AGENCY FOR INTERNATIONAL DEVELOPMENT

PROJECT DATA SHEET

1. TRANSACTION CODE: A (A = Add, C = Change, D = Delete) — Amendment Number

DOCUMENT CODE: 3

2. COUNTRY/ENTITY: AFRICA REGIONAL

3. PROJECT NUMBER: 698-0435.02

4. BUREAU/OFFICE: AFR/RA — 06

5. PROJECT TITLE (maximum 40 characters): PID-AAP-639 — Plant Resistance to Insect Attack (CDA)

6. PROJECT ASSISTANCE COMPLETION DATE (PACD): MM 08 DD 13 YY 89

7. ESTIMATED DATE OF OBLIGATION (Under 'B.' below, enter 1, 2, 3, or 4)

A. Initial FY 84 B. Quarter 4 C. Final FY 87

8. COSTS ($000 OR EQUIVALENT $1 =)

A. FUNDING SOURCE	FIRST FY 84 B. FX	C. L/C	D. Total	LIFE OF PROJECT E. FX	F. L/C	G. Total
AID Appropriated Total						
(Grant)	( )	(700)	(700)	( )	(2,500)	(2,500)
(Loan)	( )	(700)	(700)	( )	(2,500)	(2,500)
Other U.S. 1.						
Other U.S. 2.						
Host Country						
Other Donor(s)		360	360		2,221	2,221
TOTALS		1,060	1,060		4,721	4,721

9. SCHEDULE OF AID FUNDING ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	C. PRIMARY TECH. CODE 1. Grant	2. Loan	D. OBLIGATIONS TO DATE 1. Grant	2. Loan	E. AMOUNT APPROVED THIS ACTION 1. Grant	2. Loan	F. LIFE OF PROJECT 1. Grant	2. Loan
(1) ARDN	111	967		-	-	2,500	-	2,500	-
(2)									
(3)									
(4)									
TOTALS				-	-	2,500	-	2,500	-

10. SECONDARY TECHNICAL CODES (maximum 6 codes of 3 positions each): 957, 977

11. SECONDARY PURPOSE CODE: 121

12. SPECIAL CONCERNS CODES (maximum 7 codes of 4 positions each)

A. Code	R/AG						
B. Amount	2,500						

13. PROJECT PURPOSE (maximum 480 characters)

To understand the physical, chemical, genetic and morphological causes of insect resistance in Target crops and develop resistant cultivars for use in National and international breeding programs.

14. SCHEDULED EVALUATIONS

Interim MM 10 YY 86 MM YY Final MM 10 YY 88

15. SOURCE/ORIGIN OF GOODS AND SERVICES

☐ 000 ☒ 941 ☒ Local ☐ Other (Specify)

16. AMENDMENTS/NATURE OF CHANGE PROPOSED (This is page 1 of a ____ page PP Amendment.)

17. APPROVED BY

Signature: Walter Sherwin *Walter Sherwin*

Title: Acting Director, AFR/RA

Date Signed: MM 07 DD 06 YY 84

18. DATE DOCUMENT RECEIVED IN AID/W, OR FOR AID/W DOCUMENTS, DATE OF DISTRIBUTION

MM DD YY

AID 1330-4 (8-79)

THE INTERNATIONAL CENTRE OF INSECT PHYSIOLOGY AND ECOLOGY
P. O. BOX 30772 NAIROBI, KENYA

I C I P E

REF: F1/CONTR/USAID/14/121

22nd June 1984

Mr Peter J. Bloom
Acting Director
East Africa Regional Economic
Development Services Office (REDSO)
U.S. Agency for International Development (USAID)
P.O. Box 30261
NAIROBI

Dear Mr Bloom,

RESEARCH PROJECT ON CROP PESTS CRITICAL FOR TROPICAL RURAL DEVELOPMENT

We are pleased to reaffirm our gratitude to USAID for the grants we have received for this project. As a result of the Project Review Mission appointed by USAID in 1982, we are now submitting to you a Grant Proposal for further support of this project.

We appreciate your assistance in processing the grant request.

Yours sincerely,

THOMAS R. ODHIAMBO
Director, ICIPE

ENCL: Grant Proposal on the Research Project on Crop Pests Critical for Tropical Rural Development

TRO/mw

BASIS OF PLANT RESISTANCE TO INSECT ATTACK
PROJECT PROPOSAL

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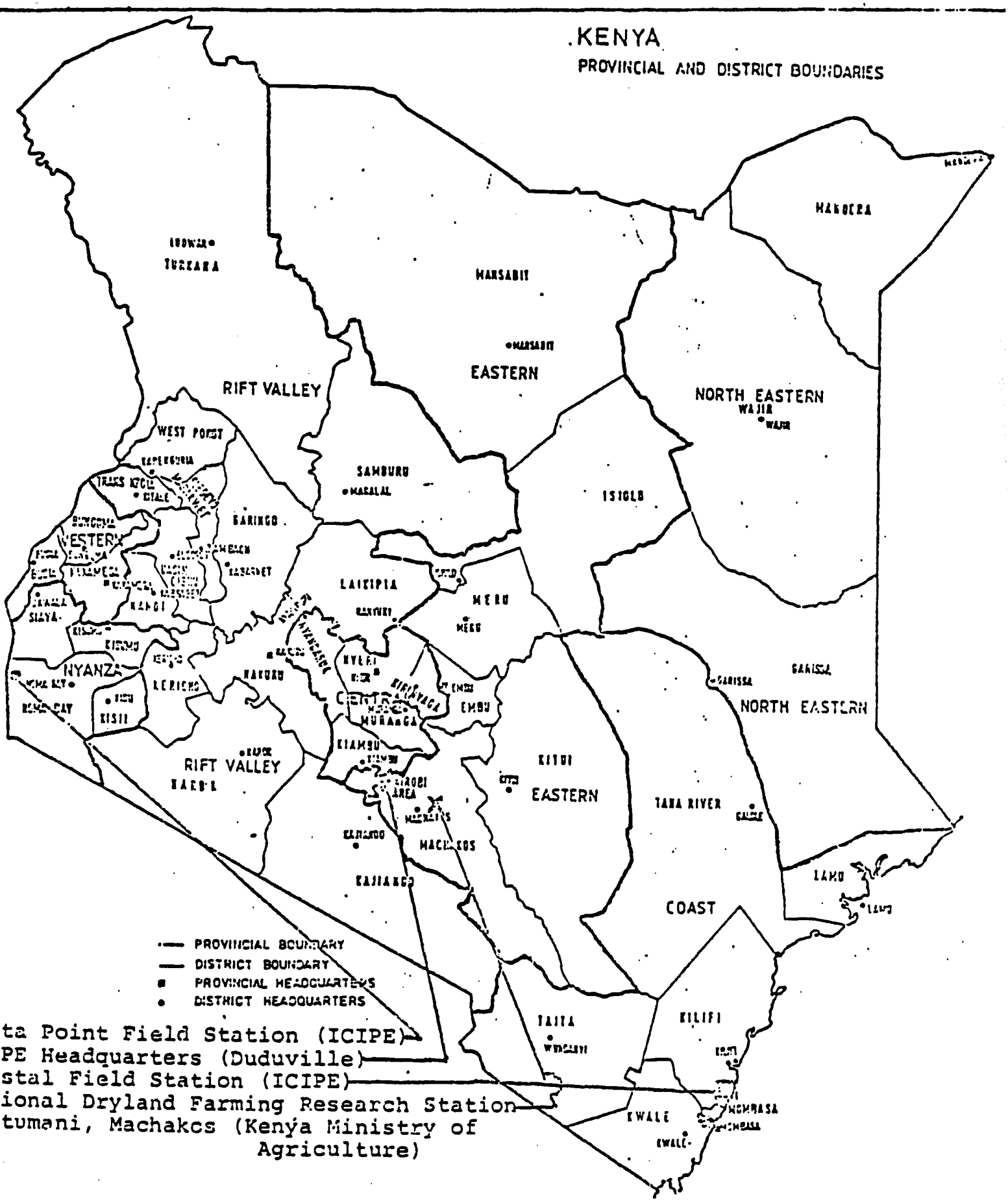
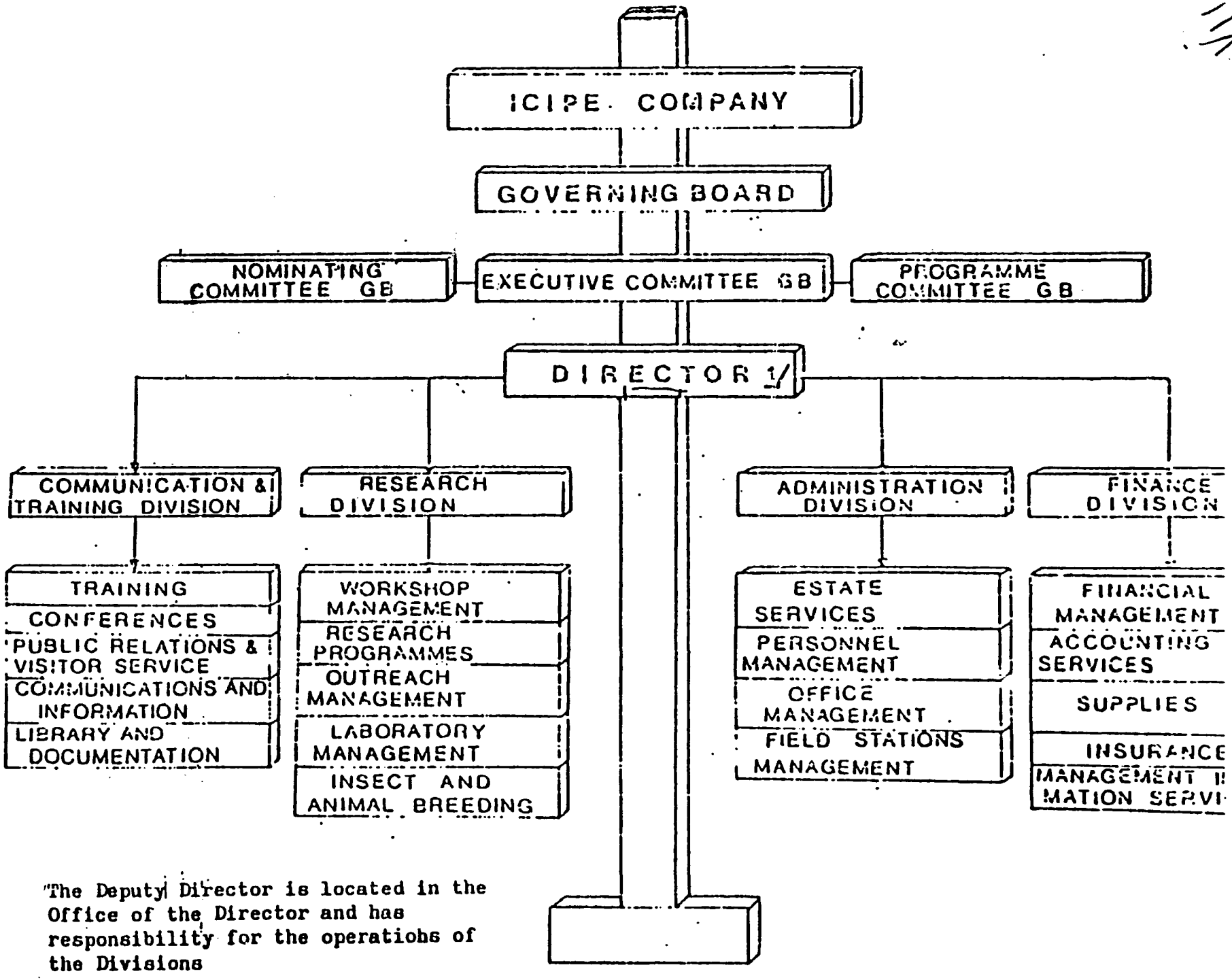
ABBREVIATIONS

AID-	Agency for International Development
BPRIA-	Bases for Plant Resistance to Insect Attack
CICP-	Consortium for Integrated Crop Protection
CIMMYT-	International Center for Maize and Wheat Improvement
CRSP-	Collaborative Research Support Program
ERS-	Economic Research Service/U.S. Department of Agriculture
FAO-	Food and Agriculture Organization
HPR-	Host Plant Resistance
IARC-	International Agricultural Research Centre
ICIPE-	International Center of Insect Physiology and Ecology
ICRISAT-	International Crops Research Institute for 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
MPFS-	Mbita Poit Field Station
R-	Resistant host plant
REDSO/EA-	Regional Economic Development Services Office/East Africa
SGI-	Sponsoring Group for the ICIPE
S-	Susceptible host plant
UNDP-	United Nations Development Program
USDA-	U.S. Department of Agriculture
WARDA-	West African Rice Development Association


KENYA
PROVINCIAL AND DISTRICT BOUNDARIES
TURKANA
MARSABIT
EASTERN
MANDERA
RIFT VALLEY
NORTH EASTERN
WAJIR
WEST POKOT
SAMBURU
ISIOLO
BARINGO
WESTERN
LAIKIPIA
MERU
NANDI
KISUMU
NYANZA
KERICHO
NAKURU
NYERI
CENTRAL
MURANGA
EMBU
GARISSA
NORTH EASTERN
KISII
RIFT VALLEY
KITUI
EASTERN
TANA RIVER
MACHAKOS
KAJIADO
LAMU
COAST
TAITA
KILIFI
KWALE
MOMBASA
PROVINCIAL BOUNDARY
DISTRICT BOUNDARY
PROVINCIAL HEADQUARTERS
DISTRICT HEADQUARTERS
Mbita Point Field Station (ICIPE)
ICIPE Headquarters (Duduville)
Coastal Field Station (ICIPE)
National Dryland Farming Research Station
Katumani, Machakos (Kenya Ministry of
Agriculture)



1/ The Deputy Director is located in the Office of the Director and has responsibility for the operations of the Divisions

I., SUMARY AND RECOMMENDATIONS

A. Uniqueness and Importance of the International Center of Insect Physiology and Ecology (ICIPE)

ICIPE was created in 1970 and is currently located in Nairobi, Kenya. An extension research station is under construction at Mbita Point, on the shores of Lake Victoria. Headquarters of ICIPE including a training center, laboratories, residential apartments and administration building will be located at Duduville, approximately 15 kilometers from downtown Nairobi. Since its inception in 1972, ICIPE has favored a three-pronged approach to development-oriented research in Africa. The approach is: (1) to carry out basic and applied research on the control of insects which most severely affect crops, livestock production and human health; (2) to provide advance training in research methodology and application of research results to graduate and post-doctoral research fellows; (3) to increase Africa's indigenous scientific capacity.

ICIPE's interest in the proposed research is based on the recognition that pests affecting cereal and grain-legume crops in the rural tropics cause severe widespread losses in Africa which is technically very difficult to solve and which requires further research. The primary basic research thrust that ICIPE is specifically interested in is the control of stem borers of cereals and pod borers of legumes, in an effective long-term manner through breeding for plant resistance [illegible] s method is the most effective means of assisting the subsistence [illegible] farmers in Africa.

The ICIPE is focusing specifically on this problem with the Bases of Plant Resistance to Insect Attack (BPRIA) research team, assisted in the field by the Bionomics and Applied Ecology (BAE) Section. The role of the BPRIA is unique. They are obtaining germplasm previously screened for resistance to certain species of insects from International Centers, National Programmes and Collaborative Research Support Programs(CRSPs) in the U.S. The material is grown at Mbita Point field research center, to confirm resistance or lack of resistance to stem borers, pod borers and other local pests, characterizing the resistance (preference, antibiosis, tolerance) and to study the basic mechanisms (physical, morphological, chemical) of resistance including the effect of the various levels of resistance on pest species populations dynamics over time. In addition methodology and techniques for improved identification of resistance and tracking the inheritance of resistance in subsequent crosses (populations) are being developed.

The information on the basic mechanisms of resistance, along with improved methods for measuring resistance mass rearing of pest insect populations, is provided to cooperating breeding programs of National Programs in Africa, including Malawi, Nigeria, Sudan, Tanzania and Upper Volta as well as Kenya and other International Centres. In addition to the direct research product, the proposed program will serve an important dual function in providing an excellent situation for postgraduate and post doctoral training for entomologists from other countries of Africa and the world to receive specialized training and experience in the plant resistance to insect area. There is no where else in continental Africa where students may obtain this unique training and return to their countries and immediately begin applying the technology. The ICIPE has

established formal linkages recently with the Ivory Coast, Malawi, Sudan, Tanzania and Upper Volta to enhance cooperative relationships in research and in training of scientists. Other formal linkages are being exploral (i.e. Uganda).

B. Networking the BPRIA Research Program

1. Networking and Cooperation with IARC's, National Program, CRSP's and Specific Maize and Sorghum HPR Programs in the U.S.: The BPRIA program has established formal relationships with IITA and has received germplasm from CIMMYT and ICRISAT. Cooperation with these centers will be continued and strengthened so that new sources of plant resistance to insects is utilized in basic studies at ICIPE, and also to insure that methodologies for rearing insect pests and screening for host plant resistance be made available to the centers. And National Program in Africa especially those mentioned in the preceeding section. Some experiments are in progres with the Kenya National Program but continued cooperation will be developed through formal as well as informal agreements with Kenya Station Director as well as through increased training by ICIPE of Kenyan Ministry Entomologists. Cooperation has been initiated with the AID Sorghum/Millet CRSP, especially with Dr. George Teeter at Texas, A & M University in the research area of resistance to sorghum midge. Also, cooperation has been established in the following programs in the U.S. and germplasm is being exchanged: (a) the USDA European Cornborer Laboratory in Ames, Iowa (Dr. W.R. Guthrie); (b) the Southwestern Cornborer program at Mississippi State (Dr. Frank Davis); and (c) the USDA Southern Small Grains Research Laboratory in Tifton, Georgia (Dr. Billy Wiseman). Dr. Frank Davis, Dr. Billy Wiseman and Dr. George Teetes formally visited the ICIPE BPRIA program in June 1984.

2. Travel Funds: Travel funds for travel by the Project Leader and the research scientists on the BPRIA team have been recommended in the projeted budget. ICIPE recognizes the importance of travel, especially by the Project Leader, to attend international scientific meetings and the biennium workshop meeting in the U.S. on host plant resistance to insects. Increased travel is also needed for extending and increasing the cooperation and coordination with the National and International centers where breeding work on maize, sorghum and cowpeas are concentrated.

Much knowledge and cooperation, along with germplasm can be obtained through visits to establish relationships with the programs and researchers in the US. mentioned in Section 1 above. The mass rearing scientist, especially, would benefit from a trip to the U.S. and CIMMYT to visit mass rearing facilities and scientists researching rearing methods.

C. Long-term Nature of Bases of Plant Resistance Project and Need for Continuity and Stability in Funding of Basic Research

Research on insect pests in Africa is one of the highest priority areas for agricultural development. In general the success of plant breeders in achieving adequate levels of host-plant resistance to African insect pests has been more difficult than breeding for disease resistance. The development of insect resistance crops requires a

basic and sophisticated understanding of the chemical, physical and genetic bases of plant resistance. This can only be achieved by a 10-15 year research program with stable and continuous funding of an interdisciplinary team of entomologists, chemists, physiologists, and geneticists. It will only be possible to design and implement an effective pest management program utilizing resistant cultivars when this basic information is available. This kind of research effort will have an extremely high pay-off in long range improvement of African crop production through the development of resistant varieties to key target pests, especially the stem borer complex.

D. Description of the Project Proposal

1. Goal and Outputs: The chief goal of this proposal is are: (a) to insure that plant breeders at National and International Research Centers have basic information on the resistance - imparting and susceptibility - imparting characters of plants for breeding resistant cultivars which will provide a major first line of defense against insect pests for the small scale farmer of Africa; (b) to provide methodology for manipulating in other ways the principles determining plant resistance/susceptibility to insect pests for their management. 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. Overall outputs of the BPRIA Project are as follows:

a. Develop or improve resistance screening methodology for maize, sorghum and cowpea to target insect species in Africa and provide to National and International plant breeding programs.

b. Identify new sources of resistance to target insect species in maize, sorghum and cowpea which can be used by National and International breeding programs.

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

d. Determine the genetic basis of resistance for use by plant breeders in National and International Centers involved with variatal development for regions of Africa.

e. Train African scientists in plant resistance methodology (i.e. mechanisms of resistance, factors affecting expression of resistance and the avoidence of development of resistance-breaking biotypes).

f. Expand interchange of germplasm and methodology through formal and informal cooperative relationships with National, International and CRSP research programs (i.e. INTSORMIL).

g. Publish results in National and International referred journals.

2. Financial Background. BPRIA is the newest and most productive of ICIPES' research programs - e - started initially in 1978 with limited funding from the Australia Government for support of rice

brown plant-hopper research at IRRI. In 1979 IITA and AID contributed support. The proposed area of research has been supported by AID at $250,000 per annum for the past four years. The ICIPE is requesting in this proposal support of $4,726,000 over a five year period for continuation of BPRIA research (1984-1989). AID has been is the primary donor to the BPRIA program during the past 4 years (1979-1983). The following data summarizes total support for the BPRIA research over the past three years. Donor support is expected to be greatly reduced during 1984/85. :

Donor	1981/82	1982/83(Est.)	1983/84(Est.)
	Thousands of dollars.		
AID	$ 250.0	283.4	250.0
UNDP	179.0	144.0	144.0
Kenya	11.0	60.0	60.0
Australia	32.0	32.0	0
Denmark	38.0	38.0	38.0
Sweden	68.0	68.0	68.0
Total	$ 578.0	625.4	611.4

The BPRIA team is located at ICIPE's Mbita Point Research Station. The group is comprised of a research project leader, and three scientists supported by field and laboratory technicians and 1 pre- and 2 postdoctoral research fellows, and assisted by the basic support units of chemistry, sensory, physiology, histology, insect pathology and fine structure. The support units are adequately staffed and equipped to provide necessary services.

In addition to field plots, laboratories and mass rearing capability, the research team has developed and will extend cooperative field research projects to the Kenya Ministry of Agriculture field stations and other African countries national research programs as referenced in summary. Research is currently being done at the Ministry of Agriculture Field Stations in Mtwapa and Katumani.

E. Summary of Acoomplishments (1979-1983)

1. Cooperation was established and germplasm obtained with IITA at Ibadan, Nigeria; IRRI at Los Banos, Phillippines; ICRISAT at Hyderabad, India; CIMMYT at El Batan, Mexico; the Kenya National Agricultural Research Institution; and The FAO/Kenya Sorghum Regional Program and other country programs.

2. One hundred local maize lines and 460 families of maize from CIMMYT were screened for resistance. From this collection 19 tolerant and 6 sensitive (very susceptible) stem borer lines were identified for further testing. Twelve lines showing good resistance to Chilo and good agronomic performance were planted and mechnisms of resistance were studied. These studies suggested that there were at least 5 levels of relationships affecting plant colonization, local survival and damage level.

3. Four different sorghum collections of ICRISAT lines previously identified as resistant to Chilo infestations under field conditions in India were evaluated. Four lines were identified as having moderate levels of resistance to stemborer. Forty sorghum lines were obtained from Texas with resistance to greenbug (Schizoaphis graminum) and/or sorghum midge (Contarinia sorghicola) were found to be drought resistant. Several of these leaves produced high yields even though borer infestation ranged from 18-45%. Tolerance appeared to be the primary mechanism involved. A number of lines were turned over to the FAO Sorghum Improvement Program for use under drought conditions and stemborers infestations in Western Kenya.

4. Resistant cowpea lines of IITA origin (Vita I, Ife Brown and TVu 946) were studied to determine the mechanism of resistance to the legume pod borer Maruca. Terminal shoots, flowers and pods of TVu 946 cowpeas lines with unidentified resistance characteristics reduced Maruca funding behavior. Work is presently being conducted on oviposition behavior of moths and on the role of biophysical and chemical factors of resistant lines that influence Maruca behavior and physiology.

5. Studies on the mechanism of resistance of cowpeas to Aphis Craccivora have revealed that cowpea resistant lines have less total sugars and more phenols and flavonoids than susceptible lines. Boassays and sensory physiology techniques are being developed for studying feeding deterrants/stimulants in various resistant and susceptible lines. Experiments are in progress in cooperation with the ultrastructure (electron microscope) section to decipher the exact tissues of the cowpea plant on which the aphids feed.

6. Mass rearing techniques have been developed for all species of stemborers attacking maize, sorghum and cowpeas. This was a major accomplishment and critical to the success of this project . Successful rearing of insects enables a constant supply of insects for laboratory, insectory and field plots the year round.

7. Two postdoctoral fellows from Sierra Leone and Ghana and one postgraduate fellow from Swaziland have received specialized training in the biochemical bases of resistance and in the methodology of conducting research on factors of biophysical and bochemical resistance in crop plants.

8. Four papers have been published, three are in press and 7 are in preparation (see Publications in Annex 3).

II. PROJECT BACKGROUND AND DESCRIPTION

A. Background: Among the various alternatives to insecticides, the use of insect-resistant plants, in combination with appropriate cultural practices, provides one of the most effective, convenient, economical and environmentally safe components of integrated pest management system. Moreover, it is a method that is fully compatible with chemical and biological control measures. In view of such an importance of plant-resistance to insects, various national and international

agricultural centres have been engaged in screening and identifying genotypes of different crop plant species from different regions for their resistance or susceptibility to insect pests. The lines/varieties, observed to be resistant, are released from time to time for use by National programs and farmers. However, observed resistance in their lines/varieties has often been found to break down fairly soon. Also, the plants resistant to an insect species in one region of the world may or may not be resistant to the same or another allied insect species in another region. Therefore, to make effective use of resistance in plants to insect pest management, it is important to have a detailed knowledge of the principles determining the resistance or susceptibility of a plant species/variety to its insect pests. The BPRIA section of the Crop Pests Research Programme of the ICIPE has been engaged in research on these aspects since 1979 under a project funded by USAID. The presently proposed project is intended to continue this research on a more extensive basis over the next 5 years.

B. Target crops. This proposed project will concentrate on insect pests of sorghum, maize and cowpea which serve as important food crops for millions of people in African and other developing countries of the tropics.

C. Target pests and distribution. A heavy toll of these crops is taken annually by several insect pests, the most important being certain stem borers and pod borers. As yield reduces, these insect pests vary in importance from season to season, from year to year and among locations, due to plant genotypes, insect populations, the environment, cultural practices and the interaction of these factors. The most important and widely distributed insect pests of these crops include the following which will be investigated in this proposal:

(a) Sorghum and maize stem borers:

. *Chilo partellus*. It is a major pest in several parts of Western Asia, East and Southern African countries. In Kenya, *C. partellus* is the most important stem borer in warmer and lower altitude areas. However, it has been recovered from 70 to 5500.

. *Busseola fusca*. This is the commonest stem borer of sorghum and maize in most parts of tropical Africa. It is found to be the dominant stem borer species in cooler and higher altitude areas above 3370' in Kenya.

. *Sesamia calamistis*. A very widely distributed stem borer in Africa. It has been recorded in many areas of Kenya from sea level up to 4700'.

. *Eldana saccharina*. It is present in most areas of Africa and appears to be widening its distribution. In kenya, it has been recovered up to 5000' on sorghum and maize, mostly in the Sugar belts.

(b) Cowpea pod borer, Maruca testulalis. A very important and serious pest of cowpea in the tropical world. In kenya it is very widely distributed.

(c) Sorghum shootfly, Atherigona soccata. It is an important seedling pest of sorghum in many areas of Africa, Middle East and Asia. The incidence of shootfly is very high on late planted sorghums and it is widely distributed in Kenya.

In view of the great importance of the above mentioned stem and pod borers Africa wide as well as in Kenya as the key pests of sorghum, maize and cowpea, these insects have been selected by the ICIPE to be emphasised in the proposed research.

D. State of knowledge

1. Maize resistance to stem borers. Resistance in maize and sorghum to stem borers is well documented, but studies on the mechanisms of resistance are limited to only a few publications.

At Kongwa, Tanzania, Duerden (1953) indicated that a plot of inbred American p^8 resistant to Pyrausta nubilalis in U.S.A. (Jepson, 1954) was attacked more by Busseola than an adjacent plot of Kenya yellow maize. Duerden (1983) further suggested that the resistance of attacked stems tended to be greater in thick-stemmed varieties. Harris (1956) observed that natural selections of Nigerian maize were less susceptible to stem borers than newly introduced higher yielding variations. Starkes and Dogget (1970) also indicated that a moderate level of resistance to Chilo zonellus (Swinhoe) existed in both maize and sorghum breeding material used in East Africa. Rating for leaf feeding provided in separating resistant and susceptible maize inbreds but not maize hybrids. These workers indicated that larval exit counts and holes per plant and total yield might be important criteria in measuring resistance. Tunneling was found to be highly variable and could not be consistently used as a measure of resistance. Analysis of the nature of internal injury caused by Chilo indicated that varietal differences exist among maize plants.

Mathez (1972) noted the high mortality of the first 3 instars of larvae in the stem but could not explain the cause of these deaths. He excluded lack of food and diseases as possible causes and concluded that the larvae were unable to survive on certain plants that have particular characteristics noted by Pant et al., (1962).

In India, 278 exotic maize lines obtained from various countries participating in the International Cooperative Maize Project were evaluated for resistance by artificial infestations with C. partellus eggs and 10 new sources of resistance were identified. (Sarup et al, 1977, 1978). The leaf injury rating obtained in single crosses was reduced as compared to their respective parents. The mechanisms of resistance in selected lines are not known.

IITA scientists compared four different techniques to screen maize for resistance to S. calamistic (IITA 1979 Annual Report). The 454 genotypes from the U.S., Asia, CIMMYT and IITA showed some differences in damage under natural infestation. Forty three lines were significantly more tolerant than all other lines.

2. Sorghum resistance to stem borers. Practically, no work has been done on resistance in sorghum to stem borers except on Chilo partellus in India. The existence of resistance in sorghum varieties to the stem borer was first provided by Trehan and Butani (1949) and confirmed by Pant et al., (1961). Swarup and Chaugale (1962) also found that certain sorghum varieties were relatively less damaged by the borer and attributed this to the presence of higher sugar content. This relationship, however, could not be established by subsequent workers.

Systematic screening for borer resistance was started by Singh et al. (1968), who screened 3,953 sorghum varieties from the world germplasm collection. This work was continued by Jotwani and co-workers who screened 6,243 additional lines finding 26 lines which were relatively less damaged by the borer in repeated screening under natural and artificial infestation (Jotwani and Young, 1971; Jotwani, 1976).

Research conducted on the basis of resistance to stem borer indicates the existence of tolerance and antibiosis in the resistant varieties. A number of lines with high population of the borer and correspondingly high stem tunnelling have shown fairly normal plant growth. Jotwani et al.(1978) have reported that development of the stem borer was adversely affected on three selected resistant varieties (IS 1151, 4764 and 4776). There was higher mortality in early larval stages, the larval period was longer and percentage population was less on the resistant varieties than on the susceptible hybrid CSH 1.

Although encouraging progress has been made by various scientists in studies on sorghum resistance to Chilo, a clear picture has not emerged. This is mainly due to the fact that different workers have tended to concentrate on one particular aspect of resistance. Kalode and Pant (1977) on the ecology and the behaviour of the first instar, while Woodhead et al, (1980) have been interested in the chemicals in sorghum that confer resistance. Sorghum plant resistance is conferred through several mechanisms.

3. Cowpea resistance to the legume pod borer. A large number of lepidopterous pests infest cowpea at both the flowering and post-flowering stage. The most important pest species is included in this proposal research. Legume pod borer, Maruca testulalis (Geyer), is found throughout the tropics of Central and South America, Asia, and Africa (Taylor 1978). It is a major pest of cowpea in Africa and can cause severe yield losses ranging up to 60% (Singh & Taylor 1978, Taylor 1967).

By screening 2,800 cowpea cultivars at IITA, two cowpea cultivars (TVu 946, TVu 4557) were identified as resistant to M. testulalis damage to stems and to peduncles. Both these cultivars have additional important characters that make them less susceptible to flower and pod damage. The additional characters include an abnormally long peduncle, usually with two pods, held well above the plant canopy at a wider angle than normal varieties. The plant configuration escapes considerable flower and pod damage by the pod borer. In large plots of TVu 4557, M. testulalis populations were always low. Reproduction was greatly reduced on the peduncles thus greatly reducing damage to flowers and pods. TVu 4557 was developed at the University of Ife, Nigeria. TVu 4557 has been re-described as Vita-5 because of its resistance to M. testulalis damage and other desirable agronomical characters (Singh et al., 1976).

Field screening for Maruca resistance in the IITA germplasm also identified VICA M. 11SP; TVu 946, TVu 3132-06, TVu 976-1g and TN-88-63 as having low scores (relatively high resistance) for terminal shoot and flower but damage and low level of pod damage (IITA, 1979).

4. Cowpea resistance to aphids. Cowpea aphid or groundnut aphid, Aphis craccivora Koch, is the main aphid pest of cowpea in Africa. It was previously reported as a major pest of cowpea in Asia and a minor pest in Africa. However, recent observations indicate that heavy aphid populations are more frequent and widespread in Africa than previously reported. Cowpea aphids infest the crop at the seedling stage and cause damage to the host plant, even when populations are small, through transmission of cowpea mosaic virus.

A selected cowpea germplasm consisting of the 'Genetic Diversified Nursery' and of the 'International Cowpea Nursery' (a pool of genetically various cowpea diseases, were screened in the greenhouse at IITA for resistance to cowpea aphid. Four cultivars (TVu 480-P-2, TVu 410, TVu 2396 and Vita-5), that have multiple resistance to several foliar diseases, were identified as resistant to cowpea aphid (Singh, 1979 after Ansari, 1978). The mechanisms of resistance are not known.

D. Research Accomplishments at the ICIPE - 1979-1983

1. Resistance/susceptibility of different cultivars/genotypes to the insect pests. Screening of several lines/genotypes of sorghum, maize, cowpea, obtained locally or from ICRISAT, CIMMYT and IITA, has given significant information on their relative resistance/susceptibility to their respective target pests, as summarised below:

a. Sorghum cultivars highly resistant to stem borers: 15-1044, 2122, 2146, 2205, 2291, 4660, 10711, 18427, 18551, 18676, and 10677, obtained from the Genetic Resource Unit, ICRISAT, India.

b. Sorghum cultivars highly resistant to shootfly and stem borers: 15-2122, 2146, 2195, 2205, 5480, and 10551, obtained from ICRISAT, India

c. Maize cultivars resistant to stem borers: CMT-324 (highly resistant) and CMT-33 (moderately resistant)- both obtained from CIMMYT.

d. Cowpea cultivars resistant to the pod borer *Maruca testulalis*: TVu-946 and Vita-3 (from IITA) were confirmed to be highly resistant to the pod borer.

2. Mechanisms/Basis of resistance/susceptibility of different cultivars/genotypes to the insect pests

a. Sorghum resistance/susceptibility to *Chilo partellus*: Comparisons of the ovipositional responses of *Chilo partellus* to different sorghum cultivars in the fields and screenhouses showed a less egg-laying on the resistant than on the susceptible cultivars. This suggests ovipositional non-preference as one of the mechanisms for resistance in sorghum. Also, less foliar damage and number of larvae in the stems in the fields/screen houses indicate more reduced larval feeding on the resistant than on the susceptible sorghum cultivars. However, these conclusions will need to be validated by comparison of quantitative food intake. The factors involved remain to be elucidated.

b. Maize resistance/susceptibility to *Chilo partellus*: Female moths laid more eggs on susceptible maize genotype Inbred A and a resistant genotype CMT-324 than on resistant genotype CMT-33 in the fields. Ovipositional non-preference for CMT-33 was associated with its resistance to *C. partellus*, but not with that of CMT-324. However, larvae emerging from eggs oviposited on the three liners moved out in greater percentage from the resistant CMT-324 and CMT-33 genotypes than from the susceptible genotype Inbred-A. Thus, larval non-acceptance of the 1st two maize genotypes was related to their resistance.

F. Research Accomplishments 1983-84

Since September 1983, an increased emphasis has been given to the study of the principles determining the resistance or susceptibility of different cultivars/genotypes of the target crops to their borer pests. The approach being followed and the aspects being investigated are the same as explained in the Sections V, VI, and VII on the Plan of Work. The highlights of the work done are presented below:

1. Methodology: A number of new methods/techniques have been developed to measure and compare different responses of the target pests to resistant and susceptible plants. These methods are described in detail in Section VIII and are designed to elucidate the role of distance-perceivable characters (visual, hygro, olfactory) as well as contact perceivable characters (physical, chemical) of the plants in determining different responses of the pests. These methods are being used for studies in the fields, screenhouses and the laboratory.

2. Results on Basis of resistance/suceptibility in sorghum to chilo partellus: Two cultivars of sorghum, one being relatively resistant (IS-2146) and the other relatively susceptible (IS-18363), have been used to compare the six main types of responses of Chilo partellus. The observations made thus far are presented as follows:

a. Ovipositional responses. The selection of a suitable oviposition plant by a lepidopterous insect is done mainly by adult females. Hence, various aspects of C. partellus oviposition behaviour have been examined first. In 2-choice tests, the percentage of eggs laid on the susceptible cultivar was almost twice that of the resistant cultivar. In no-choice tests, of the total number of eggs laid within the chamber, the percentage of those laid on the plants was greater for the susceptible than for the resistant cultivars. This clearly suggests that C. partellus showed greater ovipositional response to the susceptible than to the resistant sorghum cultivar in 2-choice as well as no-choice situations.

b. Role of distance-perceivable characters in oviposition. Resistant (IS-2146) or susceptible (IS-18363) plants were kept just outside one end wall of a nylon net test chamber and the other end wall was left blank. Each end wall had, along its inner surface, 4 wax paper sheets (15 x 15 cm) to provide suitable substrates for the insects to lay eggs. Ten females were released inside the chamber. They were able to visit the net wall facing the plants but could not come in contact with the latter. The percentage of eggs on the wax paper stuck on the net wall facing the resistant or susceptible plants was much greater than that on the opposite end wall. This showed that certain distance-operating signals from both resistant and susceptible sorghum cultivars could attract the insects to the corresponding wall where the eggs were laid on wax papers. When both the resistant and susceptible plants were presented together on the outside of the net wall of a specially designed chamber, the percentage of eggs laid on the wall facing the susceptible plants was much greater than that on the wall facing the resistant plants.

Evidently, the insects were more attracted by the susceptible plants than by the resistant plants. In other words, the susceptible cultivar had greater ovipositional attractancy than the resistant one.

c. Role of contact-perceivable characters of the plants in oviposition. On presenting to the moths a leaf each of the resistant and susceptible cultivar side by side in a specially designed test chamber, the percentages of eggs laid on both were more or less equal, showing that, on close contact with the leaves the insects do not demonstrate preference for any of the cultivars over the other. These observations suggest that differences, if any, between the two cultivars

in their mechanical or chemical characters do not have any major significance for oviposition after the insects have come into contact with the plants. At the same time, the fact that the insects allowed contact with the leaves preferred the two cultivars over the otherwise suitable glass surface suggests that both the cultivars have common charateristics which elicit oviposition by C. partellus and there is no ovipositional deterrence in the resistant cultivar.

d. Role of volatiles from sorghum in oviposition. This aspect was studied in specially designed clear plastic chambers having a perforated wax-paper bottom and a wire-net removable top. The results show that egg-laying on the wax paper above the susceptible plant leaves was much greater than above the resistant plants leaves, when both were offered together in equal amounts. When compared with an empty compartment the egg-laying on the wax paper above the susceptible leaf-bearing compartment was almost 5 times as much as the empty one.

When the compartment contained resistant plant leaves, the egg-laying above it was only about $1^1/2$ times that above the empty compartment. These observations suggest that the volatiles of both the susceptible and resistant cultivars of sorghum can elicit oviposition by C. partellus but those of the susceptible cultivars are much more effective than those of the resistant one. Since the insects could not come in contact with leaves in these tests, their responses to the volatiles, perceivable at a distance, would involve positive orientation (attractant) to the zone of the test chamber bearing the volatile.

It was also observed that the egg-laying was much greater in the zone bearing the leaves of the susceptible or resistant cultivar in a quantity 4 times (by weight) that of the same cultivar in the other zone. The observations suggest that the quantitative differences in the volatiles, caused by those in the production or release by the two cultivars, may be responsible for differences in the egg-laying by the insect.

e. Larval orientation and movements. After the adult females lay eggs on one or the other cultivar of sorghum plants the newly hatched larvae may stay on or move from the plants according to their orientation responses. A comparison of these responses of the 1st-instar larvae released on the susceptible (IS-18363) and the resistant (IS-2146) cultivars was conducted. The percentages of the larvae staying on or moving out of the plants on different days after their release was more or less identical for the susceptible and the resistant cultivars. Thus, the two cultivars did not differ in their attractancy, repellency or deterrence for the larvae.

f. Larval feeding responses. Techniques were developed to compare the feeding responses of C. patellus larvae to the susceptible and resistant cultivars in terms of area of leaves consumed. First instar larvae consumed almost twice as much leaf area of the susceptible cultivar as that of the resistant cultivar showing that the susceptible cultivar is more suitable for larval feeding than the resistant one. The factors responsible for this are under study.

g. Larval development. Studies were carried out to compare the suitability of the susceptible and the resistant cultivar for supporting larval development. Neonate 1st-instar larvae were released one each on a plant, and percentage survival at different stages of development was recorded 3 weeks later. Larval development on the susceptible cultivar was only a little better than on the resistant cultivar. Thus, although larvae have been shown to feed better on the susceptible cultivar than on the resistant one, the difference in larval development on the two cultivars was not that great. This is possibly due to their nutritional efficiency.

Our conclusion is that the difference in the populations of C. partellus establishing on the susceptible and resistant sorghum cultivars is caused mainly by those in the volatiles eliciting orientation/oviposition and in larval feeding responses.

3. Results on Bases of resistance/susceptibility in maize to chilo partellus. The response of C. partellus to two cultivars of maize, one relatively susceptible (Inbred A) and another relatively resistant (CMT 324), were examined. For some aspects, a tolerant cultivar (CMT 33) was also included in the present study. The aspects investigated and the procedures followed were basically the same as those described above for sorghum.

a. Ovipositional responses to different maize genotypes. On presenting the susceptible cultivar (Inbred A) at one end and the resistant one (CMT 324) at the other, inside a test chamber with wire-net walls (125 cm x 100 x 80 cm), the percentage of eggs laid on both was almost identical when the wind blew at right angles. But, when the wind blew from one cultivar in the up-wind direction, whether it was the susceptible or resistant one, was greater than on the one in the opposite direction. This way the ovipositional responses of C. partellus to these two cultivars could not be readily distinguished one from the other.

b. Role of distance-perceivable characters in oviposition. The responses of the females to these stimuli from both the resistant and susceptible genotypes were identical, unlike the case with reference to sorghum.

c. Larval orientation to different maize genotypes. A high degree of dispersal from CMT 324 plants into the surrounding plants of the other cultivars was observed. There was greater migration from the other cultivars into Inbred A plants than from the latter to others. Generally, the extent of migration was influenced by the relative resistance of the two cultivars in particular plots. In each plot there was a greater migration from the more resistant cultivar to the more susceptible one and less migration the other way round.

d. Larval feeding responses to different maize genotypes. The feeding responses of the 1st instar larvae to the susceptible and resistant cultivars of maize were compared by the same method as described above for sorghum. The consumption of leaves of the susceptible cultivar (Inbred A) was much greater than that of the resistant cultivar (CMT 324).

Further studies on these and other responses of *C. partellus* to maize plants in relation to their characters are in progress.

e. Larval development on different maize genotypes. The resistant genotype, CMT 324, was inferior to the susceptible Inbred A in supporting the larval development. Lesser feeding on the resistant genotype than on the susceptible one would be one of the factors responsible for this difference in the larval development.

4. Experimental bases for insect mass-rearing. Screening of maize, sorghum, rice and cowpea cultivars for insect resistance requires the development of good techniques for the mass production of high-quality insects at a minimum cost and at maximum reliability. In view of the importance attached to research on cowpea resistance to the legume pod-borer, *Maruca testulalis*, high priority was placed on the establishment of rearing procedures to ensure a continuous and abundant supply of the insect. In 1980, efforts concentrated on improving the rearing techniques developed during 1979. This technique which uses flowers as rearing food now has become a successful routine procedure. The procedure allows production of 75,000 eggs of *M. testulalis* per month.

Rearing of insects on natural food materials has advantages, also limitations. Experiments on artificial diets for *Maruca* rearing have been conducted under insectary conditions and fourteen different diets have been tested. Different portions of leguminous grain powders (beans, cowpeas, soya) and cowpea plants, were incorporated into basic wheatgerm diets used for rearing of lepidopterous species. With most of the diets,

larval mortality was high. Only Kabuli flour diet containing 5% of cowpea flower powder and wheatgerm/soya mixture satisfied the gustatory and nutritional requirements of Maruca larvae. These experiments are continuing.

Work on artificial E.saccharina diet, an important pest of maize, sugar cane, and sorghum in Africa was initiated in July 1980 with testing of over 21 diet formulations. The fecundity of moths reared on the most suitable diet ranged from 131 to 236 eggs per female. Work is still proceeding.

5. Training of African scientists: The Programme provided research facilities for Mr. G. Masina, an entomologist from Swaziland who joined the ICIPE in January 1981 and completed his Ph.D. thesis research on mechanisms of sorghum resistance to Chilo partellus in 1984. It should be mentioned that there is great interest among African scientists to receive research training on BPRIA Programs. Two Postdoctoral Fellows, one from Sierra Leone and one from India, recently joined the Programme for research training in the methodology of research on factors of biophysical and biochemical resistance in crop plants.

6. Co-operation with National Programmes: The joint proposal between the FAO/UNDP Kenya Sorghum and Millet Development Programme (Dr. F. Pinto, Dr. H. J. Enserink, Mr. Kermali and Miss Petra Penninkhoff) and the ICIPE was initiated to screen the large sorghum germplasm collection of the Kenya Programme for resistance to stem borers using the methodology developed by the ICIPE. Two experiments were planted at the MPFS to identify mechanisms of resistance in advanced lines. The breeders intend to use different identified sources of sorghum resistance to insects. The ICIPE programme has already established methodology and techniques and has the facilities to identify mechanisms of sorghum resistance to stem borers and shootfly. The methodology of screening now is being used by the Kenya Sorghum and Millet Development Programme.

Co-operation was concluded in 1984 between ICIPE programme and the Ahero Irrigation Research Station (Mr. W. Malinga) on the preliminary field screening of rice for resistance to Maliarpha separatella under natural infestation. The ICIPE scientists assisted in developing the methodology for bionomic studies on Maliarpha and other rice borers.

A joint co-operative project on maize resistance to stem borers and on the effect of cultivar upon the economic injury level of borers on maize was initiated with Kenyan entomologists working at the Coast National Agricultural Research Station, Mtwapa (Mr. C.M. Warui and J.N. Kuria). The ICIPE scientists have assisted with new methodology for screening maize for resistance to insects and will supply insects reared in the ICIPE insectary for future screening programmes. The Mtwapa Station located at the Kenya coast has ecological conditions sufficiently different from MPFS for collecting new information on maize resistance to stem borers. Also the species composition of stem borers differs in these two locations. There are two species on maize at the coast in addition to Chilo partellus. They are Chilo orichalcociliella (the coastal stalk borer) and Sesamia calamistis (the pink stalk borer).

7. Publications prepared by the scientists in the PROGRAM (see Annex for publications.)

III. PROPOSED OUTPUTS AND METHODOLOGY

1. Main Objectives

The proposal is aimed at achieving three main objectives as stated below:

1. Research Objectives

a. To elucidate the principles determining the resistance/susceptibility of different genotypes/cultivars of maize, sorghum and cowpea to their key insect pests:

b. Development information and methodology for plant breeders to develop cultivars eliminating susceptibility-imparting characters and /or incorporating resistance-imparting characters.

c. Develop methods for manipulating these principles for the management of the pests in other ways e.g., by interfering with their establishment/feeding/oviposition on the host plants.

The major areas of research to be pursued to accomplish the above general objectives are:

a. Comparison of the susceptibility, resistance and tolerance levels of sorghum, maize and cowpea to the target insect species.

b. Examination of the following insect responses to cultivars varying in resistance or tolerance and susceptibility: initial attraction or repulsion; feeding efficiency; insect growth and development; and fecundity and oviposition.

c. Identification of the visual, chemical and mechanical characters in tolerant, resistant and susceptible cultivars that are responsible for the above insect responses.

d. Determination of the genetic basis of resistance, tolerance and susceptibility of different cultivars of sorghum, maize and cowpea for the target insect pests.

2. Training objectives:

To give short-term and long-term training to the scientific and technical personnel of various national programmes in principles and methodologies in the area of plant resistance to insect pests.

3. Collaboration with other Agricultural Institutions

To increase and expand collaboration with various International Agricultural Centres, National Agricultural Programmes and other agricultural agencies and institutions in the area of plant resistance to insect pests.

B. Proposed Approach to Research on Bases of Plant Resistance/susceptibility to Insect Pests

The susceptibility or resistance of different plants to an insect is determined by their suitability to support populations of the insect. The populations of an insect established on a plant, in turn, is determined by an interaction of (a) its responses to the plant and, (b) the plant characters involved. The responses of an insect and the plant characteristics involved in the six stages of its establishment on a plant are as follows:(Saxena 1969) (1) Orientation of the insect determining its arrival on or repellency caused by its distance-operating sensory stimuli; (2) Feeding response of the insect, after its arrival on a plant, determining the quantitative food intake and depending on various distance- and contact-characters of the plant promoting or inhibiting feeding by the insect; (3) Metabolic responses of the insect involving utilisation of the ingested food resulting in its nutrition an depending on the nutritional or toxic properties of the plant constituents; (4) Development of the insect's larvae to the adult stage, depending on their food intake as well as nutrition; (5) Egg-production in the adult stage, depending on the insect's food intake as well as nutrition; (6) Ovipositional response of the adult insect, depending on various characters of the plant promoting or inhibiting the egg-deposition by the insect.

The greater the degree of positive responses of an insect in each of these stages, greater will be its population likely to be established on the plant concerned and greater will be the latter's susceptibility to the insect. Conversely, the plants which do not elicit the above mentioned responses of the insect or inhibit these responses would be resistant to it. the research approach could therefore be focused with these six areas of investigation to determine resistance or susceptibility and to develop methods and techniques for identification and screening for resistant and susceptible factors.

C. Proposed Work Plan (1984-1989)

The aspects given below will be studied with reference to each of the target insect pests and its host plant species.

1. Investigations will be conducted in the fields, screenhouses and the laboratory under narutally varying conditions as well as under controlled experimental conditions.

2. Investigations under controlled conditions will be particularly essential to elucidate individual factors requiring all the conditions except the factor under study to remain constant.

3. Methodologies for experiments in the fields, screen houses and the laboratory will have to be developed according to the aspects under study.

4. The genotypes/cultivars obtained from various national/international agricultural centres and from other regions showing resistance to certain insect pests or having other desirable characteristics will be checked for confirmation of resistance or susceptibility to target insect pests.

5. A few resistant and susceptible genotypes/cultivars of each test plant species for each target pest will be selected for detailed study:

a. The 6 types of responses of the pest, mentioned above, to the resistant and susceptible plants will be compared to find out how different responses may be responsible for the insect's establishment on the susceptible and not on the resistant genotypes/cultivars.

b. The role of distance- and contact-perceivable characters of resistant and susceptible plants will be determined utilising the above mentioned responses of the pests will be investigated.

7. Based on these studies, methods and techniques for measuring and evaluating resistance in plants to insects will be developed and provided to national and international plant breeding programmes.

8. <u>An Outline of the Plan of Work (Mbita Point Field Station and Cooperating Countries)</u>

The following scheme would be followed with reference to each of the target insect species and test plant species:

<u>PART A</u>. Comparison of resistance/susceptibility levels of different cultivars/genotypes of the test plant species, obtained from various sources, to the target insect species.

<u>PART B</u> Comparison of the 6 types of responses, mentioned under proposed approach section, with resistant and susceptible cultivars.

(1) <u>Responses of the adults involved in the selection or rejection of plants</u>

(a) Role of orientation responses (attraction/repulsion).

(i) Responses to the resistant and susceptible plants in the fields and screenhouses

(ii) Role of distance-perceivable characters of the plants in determining orientation of the adults: Visual (including colour) olfactory, hygro.

(b) Role of ovipositional responses in the selection or rejection of plants

(i) Responses to the resistant and susceptible plants in the fields and screenhouse.

(ii) Role of distance-perceivable characters of the plants in oviposition: visual, hygro, olfactory (stimulants/inhibitors).

(iii) Role of contact-perceivable characters of the plants in the oviposition: physical/chemical stimulants/deterrents

(2) Larval responses involved in the establishment the pests on the plants

(a) Role of orientation (attraction/arrest/repulsion) of the larvae in their establishment on plants

(i) Role of distance-perceivable characters of the plants in larval attraction/arrest on repulsion/departure from them: visual, hygro, olfactory attractants, arrestants, repellents.

(ii) Role of contact-perceivable characters of the plants in larval arrest on or departure from them: physical/chemical

(b) Role of feeding responses of the larvae in establishment

(i) Feeding responses to the resistant and susceptible plants

(ii) Role of distance-perceivable characters of the plants in feeding: visual, hygro, olfactory, stimulants/inhibitors

(iii) Role of contact-perceivable characters of the plants in feeding: physical/chemical; stimulants/deterrents

(c) Metabolic responses of the larvae to the plants

(i) Utilisation of the food ingested from the resistant and susceptible plants

(ii) Nutritive value of the food ingested from the resistant and susceptible plants

(d) Larval development on the resistant and susceptible plants

(e) Survival and egg-production in the adult females emerging from the larvae reared on the resistant and susceptible plants

PART C Application of the principles determining resistance or susceptibility of the plants to the insect pests for their management.

(1) The methodologies developed and the information generated will be provided to the plant breeding programme in appropriate national and international centres for developing the pest-resistant cultivars/varieties which can then be used by farmers

(2) Methods will be developed to manipulate the elucidated principles for assisting the pest management programmes as follows:

(a)Manipulation of orientation of adults/larvae
(i)Trapping
(ii)Diversion to unsuitable, non-nutritive plants
(iii) Interference with the feeding responses of the insects

(b)Manipulation of the feeding responses of the insects
(i)Inhibition of feeding on the susceptible plants
(ii)Promotion of feeding on unsuitable, non-nutritive plants

(3) Manipulation of the ovipositional responses of the insect

(a) Inhibition of oviposition on the susceptible plants

9. Methodologies: Methods are being developed and will be further elaborated for the following broad areas covering the different aspects given under the outline of the Work Plan above (Section III-C-8):

a. Measurement and parameters of resistance/susceptibility levels of different cultivars/genotypes. Methods will be developed to measure different types of damage caused to the plants by the target pests. On the basis of these damages, appropriate parameters serving as an index of resistance or susceptibility levels will be developed. These

parameters will also serve as tools for plant breeders in monitoring the resistance levels during development of insect-resistant cultivars/varieties.

b. Measurement of responses of adults to different cultivars/genotypes. Methods have already been developed for measuring orientation-cum-ovipositional responses of the adult females to naturally growing plants in the field and screenhouse. These methods have been so designed and the experimental conditions so controlled that differences in the insect's responses to the resistant and susceptible plants would be due to their characters and not due to non-plant factors. In these methods, tests are conducted in a single-compartment chamber (150 x 130 x 120 cm) having wire-net walls and lacking the bottom wall which is provided by the floor of the field or screenhouse bearing the test plants. The plants of one cultivar are arranged in a row inside the chamber along one end-wall and the other end is blank (no-choice situation) or has another row of the other cultivar (2-choice situation). Ten ovipositing females, released in the centre, can orientate and oviposit on the plants or elsewhere in the chamber. On the basis of the total number of eggs laid in 48 hours, the percentage of eggs laid on the test plants is calculated and serves as the ovipositional response.

c. Measurement of adults responses to distance-perceivable characters of the plants. For this, a specially designed triple compartment chamber (210 x 80 x 80 cm) is used. The plants or other test materials are presented just outside the wire-net wall at one or both the ends so that the oviposing females within the chamber can perceive their distance-perceivable characters but cannot come in contact with them. The percentages of eggs laid by the females on the wax paper strip (serving as ovipositional substrates) at each end will reflect the insects' preferences or non-preferences for the distance-characters of the plants viz., visual (colour, pattern, etc.,), olfactory (volatiles), hygro (water vapour). Techniques have been advised to test the role of each of these types of distance-characters by excluding or including one or the other at one or both ends of the chamber.

d. Measurement of adults' responses to the volatiles from the plants or otheir extracts. The oviposition responses to the volatiles from the plants or their extracts are tested in a specially designed twin compartment rectangular chamber (20 x 15 x 6cm) having a closed bottom and open top. A sheet of perforated wax-paper (serving as the ovipositional substrate) is stretched across the top of the chamber and is covered with a wire net cover (20 x 15 x 2.5cm) within which is released on ovipositing female. Leaves of one cultivar, or its extracts in the desired quantity, are kept in one compartment and the other compartment is left vacant or filled with the leaves or extracts of another cultivar. Their volatile vapours pass through the perforated wax paper and can be perceived by the insect within the wire-net cover. Differences in the percentages of eggs laid overnight on the perforated wax paper segments above the 2 compartments would reflect the ovipositional preference or non-preference for the volatiles tested.

e. Measurement of larval orientation, feeding and development on resistant and susceptible cultivars. Methods have also been developed for measuring the orientation of the larvae in terms of percentages arriving or departing from the plants, feeding in terms of area of leaves consumed, and development in terms of percentages reaching the pupal or adult stage during a given period on the test plants in the fields or screenhouse.

10. Personnel Assignments

The Project Leader will develop the approach and methodology for the proposed research, and will share part of the experimental investigations conducted by the different scientists. Also, he will be responsible for the overall coordination of the research carried out on different aspects by the scientists.

The research scientists and postdoctoral fellows (entomologists) will be assigned different aspects listed under the outline of the Work Plan above (Section-III-C-8), each scientist undertaking work on the responses of the adults or larvae of one of the target pests with reference to one of the target crops. Thus, the entomological work will be distributed as follows:

(a) Responses to sorghum by *Chilo partellus* adults:
(K.N. Saxena and K.V. Sheshu Reddy)

(b) Responses to sorghum by *C. partellus* larvae:
(A.M. Alghali and K.N. Saxena)

(c) Responses to maize by *C. partellus* adults:
(H. Kumar and K.N. Saxena)

(d) Responses to maize by *C. partellus* larvae:
(J.K. Ampofo and K.N. Saxena)

(e) Responses to cowpea by *Maruca testulalis* adults:
(K.N. Saxena and S.H. Okech)

(f) Responses to cowpea by *M. testulalis* larvae
(S.H. Okech and K.N. Saxena)

(g) Rearing of target insect
(R.S. Ochieng')

The Geneticist (R.S. Pathak) will concentrate on genetic aspect, the chemist (D.A. Otieno) on the chemical aspects and the physiologist (to be appointed) on the plant physiological aspects of resistance in the target crops to the target pests.

D. Contribution of ICIPE Support Sections and Units

1. Bionomics and Applied Ecology Section.

(a) Methodology of crop losses assessment (maize, sorghum, cowpea, rice).

(b) Methodology of establishing economic injury levels under mono-and intercropping systems.

(c) Life tables of stem borers under various farming systems and ecological zones.

(d) Socio-economic aspects in the implementation of the IPM programmes of maize, sorghum, cowpea and rice pests in the Eastern Africa.

(e) Performance of ICRISAT, IRRI, and IITA resistant lines under mono and intercropping systems used by farmers in Kenya (adaptability, disease resistance).

2. Insect Mass Rearing Section

a. Studies on oviposition behaviour of *M. separatella*, *S. calamistis*, *B. fusca* and *C. sorghicola* on artificial surfaces to determine the role of physical and chemical characteristics evoking oviposition (1983/87).

b. Similar studies on the feeding behaviour of larvae of the species indicated above. The identification of feeding incitants and stimulants will be part of the investigations which will form a basis for experimental mass-rearing of these species on artificial (1984/88) diet.

3. Biological Control Section

a. Field studies on important parasitoids, predators and pathogens associated with natural population of the crop borers

b. Isolutions, purification and characterization of producing pathogens of stem borers

c. Monitoring pest population build-up in rabit - to crop pheulogy, parasitoids and predators in maize, sorghum and cowpea mono and mixed crops

4. Chemistry and Bioassay Research Unit

a. Identification of feeding deterrents and toxins in cowpea, maize, and sorghum lines resistant to pod and stem borers.

b. Plant chemicals responsible for maize, sorghum, cowpea and rice resistance to sucking insects (Heteroptera and Hemoptera).

5. Sensory Physiology Research Unit will investigate Sensory physiology of stem borer (larvae and factors affecting oviposition on resistant and susceptible lines).

6. Histology and Fine Structure Unit

a. Biophysical and anatomical properties of resistant lines to insects (maize, sorghum, cowpea, rice);

b. Sensory organs of target insects responsible for host plant selection or rejection.

7. Biostatistics and computer sicence service will be provided for experimental design and data processing assistance.

E. Physical Facilities Available

1. Mbita Point Field Station. Mbita Point is located on the Eastern shores of Lake Victoria. The nearest large urban center is Kisumu at the head of the Nyanza Gulf which is two hours away by road or boat. Consequently the station is designed to be largely self contained. All major tropical pesdts of Africa over at Mbita Point, stem borers, tsetse, livestock ticks. In addition the center is located in the center of a small farmer community, practicing largely mixed cropping. Construction work of the facility was started in 1979 and phase I of the Development Scheme was completed in early 1984 and provides the following essential facilities:

a. Residential accommodation (for the key scientific and technical staff).

b. Research Laboratorties (for experimental agronomic, and ecological research) and offices.

c. Farm complex including irrigated field plots.

d. Animal and insect-mass rearing facilities, insectories, and greenhouses.

e. Maintenance complex (for the servicing of equipment, physical structures, and vehicles).

f. Utilities, site works, and infrastructure.

g. Support facilities, clinic and primary school.

2. ICIPE Headquarters

Facilities are available at ICIPE headquarters in Nairobi including chemistry, sensory physiology and histology and fine structure support laboratories and biostatistics including a WANG VS-8 mini-computer.

F. Technical Feasibility

The selection of plant resistance to insects as the appropriate technology to extend to African farmers is based on a long history of success in the U.S. and other developed countries. In addition good progress has been made in the development of resistant varieties at some of the International centers (i.e. rice varieties resistant to brown rice planthoppers in the Philippines).

Faster progress could be made if better methodology for screening and determining the biochemical, biophysical and genetic basis of resistance could be developed along with the necessary cooperative relationships to extend this information to national breeding programs in Africa and to International Centers. It was for this purpose the BPRIA research team was formed at ICIPE. The research scientists in this group are highly capable, well trained entomologists specializing in the field of plant resistance and should be able to achieve the objectives of this proposal.

G. Socio-Economic Evaluation

1. Economic Losses Stem and pod borers are the major insect problem in Africa agriculture, greatly reducing yields, especially for the subsistence farmers.

Economic Losses: In Kenya, a preliminary survey revealed that there are five lepidopterous stem borers belonging to four genera and are serious on sorghum and maize. They are *C. partellus*, *C. orichalociliellus*, *B. fusca*, *E. saccharina* and *S. calamistis*. All these five stem borers also feed extensively on the maize cobs. In Nyanza Province, the stem borers' infestation on sorghum and maize varied from 8 to 100%, and 0 to 100%, respectively. In the Western Province the infestation by borer complex on sorghum ranged from 24 to 76% as against 6.7 to 44% on maize. A maximum of 100% infestation in maize and 84% in sorghum was recorded by *B. fusca* in the entire Rift Valley Area and the Central Province *C. partellus* was the most dominant stem borer on sorghum within 40.1% infestation while *B. fusca* was very important on maize (32%), followed by *C. partellus* (5.7%). In the Eastern Province, *C. partellus* (82%) was the most important stem borer species on sorghum while on maize it was *B. fusca* with 36% infestation.

All along the coastal area, two species of Chilo, C. aricholcociliellus and C. partellus and S. calamistis were found to be the most important and serious stem borers on both sorghum and maize. In this province, maize was severely damaged by Chilo spp. (sometimes 21 larvae/plant and 5 larvae/cob) upto 92% whereas in sorghum it was 52%. S. calamistis was observed infesting 28% of maize and 5.7% of sorghum stalks. Walker and Hodson (1976) found about 1.2% reduction in maize field per 1% plants attacked by B. fusca over 3 years in Kenya. Usua (1968) found about 0.9% loss in yield per 1% maize plants attacked by B. fusca in Nigeria.

At Mbita Point Field Station (MPFS) preliminary studies conducted on the estimation of losses due to shootfly and stem borers in sorghum, indicated that there was 25% reduction in the yield of grain due to the shootfly whereas it was 46% due to the shootfly and stem borers together. In an intercropping experiment, the effect of the stem borers attack on grain yields of sorghum (main stems) and maize showed that there was 34.7% and 25% economic loss in the mono crops of maize and sorghum, respectively. When sorghum intercropped with cowpea, the economic loss was 15.8% as against sorghum (37% loss) intercropped with maize (39.6% loss). In a mixed tricrop situation (sorghum-cowpea-maize) there was 18.2% loss in maize as against 19.8% on sorghum.

The legume pod borer, Maruca testulalis is a major pest of cowpea in Africa and can cause severe yield losses ranging up to 60% (Taylor 1967, 1968; Singh and Taylor, 1978). Yield loss assessment on cowpea at the ICIPE has indicated that cowpea plants shed off about 50 to 80% of the buds and flowers. As a result, grain yield is derived from 20 to 30% of buds that survive as mature harvestable pods. Obviously, these must be protected from insect damage if any grain harvest is to be expected.

Based on the surveys and studies conducted in Kenya, these crop borers contribute subtantially to reduced fields of the target crops under subsistence farming conditions. Very little information is available on the crop losses due to these borers in other countries. However, similar damage occurs and the losses to these pests in Africa are tremendous. These studies confirm the previous statement that stem borer complex is most serious for sorghum and maize and the pod borer of cowpea in Africa.

These crop borers do not respond to insecticidal treatments and no satisfactory control measures can be obtained. Further, insecticidal control of the stem and pod borers is expensive and not practical, particularly to the resource-poor farmers in the developing countries. Therefore, the most practical and effective approach for the small scale farmer is to cultivate insect resistant varieties of crops and integrate with cultural and biological control measures which could fit ideally into IPM Programmes.

The proposed project would serve to achieve these ends.

H. Training

ICIPE has already been engaged in giving training to postdoctoral fellows from developing countries under the ongoing project on bases of plant resistance to insect attack. It is now proposed to expand the programme of giving training in the principles and methodologies in the field of plant resistance to insect pests. Such a training would be given to the scientific and technical personnel of various national programmes for a short term extending up to 3 months and for a long term extending up to 1 to 3 years. The number of persons to be trained will range from 2 to 4 for short term per year and 2 postdoctorates for long term training per year. The person to be given long term training willinclude pre-doctorate graduate scholars (for 3 years) working for a doctorate degree and post-doctoral research fellows for 2 to 3 years.

I. Collaboration with International, National, and other Agricultural Research Institutions

ICIPE has closely established formal or informal collabortion with certain international, national and other agricultural research institutions in the field of plant resistance to insect pests. The formal collaboration exists with IITA (cowpea pod borer). Plans are also being made for further cooperation with IITA on maize pests.

International collaboration has been going on with ICRISAT in reference to exchange of sorghum germplasm and with CIMMYT in respect to maize germplasm.

Scientists from the following institutions from different parts of the world participated in a HPR workshop sponsored by ICIPE and exchanged information on various aspects of plant resistance to insect pests: the international centres - ICRISAT, CIMMYT and IITA; national programmes of Tanzania, Uganda, Kenya, Ghana, Sierra Leone, Rwanda, Ivory Coast, Texas A&M University, USDA Mississippi State, Lousiana University, USA; USAID/W; REDSO/E; WARDA; SAFGRAD/OAU; Max Planck Institute, Munich; and Agricultural State University, Holland.

It is proposed to expand the collaborative programmes with several of the above mentioned institutions.

J. Environmental Concerns

No detrimental environmental effects are expected and the project may be given a categorical exclusion (See Annex 5).

IV. Project Output and Economic Considerations

The outputs of this research (present and proposed) is an intermediate product used by ICIPE to strengthen their research base and by the National and International crop breeding programs to accelerate variety development research.

The costs of the project can be easily identified, but benefits are more difficult to quantify as with all ex ante evaluations. Therefore, a qualitative discussion of the expected benefits or outputs follows:

1. Improvement of crop breeding programs. The identification of mechanisms for plant resistance and development of methodology will accelerate the rate at which new varieties flow from the crop breeding programs. Currently crop breeders screen hundreds of lines of various crops looking for varieties that can lead to higher crop yields. In doing this screening, they may observe resistance but not understand the how and why of such resistance. Therefore, they are limited in their their ability to introduce this resistance into new varieties in a systematic manner. The research undertaken by the BPRIA project will be to confirm observed resistance, identify these mechanisms, and develop methodology for identifying resistance which will aid the crop breeding program. As such the proposal, if funded will continue to play a unique role in the improvement of crop breeding techniques and development of improved crop varieties.

The proposed approach is a cost-effective method of developing research output because it allows each segment of the system to concentrate on a relatively few outputs and thus become specialized and yet interact freely with one another. This approach is very similar to the approach used in many highly successful U.S. land grant institutions. Without this the development of plant resistance to insects would undoubtedly proceed at a much slower pace and with no clear understanding of the mechanisms that control plant insect resistance.

2. Development of Methodology. The methodology developed will be used in the project to improve the accuracy and the reliability of research results. The methodology also will be made available to National and International crop breeding programs to improve the efficiency and the speed with which varieties can be developed and released to farmers.

Frequently plant resistance research cannot progress because of inadequate natural insect infestations. Mass rearing of insects by breeding programs will insure an adequate supply of insects at low coasts. Thus, the research effort within the BPRIA Project on mass rearing is logical and makes good use of scarce resources.

3. Transfer of Technology to National Research Programs. A part of ICIPE's mission is the training of African scientists. During 1980 the training output at ICIPE was 64 person-years. The major thrust of the BPRIA proposal is to develop a core research program. This core program would be augmented with postdoctoral scientists and students engaged in research training. Already two Ph.D. students have completed training and another will finish in 1985. This cost-effective research training activity will be expanded under this proposal to include several technical and scientific personnel from national programs for short durations (3-4 months) to learn principles and methodology for conducting plant resistance studies (see Budget for detail). Another beneficial feature of the program is that it will enable African scientists to study problems affecting African agriculture in a more realistic setting and

enable them to remain in Africa as experienced and valuable contributors. By studying these problems in an African setting, it will be easier for these scientists to transfer their research knowledge to National crop breeding programs with which they become involved. Also, this training will foster cooperation between ICIPE and these scientists as they assume responsiblities in their countries. Also augmenting the core research program with 1-3 year training assignment is cost-effective. Research training arrangements of this kind greatly expand the value of the core research program and allows for flexibility as new issues are identified.

Delivery of the technology by ICIPE from the proposal research will be directly to the National breeding programs in Africa and to the International Centers. The final output of the technology, will be varieties more resistant to key endemic pests of corn, sorghum and cowpeas made availab;le to the small farmers of Africa. These small, often subsistent type farmers cannot afford the cost of insecticides. As a result, resistant varieties, and perhaps cultural and biological control practices constitute the only practical means to reduce crop loss in Africa where insects destroy on the average approximately 40% of the crops before harvest. If Africa is to feed its rapidly increasing population, projected to double by the year 2000, their food production must be enhanced through every means possible. This project, because of its relevance and potential in meeting needs of African farmers, should be given extremely high priority.

4. Changes in Farming Practices. Although one cannot quantiify the ultimate impact of the output from th BPRIA proposal on farmers, a review of current methods will shed some insight into the issue. Currently, farmers use insecticides to control crop borers. However, insecticides do not control larvae in the stem. In addition, insecticides must be imported and most African countries are short of foreign exchange, and frequent insecticide application;has adverse environmental and human health impacts.

Although insecticides are possible means of controlling crop borers, it is not practical for the subsistence farmer. He often does not have the resources with which to purchase insecticides nor the equipment to apply them. The subsistence farmer can destroy crop residues as a method of cultural control but with small plots this has to be done over a fairly wide area to be effective. This type of control would have to be on a community basis which usually is extremely difficult to achieve. As a result most subsistence farmers do not employ any crop borer control methods. The result is a socially suboptimal allocation of resources.

Accordingly, the development of crop varieties resistant to crop borers would be especially important to subsistence farmers. They would only have to purchase the seed to reduce their crop losses to borers. Since the resistance to insects is transmitted in the seed, farmers can save seed from one year to another and still have borer resistance.

V. Administration Arrangements and Implementation Plans

A. Administrative Arrangements: The organization that will administer the proposed research will be ICIPE. ICIPE has a capable core of scientists and administrators to support project research activities and to provide necessary administrative services. In addition the program is well laid out for the next four years in project work plans (see Project Work Section III C).

ICIPE also is in an excellent position to develop cooperative relations with other African institutions and national programs thereby extending needed information to many countries of Africa. In this regard, ICIPE is currently negotiating cooperative agreements with several of its African neighbors. In addition, the flow of scientists and students to ICIPE will enhance the interchange of technology and the development of cooperative relationships. Also ICIPE works directly with subsistence farmers through the Kenya National program and ICIPE's Mbita Point Field Station.

B. Implementation Plan

1. Implementing Agents. This proposal will require the input of two implementing agencies, ICIPE and that being requested from AID. The areas of responsibility of both agencies are outlined in the Proposed Calendar of Events, in the following section 2.

a. ICIPE

ICIPE is the key implementing agency in the proposal. ICIPE will be the management entity and supply most of the necessary inputs including scientists and technical support staff as well as physical facilities and equipment needed to successfully carry out project objectives. In this regard, ICIPE will be responsible for the arrangement and the implementation of research activities. The institution's Director has the overall managerial and financial responsibility for project implementation.

The project leader is responsible for research direction and the day-to-day implementation of program activities. Working with individual scientist and technicians, the program leader will develop an overall program implementation strategy. Individual scientists in turn are assigned specific areas of responsibility within the project. They will develop annual work plans which list objectives and implementation procedures for each experiment. The project leader also is responsible for the development and the implementation of formal protocols to enhance cooperation between ICIPE and National programs as well as IARCs. Semi-annual reports will be provided by ICIPE to AID that outline implementation progress and other relevant aspects of the project.

Due to the international scope of ICIPE, equipment in the approved budgetary amount each year will be procured from any appropriate non-communist country. The flexibility in the choice of countries from which to purchase equipment should reduce delays in delivery as well as improve quality and reduce price/unit. Equipment purchases will be handled through normal ICIPE competitive procument procedures and financial statements will be available for AID review.

b. AID

The primary AID role will be project monitoring. REDSO/EA will conduct periodic managment reviews to evaluate progress as measured by work plan implementation schedules. In addition AID will conduct an in-depth external review of the project approximately 2 years after the funding is approved and after the fourth year and will provide upon request, scientific consultation to ICIPE from the AID-funded INTSORMIL and CICP projects.

2. Proposed Calendar of Events

Date	Action	Primary Responsibility
	Proposal Development Schedule	
June 1984	Submission of Proposal to REDSO/ESA	ICIPE
July/August 1984	Proposal Review	REDSO/ESA
August 1984	Grant authorization of 1st year funding	AID/W, REDSO/ESA
September 1984	Grant Agreement signed	AID/W REDSO/ESA ICIPE
*****	***** ***** *****	*****

Proposal Implementation Schedule

Months After Proposal Begins		
1. (October 1984)	Continuation of on-going activities	ICIPE
9.	Semi-annual Progress Report	ICIPE

11.	Semi-annual Progress Report	ICIPE
12.	Review of Research Program Develop Second Year Work Plan	ICIPE
13.	Implement 2nd Year Work Plan	ICIPE
18.	Semi Annual Progress Report	ICIPE
24.	Semi Annual Report Develop Third Year Work Plan	ICIPE
25.	Comprehensive Review	REDSO/E AID/W
34.	Semi Annual Progress Report	ICIPE
36.	Develop Fourth Year Work Plan	ICIPE
46.	Semi Annual Progressing Report	ICIPE
48.	Develop Fifth Year Work Plan	ICIPE
52.	Comprehensive Review	REDSO/E AID/W ICIPE
56.	Develop Follow-up Proposal with Cooperators for AID	REDSO/E AID/W
60.	Develop Final Report	ICIPE
	Funding of Second Phase of Proposal	ICIPE

C. Evaluation Arrangements

ICIPE will provide technical reports and financial statement on a 6-month basis corresponding to each cropping cycle. At the end of each financial year an audited account of the BPRIA proposal will be made available to AID. A final technical and financial report will be submitted at the end of the project.

Internal review of the project should be conducted on an annual basis coordinated with the ICIPE Annual Research Conference.

D. Financial Plan and Arrangements

A summary cost estimate and financial plan for the BPRIA proposal is projected in Annex 2. It is proposed that AID fund the cost of the project for 1984-1989 as as requested in the budget because current core funding will probably not be available.

Procurement of miscellaneous commodities with funds provided hereunder shall be accomplished in accordance with existing competitive procedures of ICIPE.

ANNEX 1 - - LOGICAL FRAMEWORK

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

Life of Project:
From FY 84 to FY [redacted] 89
Total U.S. Funding $[redacted]
Date Prepared: [redacted]

Project Title & Number: BASES OF PLANT RESISTANCE TO INSECT ATTACK - 698-[redacted] 0435.01

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Sector Goal: The broader objective to this project contributes: To improve crop production through utilization of plant resistance to insect attack.	Measures of Goal Achievement: Measurable increase in the use of plant resistance as an approach to reducing pre-harvest crop losses caused by insects.	Delivery of knowledge on basic mechanism of resistance and methodology to IARC and national programs as well as publications and reports on host-plant resistance from these institutions	Assumptions for achieving goal targets: Insects cause crop loss and plant resistance is an effective method to reduce crop losses caused by insect.
Project Purpose: To understand the physical, chemical genetic and morphological causes of insect resistance in target crops and to develop methods for the detection of plant resistance to insects.	Conditions that will indicate purpose has been achieved: End of project status. Crop/insect research priorities clearly delineated, and analyzed research results being published. Plant resistance to insects being increasing adopted as a central strategy by national programs and IARCs in overall pest management programs.	. Reports of IARCs . Reports of national breeding programs . Number of target crop/insect resistant cultivars in breeding programs/released.	Assumptions for achieving purpose: ICIPE will give responsibility and authority for program direction to well qualified project leader and construction of laboratory and other physical facilities will be completed on a schedule compatible with meeting project objectives.
Outputs: Scientific teams are working to identify sources of insect resistance and to develop improved methods for detection and understanding of plant insect resistance mechanism. Linkages established among IARCs and national agriculture research programs. Research training underway in the methodology and identification of plant resistance to insects.	Magnitude of Outputs: Mechanisms for resistance identified in three crop/insect complexes. Linkages established among 8 country agriculture research programs, 3 IARCs and one CRSP (INTSORMIL). Research trainin- provided for 10 scientists. Recommendations developed for future plant resistance research.	Assessment of the quality/quantity of research on targe crop/insect complexes. Evaluation 1/ of formal and informal protocol established to improve linkages. Evaluation 1/ of research training. Evaluation 1/ of research recommendations. 1/ In-depth external evaluation.	Assumptions for achieving outputs: Insect resistance has been imperically identified in the target crops and insect resistance in plants provides a practical, economic and environmental sound alternative to pesticides, particularly in LDCs.
Inputs: ICIPE: Scientific and technical staffing; laboratory and field plant facilities; equipment and furnishings; target crops/insects research training; Service units (chemistry, Sensory Physiology Ultrastructure). Proposed Request:	Implementation Target (Type and Quantity) ICIPE: 3 scientists, 8 technicians; 1 laboratory, 4 field plot locations; equipment and furnishings in accordance with laboratory and field plot needs; 3 target crop/insect complexes; 10 scientists in research training; service units assistance. 4,721,400 for 5 years. Consultation as needed, 1 in-depth external review.	ICIPE: Review of staff, budget and program records. Proposed: Review of project, financial and team review records.	Assumptions for providing inputs: ICIPE has given high priority to the subject matter area of the project, well trained enthusiastic scientists are working on the project and adequate facilities are being developed to conduct the outline research.

FIVE-YEAR DETAILED BUDGET FOR THE BPRIA PROJECT

	FY 84	FY 85	FY 86	FY 87	FY 88
Professional Staff					
*Project Leader	40.0	42.0	44.2	46.4	48.7
Principal Research Scientist (IFAD)	-	-	-	-	-
*Senior Research Scientist	28.0	29.4	31.4	33.0	34.6
*Research Scientist (ODA)	-	-	-	-	-
*Research Scientist	22.0	23.1	25.5	26.8	28.1
*Research Scientist - Chemist	22.0	23.1	25.5	26.8	28.1
*Research Scientist (Plant Geneticist)	22.0	23.1	25.5	26.8	28.1
*Research Scientist (Plant Physiologist)	22.0	23.1	25.5	26.8	28.1
*Scientific Officer	15.0	15.8	16.5	17.4	18.2
Sub-Total	171.0	179.6	194.1	204.0	213.9
Technical Support Staff					
*Senior Technician	36.7(4)	38.5(4)	40.4(4)	42.5	44.5
*Technician T4	36.0(5)	37.8(5)	39.7(5)	41.7	43.8
*Technician Jr T3 (3, CORE-1)	36.0(6)	37.8(6)	39.7(6)	41.7	43.8
*Technical Assistants	18.0(4)	18.9(4)	19.8(4)	20.8	21.8
Sub-Total	126.7	133.0	139.6	146.7	153.9
TOTAL	297.7	312.6	333.7	350.7	367.8
Gratuity/Provident Fund, 16%	47.6	50.0	53.4	56.1	58.8
TOTAL COST (Professional/Technical)	345.3	362.6	387.1	406.8	426.6
Postdoctoral-Postgraduate Training					
Postdoctoral Research Fellow	51.0(3)	53.3(3)	55.0(3)	57.8(3)	60.7(3)
Postgraduate Research Scholar	27.6(2)	30.0(2)	32.0(2)	33.6(2)	35.3(2)
Short-term, 3-4 months Research Scholars	60.0(0)	60.0(0)	60.0(0)	60.0(0)	60.0(0)
TOTAL	138.6(5)	143.3(5)	147.0(5)	151.4(5)	156.0(5)

* Support Requested in Proposal

	FY 84	FY 85	FY 86	FY 87	FY 88
Travel					
Project Leader (Intl)	12.0	15.0	15.0	15.0	15.0
Project Staff (Intl)	35.0	35.0	35.0	35.0	35.0
Local Travel	30.0	32.0	35.0	38.5	42.4
Postdoct/Postgrad	10.0	10.0	-	10.0	10.0
Project Review	-	-	10.0	40.0	-
TOTAL	87.0	92.0	95.0	138.5	102.4
Materials/Supplies/Expenditures					
Supplies	50.0	55.0	60.0	66.0	72.6
Vehicle Maintenance	15.0	15.0	18.0	19.8	21.8
Insurance	7.0	8.0	9.0	10.0	11.0
Report Costs and Photography	5.0	6.0	7.0	8.0	8.5
Maintenance of Equipment	15.0	16.0	17.0	18.7	20.6
Labour/Wages	14.0	15.0	16.0	17.6	19.4
TOTAL	106.0	115.0	127.0	140.1	153.9
Equipment					
Expendables	100.0	100.0	100.0	-	-
TOTAL	100.0	100.0	100.0	-	-
Other Costs					
Mbita Point Field Station Costs	50.0	60.0	70.0	77.0	84.7
Collaborating Units (Sensory physiology, histology and fine structure, biological control, biostatistics and computer service)	20.0	25.0	30.0	33.0	36.3
Communication	20.0	21.0	22.0	24.2	26.6
	90.0	106.0	122.0	134.2	147.6
GRAND TOTAL	866.9	918.9	978.1	971.0	986.5

ANNEX 3: PUBLICATIONS

As a result of research undertaken by scientists in the Bases of Plant Resistance to Insect Attack Project, the following papers have been published:

1. Okeyo-Owuor, J.B. and Ochieng, R.S. 1981: Studies on the legume pod borer, Maruca testulalis (Geyer). I. Ecology and biology; Insect Science and Its Application, 1(3): 263-68
2. Ochieng, R.S., Okeyo-Owuor, J.B. and Dabrowski, Z.T., 1981: II. Mass rearing on natural food. Insect Science and Its Application, I(3) 269-72.
3. Dabrowski, Z.T. and Patel, N.Y., 1981: Investigations on physiological components of Atherigona soccata larvae and sorghum interaction. I. Larval enzymes; Insect Science and Its Application, 2(1/2):73-76.
4. Dabrowski, Z.T. 1982: Principles of host plant resistance to insect pests; Proceedings fo the Integrated Pest Management course, WARDA, Monrovia, January 10-28, 1982(Review; in press).
5. Dabrowski, Z.T., 1982: Trends and needs in breeding crop plants for resistance to insect pests. Proceedings of Integrated Pest Management course, WARDA, Monrovia, January 10-28, 1982 (Review; in press).

In addition, nine other papers will be submitted for publication during the next three months.

1. Dabrowski, Z.T. and Nyangiri, E.O., 1982: Field and screenhouse experiments on resistance of maize to stem borers under Western Kenya conditions; Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their Control, 1982 (in press).
2. Omolo, E.O., 1982: Screening maize and sorghum for resistance to stem borers under Western conditions; Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their Control, 1981 (in preparation).
3. Dabrowski, Z.T., 1982: Resistance of some sorghum lines to the sorghum shootfly and stem borers under western Kenya conditions; Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their Control, 1982 (in preparation).
4. Masina, G. and Dabrowski, Z.T., 1982: Sorghum - Chilo partellus relationshjips affecting resistance; Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their COntrol, 1981 (in preparation).
5. Dabrowski, Z.T. and Bungu, M., 1982: Studies on the legume pod borer, Maruca testulalis (Geyer). IV. Effect of cultivar on behavior, survival and development. Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their Control, 1982 (in preparation).
6. Dabrowski, Z.T., McFoy, C. and Bungu, M., 1982: Studies on the legume pod borer, Maruca testulalis (Geyer). IV. Effect on cultivar behavior, survival and development. Proceedings of the International Study Workshop on Crop Borers and Emerging Strategies for Their Control, 1982 (in preparation)

7. Ochieng, R.S., 1982: Studies on the legume borer, Maruca testulalis (Geyer). V. Rearing of larvae on artificial diets. Insect Science and Its Application (in preparation).

8. Cowpea resistance to the cowpea black aphid, Aphis craccivora. Insect Science and Its Application (in preparation).

9. Ogwaro, K. and Omolo, E., 1982: Intensity leves and the effect on yield of stem borers in maize and sorghum under different intercropping patters. Insect Science and Its Application (in press).

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ANNEX 5: INITIAL ENVIRONMENTAL EVALUATION

Project Country: Regional (Based in Kenya)

Project Title and Number: Bases of Plant Resistance to Insect Attack, 698-0413.3

Funding: FY 84 - FY 89, $4,721,400

IEE/CE Prepared By: John J. Gaudet

Environmental Action Recommended:

Positive Determination _____

Negative Determination _____

or

Categorial Exclusion _____

This activity meets the criteria for Categorial Exclusion in accordance with Sections 216.2(c)(1)(iii) and 216.2(c)(2)(ii), and is excluded from further review because: See attached justification.

Action Requested By: _____

_____
Date

Concurrence: _____
Bureau Environmental Officer

APPROVED: _____

DISAPPROVED: _____

DATE: _____

Clearance: GC/AFR _____ Date: _____

A. Proposal Activities

The proposal is designed to achieve control of stem boring insects by breeding for plant resistance to insect attack. It has been, and will continue as a research project carried out under experimental conditions. The major will be to:

1. Develop and improve screening methods for insect resistance;
2. Identify new sources of insect resistance;
3. Identify and clarify mechanisms of resistance;
4. Determine the genetic basis for resistance;
5. Train young LDC scientists; and
6. Expand cooperation, interchange and publication of information on this topic.

B. Impacts

Small quantities of EPA approved insecticides and fungicides will be used to obtain and prereserve insect and disease-free seed for experimentation. The adverse effects of this action will be slight and localized.

The majority of the impacts will be positive, for example:

1. Selection and preservation of food grain germplasm;
2. Reduction in overall use of insecticides to control stem borer by developing insect resistant crops; and
3. General increase in food production and well-being of people in the LDCs.

C. Action Requested

A Categorial Exclusion is requested for this project. The project qualifies under Sections 216.2(c)(1)(iii) and 216.2(c)(2)(ii).