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CLASSIFICATION

PROJECT EVALUATION SUMMARY (PES) — PART I

Report Symbol U-447

1. PROJECT TITLE	2. PROJECT NUMBER	3. MISSION/AID/W OFFICE
BASIS OF PLANT RESISTANCE TO INSECT ATTACK	623-0435-G-00-4043-00 (698-0435.02)	REDSO/ESA

4. EVALUATION NUMBER (Enter the number maintained by the reporting unit e.g., Country or AID/W Administrative Code, Fiscal Year, Serial No. beginning with No. 1 each FY)

☒ REGULAR EVALUATION ☐ SPECIAL EVALUATION

5. KEY PROJECT IMPLEMENTATION DATES	6. ESTIMATED PROJECT FUNDING	7. PERIOD COVERED BY EVALUATION
A. First PRO-AG or Equivalent FY 84	A. Total $ 2,500,000	From (month/yr.) 08/84
B. Final Obligation Expected FY 85	B. U.S. $	To (month/yr.) 05/87
C. Final Input Delivery FY 89		Date of Evaluation Review

8. ACTION DECISIONS APPROVED BY MISSION OR AID/W OFFICE DIRECTOR

A. List decisions and/or unresolved issues; cite those items needing further study. (NOTE: Mission decisions which anticipate AID/W or regional office action should specify type of document, e.g., airgram, SPAR, PIO, which will present detailed request.)	B. NAME OF OFFICER RESPONSIBLE FOR ACTION	C. DATE ACTION TO BE COMPLETED
1. ICIPE is requested to submit a report indicating the precise mechanisms to be utilized in coordinating its activities to ensure that sorghum and maize breeders at national and international research centers have basic information and plant germplasm for breeding varieties resistant to the stalk borer. Refer to attachment 1 (detailed findings and recommendations), page 11, item 6: Networking.	Professor K. N. Saxena (ICIPE) L. A. Arao (REDSO/ESA)	10/30/87
2. REDSO/ESA and RFMC, Nairobi will request an auditors validation of a financial statement from ICIPE, (per Project Evaluation Summary, Part II, Item 23: Special Comments or Remarks).	R. Armstrong A. Kamiri (REDSO/ESA & RFMC) E. English (ICIPE)	

9. INVENTORY OF DOCUMENTS TO BE REVISED PER ABOVE DECISIONS

- [X] Project Paper
- [ ] Financial Plan
- [X] Logical Framework
- [X] Project Agreement
- [X] Implementation Plan, e.g., CPI Network
- [ ] PIO/T
- [ ] PIO/C
- [ ] PIO/P
- [X] Other (Specify) ICIPE ANNUAL REVIEW
- [ ] Other (Specify)

10. ALTERNATIVE DECISIONS ON FUTURE OF PROJECT

- A. [X] Continue Project Without Change
- B. [ ] Change Project Design and/or [ ] Change Implementation Plan
- C. [ ] Discontinue Project

11. PROJECT OFFICER AND HOST COUNTRY OR OTHER RANKING PARTICIPANTS AS APPROPRIATE (Names and Titles)

Robert E. Armstrong

ROBERT E. ARMSTRONG, CHIEF, AGRICULTURAL AND NATURAL RESOURCES DIVISION, REDSO/ESA

LEO A. ARAO, PEST MANAGEMENT ADVISOR, REDSO/ESA

12. Mission/AID/W Office Director Approval

Signature

Typed Name /Arthur M. Fell

Date - 8 JUN 1987

AID 1330-16 (3-78)

Project Evaluation Summary

art II

USAID Grant #623-0435-G-00-4043-00
(698-0435.02)

"Basis for Plant Resistance to Insect Attack"

ICIPE, Nairobi, Kenya

Principal Evaluation Team:

K. A. Stoner
D. E. Weibel
B. H. Waite

REDSO/ESA Facilitator:

L. A. Arao

Oklahoma State University - Observing Consultant:

J. Kirby

May, 1987

13. Summary

In the first three years of the Project, notable progress has been made in understanding the bases of plant resistance to insect attack. AID funding support in the current Project is confined to research on Chilo partellus on maize and sorghum.

Considerable progress has been made in identifying or confirming potential sources of resistance, and in field and laboratory experiments determining at what stage resistance interferes with plant colonization by the insect. The genetic basis of resistance has also been determined for several promising sources. Work on the biochemical and biophysical bases of resistance has begun only recently, however.

Multi-locational trials of promising maize and sorghum cultivars have been established in different ecological zones (Mbita Point, Rusinga Island, Katumani, Mtwapa, Kitale, and Busia). These trials are located on research station sites as well as with cooperating resource-poor, small farmers in the different ecological zones.

The major concern of the evaluation team is whether the information and sources of resistance identified in this project will be effectively used by national and international breeding programs to produce insect-resistant varieties. ICIPE itself does not have a mandate to do plant breeding. Thus, establishing a mutually beneficial, cooperative relationship between ICIPE and national plant breeders who will produce the resistant varieties is essential.

Comments and recommendations on various aspects of the Project are discussed below:

14. Evaluation Methodology

Aspects of the Project reviewed are: organization, effectiveness, adherence to project plan and objectives, and application of research results to future sorghum and maize breeding by national and international programs.

Evaluation techniques used were: visits with ICIPE technical and administrative personnel in Nairobi and Mbita Point, on-site visits and inspections of laboratory facilities and field tests, and the review of documents on ICIPE research concerning plant resistance to insect attack. The principal ICIPE staff contributors were Drs. K. N. Saxena (Program Leader), R.S. Pathak, J. K. O. Ampofo, and K. V. Seshu Reddy. REDSO/ESA personnel contacted were Dr. R. E. Armstrong, Mr. R. E. McColaugh, and Mr. Leo Arao (Coordinator for the Evaluation Team).

The Project Review was conducted by Dr. K. A. Stoner, entomologist, AID/AFR/TR, Washington, D.C., Dr. D. E. Weibel, sorghum breeder and professor, Oklahoma State University, Stillwater, and Dr. B. H. Waite, plant pathologist, AID/S&T/AGR, Washington, D.C.

15. External Factors - There were no major changes in project setting including socio-economic conditions and host government priorities, which have an impact on the project. Therefore a discussion of the issue is not pertinent at this time.

16. Inputs - There were no problems with commodities, technical services, training or other inputs as to quality, quantity, timeliness. Therefore a discussion of the issue is not pertinent at this time.

17. Outputs

Project objectives and accomplishments to date are indicated below:

Specific Objectives	Accomplishments
1. Develop/improve resistance screening methods to *C. partellus*. Provide information to plant breeding programs.	Excellent progress has been made in developing methods for determination of specific plant-insect interactions involved in resistance. No rapid screening methods for breeders yet developed. Transfer to Kenya national program proceeding.
2. Identify new/confirm old sources of resistance to be used in breeding programs.	Very good progress for both maize and sorghum.
3. Identify/clarify biochemical and physical nature of resistance. Identify/synthesize allelochemicals for potential insect control.	Biochemical and biophysical work only recently initiated. Have done preliminary studies to identify modes of plant resistance to insects.
4. Determine genetic basis of resistance to borer for use of plant breeders, to produce regionally-adapted varieties.	Sorghum resistance appears to be polygenic. Maize resistance dominant in cross between resistant and susceptible parents. Genetic studies for both sorghum and maize are continuing.

5.	Train researchers and technical personnel in resistance methods.	Good progress in long-term training (2 post-docs and 2 graduate students) and short-term training (3 scientists and 2 technicians) for 3-4 month periods. More training planned.
6.	Expand networking, exchange of germplasm, and resistance methods, through cooperation with national and international sorghum and maize programs.	Good collaboration with Kenya national programs and several IARC's. Networking established through PESTNET: Workshop planned for Zambia, June, 1987.
7.	Publication of research in refereed journals.	Since 1985, 27 articles published or in press on borers in sorghum and maize.

18. Purpose

"The primary goal of this proposal is to ensure that plant breeders at national and international research centers have basic information for breeding resistant cultivars which will provide a major first line of defense against insect pests of the small subsistence farmer of Africa." The End of Project Status conditions are: 1. crop/insect research priorities established and results published, and 2. plant resistance increasingly adopted as a central strategy by national programs and IARC's.

The Project scientists show considerable achievements in carrying out and publishing basic research on plant-insect interactions. Efforts to disseminate research results and resistant germplasm to national programs have begun only in the last year. Increasing use of plant resistance will not occur until after variety development.

19. Goal/Subgoal

The goal of this Project is to "improve crop production through utilization of plant resistance to insect attack." As discussed above under "Purpose", a critical step is required between publication of research results and utilization of resistance. This critical step is development of resistant varieties. This cannot be done by ICIPE, although ICIPE can promote variety development by training and cooperating with national and international plant breeders.

20. Beneficiaries

The primary beneficiaries of the Project are the maize and sorghum breeders in the national and international breeding programs (primarily in Africa). They will use the research information and resistant material identified by BPRIA researchers to develop resistant cultivars or parental lines for hybrid production.

The secondary beneficiaries are the scientists and technical personnel who are trained in methods of evaluation of resistance to insects, mechanisms of resistance, and the factors affecting expression of resistance.

If breeders properly use the technology developed by the Project, and a well-coordinated relationship between the breeders and the ICIPE scientists is established, the ultimate beneficiaries will be the resource-poor maize and sorghum farmers.

21. Unplanned Effects

The project has had no unexpected results or impact that require any change in project design or execution. Therefore, a further discussion of this issue is not pertinent at this time.

22. Lessons Learned

This Project could serve as a model for research strategies in other programs involving plant resistance to insects. More planning in the initial design of the Project should have been directed to establishing linkages with national breeding programs to use ICIPE's information and germplasm in development of resistant varieties.

23. Special Comments or Remarks

We recommend that ICIPE request its external auditors to validate the financial statement on this Project that is to be prepared by ICIPE. The ICIPE statement along with the external auditor's report should be forwarded to AID/REDSO/ESA and RFMC, Nairobi. It is our understanding that this procedure is agreeable to ICIPE and acceptable to other donors.

See Attachment 1: Detailed Findings and Recommendations
Attachment 2: List of Publications
Attachment 3: Itinerary of Evaluation Team

Attachment 1.

DETAILED FINDINGS AND RECOMMENDATIONS

External Project Evaluation

USAID Grant 623-0435-G-00-4043-00 (698-0435.02

"Basis for Plant Resistance to Insect Attack"

CIPE, Nairobi, Kenya

K. A. Stoner

D. E. Weibel

B. H. Waite

May 29, 1987

BACKGROUND

The Problem: Stem borer Chilo partellus on Maize and Sorghum

Chilo partellus is one species in the complex of stem borers in Kenya. Other species in this complex are Chilo orichalociliellus, Busseola fusca, Eldana saccharina, and Sesamia calamistis. All of these species attack both maize and sorghum, but the relative importance of the different species depends on the crop, the location, and timing of sampling during the season and during the development of the plant. Chilo partellus was chosen for intensive study in this project because it is the most abundant stem borer in the Mbita Point area; it is a major component of the borer complex across Kenya and in eastern and southern Africa; and mass rearing techniques had already been developed, so large numbers of insects could be produced as needed. Other major insect pests of sorghum in Kenya are the sorghum shootfly, Atherigona soccata, and sorghum midge, Contarinia sorghicola.

The damaging stage of Chilo partellus is the larva. The larvae hatch from eggs laid by the adult moth on sorghum or

maize leaves. Soon after hatching, they move into the whorl of the plant. This early feeding results in a characteristic pattern of damage to the leaves. The larvae then tunnel into the stem itself, reducing the flow of water and nutrients through the stem and increasing the likelihood of stem breakage. If the larvae tunnel into the growing point of the plant, this results in "dead heart", which completely prevents the plant from flowering and producing grain. One study on yield losses due to stem borers at Mbita Point estimated that 34.7% of maize and 25% of sorghum yields were lost on the average in single-species cropping.

ICIPE has had a program for control of crop borers for many years and thus has considerable expertise in all areas of the biology of stem borers.

ICIPE - Overall Mandate and Structure

ICIPE, headquartered in Nairobi, Kenya has two components to its mandate:

1) basic and applied research leading to acceptable long range integrated pest management (IPM) systems for developing countries, and
2) national capacity building to achieve this goal through local training and workshops as well as international outreach programs.

Within this mandate, the Crop Pests Research Program (CPRP), aimed at developing IPM strategies for resource-poor subsistence farmers in Africa and other developing countries, is currently broadly divided into the components of a) bionomics and applied ecology, b) mass rearing, c) biological control, and d) plant resistance/susceptibility research to insect attack.

Development of Current Project 623-0435-G-00-4043-00 (698-0435.02)

In June 1984, ICIPE submitted an unsolicited proposal for $5,000,000 in which AID was asked to fund $2,500,000 to support this project. The objectives of the Project are developing insect resistant cultivars and providing post graduate and technical training of African entomologists in reduction of insect damage through the use of resistant varieties of crop plants. The Project agreement is limited to the study of stem borers in maize and sorghum. The Project originally included sorghum shootfly and cowpea podborer research, but due to financial constraints in ICIPE these activities were deleted. The life of the project will be five years from the date of initial obligation (July 27, 1984 through July 27, 1989). Other donor support also totals $2,500,000.

ABBREVIATIONS

AID	Agency for International Development
ARPPIS	African Regional Postgraduate Programme in Insect Science
BPRIA	Basis for Plant Resistance to Insect Attack
CIMMYT	International Center for the Improvement of Maize and Wheat
CPRP	Crop Pests Research Program
CRSP	Collaborative Research Support Program
IARC	International Agricultural Research Center
ICIPE	International Centre of Insect Physiology and Ecology
ICRISAT	International Crops Research Institu the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
INTSORMIL	International Sorghum and Millet CRSP
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
OAU	Organization for African Unity
PESTNET	African Regional Pest Management Research and Development Network
REDSO/ESA	Regional Economic and Development Offic Eastern and Southern Africa
SAFGRAD	Semi-Arid Food Grain Research and Development
UNDP	United Nations Development Program
USDA	United States Department of Agriculture

Attachment 1.

DETAILED FINDINGS AND RECOMMENDATIONS

External Project Evaluation

USAID Grant #698-0435.02

"Basis for Plant Resistance to Insect Attack"

ICIPE, Nairobi, Kenya

K. A. Stoner

D. E. Weibel

B. H. Waite

May 29, 1987

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Rationale of Project Evaluation

The Project Paper calls for an external examination approximately mid-way in the project. Accordingly, the following persons were contracted to carry out the present review:

Dr. K. A. Stoner, Entomologist (specialist in plant resistance to insect attack). AAAS Fellow, AID/AFR/TR, Washington, D. C.

Dr. D. E. Weibel, Sorghum Breeder and Professor, Oklahoma State University, Stillwater.

Dr. B. H. Waite, Plant Pathologist. AID/S&T/AGR, Washington, D. C.

This evaluation was conducted during the period May 11-29, 1987 (see Attachment 3). Progress reports on Project activities and achievements have been prepared by the BPRIA team semi-annually, in accord with the terms of the Project Paper.

This evaluation will do the following:

1) Describe the Project including the original goal, purpose, outputs, and inputs. Specify the progress-to-date in achieving these outputs, and the plans for the remaining two years of the Project.

2) Assess the overall progress of the Project, including the significance and appropriateness of scientific results, the networking and exchange of information and germplasm, the training program, and the relevance of the Project to related programs elsewhere.

3) Make preliminary recommendations on the nature and scale of activities for future funding.

Project Description and Progress

A. Project Goal and Purpose, as specified in the Project Paper: "The primary goal of this proposal is to ensure that plant breeders at National and International Research Centers have basic information for breeding resistant cultivars which will provide a major first line of defense against insect pests of the small subsistence farmer of Africa. The proposed research will contribute to the development of integrated pest management (IPM) methodology within intercropping systems by helping to produce resistant varieties which will constitute the foundation upon which other IPM technology can be built."

B. Project Outputs

Specified Project outputs, actual progress toward achieving these outputs, and plans for continued progress through completion of the Project in 1989:

1. Develop or improve resistance screening methodology for maize and sorghum to the stem borer Chilo partellus in Africa and provide this information to national and international plant breeding programs.

One major goal of this Project has been to standardize methods of screening for resistance to Chilo partellus and methods of testing for resistance at different stages of colonization of the plant by the insect.

The ICIPE method of screening calls for 3-stage testing, from single rows to large plots in farmers' fields. Plants are challenged using both artificial infestation with insects raised in the mass-rearing program and natural infestation by local populations. The researchers have also standardized parameters to be measured to determine infestation and damage levels.

They have also developed methods to identify at what stages of insect colonization and establishment the plant shows resistance. Specific tests for egg-laying response, larval dispersal from or establishment on the plant, larval attraction to the plant from a distance, rate of larval feeding, and rates of larval growth and development on different plant lines have been developed.

This spectrum of possible insect responses to different cultivars has been summarized effectively as a profile of Chilo partellus colonizing responses compared to a standard for both sorghum and maize. This information provides a basic understanding of the mechanism of resistance in various lines, which is the basis for more detailed work on biochemical and biophysical factors involved, and for understanding how resistance acts to reduce insect damage in the field.

The methods developed have been presented at the Eastern, Central, and Southern African Regional Maize Workshops (at CIMMYT, Mexico and at Harare, Zimbabwe) and a workshop on methods for mass rearing, insect resistance, and crop loss assessment will be presented for the government of Zambia in June 1987.

During the last two years of the Project, the program leader expects to refine methods for the evaluation of borer damage. Also, the reliability of resistance will be tested in trials on farmers' fields and at Kenya national research stations.

2. Identify new and confirm old sources of resistance to Chilo partellus in maize and sorghum which can be used by national and international breeding programs.

Resistance to stem borers has been detected in the following sorghum lines: ICS1, ICS2, IS1044, IS4405, IS12308, IS2205, IS4660, and IS4881. Of these, IS1044 shows the highest and most consistent level of resistance. Thirty-five lines of sorghum from ICRISAT and 400 sorghum lines from SAFGRAD (OAU) were evaluated in detail in order to detect the resistant lines.

Resistance to stem borers has been found in the following lines of maize: ICZ1-CM and ICZ2-CM from CIMMYT, and MP704, MP702, and MP701 from Mississippi. The Mississippi lines, however, are poorly adapted agronomically. In order to find the two ICZ resistant lines, 105 maize accessions from CIMMYT were evaluated. The information thus far obtained on the resistance of selected sorghum and maize lines has been passed on to the concerned entomologists of ICRISAT and CIMMYT. Maize and sorghum breeders from national programs will soon join the program and have access to the resistance for breeding. The maize breeder has been identified and will be on location in June, 1987. The position for a sorghum breeder has been advertised. During the last two years of the Project additional sources of resistance will be sought from among the following categories:

a) Lines with resistance to the same insect reported at other locations outside East Africa.

b) Lines with resistance to other borers on the same crop.

c) Lines not evaluated against borers.

3. Identify and clarify the biophysical and biochemical nature of maize and sorghum resistance to insects and, where possible, identify and synthesize allelochemicals involved for potential use in controlling insect pests.

Work on the specific biophysical and biochemical plant factors determining resistance or susceptibility has just begun. Before identifying specific plant factors, the mode

of resistance and stage in plant colonization by the insect at which resistance occurs must be identified. Progress toward this objective has been outlined under output #1. In addition, studies have determined whether oviposition preference, for example, is due to a response to plant factors perceived at a distance or perceived on contact. Further studies have distinguished the relative importance of different distance-perceivable factors such as visual characteristics, hygroscopic characteristics, and volatile chemicals.

All these studies are required before specific biophysical or biochemical characteristics responsible for resistance can be isolated. Chemical studies on volatile chemicals of intact sorghum plants have identified potential chemicals for bioassay in attracting adults and stimulating oviposition. Studies on chemical extracts of sorghum plants as feeding stimulants for Chilo partellus larvae have identified some potential candidate compounds for further analysis. In addition, tests of oviposition preference for maize leaves have determined that hairiness is an oviposition deterrent. Strong emphasis will be put on determining biochemical and biophysical plant characteristics involved in resistance or susceptibility during the final two years of the project.

4. Determine the genetic basis of sorghum and maize resistance to Chilo partellus for use by plant breeders in National and International Centers involved with development of adapted varieties for different regions of Africa.

The inheritance of resistance to stem borer in sorghum has been studied and appears to be controlled by a number of genetic factors, i.e. it is polygenic. In maize, resistance to stem borer is dominant and an F_1 between a resistant and susceptible parent shows resistance. Resistance to shootfly also appeared to be dominant, but study of the segregating populations suggested polygenic inheritance in both cases. This information will be used by the breeders in national programs to select an appropriate breeding method to develop resistant cultivars or parental lines.

For the remainder of the Project additional sources of resistance for both maize and sorghum will be studied in order to find new genes for combining with older sources. Plant morphological and/or genetic characters will be sought that might be linked with resistance to facilitate breeding.

5. Train African scientists and technical personnel in resistance methodology (i.e. mechanisms of resistance and factors affecting expression of resistance).

Long term training under the Project is at the Postdoctoral level and two Postdoctoral Fellows have thus far been involved in this project. The first worked in collaboration with the Mbita Point research scientists during the first year of the Project and returned to his home institution in India in late 1985. His training was specifically on mechanisms of maize resistance to Chilo partellus. He was followed by a scientist from Ghana who has been working as a Postdoctoral Fellow since February 1986 and is due to leave in mid 1988. His work deals with the role of maize plant cultivars in soliciting or inhibiting ovipositional responses. Both of these scientists have participated in the activities of other units of the CPRP.

Two graduate students funded by the ARPPIS program have also trained with project researchers in plant resistance to insects.

Short term training to date has been given at the Postdoctoral, Pre-doctoral, and Technician levels. Training at the Post and Pre-doctoral levels is currently being given to one entomologist from Nigeria and to two from Ivory Coast who have been working since early 1986 as Research Associates under the supervision of the Project scientists. They are scheduled to work at ICIPE for 3-4 months per year for the next 3 years with approval of their home institutions. These Associates are assigned specific research projects but they also are involved in the research of other units of the CPRP. At the level of Technician, two staff members of the Uganda Agriculture and Forestry Research Organization are currently under training for a 3 month period. Another Technician from Makulu Agricultural Research Station, Zambia will be trained at this level for 3 months in mid 1987. These Technicians are being trained in mass rearing and plant resistance methods.

6. Expand networking and interchanges of germplasm and host plant resistance methodology through formal and informal cooperative relationships with national, international, and CRSP research programs.

Networking with national programs: Collaborative trials have been conducted with the Kenya National Agricultural Research Stations at Kitale, Katumani, Busia, and Mtwapa using promising sorghum and maize cultivars. The main objectives of these multi-locational trials are to 1) evaluate selected maize cultivars for their reaction to borers and 2) t assess yield and adaptability of these cultivars in different agroecological zones.

International networking: CIMMYT and ICRISAT have contributed maize and sorghum cultivars/lines for study under the Project and information on pest resistance and agronomic qualities of this plant germplasm. CIMMYT has benefited from collaboration with this Project by including material evaluated for resistance to Chilo partellus at Mbita Point into its multiple borer resistance pool for maize. Informatio and germplasm have also been exchanged with the USDA European Cornborer Laboratory (W.R. Guthrie) and Southwestern Cornborer Laboratory (Frank Davis).

A meeting to discuss the activities to be undertaken through PESTNET was held at ICIPE in June, 1986. A workshop in methods used for mass rearing, plant resistance to insects, and crop loss assessment, funded and coordinated through PESTNET, is scheduled for scientists and technicians from the Zambian national program in June, 1987.

7. Publish results of research in national and international refereed journals.

Scientists have been publishing the results of their research as indicated in the attached list (Attachment 2).

C. Project Inputs

The Project Paper is not entirely clear about what the $2.5 million USAID has put into this Project is expected to support. In particular, at various places the Project Paper specifies either two scientists and a postdoctoral fellow or three scientists and a postdoctoral fellow. Other inputs as listed in the budget are:

1. Personnel - Scientific Officer, Technical Support Staff (numbers vary over the life of the project), Research Associates

2. Travel - International travel for Project Leader and Staff, local travel

3. Materials and supplies

4. Equipment - A Gas Liquid Chromatograph, and various monitoring and recording devices to measure insect behavior

5. Other - Costs of agronomic and farm services for Mbita Point Field Station and Communication costs.

D. Assessment of Progress

1. Screening Methods:

BPRIA researchers have developed a substantial number of methods suitable for use by entomologists in the intensive study of mechanisms of resistance and verification of the level and type of resistance underfield conditions. They have not yet produced any improvements in rapid evaluation methods suitable for use by plant breeders in screening large numbers of potential sources of resistance or selection from large breeding populations. Further work on rapid evaluation methods is planned once biochemical and biophysical characteristics involved in resistance are known. Emphasis should be given to the possible use in screening of one component which correlates most highly with overall resistance. Improved screening techniques, refined for both accuracy and efficiency, need to be developed.

2. Identification of new and confirmation of old sources of resistance:

Good progress has been made in this area, but more lines need to be tested, because this is a continuing process. Some material with resistance to other borers (particularly maize resistant to European corn borer due to high levels of the compound DIMBOA) has been found not to be resistant to Chilo partellus. However, other material developed for resistance to other borers (notably maize resistant to southwestern corn borer) is also resistant to the target pest.

BPRIA scientists should be aware that unadapted lines with resistance must be preserved. If resistance is present to Chilo partellus or other borer species, agronomically inferior varieties or lines could prove very useful in future breeding strategies. New sources of resistance can provide a hedge against a biotype change in the insect, which could enable the borer to overcome former

resistance. Therefore, the new sources should be combined with older sources of resistance to provide a broad spectrum of resistant material.

3. Biophysical and biochemical nature of resistance:

Specific work on the biophysical and biochemical factors that determine plant resistance or susceptibility is only beginning. This area of study will receive major emphasis in the remaining two years of the Project. The groundwork for this research has been laid by the detailed studies of resistance in different stages of insect colonization and establishment on the plants. These studies direct the attention of researchers to 1) the specific parts and growth stages of the plant and 2) the specific behavioral or physiological responses of the insects, to be used in extracting and bioassaying the chemicals or isolating biophysical characteristics involved in resistance.

In addition to identifying factors involved in resistance through deterring oviposition and feeding or through reducing larval growth and development, an effort should also be made to determine the physiological factors involved in the tolerance of sorghum variety Serena to borer damage.

4. Genetic basis of sorghum and maize resistance:

Once resistance has been identified and verified, further studies have determined the genetic basis through crossing and generation mean analysis. These results should be useful to plant breeders in suggesting appropriate breeding methods. This work will need to continue as new lines with resistance are identified, and as plant characteristicsdetermining resistance are identified, in order to separately determine the genetic basis of these characteristics. New sources of resistance should be compared with older sources to determine if they have the same or different factors for resistance, and combined with the older sources to provide a broader base of resistance. The BPRIA breeder and associated breeders from the national programs should begin a program of germplasm enhancement to prepare the resistant material for use in variety development.

5. Training:

The Project has trained two postdoctoral fellows, three research associates (short-term training of scientists at predoctoral or postdoctoral levels), and will provide short-term training to three technicians over the next few months. This is appropriate to the level of funding

provided for training by the Project -- funds for one postdoctoral fellow throughout the life of the Project, and 3-4 month training for 4-5 research associates per year for 4 out of the 5 years of the Project.

6. Networking:

Exchange of germplasm and results with CIMMYT and ICRISAT appears to be effective and beneficial to both sides of the exchange. Project scientists have made contact with George Teetes of INTSORMIL and Billy Wiseman of the Southern Research Laboratory. Germplasm exchange with these researchers, and interaction with R. E. Atkins (Iowa State University) and the USDA maize insects laboratory in Brookings, South Dakota could benefit the Project.

Collaboration and networking with the Kenya national agricultural stations is well established and links to the Zambia national system are being formed. Collaboration with national and international plant breeders is crucial to ensuring that the basic research produced in this Project is used in the development of resistant varieties acceptable to farmers.

Although the Project Paper states that "the benefits from these (Project) outputs will be locally adapted varieties of maize and sorghum resistant to key pests...", ICIPE itself cannot do plant breeding beyond the study of the genetics of resistance and evaluation of crosses and other materials (see Recommendations, Report of the First Triannial Review, ICIPE, April 1983).

Thus, the proper role of ICIPE in production of resistant varieties is the exchange of information, methods, and germplasm with plant breeders in national programs and international centers, who will incorporate resistance to insects into otherwise agronomically acceptable material. There are various mechanisms available to promote this exchange, including regional or national workshops coordinated through PESTNET, multi-locational trials and other collaborative research, and short-term and long-term training of researchers and technicians from national programs. No special funds have been provided in this Project for regional or national workshops or to set up collaborative research. To the extent that these forms of networking have succeeded, it is due to funds from other donors and ICIPE's own initiative.

In addition to initiating its own workshops and multi-locational trials, ICIPE could also enhance cooperation by participating in other programs initiated by donors or national research programs. For example, potential cultivars such as ICZ1, ICZ2, ICS1, ICS2, and IS1044 could be included in the Kenya National Performance Trials.

Recommendations for Future Activities and Funding

The BPRIA researchers, when asked what problems they would propose to address in a renewal of the current Project, listed the following:

1. Multiple borer resistance, including studying whether mechanisms of resistance to other stem borers are the same or different from resistance to *Chilo partellus*.

2. Additional study of physiological, morphological, and chemical characteristics of plants determining resistance to borers.

3. Development of simplified, rapid methodology for use by plant breeders in screening large populations.

4. Expanded multi-locational testing in collaboration with national programs (possibly including Zambia, Somalia, Tanzania, and perhaps Uganda, as well as Kenya), and cooperation with national breeders in incorporating borer resistance into elite breeding lines.

5. Genetic studies on the inheritance of plant characteristics determining resistance or susceptibility.

Other possibilities mentioned were to expand the Project to include resistance to pod borer (*Maruca testulalis*) in cowpea and/or resistance to shootfly (*Atherigona soccata*) in sorghum.

This represents a reasonable plan for continuation and modest expansion of the current Project.

We would make the following recommendations about any follow-on project to BPRIA:

1. In the next project, strong emphasis should be placed on developing collaboration with national breeders in the countries of Eastern and Southern Africa. This may involve regional and national workshops, short-term training of practitioners, and, for those countries lacking any plant resistance expertise, long-term graduate and/or post-graduate training. Appropriate levels of funding should be provided for workshops, conferences, training, and setting up multi-locational trials and other collaborative research. As much as possible, routine screening, identification and confirmation of sources of resistance, and all plant breeding should be carried out by national plant breeders with whatever assistance is needed from ICIPE.

2. Parallel to this Project, in the CPRP, is a unit studying crop loss assessment, and a program examining socio-economic constraints on farmers in Western Kenya. In the light of this research, it is time to evaluate research priorities based on the economics of crop loss, farmers' constraints, and progress toward an IPM program for all pests on the ICIPE target crops of sorghum, maize, and cowpea. Extension of a future project to include additional pests (other borers, shootfly, sorghum midge, pod borer of cowpea, cowpea aphids, or cowpea thrips) should select target pests based on the economic importance of the pest, the prospects for finding sources of plant resistance, and whether there are other methods of control suitable for use by resource-poor farmers. Unless <u>all</u> the most important pests are addressed, by plant resistance or other methods, farmers will not be satisfied with the performance of new varieties.

3. One of the constraints consistently identified by project researchers is a severe shortage of developed land for use in field experiments. ICIPE owns 182 acres at the Ungoye Field Site, but only part of this land has been used, because road access is difficult, and no storage facilities are available. We recommend funding road improvement and storage construction, possibly on the basis of matching funds from other donors. About one-half km of murrom road would greatly improve access to the field. A closed storage building (rat proof) approximately 6 x 10 m is also needed.

4. We recommend that the Project scientists use a program of germplasm enhancement for manipulating sources of resistance to insects. Resistance is often found in wholly unadapted cultivars and/or exotic collections. This necessitates some preliminary breeding activities in a process called germplasm enhancement, an intermediate step or steps between the source of germplasm and the breeder. The source of resistance is genetically manipulated into a form in which it can be used by the breeder to develop adapted resistant cultivars or parental lines. Examples are found in the transfer of genetic factors from one species to another within a genus, the conversion of photosensitive to photoinsensitive lines, and the creation of composite populations or random mating populations. In these populations several sources of resistance to the same insect or multiple sources of resistance to several insects can be combined to form a germplasm pool from which breeders can make selections for breeding.

5. If the range of target pests included in this Project is to be expanded without greatly increasing the level of support, the topics for research on each insect-plant interaction must be more vigorously evaluated according to priority. First priority should be given to critical materials and information needed by plant breeders in order to select for resistance: identification of one or more sources of resistance and development of rapid and effective methods for evaluating the level of resistance to insects. Second priority should be given to determination of the genetics of resistance and verification of stability of resistance in different agroecological zones, although as national breeding programs focusing on plant resistance to insects are developed by the outreach and training aspects of the Project, these tasks can gradually be turned over to the national programs. Third priority should go to detailed studies of the stages of colonization and establishment of insects on the plant and how they are affected by resistance in different plant lines. Fourth priority would go to basic research identifying biochemical and biophysical plant factors involved in resistance or susceptibility. Within this area of research, priority should be given to investigating those chemical, morphological, and physiological characteristics of the plant which are most likely to be involved in the stages of insect colonization and establishment showing the greatest difference between resistance and susceptibility among plant lines. Special attention should be given to association of resistance with easily identifiable markers (any morphological, chemical, or physiological character that has a simple, rapid test).

Attachment 2.

LIST OF PAPERS ON PLANT RESISTANCE TO INSECT PESTS PUBLISHED, SUBMITTED OR PRESENTED IN CONFERENCES

Ampofo, J.K.O. (1985). Chilo partellus (Swinhoe): Oviposition on susceptible and resistant maize genotypes. Insect Sci. Applic. 6 (3): 321-330.

Ampofo, J.K.O. and Saxena, K.N. (1986). Maize resistance to Chilo partellus (Swinhoe) (Lepidoptera: Pyralidae): Some aspects of the insect responses to the plant and implications for breeders. In Gelaw, B., Ed. To Feed Ourselves: A Proceedings of the 1st Eastern, Central and Southern Africa Regional Maize Workshop, CIMMYT, MEXICO, D.F.

Ampofo, J.K.O. and Nyangiri, E.O. (1986). Maize resistance to Chilo partellus (Swinhoe) (Lepidoptera: Pyralidae): Behaviour of newly hatched larvae and movement from oviposition sites to feeding sites. App. Ent. and Zool. 21 (2): 269-276.

, J.K.O. (1986). Effect of resistant maize cultivars on larval dispersal and establishment of Chilo partellus (Lepidoptera: Pyralidae). Insect Sci. Applic. 7 103-106.

J.K.O. (1986). Maize stalk borer (Lepidoptera: Pyralidae) damage and plant resistance. Environ. Entomol. 16: 1124-1129 p.

J.K.O., K.N. Saxena, J.G. Kibuka, and E.O. Nyangiri (1986) Evaluation of some maize cultivars for resistance to the stem borer, Chilo partellus in western Kenya. Maydica, 31: 379-389.

Ampofo, J.K.O. and E.L. Kidiavai (in press). Chilo partellus (Swinhoe) larval movement and growth on maize plants in relation to plant age and resistance or susceptibility. J. appl. Ent. (accepted August, 1986).

J.K.O., Dabrowski, Z.T. and Omolo, E.O. (1986). Registration of ICZ1-CM (GP-145) and ICZ2-CM (GP-146) maize germplasm lines. Crop Sci. 26: 650.

Ampofo, J.K.O. (1986). Chilo partellus (Lepidoptera: Pyralidae) larval movement and development in maize plants in relation to plant age and resistance. International Conference on Tropical Entomology, Liberia, March 24-26, 1986.

Firempong, S.K., Ampofo, J.K.O. and Saxena, K.N. 1987. Chilo partellus oviposition, larval feeding and development on different maize cultivars in relation to their resistance levels. 2nd Eastern, Central and Southern Africa Regional Maize Workshop, Harare, Zimbabwe, March 15-20, 1987.

Kumar, H. and Saxena, K.N. (1985). Oviposition by Chilo partellus (Swinhoe) in relation to its mating, diurnal cycle and certain non-plant surfaces. Appl. Ent. Zool. 20: 218-221.

Kumar, H. and Saxena, K.N. (1985). Ovipositional responses of Chilo partellus (Swinhoe) to certain susceptible and resistant maize genotypes. Insect Sci. Applic. 6: 331-335.

Ochieng, R.S., Onyango, F.O. and Bungu, M.D.O. (1985). Improvement of techniques for mass-culture of Chilo partellus (Swinhoe). Insect Sci. Applic. 6: 425-428.

Pathak, R.S. (1985). Genetic variation of stem borer resistance and tolerance in three sorghum crosses. Insect Sci. Applic. 6: 359-364.

Pathak, R.S. (1985). Genetics of cowpea resistance to pod-borer, Maruca testulalis (Geyer). Proc. 5th SABRAO International Congress, Nov. 25-29 Bangkok, Thailand, (in press).

Pathak, R.S. and Olela, J.C. (1986). Registration of 14 cowpea cult Crop Sci. 26: 647-648.

Pathak, R.S. (1986). Induced mutations for resistance to aphids, Aphis craccivora Koch in cowpea. Proc. FAO/IAEA Workshop o improvement of grain legume production using induced mutatio July 1-5, 1986 Pullman (Wash.) USA.

Pathak, R.S. (1986). Gene action for resistance to stem borer, Chilo partellus in sorghum. International Conference on Tropical Entomology, 31 August-5 September 1986. Nairobi, Kenya.

Pathak, R.S. (1986). Genetics of resistance to aphid, Aphis craccivora in cowpea. International Conference on Tropical Entomology. 31 August-5 September 1986. Nairobi, Kenya.

Pathak, R.S. (1987). Genetics of resistance to stem-borer, Chilo partellus in maize crop science (Submitted).

Saxena, K.N. (1985). Behavioural basis of plant resistance or sceptibility to insects. Insect Sci. Applic. 6: 303-313.

Saxena, K.N. (in press). Ovipositional responses of Chilo partellus to certain sorghum cultivars in relation to their susceptibility or resistance. Proc. 6th Internat. Symp. Insect-Plant Relationships. Dr. W. Junk Publishers, The Netherlands.

Saxena, K.N. (in press). Colonising responses of Chilo partellus to certain sorghum cultivars in relation to their resistance or susceptibility to the stem borer. Proc. Symp. Plant Resistance in Tropical Insect Pest Management. Internat. Conf. Trop. Entomology, 1986, Nairobi.

Saxena, K.N. and Onyango, J.D. (accepted). Attraction of the stem borer Chilo partellus (Swinhoe) larvae (Lepidoptera: Pyralidae) by certain coloured surfaces for trapping. Appl. Ent. Zool. (Japan).

Seshu Reddy, K.V. (1985). Relative susceptibility/resistance of some sorghum lines to stem borers in Western Kenya. Insect Sci. Applic. 6 (3): 401-404.

Seshu Reddy, K.V. (1985). Integrated approach to the control of sorghum stem borers, pages 205-215. Proc. of the International sorghum Entomology Workshop, 1984, Texas A & M University, College Station, Texas, USA. pp. 205-215

Seshu Reddy, K.V. (1986). Population patterns of stem borers of sorghum in Western Kenya. International Conference on Tropical Entomology, 1986, Nairobi, Kenya.

Seshu Reddy, K.V. and Omolo, E.O. (1985). Sorghum insect pest situation in Eastern Africa. Proc. of the International Sorghum Entomology Workshop, 1984, Texas A & M University, College Station, Texas, USA. pp. 31-36.

Seshu Reddy, K.V. and Okeyo, A.P. (submitted). Some entomological and socioeconomic perspectives on the effects of insect pests on subsistence agriculture in Africa. Proc. Internat. Conf. Trop. Entomology, 1986, Nairobi, Kenya.

* Unnithan, G.C. and Seshu Reddy, K.V. (1985). Oviposition and infestation of the sorghum shootfly, Atherigona soccata Rondani on sorghum cultivars in relation to their relative resistance/ susceptibility. Insect Sci. Applic. 6: 409-412.

* Unnithan, G.C., Saxena, K.N.; Bentely, M.D. and Hassanali, A. (submitted). Role of host plant chemicals in stimulating oviposition in the sorghum shootlfy, Atherigona soccata Rondani (Diptera: Muscidae) Environ. Entomology.

* Unnithan, G.C. and Saxena, K.N. (1986). Diversion of sorghum shootfly oviposition to non-host plant using host plan: chemicals. Abst. Internat. Cong. Dipterology, 1986, Budapest, p. 244.

Unnithan, G.C. and Saxena, K.N. (1986). Certain factors influencing pheromonal trapping of Chilo partellus males using females as lures. Proc. Intern. Conf Trop Entomology, 1986, Nairobi, Kenya.

Unnithan, G.C. and Seshu Reddy, K.V. Infestation and carry-over of sorghum stem-borers and the potential role of destruction of crop residues as a cultural control practice. Proc. Internat. Conf. Trop. Entomology, 1986, Nairobi, Kenya.

Articles which do not pertain to the target pests.

Attachment 3.

THE INTERNATIONAL CENTRE OF
INSECT PHYSIOLOGY AND ECOLOGY (ICIPE)
P.O. BOX 30772, NAIROBI

ITINERARY FOR THE EVALUATION TEAM FOR THE USAID PROJECT ON BASIS FOR PLANT RESISTANCE TO INSECT ATTACK

Monday, 11 May 1987 — Review of Project documents.

Tuesday, 12 May — Visit to ICIPE; meeting with the Director, Deputy Director, Chief Planning Officer, and Programme Leader, Crop Pests Research Programme (Principal Communication Officer to coordinate). Presentation of documents/literature on the ICIPE to the team.

Wednesday, 13 May — Travel by Kenya Airways to Kisumu. Drive to Mbita Point Field Station (MPFS): Stay in the International Guest Centre. Presentations from the Programme Leader, Crop Pests Research P;rogramme (CPRP) and the USAID Project Scientists (based on posters).

Thursday, 14 May — Field visit (MPFS experiments). Visit to other Sections of CPRP. Discussions with individual scientists of USAID Project.

Friday, 15 May — Discussions with individual scientists of the USAID Project to be continued. Visit CPRP cooperating farmers' fields in Rusinga/Ogongo (accompanied by project scientists K.N. Saxena, R.S. Pathak, J.K.O. Ampofo, and J.G. Kibuka). Reception in the honour of the Evaluation Team.

Sunday, 17 May — Free

Monday, 18 May — Visit farmers' fields in Kendu Bay (accompanied by K.N. Saxena, K.V. Seshu Reddy, R.S. Pathak, J.K.O. Ampofo, and J.G. Kibuka). Visit cooperating farmers' fields in Oyugis. Proceed to Kisumu and stay at Sunset Hotel (accompanied by R.S. Pathak, J.K.O. Ampofo, and J.G. Kibuka).

Tuesday, 19 May — Visit to Agricultural Research Station, Alupe, Busia (accompanied by R.S. Pathak, J.K.O. Ampofo, and J.G. Kibuka). Return to Sunset Hotel at Kisumu (R.S. Pathak and J.K.O. Ampofo to stay; J.G. Kibuka to return to MPFS).

Wednesday, 20 May — Travel to Nairobi by Kenya Airways (accompanied by R. S. Pathak and J.K.O. Ampofo). Discussions with the Deputy Director and staff of the Outreach and Training Unit in the ICIPE Seminar Room (Dr. D.L. Haynes, Dr. Z.M. Nyiira, Dr. M.E. Smalley, and Mr. J.F. Omange). Discussion on Information Dissemination System at the ICIPE in the Seminar Room (L. Okola, N. Naubuga, R. Washika).

Thursday, 21 May — Visit National Dryland Farming Station, Machakos (accompanied by K.N. Saxena, J.K.O. Ampofo and E.L. Kidiavai). Lunch and visit of Duduville International Guest Centre (Mr. J. Achilla and Mr. Jackson). Verbal briefing by the USAID Evaluation Team (for D.L. Haynes, R.A. Odingo, K.N. Saxena).

Friday, 22 May — Visit to Chemistry Laboratory (accompanied by K.N. Saxena). Briefing by Dr. A. Hassanali, W. Lwande, and B. Torto. Return to REDSO office to begin preparation of evaluation report.

Saturday, 23 May — Evaluation Report preparation.

Sunday, 24 May — Free

Monday, 25 May — Report Writing.

Tuesday, 26 May through Friday, 29 May. Report preparation, debriefing with ICIPE, and presentation to REDSO.