain permission for the publication, use and adaptation in any language free of cost to UNDP from the persons in whom any existing copyrights therein may be vested and produce evidence to UNDP of such permission.

(2) The Contractor agrees that he will forthwith disclose and assign to UNDP all discoveries, processes, or inventions, made or conceived in whole or in part by him alone or in conjunction with others relating to and arising out of the work, and the said discoveries, processes, or inventions, shall become and remain the property of UNDP, whether or not patent applications are filed thereon. Upon request of UNDP and at its expense, the Contractor agrees to make application for letters patent of any country on said discoveries, processes or inventions, and to forthwith assign all such applications and the letters patent thereon to UNDP, its successors and assigns, or its orders; and further, to give UNDP and its attorneys all reasonable assistance in preparing said application and drawing the claims and from time to time, upon request, to execute all the claims and from time to time, upon request, to execute all papers and do all things required in order to protect the rights of UNDP and vest in it or its successors or assigns said discoveries, processes, inventions, applications or letters patent.

22 Use of Name, Emblem or Official Seal of the UNDP

Unless authorized in writing by the UNDP, the Contractor shall not advertise or otherwise make public the fact that he is performing, or has performed, services for the UNDP, or use the name, emblem or official seal of the UNDP or any abbreviation of the name of the UNDP for advertising purposes or for any other purposes.

23 Bankruptcy

Should the Contractor be adjudged bankrupt, or should the Contractor make a general assignment for the benefit of his creditors, or should a receiver be appointed on account of the Contractor's insolvency, the UNDP may, without prejudice to any other right or remedy it may have under the terms of this Contract, terminate this Contract forthwith by giving the Contractor written notice of such termination.

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UNITED NATIONS DEVELOPMENT PROGRAMME

Report of the

UNDP Consultant Mission

To Review

Research and Training in the

Development of Quality Protein Maize, Phase III (GLO/75/007)

at the International Maize and Wheat Improvement Center (CIMMYT)

12 - 15 June 1978

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I Terms of Reference of Mission

II Quality Protein Breeding in Maize Review and Progress Report at CIMMYT

III Chemical Research and Analytical Service

INTRODUCTION

In June of 1978 a review was made of the project funded within the framework of the UNDP and entitled, Research and Training in the Development of Quality Protein Maize, GLO/75/007. This review was carried out at the headquarters of CIMMYT in Mexico and covered all phases of the maize research program related to this project.

Based on the terms of reference (copy attached) developed for this review, the team has prepared its findings and grouped them into four sections which deal directly with specific aspects of the project.

Section I reviews the progress made toward the attainment of the current objectives as developed in 1970.

Section II projects the types of information that must be obtained concurrent with the initial phases of development of commercial production in actual on-farm experiences and assesses the feasibility of the introduction of currently available material.

Section III assesses the original objectives of the project in the view of current understanding of health and nutrition and makes projections for future project developments.

Finally, Section IV brings to light certain consideration which must receive attention to effectively promote interdisciplinary interaction.

The major points made in these sections have been summarized into five recommendations:

1. It is recommended that in any future phase of this project the objectives be broadened to include nutritional qualities of maize which

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go beyond the simple modification of protein quality as the basic consideration. It is further recommended that in any future phase of this project that, in addition to disciplines already represented, expertise in nutrition be incorporated.

2. It is essential that continued emphasis be placed on the agronomic improvement of the selected maize populations and that the maintenance of improved quality protein in these populations remain as an integral part of the project.

3. Training of maize specialists from participating countries must remain as a high priority function within the project

4. That additional steps including expanded bioassay procedures be taken to verify the validity of the laboratory procedures presently used for the identification of improved protein quality in maize.

5. It will be necessary to obtain data on a variety of factors which have a bearing on the socio-economic perspectives. Included in these will be on-farm trials, user acceptance, economic advantages, public policy considerations, public image and competitive advantages of the improved maize in the various agricultural systems.

The members of the mission were:

D. D. Harpstead, Chairman, Department of Crop and Soil Sciences, Michigan State University;

P. R. Payne, Reader in Applied Nutrition, Department of Human Nutrition, London School of Hygiene tne Tropical Medicine; and

Per Pinstrup-Andersen, Senior Research Fellow, Economic Institute, Royal Veterinary and Agricultural University, Copenhagen, Denmark.

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Members of the mission wish to express their sincere appreciation and grateful thanks to all concerned at CIMMYT for the courtesy, hospitality and assistance extended to them in carrying out the tasks of this mission.

The UNDP headquarters representative, Dr. K. N. Satyapal, who was scheduled to participate in this review, had to cancel his travel to Mexico due to a freak accident to his eye on the eve of his departure from New York.

The mission report is rather short, covering the salient points of the review. There was no need for a lengthy treatment on the detailed objectives of the project, as these are covered in two excellent background documents prepared by CIMMYT under the titles, "Quality Protein Breeding in Maice at CIMMYT" and "Chemical and Analytical Service" respectively, both of which are appended as Annexes II and III to this report.

SECTION I. REVIEW OF CURRENT PROJECT

Plant Breeding for Protein Quality

The history of the development of maize with a modified protein of enhanced nutritional value is a matter of record. The role of CIMMYT, starting in 1970, in breeding improved maize varieties which incorporated the modified protein has also been recorded in numerous progress reports and technical summaries. Only a broad overview of the plant breeding methodologies and most obvious results will be noted in this review of the programme.

Several basic breeding strategies were adapted at the time of the project initiation. Paramount among these was the goal to develop a series of broad genetic based populations of maize. Each population (or composite) in this series would include the best known sources of genetic materials from the various climatic regions of the world. A second objective was the continued improvement of these composites in terms of yield and agronomic usefulness without unduly restricting the genetic base and still retaining the capacity of being reproduced as open polinated varieties as opposed to seed production procedures required for hybrid production. Excellent progress has been made toward the achievement of these goals.

The objective of incorporating a genetically modified protein content in superior maize populations was set up to run in harmony with and not in competition to the agronomic improvement of the basic maize populations. These procedures have been described in detail in CIMMYT project reports.

At the time of initiation of this project, in 1970, it had become apparent that modified protein in maize could not be utilized in commercial production unless it could be incorporated into varieties with superior

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yielding capacities. Furthermore, the agronomic and physical characteristics of these varieties must be equal to the commonly grown, normal protein varieties locally available.

This requirement presented significant challenges to the breeding programme inasmuch as the classical modified protein types in maize had been in the well known soft endosperm types as compared to the more commonly produced flint or dent kernel types.

CIMMYT adopted four principle breeding strategies in its search for solutions to this problem. These were: 1) the search for new mutants, 2) recurrent selection for improved protein quality without the use of genetic mutants, 3) interaction between endosperm mutants, and 4) the selection of genetic modifiers for kernel hardness. Only strategy number four has proven to be a practical approach to the multiple problems that needed to be solved in the initial phases of the project before the successful commercial exploitation of the improved maize protein could be predicted.

Based on currently available technologies and through the experience gained in the CIMMYT laboratories, the decision to concentrate breeding efforts on the selection of genetic modifiers of kernel hardness appeared to be entirely justified. However, in terms of basic research needs, objective number two, i.e., recurrent selection for improved protein quality without the use of genetic mutants, appears to warrant further research.

Results To Date

Starting in 1970 with superior but highly diverse and variable basic maize populations, the CIMMYT maize breeding programme has developed varieties which appear to be well adapted to most of the maize producing regions of the developing world. At the same time, they have successfully incorporated the genetic systems for protein modificat on into 16 of these superior populations.

The improvement of these populations has not been limited to the simple modification of protein quality. Appropriate selection procedures brought this quality together with greatly increased kernel hardness and greatly reduced incidence of ear rot and kernel mold. The harder kernels were not as susceptible to insect damage and exhibit a near-normal physical appearance. This represented a significant advance over the original materials entering the programme.

It would be possible to develop an extensive discussion relative plant breeding approaches that are being employed for the improvement of yield and variety adaptation. In a few words, it is sufficient to note that programmes of half-sib and full-sib family selections are based on the established genetic theory of additive genetic variance for the characteristics sought in the improved populations and have been successfully employed in other maize breeding programmes. It can be further noted that these plant breeding procedures are specifically designed to produce superior maize composites which may or may not be directly useful as a production variety in a specific region of the world but would in any event provide a superior genetic source for further local improvement and/or a base for the production of locally adapted maize hybrids where desired.

Selection Methodologies

Two of the plant breeding and characteristic identification strategies are worthy of further comment. One of the important factors leading to the

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improvement of yielding ability and agronomic performances within populations has been the capacity of CIMMYT to test the component materials over a variety of environments and to utilize this information in the selection of breeding materials to be combined to make the advanced generations in each new composite cycle.

Evaluation of Protein Quality

The programme has in general relied upon chemical determination of two amino acids lysine and tryptophan as indirect indicators of the nutritional quality of maize protein. To the extent that direct measurements of biological utilization by animal feeding trials would have been impossibly time consuming and expensive as a basis for selection during the development of new varieties, the decision to use indirect indicators was for all practical purposes obligatory. Chemical methods for measuring lysine and tryptophan have been developed and applied in a very efficient manner, using techniques appropriate to the various stages of selection, and little more could be done to improve the accuracy or efficiency of the system. Nevertheless, the project objectives clearly refer to the need to improve the nutritional quality of maize protein; and it is, therefore, necessary to appraise the evidence for the extent to which this has been achieved.

Problems arise for two reasons:

a) It is desirable from the general nutritional point of view to increase somewhat the level of tryptophan in normal maize because this amino acid reduces the requirement for one of the vitamins (niacin), the

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lack of which causes pellagra. However, tryptophan levels are only poorly correlated with biological assays for protein quality.

b) Although lysine is known to be the amino acid which determines the nutritive value of both normal and modified maize, chemical determination of lysine may in some circumstances overestimate the amount which is available to an animal. There is evidence from the work which has been done in collaboration with other institutions, that lysine availability may be reduced in some of the converted varieties.

Whilst this does not invalidate the use of lysine level as a selection criterion, it does underline the necessity for direct biological evaluation by animal feeding trials of all materials at some stage prior to their release.

Training of Developing Country Participants

Since its very inception this project have given high priority to the need for developing a cadre of qualified cooperators in the participating countries. This phase of the project has been highly successful and continues to be a main cornerstone of international development. The existence of trained personnel in the local maize programme of the world also contributes significantly to the broader objective of CIMMYT's basic maize improvement programmes by providing cooperative data collection and observation records needed for the best possible decision making at the central research site.

The training of personnel is a never ending process. These individuals return to their home countries with higher skill levels and frequently move into higher level positions which remove them from the settings for which they were trained. No end point in the need for a vigorous training programme can be foreseen at this time.

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Maintaining a continuing relationship with the trainees is also a vital function of CIMMYT. This will become increasingly important in the prediction and evaluation of modified nutritional quality in locally selected breeding materials and in materials which are released for local commercial production.

In general, the plant breeding strategies employed to date have resulted in excellent progress toward the original goals of the project and have not limited the apparent opportunities for future improvement in these basic genetic stocks. It is clearly recognized that the presently selected varieties and any future selections must still face the challenges of biological usefulness, farmer acceptance and practical value in commercial production. The participant training of this project have been highly successful and will continue to be an important function within this project.

SECTION II. FEASIBILITY OF COMMERCIAL PRODUCTION

Introducing currently available Maize materials

The feasibility of introducing new technology into agricultural production in market-oriented economics depends on the individual farmers' willingness and ability to adopt the technology as well as institutional arrangements and public policy. Generally, the farmer will adopt new technology if he expects to be able to increase net revenues, reduce risks or in any other way achieve his personal goals provided that adoption is not made impossible by the existence of constraints. Hence, the feasibility of introducing ucrrently available high quality protein maize varieties developed by the project under review depends on the expected profitability to the farmer, the expected impact on production risk and the existence of constraints relative to profitability, risk and constraints associated with alternative action, e.g. adopting new varieties of normal maize or continuation of the use of currently used varieties. The relative profitability, in turn, depends on yields, costs of production and the price that the farmer can obtain relative to yields, production costs and prices associated with other varieties. Each of these factors are briefly discussed below.

Yields

The yields of currently available high quality protein maize varieties under existing farming conditions are not yet known. The project has progressed to the point of carrying out a limited number of international yield trials under experimentally controlled conditions. On the basis of these trials, it appears that the high quality protein maize varieties suffer from a yield disadvantage of 5-10% when compared to the highest yielding improved varieties

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of normal maize adapted for the particular locations. While some of this yield handicap may be explained by differences in dry matter accumulation during filling of the grain, it should be emphasized that the high quality protein maize i n each location was compared to the best normal variety adapted to the individual location. Whether the absolute yield handicap can be completely overcome is not known but this seems unlikely. It is not known if the current yield difference between high quality protein maize and the best nromal maize as found in controlled yield trials will actually show up under existing farming conditions. There is reason to believe that yield variation at the farm level caused by a variety of factors beyond the control of the farmer will in fact prohibit the identification of any small yield difference between normal and high quality protein maize under existing farming conditions. This, however, can only be a hypothesis at this point in time. To test the hypothesis and thus predict whether farmers will prefer normal maize to high quality protein maize on the basis of relative yields,there is an urgent need for extensive on-farm trials.

It seems reasonable to believe that the high quality protein maize will outyield non-improved varieties of normal maize in most locations. However, again on-farm testing is needed.

In the case that high quality protein maize outyields currently grown varieties but shows a clear yield handicap when compared to the highest yielding available variety of normal maize under farming conditions, governments may choose to remove higher yielding varieties of normal maize and thus accelerate the adoption of high quality protein maize. Such action might be justified where the social value of the higher quality protein

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exceeds the social value of the quantity of normal maize foregone by not introducing the higher yielding varieties of normal maize. The acceptable trade-off between quantity and utilizable protein of maize is strictly a national matter and may be expected to be determined on the basis of the existing nutritional situation. In order to assist national institutions regarding decisions on the preferred nutritional characteristics of new maize varieties and thus establish goals for national breeding and other adaptive research, as well as decisions on varietal release and related public policy, it is recommended that any follow-up to the project under review include work to gather and analyze information regarding current energy and protein intakes, dietary patterns and related issued for a number of countries. While such work, as part of a follow-up project, would provide information of immediate value to the collaborating institutions and CIMMYT, its primary purpose would be to demonstrate its utility and thus promote further work by national institutions. Such work would logically be integrated with ongoing activities in the agro-economic area. The relevant data from the farm sector might thus be collected as part of ongoing farm surveys. It should be emephasized that such work will require expertise from the ap plied nutrition area. In addition to providing information regarding the protein issue, the above work might also assist in detecting the neds for incorporation of other nutrition related factors into new maize varieties. This issue is further discussed in a subsequent section of the report.

Instead of removing higher yielding varieties of normal maize, governments would have a number of other policy instruments and measures

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at their disposal. A discussion of these would fall outside this report. However, the importance of assisting national institutions in obtaining relevant information to assist policy making should be stressed. In particular, it is important that information from the farm and consumer levels such as that obtained through on-going agro-economic research be utilized for policy formulation.

We should finally stress that even in the case of no detectable yield difference between normal and high quality protein maize at the farm level certain policy measures would be needed to assure that farmers would select one over the other. The difference in nutrition quality may or may not be sufficient to convince farmers to choose high quality protein maize over normal maize at the same yields. To the extent that some of the maize is used for swine feed on the maize producing farm, the demonstration effect might well convince the farmer to plant high quality protein maize instead of normal maize. These and related issues would, however, have to be dealt with locally in the same way as the introduction of other new agricultural technology.

Cost of production

Except for work carried out on Opaque-2 maize in Colombia in 1970, no studies are available on the cost of producing high quality protein maize relative to the cost of producing normal maize. The Colombian study concluded that, except for slightly higher seed costs, no differences in production costs per unit area would be likely. There is, in our opinion, no reason to believe that the production costs per unit of land would differ between normal and high quality protein maize. It might be useful, however, to carry out comparative studies of production costs in connection with on-farm trials. Production costs per unit of output would differ if yields differ.

Production risk

Currently available high quality protein maize varieties contain the same agronomic characteristics as their normal counterparts. Hence, there is no reason to believe that there would be any difference in production risk between the two sets of varieties.

Storage

High quality protein maize has traditionally been more susceptible to insect damage during storage than normal maize. This has been a major concern in connection with on-farm storage because it implies larger storage losses and higher risk. However, insect damage during storage is a much lesser problem for the modified, hard endosperm material than for the original soft endosperm Opaque-2 maize. It is recommended that comparative studies be carried out to determine the extent to which currently available modified materials are more susceptible than normal hard endosperm maize. It is further recommended that attempts be made to include work to develop improved on-farm storage practices for high quality protein maize in ongoing research on storage of farm products by FAO and others.

Consumer acceptance

The appearance of the modified material is sufficiently close to the appearance of normal maize to assume that there will be no problems of consumer and producer acceptance on the grounds of appearance. Likewise, available information appears to indicate that no significant differences exist regarding cooking characteristics. Additional analysis of the latter issue is, however, warranted to assure that traditional preparation methods can be used or to suggest changes in these methods, if necessary. On the basis of available information, it appears that the modified materials will be as acceptable to consumers as normal maize at equal prices. The higher protein quality is not likely to be a sufficient incentive for low income consumers to pay a price premium for the high quality protein maize.

Usage as livestock feed

In commercial livestock production, the choice of feed stuffs is determined by relative prices of available feed stuffs and their impact on production efficiency. The demand for high quality protein maize for livestock production will therefore depend on relative prices and production efficiency of all available feed stuffs including high quality protein maize. Feed prices, and hence the economic feasibility of using high quality protein maize for commercial livestock production will vary considerably over time and among locations. Previous work in Colombia and elsewhere has established quide lines for the relative nutritional values and prices for Opaque-2 maize, normal maize and other sources of protein for use in decision making regarding the feasibility of using Opaque-2 maize for swine feed.

High quality protein maize may be of considerable value in swine production among semi-subsistence farmers where maize traditionally is a m ajor source of feed and where other protein sources are scarce.

SECTION III. REVIEW OF THE ORIGINAL OBJECTIVES AND GUIDELINES FOR THE FUTURE

Introduction

Since 1970 there has been a substantial shift in opinion about the general nature of the nutritional deprivation suffered by people in the developing countries. In large part this has been due to new evidence pointing to the relatively greater importance of deficits in energy rather than of protein in human diets. As well as this, however, it is now much more clearly understood that these problems are in the main conditioned by deficiencies in the distribution of food and basic health facilities rather than by a failure of total production to keep pace with needs.

Current view of the causes of malnutrition

In most communities evidence points to the general importance of insufficient quantities of food consumed rather than a fundamentally inadequate balance of nutrients. Although general statements are dangerous, it does seem as if the poor would benefit most from an increased energy intake whilst maintaining a certain minimum level of protein, rather than from a fundamental change in the nutritional quality of the diet.

In respect of protein, the evidence for this is the following nature:

1) the relative proportion of protein: energy now known to be required for normal growth and maintenance is much lower than was once believed. Prior to 1965 an appropriate level of protein for young children suggested in various reports published by WHO and FAO was between 8 and 10 percent of the dietary energy. After 1965, the suggested level dropped to little more than half of this (5-6%). Changes suggested by subsequent research have been relatively minor, and in retrospect it seems that the implications

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have only slowly been recognized not so much by main line nutritionists as by those working in associated professions such as food science and technology as well as agriculture.

2. Over the past two decades there has been a gradual accumulation of information about the diets actually consumed by the poor, and of the effects on health of interventions designed to change them. Generally, it is found in a wide range of countries that the amounts of energy consumed by the nutritionally most vulnerable - small children, pregnant and nursing women, are seriously low, to the point that even if extra protein, or protein of improved quality were made available, in the absence of increased energy this would simply be used as an expensive source of calories and would be likely to have little if any impact on nutritional status.

This assessment has been reinforced by the lack of impact of numerous attempts to change the balance of nutrients of the diets of whole communities. Of particular relevance to the quality protein maize programme has been the demonstration that the addition by lysine to wheat in Tunisia, and to rice in Thailand over a period of 5 years had no demonstrable effect on the growth or health of pre-school age children.

3) Specifically with regard to young children, it is now understood that the factors which limit intake may not be simply lack of sufficient staple foods so much as the effects on appetite of frequent incidents of infections, compounded by the limitations of available time for and understanding of the problems of child care. In this context, the qualities in which staple foods are often defective are those which affect their volume and consistency when cooked and prepared. This once more suggests that the introduction of

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a cereal variety with improved quantity or quality of protein may fail entirely to have an impact even where the levels in the traditional varieties are below requirements unless the introduction is accompanied by some other changes which will overcome the constraints of bulkiness.

Finally, it is also apparent that the direct benefits of an improved protein variety would only be realized for those sections of communities who because of poverty are constrained to consume diets virtually restricted to cereals and starchy staples.

The addition of even quite small amounts of legumes or of animal protein sources to conventional cereals results in complementation of protein quality up to levels which are not only adequate from the point of view of requirements, but may be indistinguishable from those obtained with improved varieties.

Viewed against this background of contemporary ideas, the objectives of the quality protein maize programme through the project phase GLO I to III would be seen by many, if continued to a fourth project stage, as at best limited, and at worst irrelevant to the problem of malnutrition. It is also seen by some to be important to stress that this would still be true even had there been no change in estimates of the amounts of protein and energy needed to sustain health. We feel, therefore, that it is necessary at this stage to address the following questions.

Given that CIMMYT has now acquired an effective system for the genetic improvement of maize with respect to one of its nutritional characteristics, how can the potential that this represents for improving nutritional quality best be utilized? Secondly, what institutional changes both in terms of professional skills and capacities and of an organization and extension will be needed to realize these benefits?

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Significance of the Improvement in Protein Quality which has been achieved

As mentioned earlier, the currently accepted estimates of protein and energy needs suggest that for the nutritionally vulnerable groups an appropriate minimum level of utilizable protein would be in the region of 5.5%. This figure would be correct for a protein which was used by the body in a completely efficient way, a condition not in practice satisfied by any dietary component. For real food items, therefore, we need to know both the total amount of protein and its quality, i.e. the degree to which it approached the ideal. Requirements could be met in practice by any combination of quantity and quality which together are equivalent to 5.5% of a perfect protein: e.g. by 11% of a protein with a quality of 50%. When evaluated in this way, many varieties of conventional maize fall somewhat short of the required level (typically about 4.7%). On the other hand, the CIMMYT improved varieties range from 8.3% to 9.6%. Such high levels represent a considerable degree of "overshoot" which would by itself offer no known benefit to health other than would be provided by an improvement of the diet to the 5.5% level.

There are three possible ways of gaining benefit from this which could be explored in any future project phase:

a) By sustaining the quality at its present improved level of about 72% of the ideal, the selection constraints on protein quantity could be relaxed with possible advantages of trade-offs with other characteristics such as yield or resistance to drought, disease or insect attack.

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b) By selecting for higher oil content in the grain, the energy content would be increased, and perhaps even more importantly, the viscosity of cooked gruels would be reduced, thus a significant contribution would be made to the bulk problem of infant feeding, whilst still retaining an adequate protein:energy ratio.

c) In some communities the traditional methods of reducing bulk and improving palatability are by adding concentrated sources of calories such as sugar or oil to maize gruels. The quality protein varieties offer the possibility of increasing the amounts of sugar or oil which could be added without diluting the protein to an unacceptable level, However, this potential advantage could only be accomplished through an adequately designed education programme.

d) The levels of biologically utilizable protein which have been attained offer considerable advantages for farm animal production because of the much higher requirements for protein of pigs and poultry. This should be seen as a potential contribution towards improving nutrition by increasing the incomes of small producers, rather than directly contributing towards the nutritional quality of the diet, since these animal products are unlikely to be consumed by those who are currently malnourished.

However, to the extent that maize varieties developed by the project are adopted by low-income semi-subsistence farmers where malnutrition now exists, those farmers will gain both as consumers and to the extent that net profits of their marketable surplus increases, as producers. On the other hand, if these varieties are primarily adopted by larger, higher income farmers, low income urgan consumers will be the primary beneficiaries.

SECTION IV INSTITUTIONAL CONSIDERATIONS

The project under review has focussed attention on the need for improve collaboration in applied research in agriculture and nutrition, and upon the urgency for an improved understanding of the problems and concerns of both areas. It is appropriate for CIMMYT through its mandate, to pursue the agronomic improvement of maize and, with the genetic modification of protein as a starting point, to adopt a broader objective in the use of plant breeding techniques to expand the means available for meeting the nutritional needs of the poor.

In order to do this, it will be necessary to explore ways to bring about an effective working relationship with applied nutrition. The mission does not propose that CIMMYT should develop a broad technical research base in nutrition, but it is essential that in future, agricultural research aimed at improving the nutritional characteristics of maize should be influenced by an adequate perception of the current status of nutritional research, and of the relative importance and character of nutritional problems. In addition, it is vital that country institutions presently involved in applied nutrition programmes should in the future be sensitive to the relevance of the introduction of new varieties to the solution of nutritional problems with which they are confronted.

Annex I

Terms of Reference to Review

Research and Training in the
Development of Quality Protein Maize (Phase III)
GLO/75/007

A. Background

1. Since 1970 UNDP has been assisting the International Maize and Improvement Centre (CIMMYT) in its research and training programme for the development of high quality protein maize. In January 1973, the Governing Council of UNDP approved a three-year project for this purpose with an earmarking of $1,653,200. In January 1973, and again in the same month of 1976, UNDP approved additional financial assistance for a second and third phase of operations of three years duration each at a cost of $2,372,000 and $5,140,000 respectively. The general purpose of the project has been to assist developing countries in improving the protein content of maize, a crop which constitutes a major part of the diet of many people in the world, but which is notably low in protein. The protein, moreover, is low in the amino acids, lysine and tryptophan, thereby limiting its nutritional value. In the last eight years, UNDP's assistance has made it possible for CIMMYT to conduct extensive research, training and technical assistance to developing countries aimed at the development of nutritive maize with both high yield and high quality protein, as well as conventionally acceptable taste and kernel appearance and suitability for use in a wide range of ecological and farming conditions throughout the world.

2. In the above effort, CIMMYT is utilizing a multidisciplinary, coordinated approach involving the participation, interaction and collaboration of geneticists, breeders, physiologists, chemists, entomologists, pathologists and other specialists. In the last eight years, the UNDP project has made significant progress in the accomplishment of many of its objectives. As a result of the close interaction and collaboration of CIMMYT scientists and national cooperating sicentists, the research in a number of countries on upgrading the quality and quantity of protein in maize has been intensified. The project has helped train large numbers of developing country personnel in implementing programmes of nutritive maize production, including development of better equipped laboratories and training of national staff in the chemical analysis

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of lysine and tryptophan. The research on breeding and genetics, biochemical and nutritional studies and training activities which were initially concentrated in countries of Latin America have been extended to several countries in Asia and Africa in the last three years.

3. Notwithstanding the notable achievements of the UNDP global project in the last eight years, many questions have been raised as to the future direction of research on various aspects of high protein quality maize in the light of current obstacles to its large-scale introduction into developing countries where maize varieties combining high yields, disease and insect resistance and protein quality can play a major role in the alleviation of malnutrition.

4. In view of the forgoing and the fact that the present project will come to an end in March 1979, UNDP and CIMMYT jointly agreed to undertake an evaluation of the project from its inception in January 1970 in order to assess the progress achieved in relation to established schedules and targets for activities, outputs and immediate objectives and to make specific recommendations on the future of the project and a possible follow-up project. Should a follow-up be considered appropriate, the mission should bear in mind to incorporate, into one single project, agro-economic research presently being carried out under GLO/75/007 in Asia and as a separate project in East Africa under GLO/74/009.

B. Scope of the Mission

5. The review should focus on the specific research objectives with emphasis on breeding, as well as the final objectives of improving the well-being of people through expanded production and consumption of high quality protein maize, paying particular attention to questions of protein nutrition, economic feasibility and suggested policy measures to enhance the social benefit associated with high quality protein maize. Among the various issues to be considered in the evaluation, the mission might include the following:

(i) Past developments and experience in quality - protein maize breeding work at CIMMYT and around the world; major breeding approaches used in different countries and at CIMMYT; merits and demerits of such approaches.

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Critical appraisal of methodology being used at CIMMYT and progress made using such approaches in different types of materials. Has or has not protein quality been sacrificed while overcoming problems associated with opaque-2 maize?

(ii) Major problems or key issues in breeding high-lysine maize; our understanding of the underlying causes of these problems. Present gaps, if any, in the scientific knowledge in dealing with such problems. What steps need be taken to fill the gaps and to increase efficiency and effectiveness in breeding for high quality protein in maize?

(iii) Present status of development of quality-protein maize materials at CIMMYT, evaluation of such materials internationally for information, improvement and as a means of dissemination in different countries. Results of past effort and prospects for the future;

(iv) Are the available opaque-2 materials inferior, equal to or better than normal maize in protein quality, yield, and important agronomic characteristics? Do these materials meet needs of different agroclimatic regions, farmers, consumers?

(v) Work done to develop quality protein versions of floury materials. Limitations, scope and steps needed to accelerate this programme.

(vi) Are present analytical procedures and facilities for biochemical analysis adequate and satisfactory to provide requisite service to the breeders?

(vii) The present status of protein-calorie nutrition situation and the role of quality protein maize in correcting the situation. Status of nutrition and feeding trials. What arrangements CIMMYT has with other institutions to run feeding trials? How are present arrangements working and how have CIMMYT materials performed in different nutritional trials that have so far been conducted? What steps are necessary to obtain adequate information and remove the gaps?

(viii) Status of use of high quality protein maize material by various national programmes. Is there sufficient interest in developing countries towards quality protein maize? What are the bottlenecks in acceptance and large scale use of high quality maize? Are any areas particularly suited. What steps are justified and needed to increase interest in this direction and promote the cultivation and use of high quality maize?

(ix) What is the economics of cultivation of quality maize? Is cost benefit ratio satisfactory? Is adequate information available to reach valid conclusions regarding the usefulness and practicability of cultivation and use of high quality maize? If not, what steps need be taken?; and

(x) Any other constraints which may be hindering the achievements of quality maize programme and the possible means of reducing or eliminating such constraints.

C. <u>Composition of the Mission</u>

5. The mission will be composed as follows:

(i) Dr. D. D. Harpstead, Chairman, Department of Crop and Soil Sciences, Michigan State University - Coordinator of mission;

(ii) Dr. P. R. Payne, Reader in Applied Nutrition, Department of Human Nutrition, London School of Hygiene and Tropical Medicine;

(iii) Dr. Per Pinstrup-Andersen, Senior Research Fellow, Economic Institute, Royal Veterinary and Agricultural University, Copenhagen, Denmark; and

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(iv) Dr. K. N. Satyapal, UNDP headquarters, New York, to act as secretary of mission to assist in the finalization of mission's report and in the elaboration of a possible follow-up project.

5. Responsible CIMMYT scientists will associate themselves with the work of the mission. While the mission is free to discuss with all concerned anything relevant to its assignment, and to make any observations or recommendations deemed appropriate, it is not authorized to make any commitments on behalf of UNDP.

D. Timetable and Report of the Mission

The mission will assemble in New York for briefing on 9 June 1978. The review at CIMMYT will take place from 12-15 June. Mission members will return to New York on 16 June for debriefing, at which time a succinct summary statement of its findings and recommendations should be made available. The contributions of the mission members to the report in their respective areas of specializations will be assembled and finalized by the UNDP participant in New York after appropriate mutual consultations. The mission report will be treated as a confidential document by UNDP, unless otherwise agreed to with CIMMYT by UNDP headquarters.

Annex II

QUALITY PROTEIN BREEDING IN MAIZE AT CIMMYT

(REVIEW AND PROGRESS REPORT)

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A. INTRODUCTION

B. PROBLEMS & PAST DEVELOPMENTS RELATING TO OPAQUE-2 MAIZE

C. BREEDING APPROACHES USED IN THE DEVELOPMENT OF QUALITY PROTEIN MAIZE MATERIALS

- i) Search for new mutants
- ii) Improving protein quality through recurrent selection schemes without the use of genetic mutants
- iii) Sugary-2/opaque-2 double mutant combination
- iv) Selection of genetic modifiers

D. PROGRESS AND RESULTS OF QUALITY PROTEIN MAIZE MATERIALS DEVELOPED AT CIMMYT

- a) Basic information on genetic modifiers
- b) Problems and emphasis in the development of opaque-2 maize
- c) Present status of development of high quality protein maize materials
  - (1) Tropical and temperate materials
    - i) Advanced unit opaque-2 materials
    - ii) Development of experimental varieties
    - iii) Development of broadbased hard endosperm opaque-2 source populations
    - iv) Conversion of advanced and back-up materials
    - v) Conversion of special project populations that are being selected for earliness, plant efficiency and adaptation
  - (2) Protein content and quality of hard endosperm opaque-2 materials
  - (3) Highland opaque-2 program
    - i) Conversion of non-floury highland back-up gene pools
    - ii) Highland opaque-2 composites
    - iii) Floury-opaque-2 conversion program
    - iv) Protein content and quality of highland opaque-2 materials
  - (4) Sugary-2/opaque-2 conversion program

(5) Performance of quality protein maize materials developed at CIMMYT

(6) International testing program for the year 1978

E. FUTURE OUTLOOK

F. CHEMICAL RESEARCH AND ANALYTICAL SERVICE

i) Analytical procedures

ii) Establishment of service laboratories

iii) Training

G. BIOLOGICAL EVALUATION

QUALITY PROTEIN BREEDING IN MAIZE AT CIMMYT

(Review and progress report)

- o -

A. INTRODUCTION

The discovery of new genes that bring about drastic alterations in plant or kernel characteristics to achieve certain well defined goals in maize breeding has always fascinated maize breeders. Whenever such new genes have been discovered or identified, maize breeders around the world have been quick enough to transfer the desired traits from the donor stocks to their promising maize strains. Although in many cases the genetic manipulation or the introduction of such genes into inbreds or open-pollinated maize varieties seems to be a simple affair, yet the achievement of desired goals have been somewhat difficult, slow and sometimes disappointing. This is so because some other problems happen to be associated directly or indirectly with the transfer of these genes. Achieving an objective by mere introduction of one single major gene often results into more complex problems that take time to resolve. The story with the quality protein mutant genes is no way different from other mutants and their use in crop improvement.

B. PROBLEMS AND PAST DEVELOPMENTS RELATING TO OPAQUE-2 MAIZE

Improvement of the nutritional value of maize using known mutant genes has been underway for the past thirteen years. The opportune discovery of these mutants fortunately came at a time when protein-calorie malnutrition and protein-gap were the most talked about issues. Many developing countries saw this development with great interest. In several countries breeding programs were initiated to improve protein quantity or quality or both of cereal crops in order to improve the nutritional status of malnourished people. This seemed to be the most logical approach since most of the needy individuals depend largely on cereals to meet their protein and calories requirement.

Enough time has passed and enough work has been done in this field. Perhaps it seems logical at this point to review some of the developments that have taken place in the improvement of nutritional quality of maize in a period of a little over one decade. Soon after it was known that some mutants in maize can boost the levels of essential amino-acids to almost double, great enthusiasm prevailed in many breeding programs. Breeders all around the world started transferring these mutant genes into their promising inbreds and open-pollinated varieties or composites through the standard backcross approach. In converting materials to opaque-2 or floury-2, the soft chalky kernel phenotype of these mutants helped greatly as a marker in identifying opaque-2 segregates. With the phenotype of the opaque-2 kernels easily identifiable, many maize breeders around the world could carry out this breeding program without any pressing need for a biochemical laboratory.

In the beginning both opaque-2 and floury-2 genes singly and in combination were used quite heavily. The floury-2 breeding work was dropped in the early seventy's hence most breeding programs concentrated on opaque-2 gene alone. Another mutant opaque-7 (o_7) for the most part has been used on an experimental scale as it does not offer any real advantage over opaque-2 gene.

For almost one decade, the major emphasis in most breeding programs was straight conversion program of their best normal materials to opaque-2 and is still being practised in many programs. A number of quality protein maize hybrids and varieties with soft kernel phenotype were developed and some of these appeared on the commercial scene. Few countries like Colombia and Brasil made an all out effort to push these materials in commercial production. For a few years starting in 1970-71 these two countries and U.S.A. showed an upward trend in the production of opaque-2 hybrid maize seed. Production of opaque-2 maize was also underway in some other countries though no exact records ever became available. Early seventy's saw considerable enthusiasm in production of opaque-2 maize. Very soon, however, these materials started losing ground because of their poor performance. These materials could not hold ground even when certain governments fixed premiums or subsidy to popularize cultivation of opaque-2 maize. There were several reasons why soft opaque-2 maize could not become popular in many countries. In countries of the developed world, reduced grain yield and fusarium ear rots were probably the main reasons. In developing countries where maize is used for human consumption the soft chalky phenotype of the kernel was unacceptable in addition to yield and ear rots. It was important that some of these materials were released prematurely and did not find much acceptance and support for cultivation with farmers. In countries of the Andean region soft opaques could have been accepted easily because the farmers grow floury maize. However, in this case it was difficult to transfer the opaque-2 gene into floury backgrounds due to indistinguishable phenotype of the opaque-2 segregates from floury segregates. In the absence of chemical laboratories, this conversion program of opaque-2 gene to floury background could not be carried out successfully.

With one or more problems confronting opaques almost in every place, opaque-2 materials suffered a great setback and disappointment both at research and production levels. Some programs completely abandoned research work on opaques while others kept handling these materials on a small scale.

Though these problems confronting opaques became apparent no serious consideration was given to solve these problems in a systematic way. The problems became more obvious as materials started appearing on the commercial scene. In some countries systematic economic surveys were made to find markets and farmers acceptability of these materials. In general, in most developing countries the released soft opaque-2 materials were never found to be on an acceptable scale compared to the already growing normal materials.

C. BREEDING APPROACHES USED IN THE DEVELOPMENT OF QUALITY PROTEIN MAIZE MATERIALS.

As problems started getting attention of the breeders, efforts were initiated to find ways and means to solve the problems. Up until now, four main breeding strategies have been used. The merits and demerits of these approaches are discussed in the following text.

i) Search for new mutants

Protein quality of many different materials has been reported. The published reports show some collections that have elevated levels of lysine but in reality these materials have not been used in any active quality protein maize breeding program. It may, however, be mentioned based on our experiences at CIMMYT that many times it is possible to obtain such high amino-acid values if the seeds are abnormal, shrivelled or might have been affected by drought or by some other adverse causes.

The result of this is that the ratio of germ to endosperm shifts in favor of germ. If on top of this, whole kernel analysis is performed, it is very likely that one may find essential amino acid values fairly well elevated. It is, therefore, very important that quality of seed should be checked before arriving at conclusions that some collections or materials have very high amino acid levels. To conclude it may be pointed out that finding new mutants in normal flint or dent backgrounds has not so far proved to be a fruitful exercise.

ii) Improving protein quality through recurrent selection schemes without the use of genetic mutants.

This approach has been used on a limited scale and has produced some positive results to demonstrate that it is possible to accumulate favorable alleles for high lysine content in some promising materials through a recurrent selection procedure. One of the greatest advantages of this approach is that one hopes to obtain a high lysine material without changing the kernel characteristics and the agronomic performance of the material. We have tried this approach at CIMMYT and we are in complete agreement with the Purdue scientists that there are several problems in developing high lysine populations through a recurrent selection program. The main objections we have are the following:

1) Many national programs do not have well equipped laboratories and as such are unable to perform very precise analyses that are essential for a program of this nature.

2) Lack of wide range in lysine values will normally result in very small gains per cycle. This in turn will require many years before one can attain levels that are found in soft opaque-2 materials.

3) Even when improved lysine levels have been achieved in some materials, the transfer of such traits to other materials is not simple and cannot be accomplished until and unless the program is supported by a well established biochemical laboratory. Such types of support laboratories practically do not exist in any country.

4) Variation in protein values also complicates the selection process.

5) Difficulty in detecting biological values of materials that differ slightly from each other is another constraint. Also there is no assurance that improved protein quality as determined by chemical procedures will in all instances show superior biological value.

iii) Exploiting interaction of sugary-2 and opaque-2 double mutant combination

At one time it appeared that sugary-2/opaque-2 combinations could be used to eliminate some of the problems confronting opaque-2 maize. Purdue scientists were very much excited about this combination. In 1974 we initiated a conversion program at CIMMYT of obtaining sugary-2/opaque-2 versions of normal and opaque-2 materials. This combination as we now know has several advantages which include: 1) Interaction between two mutants in homozygous recessive condition results in vitreous kernels; 2) Slightly better protein quality; 3) better digestibility of the protein; 4) No serious ear rot problems; 5) No need to select for modifiers; 6) No problem of maintaining protein quality; 7) Less pressure on laboratory analyses.

One serious problem with this double mutant combination is that the kernels in these segregates in general are smaller in size and consequently result in lower yield. The grain yield in this combination may be reduced as much as 15-25% depending on the genetic background. Also the segregates in all instances are not of acceptable phenotype because of intense color. Also the suitability of such maize for different maize preparations is not known. It seems from our limited experience that considerable improvement will have to be done in these materials to attain performance levels comparable with normal maize materials. Such double mutant conversion program has been initiated only at a few institutions and at some private hybrid seed companies. There is consensus that reduction in grain yield is the greatest single drawback which will prevent these materials from coming into the forefront. There is little or no hope that straight conversion programs to recover sugary-2/opaque-2 segregates will ever result into overcoming the yield barrier. Variation for kernel size, weight, density and phenotype, however, do exist and should be exploited in different genetic backgrounds to increase the future prospects of these materials.

iv) Selection of genetic modifiers for kernel hardness

Selection of modified opaque-2 kernels with hard endosperm to correct some of the defects in the opaque-2 gene system has in fact been tried at more institutions than any other approach. Through careful and systematic selection for hard endosperm opaque-2 kernels, we are confident that some of the major problems confronting opaque-2 maize production can be overcome. Selection for modifiers is not very easy. It may be slow and disappointing and may involve complexity of decline in protein quality. It is essential that such a program should be supported by a service type back-up chemical laboratory to be effective. The laboratory should be able to provide rapid and reliable service to analyze a large number of samples.

In breeding hard endosperm opaque-2 materials, one may need to develop sources or stocks that can be used as lines or populations having superior modified hard endosperm and can also be used subsequently as donors to convert normal maize materials to hard endosperm opaque-2. In doing so, one should start looking for such modified kernels in as many different genetic backgrounds as possible. Modified kernels should be sorted out on ear or family basis and should be subjected to endosperm analysis. Endosperm analysis is essential especially if we are looking for genetic modifiers that change endosperm texture and also maintain the protein quality in the endosperm. Whole kernel analyses are likely to bias the selection process, because of differential germ size. After a few cycles of selection and when favorable modifiers have been accumulated to a fairly high frequency, one can switch over to whole grain analyses.

Developing superior hard endosperm opaque-2 protein maize materials may be somewhat difficult, slow and disappointing in the beginning especially if one is starting from the scratch. One would experience that only a small portion of the total that is planted may be worth saving. But over a period of time one would find satisfactory progress and it may be possible to move fairly rapidly in different ways as follows:

1) Modified opaque-2 sources can be used as donor stocks to convert new maize materials to hard endosperm opaque-2. In the absence of a broadbased hard endosperm opaque-2 material, two or more hard endosperm opaque-2 materials may be used as donors.
2) Modified opaque-2 sources that may be in the form of inbred lines and families can be pooled together to develop a broadbased genetic modifier source. The materials can be systematically recombined

for a number of generations and later on used as a population for further improvement. During the course of recombinations, one can continuously keep selecting for better modified opaque-2 ears at harvest coupled with selection of best modified opaque-2 kernels from each ear for planting the next cycle. Analyses for both protein quantity and quality should be carried out at all stages in an attempt to eliminate unfavorable modifiers as quickly as possible. Such a population can also serve as a broadbased source material for genetic modifiers.

Sufficient basic genetic information to capitalize on modifiers is already available. However, some aspects of modified opaque-2 breeding program need special mention: a) As one is capitalizing one modifiers to improve the kernel appearance, weight and density, every attempt should be made to maintain the quality of protein in the endosperm.

Since we are dealing with endosperm which is a triploid tissue, one is encountered with maternal influence. One would expect somewhat slow progress if one does not use proper breeding methods to handle such materials.

3) To the extent possible one should work in homozygous opaque-2 backgrounds. This is essential if one aims at building up the frequency of modifiers that are more favorable for the recessive allele of the opaque-2 locus.

4) Endosperm analysis rather than whole kernel analysis should be practised in the beginning. After some time when favorable modifiers are in abundance, analyses can be switched to whole kernel.

5) Exploit modifiers that result in regular modification of the grain, that is kernel vitreousness is attained progressively from the crown towards the base of the kernel.

6) It is important that the final product should have uniform and stable kernel appearance to find market acceptance. This will necessitate that at some point in the selection process, one should start looking for stable modifiers. It is our experience that selection of stable modifiers should wait until such time that the variability for kernel hardness within the population has been reduced to the minimum.

Very obvious and significant progress has been made at CIMMYT in this direction while other breeding programs around the world have not been so successful. Some obvious reasons for this differential progress are the following:

1) Since opaque phenotype had distinct advantage as a marker and could be distinguished easily, most breeders had been selecting for soft chalky phenotype. Even when modified opaque-2 kernels occurred, these were discarded. This selection against modifiers in earlier generations resulted in limited variability for modified opaque-2 kernels.

2) Most programs limited their conversion program to only some of their many populations. This also reduced the chances of obtaining a wide range of variability in kernel phenotype and thus limited subsequent progress. Either due to lack of variability or ignorance, many programs did not initiate this kind of work or soon gave it up.

3) In many national programs, this kind of work could not be started

because they do not have or did not employ enough resources and manpower to handle a large program necessary to make progress.

4) Many institutions could not carry out this work because of lack of laboratory analysis facilities which are a must for this kind of research work.

5) In some programs where this work was started, quite often they ended up playing with contaminants of normal pollen. It is often observed that even in normal kernels one can observe some sort of discolored area around the base of the kernel which over illuminated glass screen shows phenotype resembling very much the modified opaque-2 type. This kind of mistake can easily be made if one is not careful enough in selection. It is therefore, essential to pick-up kernels that are distinctly modified with clear cut soft and vitreous fractions as a starting point.

6) There were also problems depending on whether the material was flint or dent. In general flinty modified opaque-2 segregates were easily identifiable and probably easy to find too. On the other hand, in dent backgrounds, both identification and accumulation of modifiers were somewhat more difficult.

7) Many breeders failed to handle the segregating generations in the right way. Whenever crosses between normals and hard endosperm opaque-2 donors have been made and then advanced to F_2, breeders have picked-up segregates that may look like near normal modified opaque-2 kernels which in reality may be normal. In F_3, these kernels may segregate or may be completely normal depending upon the genetic constitution of the F_2 seed with respect to opaque-2 locus. Also, when analyses are made in the laboratory, the values

of lysine and tryptophan in endosperm may decline and approach close to the normal. This kind of mistake may result in wrong interpretation of the data and may affect the selection process adversely. If the laboratory data has to be used in an effective manner, selection of the right type of modified kernels is very important otherwise one is likely to reject families assuming that the quality of the protein has declined as a result of modification of kernel phenotype. In reality this may be due to the inclusion of one or more wrongly classified normal kernels in the sample sent to the laboratory. It is highly essential that F_2 segregates should be sorted out with utmost care. Only segregates that are 100% sure should be selected.

8) Not much has been done to develop hard endosperm opaque-2 populations in different national programs. Also little has been done to improve the existing populations further through some sort of intra-population improvement scheme.

9) Stability of hard endosperm opaque-2 character has often been found to be unsatisfactory. Based on our experiences it may be important to point out that one would often find this to be true if the material is poorly modified and has still tremendous variation within the population itself. It will not be fair or justified to talk about stability if the favorable alleles of different genetic modifiers have not been accumulated to a fairly high frequency. It may also be important to point out, that materials which have been selected for many generations show relatively more stability in different environments even though the selection has been practised at only one location. Maternal influence could also confuse the issue of stability. One may

select very good hard endosperm opaque-2 ears at harvest but if some of them have been crossed with families that may not be very good with respect to modifiers, it is likely that some of these ears will show segregation for soft segregates in the ensuing generation.

D. PROGRESS AND RESULTS OF QUALITY PROTEIN MAIZE MATERIALS DEVELOPED AT CIMMYT

At CIMMYT we have placed greater emphasis on capitalizing genetic modifiers of the opaque-2 locus in producing quality protein maize materials that will have acceptability and equality of yield and other agronomic characteristics with the normals. The progress made from year to year has provided us continuous encouragement to continue using this approach more vigorously at the present time.

The achievements made during the different phases of UNDP-CIMMYT Global Research Project are reviewed and discussed briefly in the text that follows. It may be important to mention some key points concerning our philosophy towards the development of quality protein maize materials at CIMMYT.

i) Firstly, we are satisfied with the initial jump that we got in lysine value with the introduction of opaque-2 gene. Thereafter we have tried to maintain protein quality while exerting a very strong pressure for various problems that confront opaque-2 maize production. We strongly feel that until and unless the quality protein materials have a performance level very much like the normals, it may be difficult to convince farmers to grow these materials.

ii) To attain the same yield level in opaques as the normals so that one can have the same calories but with quality protein as a bonus.

iii) To lay major emphasis in solving problems that have acted as the major hurdle in promoting these materials.

iv) To obtain opaque-2 versions of normal materials in fairly large number of genetic backgrounds so that these materials could serve as source genetic stocks for further selection in many countries that do not have the facilities to do the initial ground work.

v) Multilocation testing as a means of evaluating materials for information, further improvement and dissemination.

vi) Simple chemical analyses that can handle very large number of materials for preliminary screening followed by more complete analyses on bulk samples to get a fairly good idea about the changes in the population from year to year.

vii) Evaluate only those materials that are fairly well advanced for biological evaluation.

To start with the major emphasis in CIMMYT's maize program has been to convert normal maize materials from tropical, highland and temperate subtropical areas to opaque-2 with soft chalky endosperm. Though a start had been made in 1970 to select modified opaque-2 types, over 99% of the effort still consisted in converting normal maize materials to opaque-2 and floury-2 with soft endosperm texture. Some effort was also devoted to improving composites that had been developed earlier. This kind of activity was in full swing for about 3 years. By this time 2 or 3 backcrosses had been achieved in some materials. Also we decided at this time to stop working with floury-2 and restricted our conversion program to only the opaque-2 gene. The converted materials were tested nationally and internationally in replicated yield tests. Some of these materials performed reasonably well in different countries but in general registered a high incidence of ear rots. Through our international opaque-2 maize trial (IOMT) and also from the releases that had been made in different countries, certain problems confronting this type of maize production became very apparent. From 1973 data we got convinced that there is need to make subtantial changes in the program to develop quality protein materials that will have acceptance. From a mere conversion program to soft opaque-2, we started devoting our research efforts to solving some of the most important problems confronting opaque-2 maize production. In our tropical and temperate-subtropical programs, the major thrust was placed on capitalizing genetic modifiers of opaque-2 locus in an effort to remedy some of the most pressing problems confronting opaque-2 maize. We did not know much about the genetic modifiers but we kept accumulating the frequencies of these modifiers in different materials. Attempts were also made to generate some basic information which we thought would be helpful in increasing the efficiency of the breeding program.

a) Basic information on genetic modifiers

i) Variation in modification of kernel: We have encountered vast variation in the modification of the opaque-2 kernels. The variation is based on the pattern and distribution of vitreousness in the endosperm. For the sake of convenience we have divided this variation into two main categories - regular and irregular. In the irregular category the variation follows all sorts of patterns such as banding, bridge or sickle shape pattern, scattered and hard base. Since irregular variation will not accomplish our objectives, we have not paid much attention to this type of variation. The other type of variation which follows a regular pattern and where the kernel hardness increases from the top towards the base of the kernel is of great value in improving the kernel appearance. Most of the information that has been collected thus far relates to those genetic modifiers which are able to change the soft texture of the opaques from the crown towards the base of the kernel.

ii) Genetic background effect: We have commonly observed that some genetic backgrounds show modified opaque-2 kernels with a much higher frequency while others show a few or none at all. Also maize with different textures of the grain express differential modification of the grain. In general modifiers are difficult to find and accumulate in dent materials compared to the flints. However, by handling larger number of families, we have been able to modify even dent materials considerably better in appearance.

iii) Variation in kernel appearance: Even in regular type of kernel modification, there is so much variation that one should carefully select for kernels that have appealing appearance. Modifications that result in cloudy or dull appearance also occur and should be disregarded.

iv) Maintenance of protein quality: As selection of modifiers continues to improve kernel hardness, the protein quality tends to decline somewhat. This, however, does not occur in all families. Also the extent of decline is not the same in all materials. Apparently, kernel hardness is governed by two sets of modifiers-favorable and unfavorable. In favorable modifiers protein quality is maintained while the unfavorable modifiers slightly decrease protein quality. In the breeding program, therefore the effort should be to capitalize on modifiers that bring about kernel hardness without reducing the quality of protein.

v) Vitreousness brought about by the action of modifiers, in general, results in higher percent of protein in endosperm.

vi) Modifiers do influence different protein fractions in the endosperm. The different fractions, however, are altered differently in different genotypes.

vii) Germ size also seems to be under the influence of modifiers and is affected differently in different genotypes.

viii) Inheritance studies have shown that modifiers are complexly inherited. Additive gene effects are more important than dominance in the expression of kernel vitreosity.

ix) General combining ability effects of different hard endosperm opaque-2 materials differ. Some materials seem to be very promising for transmitting the vitreous endosperm character and thus can be used as source materials for incorporating the opaque-2 gene along with vitreous endosperm structure in other agronomically promising germplasm.

x) Large reciprocal differences have been observed in crosses between soft opaques and modified opaque-2 materials. This suggests maternal influence on the expression of kernel phenotype that could result from dosage effects of modifier genes in triploid endosperm.

xi) Considerable variation has been observed for kernel weight, and density in materials segregating for normal and modified opaque-2 kernels.

b) Problems and emphasis in the development of opaque-2 maize

In identifying problems confronting opaque-2 maize, one must consider in the first place as to what kind of materials can be accepted in different countries. Depending on the need, one must, therefore, put emphasis on the following points.

1) In areas where soft opaque-2 materials can be readily accepted, the major emphasis in the program should include increased yield and greater resistance to ear rot organisms.

2) In the Andean region where the interest lies mainly in the soft big seeded floury types, the breeding focus should be on ear rot resistance.

3) In areas where the hard flints and dents are prefered, the major emphasis should be on kernel phenotype, kernel weight, ear rot and more normal drying of the kernel after physiological maturity.

It may also be important at this point to mention that most of the endosperm mutants in maize shut-off dry matter accumulation somehwat earlier than normal maize. This is true for all mutants such as opaque-2, opaque-7 and floury-2 that improve the nutritional value of maize endosperm. This underlying defective system is the sole cause of reduced kernel weight in opaques as compared to the normals in the same genetic background. Until and unless we use some complimentary genetic system that can modify the defective opaque-2 system, the opaque-2 materials will continue to be at a disadvantage compared to normals with respect to yield. It is clear from the data collected in a number of populations that genetic modifiers of opaque-2 locus not only influence kernel phenotype, protein quantity and quality, but also influence kernel weight. Accumulation of modifiers for kernel phenotype and kernel weight can be achieved simultaneously to eliminate two major problems in opaque-2 materials.

Ear rots are equially important and may result from varied causes. It is again our observation that as materials approach the normals in appearance, ear rots have become less. There are other factors which one can exploit to reduce ear rots in opaque-2 materials. One very obvious thing that can be noticed in the opaque-2 materials is the popping or splitting tendency of the kernel. From the genetic segregation, it seems to be inherited in a simple way. At all stages of the breeding program, the kernels of families showing this kind of damage should be eliminated since such popped kernels are more prone to ear rots. While these kernels rot themselves, they also promote ear rots to the neighboring kernels. Slow drying of the opaque-2 kernels may also be another contributing factor to the ear rots. One can exercise some selection against this in the field by harvesting materials 6-8 days earlier to see if there are differences in the relative drying of opaque-2 kernels. This early harvesting will be very useful when differences between flowering of different plants is very small. Also at family level, the plants within a family that have flowered more or less on the same day can be marked. At harvest only those that dry fast enough could be selected.

This normalization of drying can also reduce the ear rots in opaques. Apart from this the genetic differences between materials and families also occur and these have been exploited at all stages of the breeding program both under natural and artificial conditions.

c) Present status of development of high quality protein materials

Considerable progress has been made with respect to the development of quality protein maize materials for different ecological adaptation. The progress made is discussed under the following sub-headings:

(1) Tropical and temperate materials

Greatest progress has been made in tropical and temperate materials because of the possibility of growing two crops a year. The major emphasis in these materials has been placed on modifiers to overcome problems of kernel phenotype, yield and ear rots. As the above three problems have improved tremendously, we have now started putting pressure for stability of modifiers in different environments.

The tropical and temperate materials that exist in the program are the following:

i) Advanced unit opaque-2 materials

There are five such materials that are being tested on family basis at the international level. Four materials possess vitreous endosperm while the fifth one has soft chalky appearance. The materials are:

1) Tuxpeño opaque-2 (IPTT-37)
2) PD(MS)6 H.E.o_2 (IPTT-38)
3) Yellow H.E.o_2 (IPTT-39)

4) White $H.E.o_2$ (IPTT-40)

5) Templado amarillo o_2 (IPTT-41)

We are handling 250 full-sibs from each of these populations. These are tested alongwith six checks in a 16x16 simple lattice at six locations in different countries. One of the six test sites is always in Mexico. The performance of each of the populations is presented below:

- PD(MS)6 $H.E.o_2$: In terms of kernel hardness and appearance of grain, this is one of the best materials in the program. It has undergone four cycles of half-sib recombination coupled with simultaneous selection for modifiers. Following one year of population improvement in Mexico, this material has been promoted to advanced unit as IPTT-38. In the first year of the population improvement, the 3 test sites were within Mexico. On the basis of progeny trial data, the mean of 93 full sib selected families showed a superiority of 9.97% over the mean of the population in across location data (Table 1). The selected families were planted in 1977A to generate a new set of 250 full sibs. These have been sent to six different sites for evaluation. The results are still awaited.

  This material is intermediate in maturity, with good plant type and with good yield performance of stable hard endosperm opaque-2 kernels.

- Yellow H.E.o_2: This is a new population that was being handled in the back-up stages of the program as CIMMYT H.E.o_2. This is also a very good looking material in the quality protein program. It is a broadbased material with respect to both genetic diversity of the materials and the modifiers. This material has undergone 4 cycles of recombination to improve the frequency of favorable modifiers without sacrificing anything on protein quality. This material has replaced the old Yellow H.E.o_2.

In 1977, 250 full sibs were generated and these were tested in 3 locations within Mexico. On the basis of the data, 96 full sibs were selected. The mean of selected families showed a selection differential of 9.66% over the mean of the population in across location data (Table 1).

The selected families were planted in 1978A to generate new 250 full-sibs. These have been sent out to six different countries for evaluation. The data are still awaited.

- White H.E.o_2: This is a white material and it has a mixture of flint and dent grain texture. This material represents some promising hard endosperm opaque-2 families derived from white opaque-2 back-up pool. These families were used to develop 250 full sibs and these in turn were tested in 3 locations within Mexico. A total of 99 families were selected.

The mean of selected families showed grain yield superiority of 9.12% over the mean of tested families in across location data (Table 1).

The selected families were used to generate new 250 full sib families. These were sent out to six different countries. We are still awating results from some of the locations.

- Tuxpeño opaque-2: This has soft chalky endosperm and is in fact very high yielding. A number of experimental varieties derived from this population have done excellently well in some locations.

- Templado amarillo o_2: This is the most advanced population from temperate-subtropical program. It has good plant type, good yielding ability and acceptable ear and kernel characteristics. Good families from Temperate x tropical H.E.o_2 composite gave origin to this population. It was sent as IPTT-41 in 1977 for the first time. In general, this material has done very well in different locations and holds a good promise for the future.

ii) Development of experimental varieties

From each population undergoing improvement, 10 best families are identified and recombined to develop site specific and across site experimental varieties. Since a very high selection intensity is practised in forming these varieties one can hope to get substantial improvement over the population mean for immediate use. On the basis of 1977 data, four experimental varieties have been developed from PD(MS)6 H.E.o_2 (IPTT-38), four from Templado amarillo o_2 (IPTT-41), and one from Yellow H.E.o_2 (IPTT-39). In all cases the formed experimental varieties have a yield advantage of the order of 10-52% over the mean of the population. These experimental varieties have been sent out in trial 15 to at least 40 countries. It will be interesting to see the performance of these experimental varieties in different locations since some of these populations are new additions to the international progeny testing program.

iii) Development of broadbased hard endosperm opaque-2 source populations

The following composites or materials at the back-up stages of the program have been developed in the last 4-5 years:

a) White opaque-2 back-up pool (Flint)
b) White opaque-2 back-up pool (Dent)
c) Yellow opaque-2 back-up pool (Flint)
d) Yellow opaque-2 back-up pool (Dent)
e) Temperate x tropical H.E.o_2 (Flint)
f) Temperate x tropical H.E.o_2 (Dent)
g) Temperate white H.E.o_2

The above materials have resulted from genetic mixing of several diverse materials. Also, the above materials are being broadened continually by the addition of some very good families with hard endosperm texture from the advanced and back-up conversion programs. 400-500 half-sib families from each population are handled in a half-sib recombination block. Once every two seasons, the families of each material are planted in at least two locations for identifying the stable families.

The major emphasis in all such back-up pools has been to increase kernel vitreosity without sacrificing protein quality. Kernel appearance in these materials has already reached a point of acceptance. Most of these materials have gone through 7 cycles of selection in a simple half-sib manner without progeny testing. Some of these materials can give rise to new advanced unit populations. Also, these can be sent out as source populations in other countries.

iv) Conversion of advanced and back-up materials

Opaque-2 versions of 19 advanced populations and 20 back-up pools have been obtained. Most of the versions have, however, gone through only one or two backcrosses. In converting normal materials to opaque-2, the empahsis has been to select for modified opaque-2 kernels. In the conversion program we are using backcrossing-cum-recurrent selection program which has the following unique features:

a) Since the recurrent parent is undergoing continuous improvement through population improvement scheme, an improved version or the latest cycle of selection of the normal population is used in each backcross.

The use of the improved version in each backcross cycle helps not only to recover the genotype of the recurrent parent but also increases the chances of addition of favorable alleles for the improved traits to the opaque-2 counterpart.

b) Since the objective is to obtain hard endosperm opaque-2 versions of normal materials, the quality of hard endosperm opaque-2 segregates will determine the next backcross. After hard endosperm opaque-2 segregates have been obtained from a segregating generation, it is often desirable to advance the segregates to F_3 or even F_4 to accumulate the frequency of genetic modifiers before attempting the next backcross.

c) The scheme permits to work in homozygous opaque-2 background though it slow the recovery of the genotype of the recurrent parent.

d) The scheme permits continuous improvement of modifiers cycle after cycle. The backcrossed families are handled in such a way that these prevent dilution of the already accumulated modifiers.

e) The scheme permits selection for stable modifiers in one season and the recombination in the other. Also in the same season when one is selecting for stable modifiers, it is possible to capitalize on within family variation for plant, ear and kernel characteristics.

f) After each backcross one does not start all over again. Thus the research effort spent in accumulating modifiers and maintaining protein quality is not lost.

g) At any stage when materials look fairly good, these can be used in evaluation trials or for other purposes irrespective of whether one, more or no backcross has been made.

h) Selection for kernel weight and density can be done in each segregating generation. Only those advanced backcross families may be used where the difference between the opaques and normals is the least.

Most of the converted materials look fairly good. The kernel modification looks excellent and fairly stable over environments(Table 3A& B).Through chemical analysis of families in each season, we have been able to maintain the protein quality like soft opaque-2 types. During conversion process we have paid careful attention to the following points:

a) At harvest select only good modified ears that are free of ear rots.

b) Reject ears or even families that are showing genetic segregation for kernel popping or splitting.

c) As we select for more and more vitreous kernels, it is a common feature to observe ears with spacing between kernel rows. The actual width of kernel spacing between kernel rows may vary from material to material and from family to family within the same material. This spacing between the rows provides a good measure to evaluate that kernels do not reach to their full potential because of early cessation of dry matter. Ears or families showing this defect are eliminated from further participation in the population.

d) During recombination phase, each family is crossed to as many other families as possible. If at harvest some families are found defective, the family and its crosses with other families are also rejected.

Some of the advanced unit conversions look very good. A special opaque-2 maize population trial (MOPT-11) has been set up this year which will be conducted over 40 locations around the world to get first hand information on the performance of these materials.

v) <u>Conversion of special project populations that are being selected for earliness, plant efficiency and adaptation.</u>

Hard endosperm opaque-2 versions of several special project materials are also available. 100-150 hard endosperm opaque-2 families of each material are being handled in each season. The materials are the following:

a) Selection precoz H.E.o_2

b) Amarillo Bajío H.E.o_2

c) Amarillo Bajío x templado H.E.o_2

d) Amarillo Bajío x Mezcla tropical amarilla H.E.o_2

e) Mezcla amarilla P.B. x Lin. Ill. H.E.o_2

These materials are being handled in the same way as opaque-2 versions of advanced and back-up normal populations.

(2) Protein content and quality of hard endosperm opaque-2 materials

Attempt is made to maintain protein quality of all materials undergoing selection for hard endosperm. In general 10 seeds from each family are analyzed for protein and tryptophan content. The families that do not meet the minimum acceptable levels are eliminated before pollination. The mean values for protein, tryptophan and lysine with respect to each material are presented in Tables 4 and 5. It can be seen from these tables that mean values for protein and tryptophan in protein of hard endosperm opaque-2 versions are in general fairly good.

(3) Highland opaque-2 program

The highland opaque-2 program can be discussed under the following sub-headings:

a) Conversion of non-floury highland back-up gene pools to opaque-2.

b) Highland opaque-2 composites.

c) Floury-opaque-2 conversion program.

i) Conversion of non-floury highland back-up gene pools

All highland pools from 1 through 14 (Except pools 3 and 8) have been converted to hard endosperm opaque-2. These materials are still not up to the mark so far as modifiers are concerned. One or more cycles of selection are needed to improve the performance of these materials.

ii) Highland opaque-2 composites

A number of highland opaque-2 composites have been developed. The names of these composites are as follows:

a) Composite I

b) Puebla opaque-2 composite

c) Barraza x Puebla o_2 composite

d) Highland modified opaque-2 composite

The first three composites possess soft chalky endosperm. These are being improved for plant type, yield and reduced lodging. Both composite I and Puebla opaque-2 composite have done fairly well in many countries of the Andean region. Barraza x Puebla o_2 composite is a relatively early material and can be grown in elevations as high as 2,600 meters above sea level.

The fourth composite namely the highland modified opaque-2 composite is undergoing its third cycle of recombination coupled with selection aimed at increasing the frequency of favorable modifiers while maintaing protein quality like that of soft opaque-2 type.

iii) Floury-opaque-2 conversion program

Conversion of soft floury types of materials to opaque-2 has received considerable attention in CIMMYT's quality protein maize program during the last three years. Though a wide range of materials varying in kernel color, maturity and cooking characteristics are being grown in different countries of Andean region, the most prominent types are white and yellow seeded large floury varieties of different maturity groups. The research efforts are, therefore, concentrated in transferring opaque-2 gene into those genetic backgrounds that will have wider use.

The use of Ninhydrin test has accelerated the conversion of highland floury pools to opaque-2. We have already obtained opaque-2 versions of Pools 3 and 8 with fairly large seeded kernels. Some other materials such as Cacahuacintle, Amarillo harinoso and some other promising varieties of the Andean region are also being converted to opaque-2. The major emphasis in these materials is being placed on recovering big seeds free of ear rots.

A floury opaque-2 composite has also been developed. It is undergoing fifth cycle of recombination. This composite has performed fairly good in some Andean countries. Considerable pressure is being exerted to further improve upon seed size and reduce incidence to ear rots. Complete amino acid analyses of endosperm and whole grain of floury-opaque-2 composite indicated that the levels of lysine and tryptophan in protein were fairly high.

(4) Sugary-2/opaque-2 double mutant

We started sugary-2/opaque-2 conversion program about three years ago. From the double mutant segregates that we have recovered, it appears that a straight sugary-2/opaque-2 conversion program will not achieve the desired goals. One will have to practice very strong selection for kernel size, phenotype and no spacing between rows to come up with something comparable in performance to the normal.

We have pooled all good families from sugary-2/opaque-2 conversion program to form a composite. This composite is in its third cycle of recombination. It seems we have improved phenotype, seed size and reduced spacing between the rows on the ear. In one or two more cycles we shall be able to determine the fate of this material.

(5) Performance of quality protein maize materials developed at CIMMYT

The performance of opaque-2 materials can be judged from the following tests:

- i) Progeny tests
- ii) EVT-15
- iii) ELVT-19

The progeny tests with PD(MS)6 H.E.o_2 and Templado Amarillo o_2 clearly demonstrate that the mean of 250 tested families approached the mean of the checks. The mean of 10 best families involved in the formation of an experimental variety had in many instances yield performance equal to the best check mean.

The results from trial 15 are given in Tables 6 & 7. It can be seen from the data that the experimental varieties derived from IPTT-37 were top performers in many locations. The experimental varieties derived from IPTT-39 in general did fairly well, the good yielders in the order of their performance were Across 7539, La Maquina 7539 and Cotaxtla 7439. Two experimental varieties from white H.E.o_2 namely Across 7440 and La Maquina 7540 were better performers. Amarillo dentado H.E.o_2 and CIMMYT H.E.o_2 as populations also did fairly well. It is interesting to note that a number of entries in each location were at least equal to the best normal check.

The results of ELVT-19 (Tables 8 and 9), also show the same trend. A number of opaque-2 entries in the trial were either equal or at least comparable to both normal and opaque-2 check entries included in the trial. The data from 29 out of 60 locations indicate that experimental varieties derived from IPTT-37 were the top yielders and in many locations outyielded the local opaque-2 check entry. In some locations, however, the performance of these two varieties was either equal or better than the normal check entry.

Two elite experimental varieties from Yellow H.E.o_2 performed similarly though the superiority of one over the other differed in different locations. The performance of Across 7441 (Composite K), San Andres 7440 and Poza Rica 7441 were also fairly good.

It may also be important to mention that normal check entries had an advantage in all trials because of detasseling.

The results of the above trials are encouraging in that high yielding quality protein maize varieties can be developed without any yield disadvantage to normal counterparts.

(6) International testing program for the year 1978

The following trials have been sent out during the year 1978.

a) Yellow H.E.o_2 (IPTT-39)

b) OMPT-11 (opaque-2 maize population trial)

c) EVT No. 15

d) ELVT No. 19

The distribution of the above trials is shown in Table 10 The opaque-2 maize population trial will be of great interest. It consists mainly of opaque-2 versions of different normal advanced unit populations. Since these conversions are being sent out for the first time, the data from different countries will give us a fairly good idea about the adaptation and performance of these materials in different locations. Also in this trial we are suggesting to include at least four normal check entries to get a fairly good evaluation of opaques compared to the best normal materials existing in the national programs.

E. FUTURE OUTLOOK

The enthusiasm of mid sixty's had hoped to help hundreds of millions of malnourished people with high quality protein maize. Unfortunately this pay off has not yet been realized. This can be ascribed to the failure of adoption of opaque-2 maize that could not compete to normals with regards to yield and other agronomic traits.

It has been stressed in the preceding text that the future of quality protein maize materials depends to a great extent on solving problems that have acted as the major bottlenecks in the acceptance of these materials at the production level. Though attempts started several years ago to solve problems in opaques yet the success resulting from this effort has been achieved only recently.

A set of complex and inter-related problems with opaques have been completely remedied through the exploitation of genetic modifiers of opaque-2 locus. Recent development at CIMMYT have demonstrated that quality protein maize materials have good yield potential, reduced incidence to ear rots and have kernel phenotype which is indistinguishable from the normals. This breakthrough is exciting and it is hoped that it will help once again in reviving interest and enthusiasm that has been declining for the past 4-5 years. Necessary steps are, however, needed at this stage to accelerate research and production efforts with this type of maize. Many breeders and visiting scientists coming to CIMMYT have made favorable comments about the opaque materials that have been developed at CIMMYT. They have shown satisfaction with the progress that has been achieved.

At CIMMYT we have developed hard endosperm opaque-2 versions of genetically diverse materials that have climatic adaptation to lowland tropics, highlands and subtropical areas. Some of these materials may perhaps be useful directly in some areas. In other areas some of our populations may serve as source populations for further selection. The available materials can also serve as good donors to convert promising locally developed materials to hard endosperm opaques. Since most of the donor stocks are in good genetic backgrounds, one may or may not need to go through the backcrossing program.

We are also sending materials to different national programs to demonstrate the performance of these materials. We are hoping that the materials in trial 11 will convince many breeders about the potential of these materials. Also in countries where we have well established laboratories we are sending hard endosperm opaque-2 families from promising materials for evaluation and for subsequent use in their program.

The future outlook of floury opaque-2 conversion program also looks very bright. The Ninhydrin test has already accelerated the development of such materials.

The recent achievements in the field of quality protein maize are encouraging. It is hoped that these new developments will provide excitement and new challenge to maize breeders working in this area. The prospects of quality protein maize are bright and the hopes more certain now than before that high lysine maize materials with superior agronomic performance can now be developed with very little extra effort.

TABLE 1 .- Summary of performance of full-sib families from four different opaque-2 populations.

Population	test site	No. of families tested	No. of families selected	Mean yield in ton/ha tested	Mean yield in ton/ha selected	Selection differential (%)	C.V.	L.S.D. (.05)	Plant height in cms. tested	Plant height in cms. selected	Days to flower tested	Days to flower selected
peño opaque-2 (IPTT-37)	Poza Rica	250	84	1958	2117	8.12	26.9	1051	193	190	59	59
	Tlaltizapan	250	84	3870	4373	13.00	27.0	2083	172	170	73	72
	Obregón	250	84	4372	4772	9.15	18.9	1647	220	216	63	63
	Across	250	84	3400	3755	10.44	-	-	195	193	66	65
MS)6 H.E.o_2 (IPTT-38)	Poza Rica	250	93	1677	1814	8.17	27.1	915	200	197	57	56
	Tlaltizapan	250	93	3751	4112	9.62	23.3	1742	201	200	67	66
	Obregón	250	93	3174	3535	11.37	20.9	1329	230	229	61	60
	Across	250	93	2868	3154	9.97	-	-	211	209	62	61
MYT H.E.o_2	Poza Rica	250	96	1832	1990	8.62	31.7	1163	203	200	58	58
	Tlaltizapan	250	96	3942	4240	7.56	18.2	1429	213	210	68	67
	Obregón	250	96	3326	3748	12.69	17.8	1191	235	232	62	61
	Across	250	96	3034	3327	9.66	-	-	217	215	63	62
te opaque-2 Back-up Pool	Poza Rica	250	99	2760	2968	7.54	26.5	1458	214	212	58	58
	Tlaltizapan	250	99	4003	4440	10.92	26.7	2130	182	183	72	71
	Obregón	250	99	3867	4188	8.30	17.4	1348	226	223	63	63
	Across	250	99	3543	3866	9.12	-	-	208	207	65	64

TABLE 2 .- Mean grain yield and other agronomic traits of experimental varieties developed by recombining the best families from advanced unit opaque-2 populations on the basis of IPTT data. 1977

TT o.	Population	Experimental Variety	Grain Yield Kg/ha. Pop. $\bar{x}$	Sel. Fam. $\bar{x}$	Checks $\bar{x}$	%Superiority of Sel. Fam. population $\bar{x}$	$\bar{x}$ over Check $\bar{x}$	Days to flower. Pop. $\bar{x}$	Sel. Fam. $\bar{x}$	Pl. Height in cms. Pop. $\bar{x}$	Sel. Fam. $\bar{x}$
	Tuxpeño opaque-2	Poza Rica 7737(E)	3671	4453	2949	21.3	51.0	62	62	195	205
	PD(MS)6 H.E.o_2	San Jeronimo 7738	4228	5140	5548	21.6	-7.4	61	62	204	204
		Tocumen 7738	1553	2371	1545	52.7	53.5	50	49	177	179
		Poza Rica 7738	3731	4424	4079	18.6	8.5	58	59	209	210
		Obregon 7738	2755	3447	2760	25.1	24.9	57	55	193	192
	Yellow H.E.o_2	Poza Rica 7739	4092	4508	3797	10.2	18.7	60	60	198	196
	White H.E.o_2	Poza Rica 7740	4366	5264	4510	20.6	16.7	60	60	209	204
		Obregon 7740	3021	3977	3239	31.7	22.8	61	58	197	196
		Tlaltizapan 7740	6323	7603	5153	20.2	47.6	66	66	233	231
	Templado Am.o_2	Tlaltizapan 7741	6467	7808	6460	20.7	20.9	62	61	202	203
		Tlaltizapan 7741(E)	6467	6853	6460	4.1	6.1	62	63	202	204
		Pantnagar 7741	5370	6604	8179	23.0	-19.3	52	51	259	249
		Khumaltar 7741	5000	6619	5323	32.4	24.4	59	57	214	209

TABLE 3A.- Frequency of difference in endosperm hardness ratings of opaque-2 families from different population grown at two locations during the year 1977.

Entry No.	Population	Frequency of difference in endosperm hardness ratings of families					Total No. of families
		0	1	2	3	4	
1.	Mezcla tropical blanca H.E.o_2	62	81	11	-	-	154
2	Blanco cristalino H.E.o_2	97	128	37	2	-	264
3	Ant. x Ver.181 H.E.o_2	121	99	12	-	-	232
4	Mix.1- Col.Gpo.1 x Eto H.E.o_2	61	54	6	-	-	121
5	Mezcla Amarilla H.E.o_2	55	64	8	-	-	127
6	Amarillo Cristalino H.E.o_2	76	64	8	-	-	148
7	Amarillo dentado H.E.o_2	75	76	14	1		166
8	Tuxpeño Caribe H.E.o_2	70	82	9	-	-	161
9	Ant. x Rep. Dom. H.E.o_2	99	95	15	-	-	209
10	La Posta H.E.o_2	126	149	12	-	-	287
11	Yellow flint H.E.o_2	112	112	13	-	-	237
12	Yellow o_2 B.U. Pool	30	41	7	1	-	79
13	Late white dent H.E.o_2	55	78	13	-	-	146
14	Amarillo Bajío H.E.o_2	78	108	26	2	-	214
15	Amarillo Bajío x Mez.Trop. Am.H.E.o_2	56	52	12	-	-	120
16	Am. Bajío x varios temp.H.E.o_2	43	59	14	-	-	116
17	Am. Bajío x maíces Argentinos H.E.o_2	29	39	8	-	-	76
18	Mezcla amarilla P.B. x Lin. Ill. H.E.o_2	20	54	11	-	-	85
19	Pool 19 H.E.o_2	48	46	5	-	-	99
20	Pool 20 H.E.o_2	39	41	4	1	-	85
21	Pool 21 H.E.o_2	46	47	4	-	-	97
22	Pool 22 H.E.o_2	70	68	7	-	-	145
23	Pool 23 H.E.o_2	30	42	14	-	-	86
24	Pool 24 H.E.o_2	70	69	23	1	-	163
25	Pool 25 H.E.o_2	39	42	5	-	-	86
26	Pool 26 H.E.o_2	93	103	7	1	-	204

TABLE 3B.- Frequency of difference in endosperm hardness ratings of opaque-2 families from different populations grown at three locations during the year 1977.

IPTT No.	Population	Frequency of difference in endosperm hardness ratings of families								Total No. of families
		0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	
38*	PD(MS)6 H.E.o_2	64	125	45	14	1	1	-	-	250
39	Yellow H.E.o_2	25	119	68	35	2	1	-	-	250
40	White H.E.o_2	20	107	71	44	8	-	-	-	250

* Two locations only.

TABLE 4 .- Protein, lysine and tryptophan in the whole grain of some promising hard endosperm opaque-2 materials

Material	Protein (%)	Lysine in protein (%)	Tryptophan in protein (%)
PD(MS)6 H.E.o_2	10.8	3.4	0.83
Amarillo dentado H.E.o_2	11.2	3.5	0.88
CIMMYT H.E.o_2	10.9	3.8	0.97
White opaque-2 Back-up Pool	10.4	3.5	0.89
Ant.x Ver.181 H.E.o_2	11.2	3.6	1.00
Temperate x tropical H.E.o_2	9.2	3.8	1.12

TABLE 5 .- Mean values for protein and tryptophan in some hard endosperm opaque-2 materials of tropical and temperate origin (1977A harvest).

(Endosperm Analyses)

Pedigree	Origin	No. of families	Protein (%)	Tryptophan in protein(%)
	PR-77A			
Mix. 1-Col. Gpo. 1 x Eto H.E.o_2	309	122	8.1	0.77
Mezcla Amarilla H.E.o_2	311	125	8.4	0.78
Amarillo Dentado H.E.o_2	308	166	8.0	0.79
Blanco Cristalino H.E.o_2	316	266	8.2	0.74
Pool 23 H.E.o_2	321	264	8.0	0.79
	TL-77A			
Amarillo Subtropical H.E.o_2	1311	243	8.7	0.72
Blanco Subtropical H.E.o_2	1312	69	8.7	0.78
Eto x Ill. H.E.o_2	1313	74	9.0	0.70
Amarillo Pakistan H.E.o_2	1314	55	8.5	0.70
Blanco Pakistan H.E.o_2	1315	12	8.4	0.80
Hungarian Composite H.E.o_2	1316	68	9.3	0.72
Pool 27 H.E.o_2	1304	61	9.0	0.66
Pool 29 H.E.o_2	1319	23	8.7	0.74
Pool 30 H.E.o_2	1317	14	9.2	0.79
Pool 33 H.E.o_2	1318	28	9.4	0.71
Pool 34 H.E.o_2	1305	75	8.2	0.73
Amarillo Bajío H.E.o_2	1302	280	9.0	0.71
Mezcla Amarilla P.B. x Lin. Ill. H.E.o_2	1303	131	9.1	0.69
Amarillo Bajío x Maíces Argentinos H.E.o_2	1306	92	8.4	0.77
Amarillo Bajío x varios templados H.E.o_2	1307	131	8.7	0.80
Amarillo Bajío x Mez. Trop. Amarilla H.E.o_2	1308	144	9.2	0.77
Amarillo Bajío x Pl. Peq. Maz. Grande H.E.o_2	1309	30	9.5	0.66
Maíces tropical selección Batan H.E.o_2	1310	80	8.6	0.69

TABLE 6 .- Results of Experimental Variety Trial No. 15 during the year 1976. (Grain yield in kgs/ha. at 15% moisture).

Entry No.	Populations	Tocumen Panamá	Bodles Jamaica	Sakha Egypt	Pantnagar India	Pichilingue Ecuador	Palmira Colombia	San Andres El Salvador	Guanacaste Costa Rica	Sn.Cristóbal Rep. Dom.	Omonita Honduras	Pirsabak Pakistan	Suwan Thailand	Poza Rica Mexico	Obregón México	Tlaltizapan Mexico
1	Guanacaste 7437	4429	5784	2625	2303	5025	4794	4079	2060	3206	2630	4345	1958	1701	4291	7103
2	Cotaxtla 7437	5240	4356	2840	2831	4420	4507	4291	1818	3012	2106	3751	3258	1812	4482	6487
3	Sids 7537	5278	5088	2258	2871	4798	4861	4185	2287	3476	2273	4276	2791	1215	4699	7275
4	Cotaxtla 7537	5091	5465	2201	2422	4820	4794	4024	2089	3003	2061	4464	1491	2219	4455	6366
5	Poza Rica 7537	5473	4759	3085	3083	5097	4919	4000	2209	3612	2997	3904	2655	1440	4327	6748
6	Across 7537	5070	5060	3302	2879	4783	4696	3709	2088	2649	2679	4229	1618	2241	4532	6475
7	Pichilingue 7439	4654	5076	3129	2538	5333	4446	3512	1549	2667	2136	3558	2712	1458	4032	5679
8	Suwan 7439	4907	4726	3817	2493	4781	3885	3394	1736	2691	2442	3820	2476	1146	4279	5709
9	Cotaxtla 7439	5029	4338	3361	2286	4558	3939	3636	1823	2746	2230	3660	3038	1356	4305	6143
10	Across 7439	4511	4359	3190	2653	4722	4077	3849	1625	2652	2042	3724	2558	1680	4277	5634
11	La Máquina 7539	4179	4808	3354	2320	4579	3915	3949	1803	2882	2442	3158	2979	1986	4197	6127
12	Amarillo Dentado H.E.o_2	4357	4464	3387	2472	3917	4492	3339	1771	3279	2649	3806	3227	1946	4591	6215
13	CIMMYT H.E.o_2	4403	5581	3033	2639	4168	2973	3624	1473	2673	2533	3006	2636	1488	3338	5937
14	Across 7539	5007	4701	3384	2933	4469	3834	4039	1851	2785	2794	3122	2467	1468	4137	6349
15	Temp. x Trop. H.E.o_2	4074	3783	2312	2445	3463	2841	3164	989	2079	1827	3244	2206	692	3763	5307
16	Across 7440	4306	5010	3392	2811	4222	3830	3321	2088	2646	1706	3411	3191	1758	4179	6043
17	La Máquina 7540	5042	4775	3836	2314	4841	3786	3630	1570	2676	2206	3668	2573	1914	3903	5907
18	San Andres 7440	3749	4271	3157	2475	4074	3258	3527	1654	2403	2158	3141	3133	1066	3613	5323
19	Ferke 7537/2	5395	5067	2400	2718	4678	3951	3858	1986	2842	2006	3806	1897	1682	4391	6753
20	Tuxpeño opaque-2	4916	5015	3012	2287	4142	4953	3933	1697	2303	2424	2952	1661	1228	4029	7113
21	Yellow H.E.o_2	4397	4681	3467	2417	4546	3913	3488	1353	2342	2036	3492	1639	1753	4137	5883
22	White H.E.o_2	4178	4546	2881	2187	4311	3317	3497	1526	2776	2082	3443	1900	1251	3907	5124
23	PD(MS)6 H.E.o_2	3875	4093	3770	2367	4338	3653	3330	1756	2570	2173	2747	2321	1585	3693	5023
24	Check 1*	3301	4780	1722	775	3293	2953	3912	451	3288	1391	2108	4315	1713	4307	6191
25	Check 2*	4631	5241	3395	2491	5979	5321	3970	1559	3146	1576	2603	6573	2243	4303	6732
Means		4640	4813	3052	2480	4534	4072	3730	1712	2836	2260	3498	2693	1602	4167	6148
LSD (.05)		638	969	947	828	676	971	815	542	536	715	912	832	642	514	1008
C.V.		9.7	14.2	21.9	23.6	10.5	16.9	15.4	22.4	13.4	22.4	18.4	21.9	28.4	3.7	11.6

* not the same checks at each location.

TABLE 7.- Results of EVT No. 15 during the year 1977

Entry No.	Pedigree	San Jerónimo	La Calera Nicaragua	Tocumen Panama	Poza Rica Mexico	Obregon Mexico	Tlaltizapan México	Guanacaste Costa Rica	San Andres El Salvador	Cotaxtla México	Jamaica	Ludhiana India	Pirsabak Pakistan	Suwan Thailand	Across Mean
1	Ferke 7537	4914	3946	2903	5461	2297	6830	3479	3394	4315	2406	5458	4394	5611	4005
2	Cotaxtla 7537	5030	3539	2752	5497	1948	6779	2900	3146	4400	2661	5473	4021	5253	3837
3	CIMMYT H.E.o_2	4141	3106	2652	4561	1578	4894	2900	3149	3858	2491	5282	4200	4821	3537
4	Ferke 7539	4217	3479	2600	4321	1869	5394	3370	2964	4039	2730	5624	4176	4785	3659
5	Suwan 7539	4025	3776	2755	5382	1766	5324	2849	2958	4288	2864	5767	3982	4800	3690
6	Poza Rica 7539	3351	2897	2824	4612	1539	5412	3052	2955	3900	2646	5515	4176	4861	3510
7	Ant.x Ver.181 H.E.o_2	4379	3818	2721	4861	1867	5397	3333	3252	3855	2821	5797	4297	4562	3728
8	Poza Rica 7540	4303	3033	1761	4727	1824	4706	2652	2524	3470	2133	5146	3382	4499	3232
9	Across 7437	3394	3930	2621	5415	2093	6015	2509	2906	4152	2403	6036	3252	4673	3551
10	Check (opaque-2)	4134	4409*	1736	4867	1649	5100	2903*	2867*	2991	3452*	5549*	2524*	4141	-
11	Check (normal)	3644	3079	2649	2103	1491	2791	1055	3958*	3855	3761*	5449	2742**	6692	-
	Means	4194	3502	2621	4981	1864	5639	3004	3027	4030	2572	5566	3986	4873	
	L.S.D.	1234	897	599	617	445	1053	979	665	695	575	800	796	596	
	E.V.	20.9	17.7	16.5	9.2	17.2	13.8	24.3	15.0	12.4	14.6	10.1	14.9	8.4	

* Normal
** Opaque-2

TABLE 8 .- Results of ELVT No. 19 during the year 1976.(Grain yield in kgs/ha. at 15% moisture).

Pedigree	Cuyuta Guatemala	La Máquina Guatemala	Sta. Rosa Nicaragua	Tocumen Panamá	Guarare Panamá	Danli Honduras	Guanacaste Costa Rica	Alajuela Costa Rica	San Andres El Salvador	San Cristóbal Rep. Dom.	Cayes Haiti	Bodles Jamaica	Texaco Trinidad	Poza Rica Mexico
Poza Rica 7437	3692	4904	4330	4894	2133	8018	3673	5206	3873	5007	5124	4667	1677	2518
Across 7437	3318	4753	4358	4739	1488	7352	3358	4791	3879	5120	4082	4088	1347	2218
Delhi 7439	3465	4561	4412	4897	1391	7158	3842	5909	3688	4383	4167	4658	1883	2342
Poza Rica 7439	3361	3808	3618	5042	1794	6955	3464	4894	2988	4343	4803	4588	1585	2230
San Andres 7440	3235	4222	3855	4255	1103	6579	2827	4618	2452	3690	4394	3915	1265	2230
Poza Rica 7441	3455	3886	4179	4779	1685	6346	3558	3991	3355	4127	4149	3452	1302	2009
Across 7441	2927	4546	4261	5155	1442	7136	3670	5806	3612	4457	5121	4433	1711	2303
Check 1 PD(MS)6 H.E.o_2	2977	4056	4088	4442	1455	6473	3376	3806	3258	3977	4321	3946	1552	2839
Check 2 (opaque-2)	3114	4351	2670	4115	1636	7364	4697	2355	3097	2907	2230	5767	1118	2924
Check 3 (normal)	4316	5184	2624	4621	1976	8185	4330	7533	3700	4727	4467	7618	923	3164
Means	3386	4427	3840	4694	1610	7157	3680	4891	3390	4324	4376	4713	1436	2478
LSD (.05)	838	796	1133	414	865	852	873	1672	904	766	1624	988	602	728
C.V.	17.3	12.6	20.7	6.2	28.9	8.3	16.6	23.9	18.7	12.4	26.0	14.7	29.3	20.6

Pedigree	Obregón Mexico	Tlaltizapan Mexico	Cotaxtla Mexico	Saavedra Bolivia	Pichilingue Ecuador	Porto Viejo Ecuador	Kawanda Uganda	Sids Egypt	Delhi India	Pantnagar India	Pirsabak Pakistan	Khumaltar Nepal	Rampur Nepal	Site not men. Nepal	Suwan Thailand	Means
Poza Rica 7437	4167	6627	4888	4812	5206	5976	2692	6612	1367	4452	2742	5133	1602	6252	1800	4277
Across 7437	4003	7449	4761	5146	4291	6388	2829	5840	1961	5170	3049	4176	2505	6621	1976	4306
Delhi 7439	3764	6376	3915	4358	5079	5036	2614	6700	1230	5214	2700	4055	2411	5988	2149	4102
Poza Rica 7439	3939	5246	3591	4321	4806	5242	2373	6439	1594	4488	3406	4109	2264	5364	1882	3390
San Andres 7440	3891	4842	3639	4091	3824	4691	2350	5675	1376	4614	3103	4861	2366	5394	1806	3526
Poza Rica 7441	3621	5827	3761	4642	4158	5067	2361	6399	1855	4218	3558	4197	2168	5158	1749	3762
Across 7441	3039	6197	4185	4652	4455	6158	2076	6759	1839	4696	2424	4197	2241	5961	2500	4099
Check 1 PD(MS)6 H.E.o_2	3700	5881	3912	4267	4036	4406	2224	6614	1107	4427	3188	4018	2355	5152	1700	3711
Check 2 (opaque-2)	3897	6376	4403	5285	5539	6527	3138	7337	1570	5592	1788	3561	1598	4149	3321	3877
Check 3 (normal)	5421	6739	5955	5600	6570	5455	2212	8707	985	3609	2382	4270	2125	3509	4609	4535
Means	4034	6164	4301	4717	4796	5495	2487	6709	1497	4648	2834	4318	2164	5355	2349	
LSD (.05)	773	1287	721	927	703	944	562	1221	848	816	847	1074	586	1359	795	
C.V.	13.4	14.6	11.7	13.8	7.3	8.5	15.8	12.7	39.6	12.3	20.9	17.4	19.0	17.8	23.7	

1/ . Check 2 and Check 3 did not have the same pedigree at all locations.

TABLE 9 .- Results of ELVT No. 19 during the year 1977 (Grain yield in kg/ha at 15% moisture).

Entry No.	Pedigree	La Máquina Guatemala	Cuyuta Guatemala	La Celba Honduras	La Calera Nicaragua	Tocumen Panama	Bodles Jamaica	Poza Rica México	Obregón México	Tlaltizapan México	San Andres El Salvador	Río Hato Panama	Cotaxtla México	Jamaica	Gemiza Egypt	Sids Egypt	Ibadan Nigeria	Pirsabak Pakistan	Yousafwala Pakistan	Kisolon Philippines	Suwan Thailand	Across Mean
1	Cotaxtla 7437	4018	3882	4179	4597	3639	4119	5636	1539	7606	2955	2755	3058	2727	5631	4392	2600	3936	5536	2146	4832	3982
2	Poza Rica 7537	4126	3412	3664	4042	3561	3789	5070	1941	6349	3161	2742	3352	2539	4588	3293	2597	2997	5127	1918	4559	3634
3	Across 7537	4657	3909	3258	3700	3330	3861	5891	1935	7058	3236	2946	3239	2224	5168	2500	3421	3703	6276	1982	5164	3874
4	La Máquina 7539	4157	3558	4024	3991	3427	3625	4730	1531	6039	3018	3024	3488	2661	5014	4097	2921	3203	5212	3200	4842	3797
5	Across 7539	3909	3873	4109	4206	3603	3883	4861	1935	6203	2627	3118	3424	2430	7009	4827	3012	3191	4103	2339	4838	3875
6	Across 7440	3823	3021	3179	3694	3391	3175	4046	1467	5791	2879	2676	2942	2285	5261	3563	3079	3664	4573	2124	4456	3469
7	Poza Rica 7437	4669	3621	4100	4394	3897	4028	5591	1820	6442	3294	3309	3239	2264	5196	3713	2394	3455	6076	2870	4864	3958
8	Across 7441	4510	3203	3961	3736	4073	3797	4670	1554	6218	2797	2888	3100	2930	6364	4901	3400	3624	6012	2873	5086	3995
9	Check (o_2)	5124	3439	3388	4391*	2076	3869	4482	1792	5882	3697	909	4085	3649	6261	5347	3261	2430	3385	3658	4673	-
10	Check (N)	4861	3776	4570	4794	3218	4603	6042	1865	6352	3649	1430	1942	3491	7815	6599	3464	1812	5733	3997	5976	-
	Means	4233	3559	3809	4045	3615	3784	5061	1715	6463	2995	2932	3230	2507	5528	3910	2928	3471	5364	2431	4830	
	LSD (.05)	565	764	978	989	744	744	702	387	886	605	655	674	704	1666	844	853	1075	1630	581	559	
	C.V.	9.0	15.0	17.8	16.7	15.2	13.4	9.6	15.6	9.7	13.5	17.8	14.8	18.1	20.0	13.7	19.8	23.5	21.9	15.0	7.9	

* Normal

TABLE 10.- Distribution of progeny and experimental variety trials during the year 1978.

	No. of sets distributed							Total
	S.America	C.America	Caribbean	Mexico	Africa	Asia	Others	
Yellow H.E.o_2(IPTT-39)	2	-	-	1	2	1	-	6
OMPT-11	5	14	7	5	6	6	1	44
EVT-15	9	4	3	5	9	6	-	36
ELVT-19	9	8	5	7	11	12	-	52

CHEMICAL RESEARCH AND ANALYTICAL SERVICE

The search for improved simple, rapid and reliable methods for protein quality evaluation has been a continuing part of the protein quality laboratory during the past years.

For the preliminary screening of thousands of small maize samples, simple direct or indirect methods to estimate the content of the two limiting amino acids, tryptophan and lysine in the maize protein, have been used. In this way the laboratory has provided a continuous service to the high protein quality maize breeding program, and the genetic improvement of hard endosperm opaque-2 and floury-opaque-2 maize lines has been achieved with the aid of the chemical data provided by the laboratory.

Analytical Procedures

The chemical evaluation has been performed on basis of genetic family or single kernel analysis.

Protein Determination

The nitrogen content is estimated by the conventional micro-Kjeldahl procedure or by the automated technicon method (Hofstader, R. A. 1966).

Tryptophan

This amino acid is determined in deffated maize endosperm samples using the CIMMYT modified Opienska and Blauth colorimetric method after papain hydrolysis (Hernandez and Bates, 1968).

Lysine

The CIMMYT modified colorimetric method of Tsai has been used to determine lysine and deffated endosperm or whole kernel samples (Villegas and Mertz, 1971), in the screening for high quality materials. Ion exchange chromatography has been used to verify the quality of selected materials (Moore, et al 1958, Spackman, D. H. 1962 and Liu and Chang 1971).

Dye Binding Capacity (DBC)

As suggested by Mossberg (1969), and Munck (1972), the ratio of DBC/KP (Kjeldahl Protein) can be used as an estimation of the level of basic amino acids in the protein. The levels of lysine, histidine and arginine are highly positively correlated in cereals. The ratio DBC/KP called quality index (Q. I.) is used in the screening for high lysine maize whole kernel samples.

Zein

The method used is a simple turbidimetric determination of zein. (Paulis, Wall and Kwolek, 1974). The procedure is based on an inverse correlation of the zein content with percentage of lysine in protein, it can be used in endosperm or whole kernel evaluation.

Ninhydrin Test

The test measures the quantity of water soluble free amino acids which has been found to be in greater amount in opaque-2 maize than in the normal counterpart. This test has been used in CIMMYT's laboratory only in the preliminary screening of floury 1-opaque-2 materials (Mertz, Misra, and Jambunathan, 1974). It is a qualitative test that only indicates high or low content of free amino acids because of the presence or absence of the opaque-2 gene.

Protein Fractionation

Some of the best promising hard endosperm opaque-2 materials, as well as some sugary-2-opaque-2 lines have been subjected to fractionation of their endosperm proteins using the procedures of Mertz and Bressani, 1957, and the method of Landry and Moureaux, 1970.

Standarization of Procedures

Among the service laboratories of national programs and CIMMYT's laboratory, the standarization of procedures for protein evaluation has been attempted for the past 3 years. Check samples have been prepared at CIMMYT and distributed to the different laboratories where CIMMYT has been involved in training of personnel and the establishment of the laboratories by providing equipment with UNDP funds.

In most cases the results have been satisfactory with regard to check samples, which were distributed for analysis and the methods tested were the same. However, we have found when visiting the laboratories, some difficulties in providing the right service to the breeding programs because critical details in sample preparation, or criterium for selection of the appropriate method to be used depending of the material to be evaluated have not been considered. We are convinced that it is very important to continue with standarization of procedures and to follow as closely as possibly the needs and difficulties of these laboratories, and to solve the problems in our capacity in the shortest time to make the laboratories functional and effective to the programs.

Establishment of Service Laboratories

Equipment has been provided with the funds from the UNDP-CIMMYT Global Research Project to the following national maize breeding programs:

Latin America	Africa	Asia	Europe
Brazil	Egypt	India	Rumania
Peru		Philippines	
Colombia		Thailand	
Ecuador			
El Salvador			
Mexico			

Argentina and Nepal also have analysis laboratories, but CIMMYT has not provided any equipment so far.

Training

The following countries have trained young scientists at CIMMYT's laboratory for periods of 2 to 4 months.

Argentina	(1)	Guatemala	(1)	Egypt	(1)
Brazil	(1)	Mexico	(2)	Kenya	(1)
Peru	(2)	India	(2)	Yugoslavia	(1)
Colombia	(1)	Pakistan	(2)	Rumania	(1)
Ecuador	(2)	Philippines	(3)		
El Salvador	(1)	Thailand	(3)		

We consider that the laboratories that are giving true support to the breeding programs at the present time are the following:

Peru, El Salvador, Guatemala, Mexico, India, Philippines, Thailand, Egypt.

We also feel that if some of the problems can be solved in the national programs that are really interested in the improvement of maize protein quality, effective production programs could be underway.

Biological Evaluation

Promising new maize genotypes that by chemical analysis have shown to be high in lysine and tryptophan were selected for biological evaluation at different nutrition laboratories.

CIMMYT established a proper feeding test laboratory using as test animal the meadow vole (microtus pennsilvanicus) in 1971. A cooperative experiment was conducted to evaluate different laboratory animals (the white rat, mouse, meadow vole and chicks) during 1972 to 1973.

The study was done on samples of maize, triticale, wheat and sorghum. The 5 maize samples involved included opaque-2 hard and soft endosperm and two normal types, listed below:

1) Veracruz 181 antigua gpo I x Venezuela, normal

2) Veracruz 181 antigua gpo I x Venezuela O_2 (hard endosperm)

3) Veracruz 181 antigua gpo I x Venezuela O_2 (soft endosperm)

4) Tuxpeño Opaco (soft endosperm)

5) Tuxpeño Normal

The most important results of these studies were the following:

- Satisfactory and comparable results were obtained with rats when using 2 or 4 weeks experiment duration periods (Purdue University). The PER values reported by Mertz (Table 1) using the rat as the test animal, showed superiority of the protein quality of the soft opaque-2 samples (3.31 and 3.25) over the hard endosperm opaque-2 maize (2.96). However, the hard endosperm was quite superior in quality when compared with the protein quality of the normal maize samples (1.67 and 2.07).
- No data was reported from the mouse evaluation, but according to personal communication from Dr. Kiess, the results were not satisfactory.
- The results obtained at CIMMYT with the meadow vole did not rank the material with different protein quality among different cereal grains. They also did not correlate with the PER values obtained from the rat bioassay.
- Data obtained from Pennsylvania State University using voles, did not agree with results obtained at CIMMYT.

In 1973, a more complete study of the requirements and the physiological behavior of the meadow vole was conducted at CIMMYT. Due to negative responses of the test animal, the feeding trials using the meadow vole were discontinued at CIMMYT.

In 1974 three opaque-2 hard endosperm and two opaque-2 soft endosperm maize samples were evaluated at INCAP (Instituto de Nutrición de Centro América y Panamá). The results are reported on Table 2 and show similar

PER values for the Veracruz 181 opaque hard endosperm and Tuxpeño x La Posta opaque-2 soft endosperm, even though the lysine of the soft endosperm sample was higher than that of the hard endosperm maize.

In 1977 the National Institute of Animal Science at Denmark evaluated seven maize samples, from which one was normal maize, one opaque-2 soft endosperm and five opaque-2 hard endosperm samples. The samples evaluated were the following:

A Tuxpeño O_2 (Soft E.) PR-76A # (IPTT-37)

B CIMMYT HE O_2 PR-76B, Bh-101

C PD $(MS)_6$ HE O_2 IPTT-38

D Yellow HE O_2 IPTT-39

E Amarillo Dentado HE O_2 PR-76-13, 801

F Ant. x Ver 181 HE O_2 806 #

G White Maize Cr Tl-77A

Groups of five Wistar male rats weighing approximately 75g were used in this experiment in which a preliminary period of four days and a balance period of five days were employed. Each animal received 150 mg N in 10 g dry matter daily throughout the preliminary and balance periods. Feeding took place once a day. The N was adjusted by using N-free mixture (Eggum, B. O. 1973).

The response criteria are True Digestibility (TD), Biological Value (BV) and Net Protein Utilization (NPU).

TD is the percentage of nitrogen intake which is absorbed by the organism. In cereal grain protein it is known to be between 80 and 90%. The maize samples show higher values (95.3 to 96.6%). Less than 5% of the dietary nitrogen was not absorbed by the rats (Table 3).

Since the BV is the part of absorbed nitrogen which is retained in the organism, it indicates protein quality. The respective values are fairly high between 72 and 78%. The BV values agree very well with the lysine values of the respective samples (Table 4), being higher in the samples with higher lysine content (more than 4.0%).

It should be mentioned that in the group of the three top samples (A, E, F.) one is a soft endosperm type (A), the others are hard endosperm types. The other hard endosperm samples also performed well. It is satisfying to see that the nutritional quality of the hard endosperm types is as good as the quality of the soft endosperm type. In addition, hard endosperm has more desirable kernel characteristics and consequently good acceptability, and is by far superior in nutritional quality to normal maize.

Concluding Remarks

Progress in quality protein maize during the last five years can be summarized as follows:

- Considerable progress has already been made in developing quality protein materials that approach more nearly in kernel appearance and performance to normal materials, including yield performance.
- Biological value of hard endosperm materials, as shown in previous section,

is comparable to that of soft-endosperm opaque-2, and much superior to normal maize.

- Simultaneously new laboratory techniques have been devised to assess quality characteristics. Laboratory activities employing simple and rapid screening techniques are supporting breeding work in several countries in the world. Standarization of procedures among the different laboratories have been developed.
- Equipment has been provided to establish service laboratories for chemical evaluation in five countries in Latin America, one in Africa, one in Asia and one in Europe.
- Twenty five scientists from sixteen countries have received training at the CIMMYT protein laboratory and also numerous trainees from the maize breeding program, spent short periods of approximately one week in the laboratory to become familiarized with the techniques used in the chemical evaluation. We consider this understanding between breeders and chemists is essential for accelerated progress of the breeding programs.

TABLE 1.- COMPARISON OF BIOLOGICAL EVALUATION OF FIVE MAIZE SAMPLES WITH RATS, VOLES AND CHICKS

Average Protein Efficiency Ratio

Sample No.	Pedigree	Rat (Mertz)[a] Purdue University 28 days	14 days	Vole (Shenk)[b] Penn. State University	Vole (Bauer)[c] CIMMYT	Chick (McGinnis)[d] Washington State University
4854	Ver 181 (Normal)	1.59	1.67	0.87	1.30	2.10
4855	Ver 181 (Hard End)	2.83	2.96	1.41	1.65	2.45
4856	Ver 181 (Soft End)	2.90	3.31	1.89	1.62	2.81
4857	Tuxpeño Opaco (Soft End)	2.84	3.25	2.28	2.27	no value
4858	Tuxpeño Normal	1.72	2.07	1.08	2.00	2.33
8262	(Casein)	3.34/3.22	4.38/3.64	2.15	2.37	2.81

a) Ten male rats in each group

b) Each value represents the average response of 6 voles over six-day period

c) Each value represents the average response of 5 voles over five-day period

d) Each mean is the average of four replicate groups of 5 chicks each

TABLE 2.- BIOLOGICAL EVALUATION OF FIVE MAIZE OPAQUE-2 SAMPLES *

INCAP No.	CIMMYT Lab. No.	PEDIGREE	PROTEIN %	LYSINE %	PER**
14593	14358	Composite White (HE)	9.7	3.9	2.22
14594	14360	Composite Yellow (HE)	9.6	3.8	2.14
14595	14359	Composite K O_2 (Soft E)	10.4	3.1	2.25
14596	14361	Veracruz 181 O_2 (HE)	9.4	4.0	2.41
14597	14357	Tuxpeño x La Posta O_2 (Soft E)	8.7	4.6	2.41
		Casein 8%			2.86
		Casein 10%			2.01

* By INCAP, Dr. Bressani.

** Diets prepared at 8% protein level, four male and four female rats per trial.

TABLE 3. - TRUE DIGESTIBILITY (TD), BIOLOGICAL VALUE (BV) AND NET PROTEIN UTILIZATION (NPU) FOR SEVEN MAIZE TYPES.

Sample	Identification	RESPONSE CRITERIA					
		T D		B V		NPU	
		%	(s)	%	(s)	%	(s)
A	Tuxpeño O_2 (Soft E.) PR-76A # (IPTT-37)	96.0	1.8	77.6	2.1	74.5	1.3
B	CIMMYT HEO_2 PR-76B, Bh-101	95.6	0.4	73.5	.8	70.2	.9
C	PD $(MS)_6$ HEO_2 IPTT-38	95.7	0.5	71.8	1.4	68.7	1.3
D	Yellow HEO_2 IPTT-39	95.3	1.0	74.0	1.4	70.5	1.9
E	Amarillo Dentado HEO_2 PR-76-13, 801	95.8	1.4	74.5	0.8	71.4	1.4
F	Ant. x Ver 181 HEO_2 806 #	96.6	1.1	76.2	1.5	73.6	1.2
G	White Maize Cr T1-77A	98.1	1.2	62.7	1.0	61.5	0.8

TABLE 4 .- AMINO ACID COMPOSITION OF MAIZE SAMPLES USED IN NUTRITION STUDIES

	SAMPLE						
	A (S)	B (HE)	C (HE)	D (HE)	E (HE)	F (HE)	G (N)
AMINO ACIDS (g/16g NITROGEN)							
Valine	5.22	5.08	5.15	5.26	5.39	5.33	4.74
Isoleucine	3.29	3.08	3.25	3.23	3.29	3.25	3.59
Leucine	8.63	8.45	9.58	8.84	9.02	8.74	13.17
Tyrosine	3.55	3.40	3.56	3.54	3.62	3.47	4.31
Phenylalanine	3.99	3.80	4.01	4.02	4.11	3.99	4.78
Lysine	4.18	3.79	3.54	3.98	4.09	4.04	2.63
Methionine	1.88	1.65	1.78	1.79	1.82	1.76	2.16
Cystine	2.56	2.54	2.73	2.65	2.75	2.67	2.03
Tryptophan	0.96	0.91	0.95	1.35	1.16	1.03	0.64
NPU	74.5	70.2	68.7	70.5	71.4	73.6	61.5

NPU on Ly. r = 0.7[illegible] NPU = [illegible]

NPU on Cry. r = 0.6[illegible] NPU = 11.3 L + [illegible]

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UNITED NATIONS DEVELOPMENT PROGRAMME

Report of the

UNDP Consultant Mission

To Review

The CIMMYT Programme for Strengthening Agricultural Economic Research in East AFrica (GLO/74/009)

June 1978

Report of review of CIMMYT Program for Strengthening Agricultural Economics Research in Eastern Africa (GLO/74/009)

Per Pinstrup-Andersen

Development of agricultural technology appropriate for the farmers for whom it is intended must be based on a thorough knowledge of actual farming systems, the farmers' economic problems and constraints, and the characteristics of the specific ecological and socio-economic environment in which the farmers operate. Lack of such knowledge may result in technology that either does not meet the needs of the farmers or is difficult for the farmers to adopt. Farm level studies may help generate such knowledge.

The project under review makes provisions for advising and assisting Eastern African countries in agro-economic research at the farm level. The immediate project objectives are:

(a) To stimulate increased research on the individual farming systems in use in the area, on the resources available to the farm family, and on farm-level problems and constraints, as well as on agricultural markets for both inputs and products;

(b) To help indigenous researchers gain proficiency and experience in this type of research;

(c) To increase co-operation between agricultural scientists, extension workers and policy makers, by presenting quantitative evidence concerning the socio-economic and technical problems which impede the adaptation of new technology at the farm level.

(d) To promote support for regular financing of farm-level research among the national governments involved.

The project became operational in October 1975 with the recruitment of an agricultural economist, Dr. M.P. Collinson, who initially spent 3 months in Mexico at CIMMYT headquarters to get acquainted with pertinent aspects of the maize and wheat improvement programs. He has been stationed in Nairobi, Kenya since January 1976.

In view of the impending termination of UNDP support to GLO/74/009 scheduled at the end of December 1978, and also because UNDP and CIMMYT have jointly agreed to undertake the evaluation of the UNDP supported Global Project, Research and Training in the Development of Quality Protein Maize, Phase III (GLO/75/007) during the period 12-15 June, it was agreed that immediately upon completion of this review, an evaluation of CIMMYT's Agro-Economic Research in East Africa with UNDP support under GLO/74/009 should take place in order to assess the progress achieved in relation to established schedules and targets for activities, outputs and immediate objectives, and to make specific recommendations on the future of the project.

The present report is the result of such an evaluation. The terms of reference for the evaluation is attached. The remainder of the report is divided into four parts. The first part provides a brief description of project activities accomplished and in progress. Then follows an assessment of project content, accomplishments and activities in progress in the light of project objectives.

Part three presents suggestions for improvement in project approach and procedures and the report terminates with a series of recommendations for future project direction and content.

Activities accomplished and in progress

The project under review is focused on assisting national and local agricultural research and training institutions in the project countries in developing or improving their capacity in the area of farm level agro-economic studies and orienting agricultural production research towards farm level problems and farmer environment.

The project activities may be divided into three areas as follows:

1. Identification of collaborators (institutions and individuals).
2. Advise, guidance, training and other participation in demonstration surveys.
3. Other activities aimed at: a) promoting relevant farm level economics research, and b) assisting national and local agricultural research institutions and individuals in orienting agricultural research towards the generation of technology best suited for the low income farmer.

Each of these areas is discussed below.

Identification of collaborators. Attempts have been made to identify collaborators in all six countries included in the project; Ethiopia, Kenya, Tanzania, Malawi, Uganda, and Zambia. Assistance has been offered to five of these countries. Assistance was not offered to Uganda for security reasons. The offers of assistance have been positively received by national institutions and individuals in four countries (Ethiopia, Kenya, Zambia and Tanzania) and collaborative studies were initiated in these four countries. The project has not yet been invited to initiate activities in Malawi primarily because of rapid turnover in that country's research management and lack of interest among the persons initially approached. Collaborative activities initiated in Ethiopia have been postponed at the request of the Ethiopian institutions for security reasons. The content of the activities completed or in progress in the remaining three countries: Kenya, Tanzania and Zambia is discussed in a subsequent section.

The closest collaboration has been established in Kenya. This is probably due to two factors: a) Top management of the division of research in the Kenyan Ministry of Agriculture had a desire to re-orient agricultural research to conform more closely with on-farm needs prior to the initiation of this project although little or no progress had been made in that direction, b) The location of the project staff in Kenya.

Demonstration surveys. The principal component of the project has been promotion of and assistance in the planning and execution of farm level studies. These studies have performed a dual purpose: a) To demonstrate the utility of such work for agricultural research planning and b) To train national economists in carrying out relevant farm level economics research in collaboration with agricultural scientists. The project under review has developed a methodology for such studies and has assisted in a variety of ways to assure a successful completion of the studies undertaken. The methodology developed is presented in the attached papers by M. Collinson. Briefly, the methodology attempts to gather, analyse and interpret information about the environment in which the farmer operates of most relevance and utility for future research, extension and policy planning. This is done by means of a) gathering and analyzing available information, b) un-structured gathering of data from the farms of interest through visits to these farms (pre-survey), c) structured farm survey and d) data analysis and interpretation. The assistance provided by this project has involved advise, guidance, particpation in various phases of the project planning and execution as well as financial support to the extent necessary. In some studies, M. Collinson has carried out a large part of the actual work while national collaborators have been able to assume the major work load in others. Likewise, the need for financial support has varied among studies. In general, the project has carried a large share of the direct field costs associated with the surveys (transportation, payment of interviewers, etc), while collaborating institutions in many cases have covered salaries of their participating staff members. The share of total costs covered by the project has been highest for the first survey in each country partly because the collaborating institutions in some cases needed to see the results from the first survey to be convinced of the value of investing in such work and partly because the institutions which are likely to benefit from such work, e.g. agricultural research institutions, were not equipped to carry out the work either because they did not have economists on their staff or because no funds were allocated for the purpose. As more surveys are initiated, the share of total costs to be covered by the project under review has decreased and the most recent surveys in Kenya and Tanzania include no financial support from the project.

The project - through M. Collinson - has promoted and participated in a number of demonstration surveys. In Kenya, five such surveys have been initiated in the following districts:

1. Part of Siaya District
2. Kwale District
3. Part of Embu District
4. Machakos East
5. Machakos West.

A final report has been completed for the survey of Part of Siaya District (Report No.1) and data processing and analysis have been completed for the survey of East Machakos. Pre-survey and actual data collection have been completed in the other three.

One survey has been completed in Tanzania (The Drier Areas of Morogoro and Kilosa Districts, Report No.2) and another (Uyole District) is expected to be completed within 2-3 months. Three additional surveys have, according to M. Collinson, been initiated by one of the regional research stations in Tanzania. These surveys are based on the expertise gained during the first two surveys and only minor assistance will be required from M. Collinson. One survey is under way in Zambia. In that survey, data have been collected and data processing is currently taking place. Problems with data processing facilities have delayed this project. One survey was well under way in Ethiopia but was postponed for security reasons.

Eight national economists participated directly in the above surveys. It is expected that the training received by those economists has enabled them to carry out similar work with little guidance from the CIMMYT/UNDP project at the same time as their attitudes towards economics research may have changed in favour of more relevant farm level studies.

Regarding the specific findings of the individual surveys and their utility for research planning, the two published report present the findings of the first survey in Kenya and the first survey in Tanzania. On the basis of these findings, the studies suggest desired characteristics of new technology for maize production in the regions studied and outlines a framework for future maize research (pp.29-39 of report No.1 and pp. 40-44 of report No. 2). Suggestions for research and development for other crops of importance to the regions are also provided in the reports.

Other activities

In addition to the above mentioned, the project has been involved in a series of activities aimed at the promotion of relevant farm level economics research and assisting national research institutions and individuals in developing procedures for orienting agricultural research towards the generation of technology best suited for the low income farmers. These activities are complementary to the earlier mentioned surveys. Only the activities where the project has been directly involved are discussed here. Activities brought about by the project without direct project involvement are discussed in the subsequent section.

M. Collinson has participated in the development of the Kenyan 5-year research plan. He is responsible for providing the justification and outlining the responsibilities and areas of work for economists in the Research Division of the Ministry of Agriculture. With the exception of one, who will be located at the Division Headquarters, these economists will be located at the regional research stations and their workplan calls for activities along the lines of the project under review to be carried out in close collaboration with agricultural researchers. As will be further elaborated in the subsequent section, the Division had no economists prior to this project. M. Collinson works closely with the Division director and the Harvard group of economists in the Ministry of Agriculture on this matter.

M. Collinson has worked with survey collaborators at Egerton College (a 3-year agricultural college from where a large proportion of Kenya's extension agents graduate) in re-orienting teaching of economics towards farm level issues. Most of this work has been part of the training for survey work with additional work limited to a few seminars and informal guidance.

M. Collinson is collaborating with the Eastern Africa Agricultural Economics Society in planning of "The First Farm Level Socio-Economic Studies Workshop" to take place in Nairobi during the period 4th September - 16th September, 1978. Invitations have been sent to economists in 9 African countries and the primary purpose of the Workshop is to train the participants in carrying out farm level economics research. The initiative to the Workshop came about largely because of the activities of the project under review and M. Collinson will be responsible for a number of the workshop sessions.

Contrary to Kenya, regional agricultural research stations in Tanzania had economists on their staff prior to this project. However, according to M. Collinson, the work of those economists was not focused on providing farm level information useful for research planning, and collaboration with agricultural researchers was very limited. Partly through the surveys and partly in a more direct way, M. Collinson has worked with research station management, economists and agricultural researchers to create collaborative work on farm level issues. As a consequence, a committee on farm level research has been formed and work is now under way in that area. M. Collinson has worked with the national maize production program on the incorporation of farm level surveys, on-farm trials and demonstrations into the work of the Program and a proposal along these lines have been developed and well received by the Program staff. Work in Tanzania includes collaboration with CIMMYT maize researchers and the national maize research program regarding the survey results and village trials.

Further work in Zambia is awaiting the results of the first demonstration survey and the reactions to these results.

Assessment of project activities and progress in the light of project objectives, design and content

Overall, the project has been very successful. Significant contributions have been made along the lines of the objectives. The project has stimulated increased research at the farm level (obj. No.1), it has helped national researchers gain proficiency in such research (obj. No.2), it has promoted co-operation between economists and research administrators (obj. No.3), and it has promoted increased financial support for farm level research. However, the project impact to date has been limited to two countries, Kenya and Tanzania, with some work now under way in Zambia as well. The reasons why work in Ethiopia and Uganda have not progressed are obvious and the problem in Malawi has been that the people initially contacted expressed no interest in collaboration. On the other hand, the project has been extremely successful in Kenya and Tanzania where the accomplishments have exceed the objectives, when the latter are interpreted in a narrow sense. I refer here to the impact of the project on research planning in general as discussed below. However, more time is needed to fully incorporate the project activities into the national institutions in Kenya, Tanzania and Zambia and to develop the required capacity for handling these activities on their own. Likewise, with an extension of the project, it should be possible to carry out similar activities successfully in other countries, particularly if the accomplishments in Kenya and Tanzania are used for demonstration purposes.

Let us now turn to a brief discussion of the impact of the project activities to date. Of greatest importance is probably the Kenyan Ministry of Agriculture's decision to include economists in its staff to work closely with agricultural scientists at the various research stations and at headquarters on the design of new technology along the lines suggested by this project. Although the attitude towards such an arrangement appears to have been favorable prior to the initiation of this project, there is no doubt that it was the demonstration surveys and the interaction between this project and the research division of the Ministry of Agriculture that convinced top research management to locate economists at the research stations. Five agricultural economists have been hired by the research division and located at the research stations. Two of these have Masters degrees from Morogoro, Tanzania. Current plans call for a total of 9 agricultural economists in the Research Division, of which 8 will be placed at the various research stations and one at headquarters. The total five year budget for these economists is approximately 880,000 U.S. dollars. Mr. Thairu, Director of the Research Division, expects that the economics group will be able to carry out the relevant activities without external assistance within three years provided the group gets the assistance and supervision needed during the first three years from the CIMMYT/UNDP project. Such supervision and assistance has been requested by the Division. The Harvard Institute of International Development has a mission of four economists in the planning section of the Kenyan Ministry of Agriculture. At least partly due to the activities by M. Collinson, it has been arranged that one of these economists, Dr. David Feldman, will move to the Research Division to work closely with the Division director in research planning and execution of the 5-year research plan currently being developed. This is the first time an economist is located in the Division. As part of the project, M. Collinson has participated in the development of the five year plan and he is responsible for providing the justification and outlining the responsibilities and areas of work for the economists in the Division as prepared for the five year plan.

In another Kenyan institution, the Egerton College of Agriculture, the project has created considerable interest. Two economists and a number of students from that College participated in three of the five surveys carried out in Kenya. This participation has enabled those economists to carry out other, similar surveys and they are currently planning two surveys of tea growers with the objective of identifying the reasons why tea yields appear to be much lower on small than on larger farms. Those surveys were requested by the Tea Research Council after the Council became aware of the first Kenyan survey under this project. In addition to creating awareness of the potential utility of relevant farm level economics research for identifying yield limiting factors and developing the ability to carry out such research, the project appears to have had considerable influence on attitudes and teaching at Egerton College. M. Collinson has presented seminars at the College on the work and a course on farming systems has now been introduced. This course is being taught by one of the economists involved in the surveys and will focus on the small farmers' production environment and needs for technology relying to a considerable degree on case study material developed from the surveys. The enthusiasm for relating teaching more closely to the situation of the Kenyan farmer was strong among the two economists I talked to and I was informed that the livestock department of the College, due to the activities of the CIMMYT/UNDP project, was planning farm/ranch surveys for the purpose of focusing teaching on existing conditions. Since the majority of Egerton College graduates join the extension service, a change in teaching emphasis towards obtaining a better understanding of the farm level situation as a basis for extension recommendations could have a very significant impact on the extension services ability to transmit farmers needs for new technology to the research station in the future.

Participation in the planning and execution of "the First Farm Level Socio-Economic Studies Workshop" sponsored by the Eastern Africa Agricultural Economics Society, the University of Nairobi and the Ford Foundation is likely to further promote relevant farm level economics research through the workshop training.

The project has worked with maize researchers at two research stations in Kenya. However, there is a severe scarcity of experienced manpower in Kenyan maize research at the moment and the actual research being carried out on maize in Kenya at present appears to be very limited. For these reasons, the project probably has not yet had any significant impact on Kenyan maize research. However, as the maize research staff is re-build, results from surveys completed and in progress as well as the incorporation of economists into the research stations are likely to be very useful in future research on maize in Kenya. Unfortunately, I could not see the heads of the two research stations Kitale and Katumani where maize research is part of the program because of travel and illness on their part.

As is the case in Kenya, the project has had a considerable impact in Tanzania. First, the project activities have caused the establishment of a research committee to promote and coordinate farm level studies to be carried out by research station economists in collaboration with agricultural scientists. Secondly on-farm trials are being planned on the basis of the findings of the first survey. Thirdly, additional surveys are being planned or under way by research station economists in regions not covered by the two demonstration surveys. Fourth, a complete sequence of farm surveys, on-farm trials and demonstration has been proposed and developed by Tanzanian staff for consideration and use by the national maize production program. Fifth, survey results have re-inforced the emphasis on examining the advantages of short season maize varieties by the national maize research program (this program is supported by two CIMMYT maize scientists). Sixth, survey findings have been used in on-going village trials. Seventh, the two surveys have caused increasing collaboration between economists and agricultural scientists in that the surveys were carried out jointly.

Eighth, because of interest in the project approach on the part of participating economists from the University of Dar-es-Salaam, exposure to farm level work and actual farming conditions has been incorporated into the last year students' activities. Since I did not visit Tanzania, the above was derived from discussions with M. Collinson and available written material.

Follow-up activities in Zambia will depend on the reaction to the results of the survey currently in progress.

Thus, to briefly summarize, the project has created a considerable interest in carrying out farm level economics research in Kenya and Tanzania and it has helped national economists gain proficiency in such research (as earlier mentioned, 8 economists were directly involved in the demonstration surveys plus a number of students). The project has increased the awareness of the utility of farm level economics as well as agronomy research in research planning and adaptation of technology to farmers' needs among research managers and economists and as a result, a number of additional projects with little or no support from the CIMMYT/UNDP project is now under way or being planned. Furthermore, the project has demonstrated the utility of integrating the work of economists with that of agricultural scientists. Future efforts should explore how the extension service may be better utilized in the overall efforts to design technology that meets farmers' needs and takes account of farmers' production environments and constraints. Furthermore, the project may now turn its focus on assisting the economists recently incorporated into the Kenyan agricultural research system as well as continuing the assistance to the efforts in Tanzania and Zambia. Efforts should be made to initiate demonstration surveys in other countries. In order to fully integrate the farm level economics research with agricultural research, the project might undertake assistance to and demonstration of on-farm trials in the regions where surveys have been carried out. This, however, would require an agronomy input from the project.

While the project is focused on cereals with particular emphasis on maize, there has been a considerable spill-over effect. Thus, farm level economics research must, to be relevant, take account of the farming system within which cereals - or maize - are grown. This implies that farm level research may be useful for planning research on crops other than maize to the extent they are part of the farming system. The surveys carried out to date have, however, focused on farming systems where maize is an important component and data interpretation has been most complete for that crop. Whether, in fact, it would be preferable to avoid commodity orientation in these surveys is another matter. But since the CIMMYT mandate relates to specific cereals, a broader focus would, I presume, require collaboration among a number of international centers. However, this project is fully justified on the basis of its contribution with respect to maize, and any impact on other crops or on agricultural or economics research and training in general may be considered a bonus.

In carrying out project activities, the project has interacted with a number of entities such as the Eastern Africa Agricultural Economics Society (participation in planning and execution of earlier mentioned workshop) and the Ford Foundation. The latter has provided funds for graduate training of economists to work in the Research Division of the Kenyan Ministry of Agriculture and talks with Dr. Gerhart, Ford Foundation program adviser, indicated that the Foundation is interested in a continued collaboration. It should also be mentioned that a number of the people I talked to, emphasized that the success of the project was, to a considerable degree, due to M. Collinson's professional and personal abilities to get the job done, filling in the gaps where they existed, yet maintaining a low profile, giving the credit of the work largely to nationals and national institutions. Skills in dealing with people are important in the kind of work included in this project. On the basis of other people's comments and my own observations I am convinced that M. Collinson has such skills in addition to his professional qualifications.

Suggestions for improvements in project approach and procedures

I believe that the approach and procedures used in the demonstration surveys and the linkage of the surveys to agricultural research planning and execution are sound. To have its full impact on research planning and execution it is important that the project takes responsibility for certain follow-up activities not specifically mentioned in the project proposal. I am here referring to assistance to actually incorporating survey findings into research planning and assistance to design and develop institutional frameworks to continue the required work. M. Collinson has involved the project in these activities and I suggest that they be continued in any extension of the project. In addition, I believe it would be useful to involve the project in the demonstration of how on-farm trials can be planned and carried out on the basis of survey findings. As mentioned earlier, such demonstrations would most effectively be carried out collaboratively by M. Collinson and an agronomist. While national research institutions obviously have agronomists on their staff they tend to focus their efforts on controlled experiments, whether such experiments are carried out on or outside the research station, and it is my impression that planning and execution of the type of on-farm trials needed to follow up on the surveys would require assistance in agronomy from outside the national institutions.

While the pre-survey visits to the farms do include direct field observations, the actual survey is based on interviews with farmers. Experience from farm level work carried out by CIAT indicates that small farmers often are unable to correctly evaluate the importance of individual diseases, pests and certain other yield limiting factors. On the other hand, direct field observations combined with structured data collection related to these observations provided good estimates of the yield losses caused by each of the principal yield limiting factors in beans and cassava in Colombia. Such estimates may be useful for decisions regarding the characteristics of improved varieties to be sought through breeding and selection. However, considerable training of the persons responsible for the field observations is needed to assure success. Furthermore, the time of the observation is critical and a number of observations during the growing season may be required. The feasibility of incorporating direct field observations in a structured form must, therefore, be determined on a case by case basis. I suggest that the feasibility of incorporating such direct field observations in future demonstration surveys be explored.

CIMMYT is concerned with the nutritional quality of maize as one of the characteristics of improved maize varieties. In order to assist national research and extension in selecting and promoting varieties from a nutritional point of view, information is needed on the nutritional situation in the various regions. In so far as the farm families' nutrition is concerned, the relevant information might be obtained through the farm level surveys. Some of the demonstration surveys carried out to date provide data on this topic. It is suggested that procedures for obtaining the required data be incorporated in any future demonstration survey provided that the necessary expertise on nutrition can be obtained. This suggestion correspond to suggestions made by the recent review team on the high quality protein maize project.

The current project makes provisions for a consultative panel to assist the project staff in understanding technical and organizational aspects within the region. Attempts were made to establish the panel primarily through UNDP offices in the various countries. Those attempts were, with the exception of the identification of representatives from Kenya, unsuccessful. In view of the rapid development of the project in Kenya and Tanzania I believe that instead of the consultative panel it would be more useful to include in any extension of this project funds to permit the appropriate persons from countries outside Kenya and Tanzania to visit Kenya and Tanzania, either individually or in the form of workshops, to become familiar with the utility of the project in these countries and thus promote the spread of project activities to other countries. At the same time the project staff should be encouraged to travel to these other countries to obtain whatever information the consultative panel was meant to provide. The latter has in fact been occuring during this project.

Finally, the terms of reference calls for suggestions regarding the procedures for reporting to UNDP. Since the project content is of a long term nature, I believe that one report to UNDP per year on project progress is sufficient. However, it is important that the annual report incorporate all major accomplishments and progress of the project during the year in some detail to keep the relevant parties informed.

Recommendations for future directions and project content

On the basis of my review of this project I recommend:

1. That the project be extended by at least 3 and preferably 5 years.

   Justification: In order to obtain the full benefits of this project, and I believe they are likely to be large, it is important that the project be extended to the point where the project activities are fully integrated into national institutions and where the project activities can be maintained by these institutions. While it is difficult to predict how soon this may occur, it is my judgement that at least three more years are needed in Kenya, possible less in Tanzania but most likely 5 years or more in other countries currently included in the project and countries to be included at a later date.

2. That an agronomist be added to the project staff for the duration of the project extension.

   Justification: As demonstration surveys are completed, on-farm trials are likely to play an increasing role in overall project activities. Furthermore, if direct field observations are included in the survey (see recommendation No.4) there will be an increased need for expertese in agronomy. Even in the absence of direct field observations, agronomy expertese on the staff might facilitate pre-surveys and certain parts of data interpretation. Finally, an interdisciplinary project staff may be in a better position to promote interaction across disciplines in national institutions and to collaborate with the staff and management of these institutions in matters related to research planning.

3. That the location of the project staff be maintained in Nairobi for three more years. At the end of the 3 year period, and provided that the project extension goes beyond that period, it is recommended that a transfer of the project staff to one of the other countries included in the project be considered in the light of the progress made by Kenyan institutions during the first three years of the extension.

   Justification: It is to be expected that the project can provide the most effective assistance in the country where the staff is located. An effective assistance is critical in Kenya over the next three years to fully integrate the project approach into national institutions. Thereafter the assistance may be more urgently needed elsewhere.

4. That the feasibility of including direct field observations on yield limiting factors in future demonstration surveys and training under this project be explored.

   Justification: Information on yield losses caused by individual diseases, pests, or other factors on farmers fields and the area where such yield limiting factors appear in the region under study might facilitate decisions on which resistance and tolerance factors should take high priority in selection and breeding. Experience from farm level research carried out in Colombia under my supervison has shown that such yield and production loss estimates cannot usually be obtained in a small farmer environment either from farmer interviews or from controlled experiments. Direct field observations, on the other hand, showed great promise.

5. That the necessary questions and procedures to obtain information on dietary patterns and nutritional issues among low income farm families, as outlined in the recent consultants' report on high quality protein maize, be incorporated in future demonstration surveys and training under this project, provided that the necessary expert se on nutrition will be made available through the extension of the high quality protein maize project or otherwise.

   Justification: As improved plant materials with different nutritional characteristics are made available from CIMMYT and possibly elsewhere, national institution will need information to establish criteria for breeding and selection as well as technology diffusion on nutritional grounds. Such information must focus on a specification of the nature and extent of the existing nutritional problems. While it is recommended that this project gather such information from farmers only, it is recognized that similar information will be needed from non-farming communities. However, urban consumer surveys fall outside the scope of this project, as currently visualized.

6. That demonstration of procedures and utility of on-farm trials be included in any extension of this project provided that an agronomist is added to the project staff.

   Justification: Only if the findings of the farm level surveys are utilized properly in agricultural research planning and execution will the full value of such surveys be realized. Sound on-farm trials requires, in addition to survey results, procedures somewhat different from those normally applied in controlled experiments. These procedures may not be known or fully understood among agricultural researchers. Likewise, the need for and potential utility of on-farm trials are often undervalued. However, sound on-farm trials can greatly facilitate the adaptation of agricultural technology to farm level constraints and environments and thus promote rapid adoption of technology.

7. That future demonstration surveys, training, on-farm trials and follow-up activities attempt to incorporate the extension service into those efforts to the fullest extent possible given institutional arrangements.

   Justification: I believe that the most effective means to maintain a constant flow of information from the small farmer to the research institutions in the long run would be the extension service. However, the extension service in most countries is focused on providing information towards the farmer only. To be truly effective, however, I believe the extension service must provide a two-way flow of information: the extension agent must continuously gather information at the farmer level to improve his understanding of the farmers need for new technology, he must communicate such information to the appropriate research institutions with assistance from economists in interpretation, he must participate in on-farm trials and testing of new technology and he must finally communicate, through demonstrations or otherwise, the characteristics of technology available to the farmer and assist the farmer in incorporating the best suited technology into the farming system. The project under review may play a significant role in bringing research, extension and the farmer closer together. But it is likely to be a difficult and time consuming job and institutional arrangements may prohibit success in some countries.

8. That any extension of this project include funds for training of nationals from the countries included in the project at CIMMYT or other appropriate institutions in the area of on-farm trials and other areas relevant to the activities of this project, provided that such funds cannot be obtained from other sources.

   Justification: As the national institutions become convinced of the utility of the type of activities carried out by the project under review, and as a result will expand such activities on their own, there will be a need for training beyond that which can be provided through participation in the demonstrations. This is already apparent in Kenya and possibly in Tanzania. The production training programs of CIMMYT and other international centers might be utilized for this purpose.

9. That the choice of countries to be included in the extension of this project be reviewed on the basis of expected probability of establishing fruitful collaboration.

   Justification: Some of the countries currently included in the project clearly offer little opportunity for fruitful collaboration while certain countries not currently included might offer excellent opportunities. Since the factors determining whether fruitful collaboration is possible may change during the course of the project, it may be advisable to leave considerable flexibility in any future projects regarding country selection.

10. That CIMMYT be encouraged to arrange for periodic meetings of the CIMMYT regional agro-economics project staffs for the purpose of interchange of ideas and experiences regarding project procedures and methodology applied in the various regions and that any extension of this project include funds that would make it possible for the project staff to participate in such meetings and any other arrangements that would further fruitful collaboration with the other CIMMYT regional agro-economic projects.

   Justification: Since all the CIMMYT regional agro-economics projects are aimed at basically the same goals, yet with each project given considerable flexibility to develop procedures and methodology best suited for the particular region, it appears that periodic interaction of the persons involved might be of considerable mutual benefit. The current development of a manual for the agro-economic work is a step in that direction.

Appendix 1. Persons consulted in Kenya:

1. Derek Byerlee, CIMMYT economist.
2. Michael Collinson, CIMMYT regional economist.
3. David Feldman, Economist, Harvard group (HIID), Min. of Agriculture.
4. John D. Gerhart, Program Advisor, Ford Foundation, Nairobi.
5. J.A. Lugogo, Head, Department of Economics, Egerton Agricultural College, Njoro, Kenya.
6. Conrad ter Kuile, FAO/UNDP, Nairobi.
7. D.M. Thairu, Director, Research Division, Ministry of Agriculture.
8. S.M. Machooka, Lecturer, Dept. of Economics, Egerton Agricultural College, Njoro, Kenya.
9. John Thomas, Head, Harvard Group, Ministry of Agriculture.

Appendix 2. Written material reviewed

Demonstrations of an Interdisciplinary Farming Systems Approach to Planning Adaptive Agricultural Research Programmes:

Report No.1, Part of Siaya District, Nyanza Province, Kenya, April 1977

Report No. 2, The Drier Areas of Morogoro and Kilosa Districts, Tanzania December 1977.

CIMMYT/Medical Research Center, Nairobi. Research Planning Study. Data presentation: Parts of Lower, Drier Areas of Northern Division, Machakos.

UNDP grant - GLO/74/009. Annual Report, October 1976.

UNDP grant - GLO/74/009. Annual Report, December 1977.

UNDP. Project Recommendation of the Administrator GLO/74/009, April 1975.

Contract between the UNDP and CIMMYT regarding GLO/74/009.

Program for First Farm Level Socio-Economic Studies Workshop held by the Eastern Africa Agricultural Economics Society, Sept 4 - 16, 1978.

*M.P. Collinson, The Economic Programme of the International Maize and Wheat Improvement Center - East African Region 1976 (mimeo).

* M.P. Collinson, The Methodology of the CIMMYT approach to technology selection and adaptive research planning (mimeo).

M.P. Collinson, Diagnosing the need for new technology. Paper presented at Rural Technology Meet, Arusha, Tanzania, Aug 29 - Sept 9, 1977.

*M.P. Collinson, Detailed guidelines for pre-survey sequence: by discussion with farmers (mimeo).

M.P. Collinson, A Case for agricultural economics in institutions responsible for adaptive agricultural research. Memorandum to the working group on agricultural research - Kenya's 4th Five year Plan 1979 - 84.

Various folders, questionnaires, etc.

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* Attached to the report.

THE METHODOLOGY OF THE CIMMYT APPROACH TO TECHNOLOGY SELECTION AND ADAPTIVE RESEARCH PLANNING

1. INTRODUCTION

The objective of the approach is to identify the existing management strategies of local farmers which are important enough in satisfying their priorities to limit the acceptability of new technologies for a crop in their farming system for which a research or development programme is to be mounted.

A recursive sequence in a homogeneous type of farming area focuses the investigation on present management strategies of the local farmers. The table is a matrix of management strategies and possible reasons for farmers using these, it is not exhaustive. As is apparent most strategies listed may be utilised for several reasons, it is important to determine in the investigation which reason or reasons play a part in the local situation. The sequence is carried out by a small team of crop and social scientists and is broken down into four stages:

(1) Collation of background information
(2) Pre-survey
(3) Farmer survey
(4) Data interpretation and post survey.

2. COLLATION OF BACKGROUND INFORMATION

Several sets of information are usefully collated, where available, to guide the fieldwork and begin to focus the investigation.

(1) RAINFALL DATA

(a) Monthly rainfall averages give the rainfall profile for the area which, unless irrigation is used, is a good guide to the cropping calendar. The profile also shows up times of the year likely to be very busy on farms in the area, times when food and cash may be a problem and periods when rainfall reliability could be awkward for the farmer.

(b) Crude estimates of rainfall reliability are made for months of the growing season (say 50 mm +). Low reliabilities show where farmers face a hazard in management and they will have evolved strategies to offset it.

(2) SOIL AND TOPOGRAPHY

(a) Identification of different soil types in the area, their relative extensiveness, their local names and any selective use of soil types by local farmers. Such information provides a background to assess whether to follow up the possibility of farmers using soil types as a management strategy under varying circumstances.

(b) Chemical and mechanical analysis of soils in the area offers a commentary on specialised use of soil types by farmers and on the likely benefits from management practices designed to maintain fertility or structure and to prevent erosion.

(c) Information on the topography of the area provides a background against which to assess the possibility of farmers utilising different locations under varying circumstances as well as the likely importance of soil erosion and the need to explore farmers management for conservation practices.

(3) POPULATION AND SETTLEMENT PATTERN

(a) Population density gives an indication of the land scarcity and of the feasibility of fertility maintenance by shifting cultivation. Such information is more valuable if the potential arable proportion of the total area is known.

(b) The settlement pattern has consequences for the structure of the farm unit, for the assessment of the payoff between land scarcity and fragmentation in clustered settlements, and the possibility of utilising specific soil types.

(4) THE CROP AND STOCK ENTERPRISE PATTERN

Data on the enterprise pattern, the area under various crops and numbers of animals, derived from secondary source data indicates the relative importance of the various crop and livestock activities to local farmers and gives a start in describing the local farming systems. If two sets of data some years apart can be studied trends in the system can be identified and followed up for further assessment in the pre-survey. Activities being dropped from or introduced into the system under natural or market pressures often form a focus for development effort and warn of expected variations in survey results within a basically homogeneous farming area.

(5) CROP AND STOCK PEST AND DISEASE PROBLEMS

By discussion with local agricultural staff or crop researchers prior information on dominant pests and diseases focuses the pre-survey questionning and allows the preparation of visual aids to recognition for presentation to farmers.

(6) FOOD AND CASH CROP MARKETS AND PRICES

(a) Information on the food distribution network and availability of basic staples through the area, with emphasis on seasonality in supply, price levels and seasonal price changes will evidence a need for the farmer to grow his own food.

(b) Information on cash crop marketing channels' the volume traded and the main periods for purchasing will help assess the relative importance of crops as sources of cash to local farmers and likely periods for cash flow problems in the area.

(c) Information on the cash crop price mechanism, price trends and any seasonal or locational variability will allow assessment of farmer uncertainties of cash incomes.

(7) INPUT DISTRIBUTION

Information on local sources of inputs, types stocked and stocking problems will help assess the availability of inputs to farmers in the area. Credit sources, methods of application and numbers using facilities are usefully included here.

(8) PAST EXTENSION PROGRAMMES

It is useful to have a history of the extension efforts made in the area as a basis for judging effectiveness and to help explain apparent departures from traditional practice among farmers.

3. PRESURVEY

The pre-survey involves talking to farmers in the area about their farming. It is important that the farmers met are not a special selection or the information obtained will be misleading. The pre-survey needs some ten days of professional time. It follows a recursive pattern of farmer interviews and group discussions, writing up, absorption of the material, structuring of the next set of discussions. Perhaps a day of interviews followed by half a day of evaluation and planning is a rough guide on the use of time, the aim being to move deeper into critical areas of the farming system. Participation of crop scientists is particularily valuable in the later stages when management strategies involving varieties and husbandry practices are being explored.

(1) DESCRIPTION OF THE LOCAL FARMING SYSTEM

(a) The enterprise pattern and detail of the end uses of products including identification of end uses which are variety specific.

(b) Food supply; main and preferred staples and relishes. Dishes prepared. Seasonal availability of main foods, substitutes used in offseasons, food purchases and periods of the year.

(c) Cropping calendar: Usual time of planting of each crop, length of period in the ground and time of harvest. Make a distinction by variety where appropriate.

(d) Main sources and uses of cash: Crops and livestock products sold, alternative outlets. Price levels and seasonal price variations. Off farm work timing of cash income. Main expenditures during the year, timing of those expenditures. Particular attention on purchased inputs for use on farm.

(e) Husbandry: A detailed description of husbandry practices for the crops under investigation. How does he grow the crop. Operational sequence and methods involved.

(2) IDENTIFICATION OF RESOURCE CONSTRAINTS

(a) Land as a possible constraint on farming activities. Can extra land be obtained, if so how and where. Are there specific soil types which are scarce; which crops does this affect or how does it affect his management. Is he using other land?

(b) Labour - Busiest period in the year. The crops and type of work contributing to this peak. Are there secondary peaks. When and what crops and operations are involved. Does he hire any labour - permanent or casual; if casual when and for which crops and operations.

(3) FARMERS OPINIONS ON HAZARDS

(a) Yield variability. What variation in yields does he expect from his major crops? Range. What are major causes of poor yields on major crops with particular detail for the programme crop.

(b) Rainfall. Types of rainfall problem, frequency of such problems and severity of the effects.

(c) Pests and diseases. Types of pests and diseases faced, frequency of the attacks and severity of the effects.

(4) IDENTIFICATION OF FARMERS MANAGEMENT STRATEGIES IN THE FACE OF RESOURCE LIMITATIONS AND HAZARDS FACED

The table is a matrix of small farmer management strategies and reasons for using them. It is used as a checklist in this last step in a recursive sequence of investigation into local farming. By this stage some of the strategies listed will have been eliminated, some will have been identified in use in the system new ones may have been recognised. Three steps should be followed up in a final round of discussions with farmers.

(a) Discuss listed strategies not yet covered, identify or eliminate them.

(b) For each identified strategy discuss its main objectives with farmers. The previous description of the system should guide this discussion. Preferences, Resource constraints and hazards the sources of such strategies having all been covered in the course of the pre-survey.

(c) For strategies capable of use as a reaction to a hazard within the single production period, the season, look for some idea of the frequency with which it employed.

(5) HYPOTHESES DEVELOPMENT

In the final part of the pre-survey the team are concerned to develop hypotheses on the objectives and importance of identified management strategies in meeting the priorities and preferences of local farmers. The hypotheses is need to be related to the potential technology components which would be examined in a crop research programme for local farming or the available components being evaluated as the basis for a crop development programme in the area. For example; beans, for which a programme is being planned, are at present planted over a prolonged period and this is identified as a strategy to give a continuous flow of fresh beans which is preferred food for local farmers. Because timely planting is a component of improved crop technology it is important that this hypothesis is tested in the farmer survey and an evaluation made of the importance of this prolonged supply of fresh beans in terms of total relish supplies over this same period, and in terms of relative preferences for alternatives available over this same period. The question to be answered is will the farmers sacrifice the prolonged flow of fresh beans to get the higher yields from timely planting, or should this component be excluded as an experimental variable in a research programme or as a package component if a development programme is being planned.

A list of technology components featuring in crop improvement packages is given below. It is not exhaustive.

(1) Varieties

(a) End use - product characteristics

(i) Palatability
(ii) Processability
(iii) Storability.

(b) Growth characteristics and by-product considerations.

(i) Plant habit
(ii) Length of season
(iii) by-product suitability

(2) Cultural practices

(a) Seed bed preparation
- (i) timing of the work
- (ii) state of tilth required
- (iii) form of seed bed.

(b) Time of planting

(c) Method of planting
- (i) How the seed is put in the ground
- (ii) Number of seeds placed per hole
- (iii) Spacing of planting stations.

(d) Weeding
- (i) Method of weeding
- (ii) State of cleanliness sought
- (iii) Timing and frequency.

(e) Harvesting and processing
- (i) Method of harvesting
- (ii) Timing and frequency
- (iii) Method and timing of processing

(f) Storage
- (i) method
- (ii) Required duration.

(3) Use of purchased inputs

(a) Type
- (i) Fertiliser
- (ii) Insecticide
- (iii) Herbicide
- (iv) Fungicide

(b) Rate of application
(c) Timing and frequency of application
(d) Method of application

4. FARMER SURVEY

The farmer survey is used to verify or modify the findings of the pre-survey. A one visit survey best mounted at a time of the year when crops are established but harvesting has not yet started. Some sixty farmer interviews are adequate for each area investigated. The questionnaire is built and the survey designed to:

(1) Verify the description of farming obtained in the pre-survey, including farmers priorities and preferences, and thus the homogeneity of farming in the area under investigation.

(2) Verify the limiting factors identified in the pre-survey.

(3) Verify the hazards faced by farmers and their relative importance.

(4) Verify the management strategies used by farmers and test the hypotheses on their objectives and importance to farmers.

5 POST SURVEY

Interpretation of the survey data may modify the picture obtained in the pre-survey or it may give further insights into the farming system. Either of these possibilities will be developed by further discussions with farmers in the area under investigation.

6. THE RESULT

Interpretation of the investigation allows evaluation of the acceptability of technology components to local farmers. In planning a research programme for the area the evaluation will be of potential components. It will indicate criteria for variety selection and experimental variables for agronomy work. It will also set management practices for non-experimental variables and indicate the acceptable range of treatment levels on the feasible experimental variables. In planning a development programme the evaluation will be of available technology components. It will select those acceptable to farmers and as such suitable for inclusion in a crop improvement package as a basis of the development effort.

In planning the research programme the focus of effort on acceptable components will improve the productivity of the research resources employed. In planning the development programme the improved rate of adoption experienced due to the acceptability of the improved technology offered will speed the spread of benefits across the local farm population.

AN INVENTORY OF SMALL FARMER MANAGEMENT STRATEGIES AND THEIR OBJECTIVES

OBJECTIVES A – L / STRATEGIES 1 – 24		PREFERENCES:		RESOURCE LIMITS		HAZARDS NATURAL			BIOLOGICAL		ECONOMIC		
		Specific staple or relish	Foods needs at specific time of year	Land scarcity	Labour scarcity	Rainfall uncertain	Floods	Soil Erosion	Pests	Diseases	Poor food markets	Food and cash crop prices uncertain	Seasonal variation infood prices
		A	B	C	D	E	F	G	H	I	J	K	L
Flexibility of crop choice	1		*			*	*		*	*		*	
Growing subsistence crops	2										*	*	*
Growing non-preferred foods	3		*	*	*	*			*	*			
Use of specific varieties	4	*	*	*	*	*			*	*			
Joint Products	5			*									
Long Term Storage	6		*			*	*		*	*	*		*
Hire of machinery or labour	7				*	*							
Renting of land	8			*									
Crop Rotation	9							*	*	*			
Choice of Location	10		*			*	*	*	*	*			
Choice of soil type	11		*		*	*	*	*	*	*			
Irrigation	12		*	*		*							
Staggered Planting	13		*		*	*							
Mixed Cropping	14		*	*	*	*		*	*	*			
Land Prep. methods	15				*	*		*					
Time of Planting	16		*	*	*	*			*	*			*
Low Planting Density	17				*	*			*	*			
High Plant Density	18			*				*	*	*			
Mulching	19				*	*		*					
Interpenetrating cropping	20		*	*	*			*					
Fresh harvesting	21		*		*				*	*			*
Use of herbicides	22				*								
Use of insecticides & fung.	23								*	*			
Use of fertilisers	24			*				*					

DETAILED GUIDELINES FOR PRE-SURVEY SEQUENCE: BY DISCUSSION WITH FARMERS

1. DESCRIPTION OF THE LOCAL FARMING SYSTEM

(1) Enterprise pattern and end uses:

(a) List the crops grown and livestock kept by local farmers. Note for each one whether it is grown by the majority or few local farmers. If a few only what is special about those few e.g. Large with plenty of land and capital, close to specialised markets or processing facilities, old and traditional etc.

(b) For each major crop list the varieties grown, give the local name and, where possible, relate to known variety names. Assess whether each variety is important to most farmers, to a few, or to all on particular occassions. Detail why it is important.

(c) For all major crop, varieties and animals, list the end uses to which they are put. This should include the fruit in the case of crops and any other part of the plant used as a product. Animal products and by-products are equally important. Where different varieties of the same crop may be grown by the same farmer it is particularly important that differences in end uses are described.

(d) For each identified product, including varieties with different end uses, detail the sequence which is followed when it is taken from the plant in the field or from the animal. Include when it is taken in the life cycle of the plant, how it is prepared or processed or used, and if sold what exact use is it then put to. In describing these end uses it is important to be detailed right through the sequence.

(e) Note particularly any crops, crop varieties or animals
(i) that used to be widespread among farmers of the area but are now disappearing. Assess why such crops, varieties or animals are disappearing.

(ii) that have recently become popular with farmers of the area and appear to be spreading. Assess the reason for their popularity.

(2) Food supply and preferences.

(a) Detail the main dishes eaten by farm families in the area. The constituents of the dishes and the preferred state of each constituent. What alternative constituents are used when preferred ones are not available?

(b) List the preferred starch staples and relishes, and the substitute staples and relishes used when preferred ones are scarce. Indicate on a chart:

(i) the months when each is readily available from farm production.

(ii) months when supplies may be uncertain

(iii) months when supplies are definitely not available from farm production.

(c) Assess whether any new foods are becoming popular and replacing traditional ones.

(d) List foods commonly purchased by farm families

(i) All the year round

(ii) At certain periods of the year which should be specified.

(e) If major foods are bought at certain periods assess whether

(i) Most farm families buy some major foods at particular periods in some years.

(f) If families have to resort to buying only in some years assess how frequently this is and the reasons for this problem arising in those years.

(g) See whether prices of the major foods vary over the year. Give an indication of price levels at seasons when food is:
(i) plentiful (ii) Scarce.

(h) Which is the most difficult period of the year for feeding livestock and why?

(3) Cropping Calendar

For each crop, and where different varieties are grown by the farming community, for each variety, indicate:

(a) The usual planting time for the crop.

(b) The range in possible planting times, including the latest time that farmers will consider it worthwhile to plant that crop or variety.

(c) The length of time the crop spends in the ground.

(d) The usual harvest time for that crop.

Also assess the major reasons for farmers planting each crop variety at the time they do.

(4) Cash sources and uses

(a) List the major crops and livestock products sold by farmers in the area and the main channels through which each is sold.

(b) Assess whether prices earned through the major outlets are subject to large variations

(i) between seasons

(ii) within seasons.

seek to identify reasons for large variations, examples of the extent of variations and, for within season variations, the periods of high and low prices.

(c) Assess the 'usual' level of cash incomes from the major products sold on local farms.

(d) For products that are foods as well as sources of cash evaluate the different circumstances in which farmers will decide to sell rather than store for food. Assess which circumstances are most common in sales decisions.

(e) Assess how common is off farm employment among farmers and farmers' families. The main types of off farm employment and the usual level of cash income earned from these sources. Distinguish temporary and permanent off farm work. For temporary work identify the periods of the year when it is undertaken. Evaluate whether this is because opportunities arise then, or farmers' need cash at these times.

(f) Assess what are farmers' main cash expenditures during the year, when do these arise.

(g) List the purchased inputs recommended to farmers in the area, assess how far farmers know of them and what proportion use them. When are the major inputs purchased during the year, assess whether the farmer has cash at this time.

(h) How much does the typical local farmer spend on purchased inputs in a year?

(5) HUSBANDRY

Detail the husbandry practices which most farmers follow for their maize crop. It is important that the description is as detailed as possible.

(a) How does the farmer decide where he will plant his next maize crop? What factors does he consider in the decision?

(b) Land preparation:

(i) What is the method of land preparation?
(ii) When, in relation to the start of the rains and to planting time does the preparation start.
(iii) What sequence of work is involved if there is more than one operation?
(iv) How does the farmer work; does he prepare a whole field before planting, or prepare and plant a bit the same day, or what?
(v) What is the final form of seedbed?
(vi) Are there alternative methods of land preparation.

(c) Planting:

(i) What is the arrangement of plants in the field; maize and any mixtures.
(ii) Where other crops are mixed in it will be important to describe in what sequence all the crops are put in the ground.
(iii) How do farmers plant in relation to rainfall; dry planting before rain, the same day as rain falls, within a limited period after rains?
(iv) Do farmers just make one planting of maize each season or there are usually several.
(v) Do farmers commonly have to replant or in fill fields?
(vi) What is the method of putting the seed in the ground, and how many seeds are put per hole?

(d) Weeding and Thinning.

(i) What implement or implements are used for weeding and what pattern of work is followed between the plants in the ground.
(ii) How soon after planting is the first weeding done? Does the timing vary very much with conditions, if so how much and which conditions.

(iii) How many weedings will normally be done? Will this vary with the date of planting, the weather or the soil in the field selected?

(iv) Do they thin the maize plants either in the row or from each planting hole. If so at what age. Do they use the thinnings for cattle feed?

(e) Pest control

(i) major pests for which control is sought
(ii) timing and method of control

Assessment of proportion of local farmers using pest control.

(f) Use of fertiliser on maize (if any)
(i) Type of fertiliser, source
(ii) Usual rate, method and time of application

Assessment of proportion of local farmers using fertiliser.

(g) Use of leaves, tops and stalks for cattle feeding.

(i) Proportion of local farmers using
(ii) Method of feeding to animals
(iii) For leaves; number of pickings made, number of leaves taken and the timing in relation to plant growth.
(iv) For tops; stage of plant growth that the top is taken. Is this a critical time for cattle feed?

(h) Method and timing of harvesting and storing.

(i) At what stage does harvesting begin?
(ii) What method is followed in picking cobs, dehusking shelling and disposing of stover?
(iii) How is the crop stored, is any preservative used?

(i) Seed selection and preservation

(i) Do the farmers usually select seed in the field or from their stored harvest. If from store, when is it selected?
(ii) What criteria do local farmers use when they choose next years seed from their own crop?
(iii) Do they process and preserve the chosen seed in a special way?

Is the crop treated in any other way, either while in the field or in the household?

2. IDENTIFICATION OF RESOURCE CONSTRAINTS

(1) Land.

(a) Are farms in the area registered or held under traditional custom?

(b) What proportion of the area of land held by the typical local farmer is cultivated in any one season and what proportion is under grass or fallow.

(c) Is the arable area changed periodically and allowed to fallow?

(d) Are crops rotated, if so what crop sequences are followed?

(e) Can farmers get new land; by clearing, by renting, by purchase. If so how far away would new land for clearing be? How much money would be needed to rent or purchase an acre. Would this vary by the type of soil and location of the piece of land?

(f) Soil types and maize management.

(i) Do farmers prefer a specific type of soil for growing maize, if so which and why?

(ii) Do farmers prefer a special location for their maize crop?

(iii) Do farmers vary the soil type and/or location where they grow their maize depending on the sort of season they expect. If so what influences their decisions?

(2) Labour

(a) What is the busiest month of the year for local farmers? During this month what work are they doing mainly and with which crops?

(b) Is this the busiest month every year, or does it vary from year to year?

(c) Which is the second busiest time of the year for local farmers and what work are they doing then and on which crops?

(d) Do many local farmers hire any labour

(i) Permanently throughout the year?

(ii) Temporarily for a particular job or particular period?

(iii) When farmers hire casual labour what month or months is it mainly hired and for what type of work?

(e) Do many farmers hire machinery? If so is it tractor or ox driven, which operations is it mainly hired for, at which time of the year and for which crops?

(f) How much money will a typical farmer spend on hired labour and machinery in a year - if any?

3. FARMERS ASSESSMENT OF HAZARDS

(1) Yield variability

(a) What variation do farmers expect in maize production from season to season:

(i) What sort of production would they expect in a 'bad' year.

(ii) How frequently do such bad years occur in the area?

(iii) What are the main factors that make a year bad for maize.

(iv) What sort of production would they expect in a 'good year'

Repeat for the three or four major crops in the system.

(b) As far as the farmers are concerned low yields in which crop are the most serious for them and their families.

(c) What measures do they take to combat the effects of low yields when they occur - how do they manage when production of this vital crop fails.

(2) Rainfall problems

(a) Which crops sometimes give poor results because of rainfall.

(b) With reference to maize, which type of rainfall problem is most serious?

(i) Late start to the rains

(ii) Too little rain during the growing season

(iii) Early finish to the rains

(iv) Too much rain

(c) When did this type of rainfall problem **occur on** a widespread basis in the area and give a poor maize crop.

(d) Discuss with farmers how they react to this type of failure; i.e. they know their next maize harvest will be poor:

(i) In preserving food supplies in the household.

(ii) In managing their farms to offset the effect on their food supplies.

It may be important to go through this sequence with reference to another major starch staple - sorghum where grown, and a major relish crop.

(3) Pests and Diseases

(a) What do local farmers consider as their major pest and disease problems. Specify:

(i) Crops and pests

(ii) Frequency with which the problems occur.

(b) Do local farmers believe they have any means managing their farms to prevent these pests and diseases occurring? Discuss them one by one.

(c) Do local farms have any way to treat the crops or the land once they see these pests and diseases appearing? Discuss them one by one.

4. FARMERS OPINIONS ON COMPONENTS OF CURRENTLY RECOMMENDED MAIZE TECHNOLOGY

From the Ministry of Agriculture write out, in full, the current recommendations for growing maize in the area. Taking one component of the improved management at a time discuss it with local farmers. Attempt to assess the problems which each component presents to them in their situation.

C I M M Y T'S E A S T E R N A F R I C A
E C O N O M I C S P R O G R A M M E

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZY TRIGO

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

OCTOBER 1976

INTRODUCTION

CIMMYT's mandate is to work with national programs in developing and diffusing new technologies in maize and wheat. In pursuing these ends the Center focuses on improving the genetic material available to national programs, on investigating the interaction among improved genetic material agronomic practices, and agro-climatic factors; and on training nationals in breeding and production techniques.

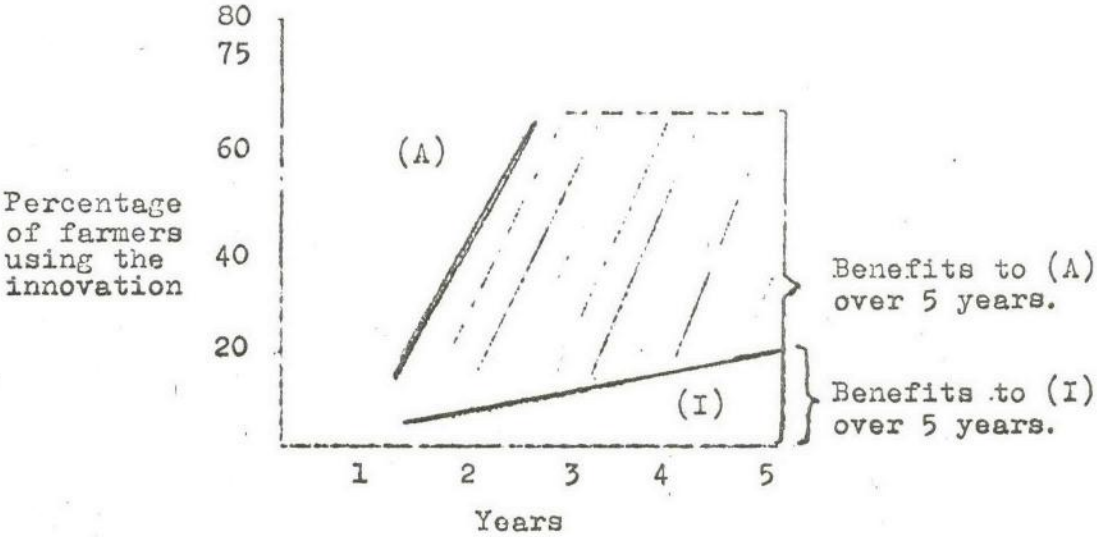
CIMMYT's economics section supports the activities of the crops programs in developing and diffusing new technologies. It is recognized that many elements impinge on farmers' behaviour and on their response to new technology. Some of these forces are natural, related to weather and soils. Other are biological, related to the interaction between plants and their environment. Still others are economic related to markets and to the allocation of resources.

The farmer reaches decisions about his farming activities by blending these elements. Research aimed at developing technologies must incorporate the same elements or run a substantial risk of being irrelevant to farmers. CIMMYT's economics section emphasises incorporating the economic dimensions of farmer circumstances at the earliest stages of programs for developing and diffusing new technologies, "that is in planning the adaptive research work."

CIMMYT believes that appropriate technology is the key to successful agricultural development efforts. In rural development programmes, huge institutional and infrastructural edifices, perhaps covering roads, water supplies, marketing, extension and credit services are built up around a chosen technology to enable its use by farmers. If the wrong technology base is chosen for the programme, not only has the research effort in producing the technology been wasted, but a whole range of development resources have been misapplied. Even if the sheer weight of effort pushes the new techniques to some farmers, diffusion through the farming community will be poor and adoption is unlikely to be sustained once the special push is removed.

The more appropriate the new technology is to the needs and conditions of the majority of farmers in the community, the more rapidly will it spread and the more farmers it will eventually reach. A comparison of the effects of introducing (relatively) inappropriate (I) and appropriate (A) technology into a farming community is shown in Figure 1.

...../2.....



The appropriate technology (A) reaches 75% of the community in a three-year period. The (relatively) inappropriate technology reaches only 20% of the community over a five-year period. The incremental economic benefits to A over the five years, represented by the shaded area, are several times the benefits to I, possibly from a similar level of Government investment in research, enabling facilities and services. The social benefits of reaching 75% of the community in three years compared to 20% in 5 years are equally clear.

"Increasing the speed and extent of diffusion of improved technology through a farming community is a major thrust of CIMMYT's efforts. CIMMYT has thus placed priority on improving procedures for formulating technologies. Economics has a significant, if little understood, role to play. Developing that role, demonstrating its utility, and promoting its use are the goals of the East African program in economics. All of this will, of course, add to the dimensions of agricultural economics research in East Africa, strengthening one facet of the disciplines contribution to development".

THE ECONOMISTS CONTRIBUTION TO RESEARCH PLANNING

The key to these increased benefits in agricultural development efforts is in identifying and designing appropriate technology through problem oriented research efforts.

The desirability of a contribution from economists is based on the fact that economics - whether of family security or profit - plays the dominant role in farmers' decisions. Farmers decide what they will produce, how much of it they will produce and how they will produce it in the light of the full set of circumstances in which they find themselves. This set of circumstances includes both natural conditions of climate and soil, important to the farmer for their economic implications,

..../3....

(2) Variability, year to year, in yield, price and costs

Stability in the results to be expected from new technology is also of particular importance to the small farmer, especially, in the case of the subsistence or semi-subsistence farmers, with new technology for their food crops. Such farmers live relatively close to subsistence level. Significant year to year variations in output, which to a large grower may make the difference in the size of car he can afford to run, may mean semi-starvation to the small farmer. Thus, although on a year to year average, results may be better from the new technology, with family security as a dominant objective of small farmers, wide variations in yields are unacceptable. Interactions between crops in the farming system are inevitable. New technology on cash crops often demands changes in management on basic food crops. This also may increase the year to year variability of food production, reducing farmers' security. Similarly security may be reduced by the uncertainty created by wide fluctuations in the costs of inputs required to implement the new technology.

(3) Management complexity

Absorbing new technology into the farming system demands a degree of management reorganisation. The more complex the repercussions it creates within the system, the more complex the reorganisation required. Managerial ability is an attribute distributed approximately normally in a farming population. The more complex the reorganisation required to absorb new technology, the fewer the farmers with the required ability and the poorer the diffusion of the technology over the population. Each component of a technological package (improved seed, correct spacing, pure stand, correct time of planting, timely weeding, use of fertiliser, etc.) contributes both to added profitability and to added management complexity. Dropping components which make large contributions to management complexity increases the degree and speed of diffusion over the farm population. More farmers are capable of handling the reorganisation required by simpler new technology. At the same time, dropping such components entails some loss of profitability. Using hypothetical examples based on Fig. 1; if (I) is a complex technological package and (A) a relatively simple one, the comparison of benefits in a 100,000 farm population might be:

1) (A) (a) Profitability per farm of Shs.90, spreads to 75% of farms over 3 years at 25% per year.

(b) Aggregated benefits of Shs.27 million over a 5-year period.

2) (I) (a) Profitability per farm of Shs.120, spreads to 20% of farms over 5 years at 4% per year.

(b) Aggregated benefits of Shs.7 million over the 5-year period.

From a similar investment in government services, gross economic benefits to the country would be three times as high from A. and would be shared over 75% of the farming community, against 20% for benefits from I. Such a comparison, although based on hypothetical examples, clearly demonstrates the importance of management complexity as a criterion in identifying appropriate new technology.

To illustrate the variety of facets which can be involved, a hypothetical example of an existing and recommended maize growing practice, showing what each offers the farmer and detailing the costs of changing to the recommended practice from the farmers point of view is set out as an annex to this programme description.

The critical contribution of the economist is a description of the existing system in farming populations to allow advance diagnosis of the likely importance of these three sets, or sources, of costs of change. With such a diagnosis, agricultural researchers can guide their programmes into those components of new technology most compatible with farmers' production objectives and therefore most appropriate to the local situation. In short, the aim is to identify the line of least resistance to change in the existing farming system.

PROCEDURES FOR A CO-OPERATIVE EFFORT BETWEEN NATURAL SCIENTISTS AND ECONOMISTS IN PLANNING ADAPTIVE AGRICULTURAL RESEARCH

Considerable space has been used in setting out the role of the economist because of the newness of the idea of his contributing to research design. As an agricultural research centre, CIMMYT is by no means suggesting a take over by economists of research planning, almost certainly a disastrous step. The success of the approach recommended depends on interaction between natural scientists, as experts in crop and livestock improvement, and farm economists, as experts in the economic circumstances facing the farmer. There has been considerable reference in the literature to the need for an interdisciplinary approach to research problems in developing agriculture, but little practical guidance as to how such an approach might be organised. Having noted that the economist has been playing an exposte role, usually in criticising the inappropriateness of the results of adaptive research programmes, CIMMYT economists have sought procedures for a positive approach by bringing the economics input into research planning. To do this, a rapid turnover of data is needed which precludes a protracted full farm economic survey. The emphasis is on descriptive information and an intuitive evaluation of the relationships it reveals, the whole effort demanding months rather than years. The sequence of procedures which follows is essentially an interaction between natural scientists and economists to produce a more relevant orientation of research programmes. The sequence would be appropriate for scientists working from a centre with responsibility for adaptive agricultural research in a region with a farming population operating under a variety of natural and economic conditions. The sequence can cover the orientation of as many crop or livestock research programmes as are mounted from the centre. The economist will liaise with each of the specialist groups involved. The sequence is outlined in relation to a single crop programme.

(1) Crop specialists, breeders, agronomists, pathologists, entomologists and soil scientists relate critical aspects of crop physiology to natural conditions as they occur in the region. Working from basic principles, they attempt to establish the relative importance of possible package components to potential yield, given local conditions of climate and soil, and the prevalent pathogens.

(2) The economist outlines critical aspects of crop economics, present end uses, product specifications, cropping patterns and existing production technology for all areas of the region.

(3) From these two sets of information

(a) The region is divided into 'Recommendation Domains' or 'Customer Zones'. This is an initial agro-economic zoning of the target population into domains which, because of the variability among them in natural potential or economic conditions, are likely to require different technologies and for which different experimental programmes may be justified. Zoning also creates a framework for deciding research priorities. If the criterion is the greatest benefit for the greatest number, other things being equal, zones with the largest farmer population would take priority in experimental work. However, crop scientists, economists and the policy planners would weigh factors such as the number of growers of the crop in each zone, the importance of the crop to these growers, and the potential performance of the crop in each zone in allocating priorities.

(b) The economist builds a schedule of descriptive information required for each zone as a whole and for the on farm situation in each zone. The schedule for the on farm situation seeks a description of how farmers currently manage the crop, and how this management interacts with management practices on other crops in the farming system. It emphasises how farmers presently manage those aspects of the crop which the specialists have identified as probably important to yield potential.

(4) The economist makes a preliminary, informal pre-survey of the zone. He discusses the scheduled information with officials and farmers in the area over a period of one or two weeks. This pre-survey verifies the homogeneity of farming within the zone and provides a basis for the organisation of a farmer survey.

(5) The conomist mounts a farmer survey within the zone. The main objective of the survey will be to verify the incidence of features of existing farm management and identified farmer problems among the farming population. Close coordination will be required with crop scientists in drawing up the survey content and training the enumerators. The survey will be used to establish the incidence of pests, diseases, present farming, as well as economic features of the farming population. The information is analysed and used, together with that collected less formally during the pre-survey, to give a detailed description of existing farm management practices. It will show how each facet contributes to the achievement of farmers' production objectives. The economist will identify the 'costs of change' related to each potential component of an improved technology package.

(6) Crop scientists discuss with the economist the weighting of these costs and the implications for experimental programmes aiming to develop technology to take advantage of 'lines of least resistance' into the existing system for easy absorption by the farming population. There will be four areas of discussion:

(a) Programme framework. It is important to breeding, agronomy and crop protection work that a general context is fixed for the research programme. Ideally existing farm practice should form a basic framework; any step away from it may contribute to profitability and to 'costs of change' and need assessment in the programme itself. Mixed cropping is a particularly pertinent and critical example. For zones in which farmers grow (say) 80% of the crop in question mixed with other crops, an explicit decision is required whether improved varieties and management practices should be sought within the framework of a crop mixture. Crop scientists will evaluate the physiological inter-relationships between plant components and between plants and the local soil and water conditions. The economist will evaluate the importance of the practice to the farmers' production objectives and the management complexities consequent on reverting to pure stands. It may be decided that mixtures are crucial to water utilisation or soil conservation, and to the subsistence farmers' preferred food supply patterns, or that the managerial consequences of changing to pure stands would be too complex for most farmers to cope with. In this case, the best strategy would be research to improve the productivity of the mixtures; breeding and agronomy within the context of mixtures already present. On the other hand it may be decided that there are no physiological or crop protection or soil conservation advantages to mixtures, nor are the managerial consequences of changing to pure stands too complex. In this case the experimental work would be done in the context the crop scientists believe would offer the greatest potential for the improvement of crop productivity. The important point is that the framework for the experimental programme is given explicit consideration and not settled by default. An important part of the framework for consideration would usually be whether experimentation should be done within the rotational sequence followed by the farmer.

(b) Specification of supplementary breeding criteria. Present cultural practices as well as harvesting, processing and storage techniques will have implications for desirable features in any new varieties. An economic assessment can be made of the costs of changing present practices or, alternatively, of the losses involved in putting a poorly adapted variety through the existing techniques.

(c) Locational characteristics of experimental fields. The descriptive survey data will allow the location of experimental work on the soil types and topographical situations characteristic of farmers fields.

(d) The content of agronomic trials. Perhaps the most detailed area of discussion is the content of agronomy trials. Having emphasised the need to document the profitability and complexity of each step away from existing farmer practices to allow the compiling of appropriate technological packages, in practical terms few research programmes have the capacity to treat all management practices as experimental variables. The selection of experimental variables requires a detailed dialogue between the agronomist and the economist.

(i) The description of present management practice from the survey provides a basis for control treatments in the agronomy programme. Similarly it provides a basis for the levels of all non-experimental treatments.

(ii) All potential experimental variables - facets of management which the agronomist believes will improve the yield of the crop - should be discussed by the agronomist and the economist. The agronomist will be concerned to estimate, from first principles, their likely impact on yield. The economist will be concerned to establish the 'costs of change', including management complexity, for the farmer in absorbing each facet. Those facets which will have no or low costs of change but have a significant potential impact on yield may be readily incorporated as blanket, non-experimental ...

(iii) Out of the remainder: candidates for the experimental variables, a balance will be struck between the weighting given by the agronomist in terms of possible contribution to yield and that given by the economist in terms of 'costs of change'. Initial factorials should incorporate as experimental variables those facets of management with the highest possible contribution to yield and the lowest 'costs of change' to the farmer

This sequence of interaction between crop scientists and the economist will be extended to lower priority customer zones as manpower and funds permit expansion of the research programmes Where more quantities information on existing resource use and productivity is required to crystallise the costs of change to the farmer, a full scale farm economic survey may be mounted as a follow-up to the initial survey aimed primarily at identifying the nature of these costs. In most cases the initial, ncn-quantative but rapid survey will be adequate to provide clear research guidelines. The diagram attached shows the sequence.

THE OPERATION OF CIMMYT'S EAST AFRICAN REGIONAL ECONOMIC PROGRAMME

CIMMYT fully appreciates the scarcity of research personnel and funds. The initial and very limited projects are as a result of an interest expressed by research administrators, and are in association with on-going research programmes. The aim, as already stated, is to convince workers in these programmes and particularly the administrators responsible for research policy, that this interdisciplinary approach has considerable potential benefits. Benefits measured in terms of the effectiveness of the research programmes in producing new technology which is appropriate for and therefore rapidly accepted by farmers

Given interest by research administrators, CIMMYT's Regional economist works to bring together local professional staff in small demonstrations of the approach. CIMMYT provides professional advice and supplementary funding if required. By co-operating with interested local professionals rather than using its own staff, CIMMYT seeks to create an awareness of the approach, and the capacity to implement it, within national research services.

The belief is that if the demonstration is convincing, a demand for this approach will arise amongst research workers and a willingness to supply funds and manpower will arise among research administrators. At this stage CIMMYT will cooperate with research administrators in identifying ways for incorporating the approach into the national agricultural research planning process.

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DIAGRAM: INTERACTIONS BETWEEN CROP SCIENTISTS AND ECONOMISTS IN THE ORIENTATION AND PLANNING OF A PROGRAMME OF AGRICULTURAL RESEARCH

CROP SCIENTISTS

Identify vital crop characteristics to guide initial zoning and focus a preliminary survey

ECONOMIST

Identify market and production characteristics of the crop to guide initial zoning and focus a preliminary survey

INITIAL ZONING AND DOMAIN DEFINITION SELECTION OF PRIORITIES

PRELIMINARY INFORMAL PRE-SURVEY

FARMER SURVEY

Assess possible improvements in crop yield from all potential revisions in management practice and breeding criteria

Assess 'costs of change' associated with variety characteristics and potential revisions in management practice

CLOSELY FOCUSED TRIALS PROGRAMME

TRIALS EVALUATION

FARMER RECOMMENDATION AND DEMONSTRATIONS

ANNEX: AN EXAMPLE OF COSTS OF CHANGE

Present practice: Maize production is wholly for subsistence. Maize is grown in mixtures with groundnuts and sweet potatoes. Maize is planted into the prepared field spaced approximately 75 cms between rows and 75 cms in the row. A weeding is done at three weeks when grounds and sweet potatoes are interplanted and rapidly cover the ground. No further weeding is done. Three or four fields are planted with this mixture at intervals, as the rain falls, between mid-November and mid-January. A short term variety of maize is used for the first and final plantings.

This enterprise gives the farmer the following returns:

(a) Dry maize, usually sufficient to feed his family until the following harvest, mainly from the middle plantings of a longer term variety which has good storage qualities under traditional storage practice.

(b) A complementary, high flavour food in the form of groundnuts used to garnish the maize staple as the basic dish in the local menu.

(c) The staggered planting times give a prolonged flow of fresh foods; initially green maize from the short term variety planted early, then green maize from subsequent plantings followed by the sequence of sweet potatoes. In a good year the family will have fresh foods available as part of their diet the season round, as the sweet potatoes can be kept in the ground and used, fresh, as required.

(d) The staggered planting reduces the risk of crop failure as maize will be at varying stages, with varying water requirements, over dry periods.

(e) The short term variety used in the first planting gives early food availability in seasons following poor harvests. The short term variety used in the final plantings fits into the water availability pattern where a longer term variety would come under severe stress at tasselling from the same planting date.

Recommended practice for maize growing: Maize should be planted in a pure stand in the first week of December. Fresh hybrid seed (a long term variety) should be purchased each year. The seeds should be spaced 75 cms between rows and 30 cms between plants in the row. Weeding should be done at 2, 5 and 8 weeks. 50kg/ha P should be applied in the seedbed and 75 kg/ha N top dressed after the second weeding. At knee high the crop should be protected from stalk-borer by the application of DDT dush into the funnels of the plants.

This gives the farmer (if planted on the same area as his traditional maize mixture enterprise) more dry maize than he needs to feed his family in most years. A relatively short period of green maize before the crop dries off. It can be questioned whether the new maize enterprise is really a substitute for the old one. Costs of changing, as they will appear to the farmer, are listed under the three sources: Direct costs, Opportunity costs and Complexity.

(1) Direct costs Direct costs of the change will be for hybrid seed, P and N fertilisers and DDT dust.

Where hired labour is used, the costs of extra labour for planting, increased weeding, fertiliser application, thinning and harvesting the larger crop will all be direct, additional costs to be set against the value of the increased output. The changes in the timing of operations, when it creates peaks, may require an additional work force to adhere to the recommended crop calendar. These would be additional direct costs.

(2) Opportunity costs In farming situations where additional resource are not available for one reason or another, opportunity costs are incurred when resources are re-allocated from other uses to implement the change and are represented by the lost output from other uses or opportunities. In situations where there is a full knowledge of the existing farming system, of the resource allocations and their productivities, these costs can be quantified. In situations where there is little or no knowledge of the farming system, quantification becomes difficult and even impossible. Even where there is knowledge of the system, quantification is difficult where risk is a large factor weighting farmers' decisions, and when a significant part of the farm operations are in subsistence production. The opportunity costs in this example can be divided into: (a) Possible quantifiable; (b) not quantifiable in practice.

(a) Possible quantifiable: Where there is no labour market and existing labour resources must be re-organised to implement the change:

(i) Extra labour required may mean reducing the production of another existing enterprise.

(ii) The concentration of planting date, or indeed any change in the timing of operations, may create or increase labour pea[k] at planting time, weeding time or harvest time. This also may enforce a reduction in the size of other farm enterpris[es] the losses from which would represent a cost of the change.

(b) Not usually quantifiable in practice.

(i) Concentration of planting time will increase the risk of crop failure in areas of uncertain rainfall.

(ii) We can say that the recommended hybrid is a relatively poor keeper under existing storage and processing practices.

(iii) The single planting time reduced the length of the period when green maize as a preferred food is available. Togethe[r] with the fact it is a long term variety, this also sacrific[es] early staple food in years when stocks are poor and sacrifices early green maize from the early planted short term variety in all years.

(iv) The pure stand involves: the sacrifice of the legume intercrops grown as complementary food; the sacrifice of sweet potatoes which gave a fresh food to follow the period of green maize.

(3) Complexities Several facets of this change create complexities i[n] the management re-organisation required to absorb it successfully.

(a) Growing maize in a pure stand raises the problem of how to obtai[n] the legumes and sweet potatoes valued for their dietary contribut[ion]

(b) Shifting the time of planting, and consequently of most subseque[nt] and preceding operations, involves re-scheduling of long-establis[hed] routine timetables both on the maize mixture enterprise and other enterprises. Where there are periods of labour shortage or capi[tal] scarcity, re-allocation problems may present difficult management situations.

(c) The purchase and application of inputs demands a new management function. It may also aggravate the capital allocation problem. Which of these costs and complexities are relevant, and whether the extra labour requirements will be direct costs or will create opportunity costs, depends on a detailed description of the local farming system for which the adaptive research programme is being planned. But it is clear that evaluating the true profitability of such a change to the farmer requires consideration of all these aspects.

Terms of Reference to Review
CIMMYT Programmes for Strengthening Agricultural
Economic Research in East Africa (GLO/74/009)

A. Background

1. The International Maize and Wheat Improvement Centre (CIMMYT) was established in 1963, and since 1966 has functioned as an International Centre with autonomous status under an international Board of Directors. UNDP has been assisting the Centre's work since 1970 through a global project on research and training in the development of quality protein maize. Since its inception, the Centre has devoted its main efforts, with outstanding success, to increasing yields of maize and wheat, two major staple crops of developing countries. In the course of its evolving research programme, CIMMYT has developed co-operative links with approximately 60 countries in Asia, Africa and Latin America. The Centre's collaboration with these countries is aimed primarily at strengthening national agencies so that they can contribute to increasing national production, while simultaneously forming part of the international agricultural research and problem-solving network.

2. The experience of CIMMYT shows that supporting economic research, including farm level and marketing studies, are an essential complement to scientific agricultural research if adoption of new technologies is to proceed rapidly. The weakest link in the system is generally between the applied research apparatus and the farmer. Important gaps in understanding exist on both sides. Insufficient knowledge of actual farming systems, the farmers' economic problems and constraints, and the characteristics of the specific ecological and socio-economic environment, too often prevent the final adjustments in technology that are required to ensure speedy adoption. Farmers and farm families, for their part, are often unaware of the opportunities offered by newly developed technologies and practices. The gap can be bridged only by expanding micro-level studies of the farm and the farm family, including the associated markets for inputs as well as for products; and by bringing this information effectively to bear on scientific research and extension activities. When such information is available, both technology and agricultural policy can be made more consistent with farmers' goals and problems, leading to more widespread and rapid acceptance of new varieties and practices. This is confirmed by CIMMYT's experience with research on the adoption of new maize technology carried out in Colombia, El Salvador, Kenya, Iran, Tunisia, Turkey, Zaire and Pakistan.

3. In June 1975, the UNDP Governing Council approved a project of three and one-half year duration comprising primarily an agricultural economist to advise and assist East African countries in agro-economic research at the farm level with the following immediate objectives:

(a) To stimulate increased research on the individual farming systems in use in the area on the resources available to the farm family, and on farm-level problems and constraints, as well as on agricultural markets for both inputs and products;

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(b) To help indigenous researchers gain proficiency and experience in this type of research;

(c) To increase co-operation between agricultural scientists, extension workers and policy makers, by presenting quantitative evidence concerning the socio-economic and technical problems which impede the adaptation of new technology at the farm level.

4. The project became operational in October 1975 with the recruitment of the agricultural economist, Dr. M. P. Collinson, who initially spent two months in Mexico at CIMMYT headquarters to get acquainted with pertinent aspects of the maize and wheat improvement programmes. He has been stationed in Nairobi, Kenya since December 1975 where he is conducting farm-level economic research in close collaboration with Kenyan maize specialists. The work thus far conducted has brought to light the importance of a short-season maize variety for farmers of the area studied. Similar collaborative farm-level studies are under way in Tanzania. While useful contacts have been established with Ethiopia and Uganda, various difficulties have hampered the full-scale implementation of projected activities in these countries.

5. In view of the impending termination of UNDP support to GLO/74/009 scheduled at the end of December 1978, and also because UNDP and CIMMYT have jointly agreed to undertake the evaluation of the UNDP supported Global Project, Research and Training in the Development of Quality Protein Maize, Phase III (GLO/75/007) during the period 12-15 June, it was also agreed that immediately upon completion of this review, an evaluation of CIMMYT's Agro-Economic Research in East Africa with UNDP support under GLO/74/009 should be taken in hand in order to assess the progress achieved in relation to established schedules and targets for activities, outputs and immediate objectives, and to make specific recommendations on the future of the project.

B. Scope of the Mission

6. In carrying out the evaluation of GLO/74/009, the consultant should assess whether the work performed corresponds to project objectives, design and content, as outlined in the project proposal. The following issues need to be clarified:

(i) To what extent have project objectives been met or can be expected to be met before the project expires?

(ii) To what extent has the project increased the understanding regarding farm level constraints to maize production, yields and productivity in the areas studies?

(iii) To what extent has such understanding been useful to and incorporated in decision-making regarding research priorities, extension and public policy? What are the attitudes of natinal maize researchers and economists regarding the utility of the project activities? Has the project contributed to useful communication across disciplines?

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(iv) To what extent has the project contributed to national capabilities, training, interests and awareness of the potential utility of relevant farm level research?

(v) Is the project contributing in some other ways? If so, which?

7. Based on the above review, the consultant will determine whether the approach and procedures, including reporting to UNDP, used in the project might be improved and suggest how such improvements might be made. He will also assess the actual and potential future contribution of the activities of this project. It is understood that within a short duration of one week, quantitative evaluation would probably not be possible and would not be expected as part of this mission.

8. Subject to a careful analysis of his findings and recommendations, the consultant will suggest future directions and content of possible extension of the present project which could be incorporated into a likely Phase IV of the current GLO/75/007 project. Should the consultant's recommendations on the possible extension of GLO/74/009 be positive, he should append to his report a detailed proposal, including approximate costs for eventual consideration by UNDP.

9. The review will focus on project activities in Kenya because only that country will be visited by the consultant. Activities in other countries will be included on the basis of the availability of written evidence and discussions with the project staff.

C. Composition of the Mission

10. The mission will be composed of Dr. Per Pinstrup-Andersen, Senior Research Fellow, Economic Institute, Royal Veterinary and Agricultural University, Copenhagen, Denmark, who is being retained as consultant to UNDP for the purpose of evaluating this project.

11. The CIMMYT Agricultural Economist based in Kenya and staff associated with him on this project will assist the UNDP consultant in carrying out the tasks of his mission as set forth in the Terms of Reference. While the UNDP consultant is free to discuss with all concerned anything relevant to his assignment, and to make any observations or recommendations deemed appropriate, he is not authorized to make any commitments on behalf of UNDP.

D. Timetable and Report of the Mission

12. The UNDP consultant will be briefed in New York on 9 June 1978 as part of an overall briefing on the UNDP supported Global Project, Research and Training in the Development of High Quality Protein Maize, Phase III (GLO/75/007) at CIMMYT, Mexico, in the evaluation of which (12-15 June 1978), the UNDP consultant is participating along with two other UNDP consultants,

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Dr. D. D. Harpstead and Dr. P. R. Payne. Additional background on GLO/74/009 will be available to the UNDP consultant at CIMMYT and further briefing as appropriate will be provided to him on his return from Mexico to New York on 16 June enroute to Nairobi, Kenya. The mission in Kenya will commence on 19 June and will last approximately one week. The consultant will complete his draft report in the field and forward it to UNDP headquarters. He will then return to Copenhagen, Denmark by about 28 June. At the present time, his debriefing in New York is not considered essential.

New York
9 June 1978