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INTEGRATED CROP PROTECTION PLANNING STUDY

ASSESSMENT DOCUMENT

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TABLE OF CONTENTS

		PAGE
	EXECUTIVE SUMMARY	i
	RECOMMENDATIONS	v
I	INTRODUCTION	1
II	THE INTEGRATED CROP PROTECTION CONCEPT	3
III	FOOD DEFICITS: A PROBLEM OF THE DEVELOPING COUNTRIES AND POTENTIAL SIGNIFICANCE OF CROP PROTECTION	7
	Potential Significance of Integrated Crop Protection	9
IV	INTEGRATED CROP PROTECTION AS RELATED TO FARMING SYSTEMS RESEARCH	12
	Limiting Factors of Agricultural Practices	12
	Multiple Cropping Systems	13
	Farming Systems Research	14
	The Advantages of Integrated Crop Protection and Farming Systems Research	17
V	REGIONS, COUNTRIES, AND CROPPING SYSTEMS	20
VI	AGRICULTURAL PRODUCTION CONSTRAINTS	26
	Technical Element	26
	Key Pre-Harvest Pests	27
	Human Element	33
VII	INTEGRATED CROP PROTECTION RESEARCH	35
	Advantages of Collaborative Research Support Program (CRSP)	35
	Institution Participation and Linkages	38
	U. S. institution Interest in Participation	38
	LDC Interest in Collaborative Participation	39
	Potential Linkage	39
	Approach to Implementation of Integrated Crop Protection Research	43
VIII	RECOMMENDATIONS	45
IX	OBJECTIVES OF PHASE II	47
X	IMPLEMENTATION OF PHASE II	47

TABLE OF CONTENTS

		PAGE
XI	ADDITIONAL CONSIDERATIONS	50
XII	PROJECT STAFFING	51
XIII	REQUEST FOR APPROVAL	52
XIV	LITERATURE CITED	53
XV	ACKNOWLEDGEMENTS	55

APPENDICES

Appendix I . . . . . Study Team Members and Countries Visited

Appendix II . . . . . Agenda and Minutes of July 15-16, 1980 Meeting at Purdue University

EXECUTIVE SUMMARY

AND

RECOMMENDATIONS

EXECUTIVE SUMMARY

USAID awarded Purdue University a Title XII Planning Grant for Integrated Crop Protection (ICP) Research Support Program. The process is a two phase activity. Phase I is an assessment of the feasibility for the development of an ICP research program in the Collaborative Research Support Program (CRSP) or other suitable mode. Phase I also includes the identification of (1) important geographic regions where improved crop protection is needed, (2) priority countries of each region, (3) key pest related production constraints, and (4) potential LDC collaborating institutions.

The Phase I assessment is based on a review, by the Grantee, of the State of the Art, study team visits in selected LDC's, and assistance of a Planning Study Advisory Committee. This assessment document summarizes our findings and states our recommendations for Phase II.

Countries in Africa, Latin America, Southeast Asia, and the Mideast regions were evaluated on the basis of food deficits, GNP, and other criteria utilized by FAO, World Bank, and International Agricultural Development Service to delineate the development status of individual countries. A list of potential research sites was developed and categorized according to the predominant cropping systems of the area, e.g. African maize-root crop based systems, Asian rice based systems, etc. The selected systems include, or could include, several crops in rotation or in intercropping that are economically or nutritionally important to the small farmer.

Pre-harvest pest losses of agricultural crops are estimated to be 25-40%, a totally unacceptable level in developing countries where serious food shortages are prevalent. These losses are caused by the attack or competition of noxious vertebrate and invertebrate animals, diseases, nematodes, and weeds. Losses are often more severe in the tropics and limit the range of crop plants that can be produced.

In the developing countries approximately 65% of the population is involved with traditional agricultural practices, i.e. small, family-operated, multiple-cropped farms. These are typically labor-intensive without significant capital inputs. Small farmers rely to a great extent

on traditional practices for all phases of production including crop protection. Comparatively little modern technology is used for pest control in developing countries.

Integrated crop protection research has the potential to reduce pest related production constraints through the use of multiple control tactics. Multiple control tactics implies the use of cultural controls, resistant cultivars, biological controls, and the judicious use of pesticides in cost effective crop protection systems.

Partial or completely successful implementation of ICP technology has occurred in Central and South America as well as Southeast Asia, which supports the feasibility of the approach for crop protection in LDC's.

ICP research is a holistic approach to crop protection and is analogous to the farming systems research (FSR) philosophy. Both consider similar variables in the small family household farming system. System constraints are identified as belonging in the technical element (pests, agronomics, etc.) and human element (agricultural policy, capital, credit, farmer acceptance of technology, etc.).

ICP research considers the technical element of the farming system as a whole and not in relation to a single commodity or discipline. The crops in ICP-FSR as well as the pest complex involved with the production system are considered together. Thus secondary, but nutritionally important crops such as vegetables and fruits, are included in the management strategy. Also, concern for the human element is incorporated into the experimental design. Thus the holistic ICP approach has the obvious advantage of developing <u>management strategies</u> that encompass all facets of the small farmers' needs. Such broad strategies do not result from narrow approaches usually used for single crop research programs.

Because integrated crop protection relies on multiple tactics the resulting strategies developed through ICP research will be cost effective, and environmentally sound. Control of pre-harvest pests will result in increased crop yield and stabilization of yields of food commodities. Reduction of external inputs to the minimum will encourage adoption of the technology across regions.

Only a small part of the global research and development budget is shared by developed countries, and only a few of the world's agricultural

scientists reside in developing countries. Developing countries have been overly dependent upon imported, and often inappropriate, technology. It has been stressed that new R & D projects should be conceived, designed, and executed by scientists of the developing world in collaboration with counterpart scientists of the supporting country(ies).

A Collaborative Research Support Program for the conduct of agriculture meets these philosophical demands and will in the long run provide appropriate means for increased food production through the concept, design, and implementation of research on food crops. In addition, the training of agricultural research scientists in connection with the ICP-CRSP will alleviate the serious shortage of trained personnel experienced by some of the LDC's.

The CRSP research mode is uniquely valuable because it promotes a joint interdisciplinary research activity on the part of a reasonable number of interested U. S. institutions through the creation and management of a programmed and coordinated research effort over the extended period of time required to establish a program of integrated crop protection. Crop protection problems in developing countries require a sustained research effort over a long period of time, at the minimum five years, and undoubtedly much longer.

The unique nature of CRSP-ICP research utilizing a holistic, and therefore interdisciplinary approach, is a feature which is not inherent in centrally funded or other USAID sponsored research. The proposed ICP-CRSP offers a more comprehensive research program based on farming systems and should result in management strategies which will significantly benefit the small farmers of LDC's.

Each partner of the interdisciplinary effort stands to benefit from the relationship through translation of ideas and implementation of research results in the solution of major problems. The minimum of interdisciplinary action of the past can be overcome if a collaborative research effort is put in place. U. S. institutions will benefit from a CRSP mode through the discovery of new interdisciplinary technology, some of which may be applicable to U. S. agriculture. U. S. agriculture research seeks new management systems, whether in pest control or in more general agronomic practices. Much is to be learned from understanding and

modifying traditional farming systems, some of which may benefit the small farmers of the U. S.

In addition, there are other advantages to the CRSP mode. Research in integrated crop protection can not be confined to a single cropping system in a single ecological situation, but will have to involve study of varied multiple cropping systems for food crops, many times dealing with the same key pests, but under differing geographic, ecological and population parameters. Research results obtained in one ecological area can be utilized in developing management strategies for similar pests in other agroecosystems. The CRSP mode using farming systems research approaches, i.e. evaluation of promising tactics under small farm conditions and farmer testing of tactics, should produce results in a form which will be clear and immediately compatible with the form in which information is needed in outreach programs. The CRSP approach also increases the potential for exchange of biological materials, scientific information and the development of strong interdisciplinary relationships among scientists of developing countries in different geographic regions.

The collaborative research approach using the expertise of a number of U. S. institutions working with the scientists of the developing countries offers the most promise for significant reductions in food losses caused by pests. Such an effort is of considerable magnitude but offers potential improvement of the food needs of developing countries.

RECOMMENDATIONS

The Grantee makes the following recommendations based on team visits, State of the Art, and advice from Advisory Committee as well as Phase I Assessment of the potential and significance of Integrated Crop Protection research and the potential benefits of a Title XII Collaborative Research Support Program for the conduct of an ICP research program.

1. That the Integrated Crop Protection Planning Program be continued with initiation of Phase II Planning Activities which constitutes the development of a CRSP Proposal:
   a. That research programs should be established in each of the following regions: Africa, Latin America and Southeast Asia,
   b. That priority research be conducted on the following cereal based cropping systems:
      (1) African sorghum/millet-cotton or groundnut system
      (2) African maize-root crop system
      (3) Latin American maize system
      (4) Asian rice system

2. That the following countries, as well as others which were ranked according to priority (see Interim Report), be considered as potential primary and secondary collaborating countries:

Region	Primary	Secondary
Africa	Sudan	Tunisia, Cameroon
Latin America	Peru	Colombia
Southeast Asia	Sri Lanka	Indonesia

The recommended countries are based on Study Team visits and no intent is made to discriminate against other LDC's. Final consideration of potential countries will be made in Phase II Planning.

3. That a Title XII Collaborative Research Support Program be adopted by USAID/DS/AGR for an Integrated Crop Protection research program on small farmer food (and related cash) crops.

4. That linkages be initiated between CRSP-ICP collaborators and International Agricultural Research Centers in order to assist and facilitate training of nationals and to make available the IARC's knowledge base and resistant plant cultivars to the ICP research effort. Further, it is recommended that linkages with regional research centers such as CATIE be included at a similar secondary level of participation in the research program.

PHASE I

ASSESSMENT

INTRODUCTION

Crop protection was ranked by JRC (Joint Research Committee of the Board for International Food and Agricultural Development - BIFAD) as a priority problem confronting the improvement and/or expansion of crop production in most LDCs, especially those having tropical or subtropical environment. It was also identified as an area needing urgent and extensive research if these problems are to be overcome; and, further it was determined that solutions to these problems may best be addressed through the development and application of Integrated Crop Protection (ICP) practices and systems.

The JRC-BIFAD recommended to AID that Purdue University be awarded a Title XII Planning Grant for Integrated Crop Protection Collaborative research. The planning process was proposed as a two phased activity, Phase I being devoted to the assessment of the feasibility for the development of a Collaborative Research Support Program on integrated crop protection.

The Phase I effort was designed in a manner to provide a basis for determining how major future research efforts on Integrated Crop Protection may be focused on the needs of small farmers in the developing nations, and attempted to identify ways in which U. S. expertise can effectively be brought to bear on the problems identified.

Phase I emphasis was placed on the identification of pest related constraints on production within the farming systems in use on LDC farms, describing the existing "state-of-the-art" for integrated crop protection, and an analysis of the means of developing subsequent research efforts within the scope of the U. S. development assistance program.

This assessment document is the result of the Integrated Crop Protection (ICP) Planning Program activities during 1979-1980. Phase I activities initially included the selection of an Advisory Committee of integrated pest management specialists to assist the Grantee in the development and conduct of Phase I activities, including the selection of potential countries for study team visits as well as an evaluation of potential sites for a Collaborative Research Support Program (CRSP), definition of important commodities and cropping systems, and

identification of key pre-harvest pest related production constraints. In addition, a list of potential consultants to serve as study team members was developed from advice offered by the Advisory Committee, university and Federal sources. Teams were in the field (Africa, Central and South America, Southeast Asia) during May, 1980.

Details of the initial planning mentioned above were presented to the Joint Research Committee, Board for International Food and Agricultural Development, and AID in an Interim Report issued by Purdue University in March, 1980.

Appendix I lists the team members and countries visited. Due to circumstances beyond the control of the Grantee, clearance to visit the West African countries of Senegal, Mauritania, Upper Volta and Niger was not granted and as a result no evaluation of the FAO-Integrated Pest Management program underway in that region or of pest management problems of the Sahel was conducted.

Subsequent to the return of the Study Teams to the United States a meeting of a group comprised of either the team leader, or in his place, a member of each of the teams, as well as one member of the Advisory Committee was held at Purdue University on July 15 and 16, 1980 to discuss recommendations concerning Phase I activities, including the results of the Study Team findings. The agenda and minutes of the meeting are presented in Appendix II.

Final consideration of the Assessment Document draft was made in Washington, on October 15, 1980 by the USAID Program Manager and three members of the Advisory Committee.

The Phase I assessment is based on a review, by the Grantee, of the State of the Art, study team visits in selected LDC's, and assistance of a Planning Study Advisory Committee. This assessment document summarizes our findings and states our recommendations for Phase II.

THE INTEGRATED CROP PROTECTION CONCEPT

Crop protection in agricultural production is complex in its simplest scope. The farm production process is involved with multiple pests whose potential for damage are usually not independent. The production system may involve monoculture practices, or in other situations a variety of crops of a multiple cropping system, each of which is susceptible to some combination of pests. "Pests" is used in the broad sense to include all organisms, vertebrate and invertebrate animals, plants, and microorganisms which are pre-harvest constraints to agricultural productivity. The susceptibility of the farming system to pest damage is some function of not only the crops grown but also the manner in which they are combined in a cropping system and the farming practice employed as well as the environment in which they are grown. On the control side, there are numerous means of reducing pests and pest related crop yield losses. Each measure has its own set of costs and benefits. The cost/benefit ratio of any single protection measure is not independent of other measures which are or might be employed.

Single crop protection methods seldom will constitute the least cost means of achieving the level of pest control associated with maximum profitability of the farm enterprise. It is far more likely that some combination of control measures will be employed and which will tend to be specific to particular farming systems in specific agroecosystems. The relative costs of the alternative control methods will likewise be specific to a specific locale. Identification of a particular group of control measures which will "best fit" the physical, biologic, economic, social and cultural milieu characteristic of the various farming systems constitutes Integrated Crop Protection research. ICP is the logical optimization of pest control in an economically, socially, and ecologically accepted manner.

<u>Integrated crop protection</u>, used here synonymously with integrated pest management (USA) and integrated pest control (Europe), is a holistic philosophy to the solution of pest problems. It is a systems analytical logic for the management of pests (Ruesink, 1976) and therefore considers the whole agricultural production system. Integrated crop protection

research thus involves not only biological studies on specific pest species but also studies concerning the various biological interactions resulting from altering an existing ecological system by controlling one or more pest species, whether by natural, cultural, biological, or chemical means, (Levins and Wilson, 1980).

In the broadest concept, ICP includes all key pests in the agroecosystem. In its most restricted concept ICP may apply to a single major pest. An agroecosystem may be conceptualized as a series of interlocking physical, biological and management functions which interact to affect the yield(s) of a particular farming system. In this model system the crop pests are considered as individual, isolated elements of the agroecosystem, and they are not managed as a primary objective but only as they reduce the productivity of the farming system by an amount greater than the cost of implementing a crop protection strategy. The mere presence of an organism in association with crop plants does not always constitute a pest relationship. Key pests, those which are perennial, are those which usually cause significant damage in the absence of control. Of lesser importance are pests which occur only occasionally and sporadically cause economic damage to crops. In addition there are migratory pests which may cause serious damage periodically and potential pests which cause no economic damage under normal circumstances.

A management strategy is developed from a knowledge of physical and biological interacting component inputs into the system and in which multiple control tactics are integrated to provide maintenance of pest density or disease incidence and related damage at an economically acceptable level. The management strategy is based on "Economic Injury Levels" and "Economic Thresholds" within the context of pest population damage and density. Most crops are able to withstand some pest related damage without significant economic loss. However, there is a degree of injury beyond which pest related damage causes significant economic loss. Control measures are employed at a predetermined pest density (or incidence) below that causing economic injury, the <u>economic threshold</u>. Establishing the economic injury levels and economic thresholds involves reliable loss estimates for a particular crop, financial costs of various control inputs, as well as biological information on the impact of single

or multiple control components on the agroecosystem. The additional component in the model is the sociological acceptance or rejection of a particular control practice or practices. Because this is a dynamic system driven by biological and physical environmental conditions the economic threshold values for a given multiple cropping system will change in time depending on the external economic constraints as well as ecological conditions acting on the production system.

From the above it is apparent that reliable loss estimates resulting from the impact of pests, singly or collectively, are fundamental in an integrated crop protection management strategy, irrespective of whether control measures involve pesticides, biologicals, resistant varieties, or cultural means. The magnitude of losses and their associated costs must be established and compared to the costs of pest reduction. Cramer (1967) has provided valuable estimates of crop losses caused by pests in developing countries, but while they indicate the magnitude of the problem they are of little use to the farmer for guidance on the use of pesticides. We feel obliged to emphasize the necessity for the acquisition of reliable loss data derived from the farmers field to be used in establishing economic thresholds.

Each of the plant protection disciplines play a significant role in an ultimate crop protection "package" because ICP includes control of each of the key pests in the agroecosystem. Historically, traditional agricultural research has addressed the isolated variables within the production framework and the resulting information has been disseminated to the producers by extension specialists and their associated farm advisors. Using this specific crop or discipline approach has the obvious disadvantage in the lack of synthesis of the information derived from each of the disciplines into a comprehensive system of pest management.

As already stressed, integrated crop protection is a complex multidisciplinary systems approach involving all of the plant protection disciplines, i.e. weed science, plant pathology, entomology, and nematology. Directly involved with these biological aspects is socioeconomic research which focuses on the optimization of the various pest control inputs.

Pesticides remain the primary control of agricultural pests and no new

revolutionary pest control tactics are expected to be implemented over the next 15 years. Integrated crop protection offers an approach to pest control which results in stable crop production and protection with the least hazard to man and the environment (Glass,1979).

FOOD DEFICITS
A PROBLEM OF THE DEVELOPING COUNTRIES
AND
POTENTIAL SIGNIFICANCE OF CROP PROTECTION

Review of current documentation supplied by The World Bank, The International Agricultural Development Service, and Food and Agricultural Organization, United Nations, leaves no doubt that the food situation is most critical in the developing countries. The much publicized famine of the future is not likely to be as chaotic and indiscriminate as imagined. In fact, we may be witnessing it now. It is highly discriminating against the poor and well organized by the market place. In short, there is more than sufficient food for those who can afford it. If food production and distribution is to be improved in Least Developed Countries (LDC's) it will have to be accomplished mainly in local economics through the efforts of the small holders who work some 65% of the arable land. In addition, evidence indicates that the multiple effects of increase in small-holder (farm) income are greater than those of comparable increments in income of large farms, suggesting that a small holder oriented agricultural development strategy would enhance the expansion of a domestic market for industry (World Bank, 1979). Increasing agricultural productivity is therefore not only important in alleviating nutritional deficiencies for the populations of LDC's but also basic to the progress of development in those countries.

Continual or recurrent food production shortages in developing countries are due in a large part to losses caused by insect, nematode, and disease attack and through competition with weeds for adequate nutrition and water. It is recognized that crop losses in developing countries are particularly devastating with annual losses having been estimated at 30-40% due to pre-harvest pests. The estimates do not include losses resulting from the activity of birds and rodents, pests which often play a large role in overall loss. Smith (1979) conservatively estimates a 50 per cent reduction of pest losses by implementing pest control technology in the LDC's.

The current population trends in LDC's require significant

improvements in food production and distribution systems to avoid even greater maldistribution of nutritious food among the poor majority. The overall economic development of most LDC's is contingent upon a resiliant and self-reliant agriculture that is capable of assuming high risks while feeding the nation and increasing production of export crops. Governments have paid attention to export crop protection systems, but very little has been done for mixed crop farming systems. In the eyes of those accustomed to high technology, a seemingly small input in pest control can significantly increase food production. A prime example is the development of high yielding rice varieties for East and Southeast Asia post-World War II. Significant production increases were realized with relatively small capital input and incremental changes in agricultural technology. In so far as mixed crop farmers are by nature seeking ways to deal with high risk, cost effective technology such as ICP that promises to modify risk while increasing production should be taken very seriously.

It can be further argued that even small increases in productivity have a particularly significant effect on feeding the poor majority in LDC's. In economic terms it is argued that the income elasticity of demand for food by relatively poor farmers and farm labor in LDC's is often near unity - each additional unit produced is consumed directly. Meanwhile, production gains of well fed farmers in developed countries may be consumed by installing air conditioned cabs on six-bottom plow tractors or 18-foot combines and by food programs for the indigent, either domestically or in LDC's. The latter is not the answer to malnutrition in LDC's. More productive mixed crop farming among the poor majority is clearly a more direct solution and probably more efficient.

It is axiomatic that traditional agriculture has to undergo technical transformation if it is to do its part in feeding the world's expanding populations. There are many potential crop protection problems that will require solution by agricultural scientists. Historically, many of these problems were solved empirically through cultural practices by the farmer or more recently by the extensive use of pesticides. However, the contemporary philosophy for the solution to pest problems is based on a holistic approach resulting in the development of ecologically sound pest management systems which utilize all available tactics such as crop

resistance to pests, biological controls, cultural controls, and the judicious use of pesticides.

The use of crop protection technology in developing countries exists in uneven patterns with gross differences between countries of the same geographic region and significant differences between farming systems within country. To impose modern agricultural technology, particularly easily used pesticides, on traditional farming systems without first learning from existing traditional methods of pest control is to invite biological and economic problems. Therefore, it is necessary to evaluate the traditional farming system for what it is, determine what is essential, to be preserved or augmented, and finally make changes in a rational manner consonant with the environment. Furthermore, in addition to the ecological environment, the social customs, national and local politics, as well the economy all interact to establish the magnitude of a specific pest problem and further complicate efforts toward solution. Properly approached, however, the mixed crop farmer should find ICP methods to be natural allies.

Potential Significance of Integrated Crop Protection

Even though there are difficulties in establishing an ecological approach to pest control it has been demonstrated that integrated crop protection can be implemented in developing countries. Brader (1979) has cited examples of successful integrated crop protection applied to both annual and perennial crops in small and estate farming systems. Integrated crop protection, when placed within the total farming system framework, has to be advantageous both economically and environmentally.

Economic advantages of ICP for the farmers of the LDC's are just as important as those advantages already established for the farmer of developing countries. Control of pre-harvest pests will result in increased crop yields or in the stabilization of yields through reducing the risks associated with pest problems. Without a stable production system people are unlikely to commit investments in agriculture that require more than one growing season for amortization. In addition, optimization of control strategies based on natural controls provides the farmer with advantageous cost/benefit ratios in crop production.

Improved crop protection technology can improve the nutrition of the

people and the general well being of the population. Improved nutrition may result from protection technology that permits growing of more nutritious crops, the culture of which is restricted by a severe pest constraint, e.g. nematodes as pests of tomatoes. Development of new vegetable varieties that are resistant to pest attack presents a potentially useful means to upgrade nutrition, a means not yet fully exploited in developing countries. Improved nutrition is reflected in improved general health and as a consequence increased resistance to microbial diseases. As a result, a more productive society may be expected.

Integrated crop protection practices require fewer cash inputs at the farm level and thus encourages adoption of the technology across geographic regions. Integrated crop protection based on biological control has been more successful when designed for a specific region, yet there is a commonality in the tactic that cuts across regions with similar agroecosystems. Development of resistant cultivars and cultural control practices are generally more transferable. To a degree success in one region should encourage and breed success in other regions.

ICP research that results in the solution of pest problems for small mixed crop farmers will also yield a "spill over" effect. Successful solution to the problems of small farmers will also offer the same solutions to the larger farmers of a region. This is particularly true of strategies that are dependent on a high degree of public sector effort, with individual farmer contributions little beyond that which is normal for crop production. Examples of such tactics are biological, genetic methods of control, and breeding of resistant cultivars (Smith, 1979).

In general, integrated crop protection technology should have little or no deleterious effects on the environment. Certain cultural controls such as increased cultivation of weeds may bring about adverse effects, e.g. cultivation may increase erosion problems. In this case a potential solution may be the incorporation of herbicides into a "no till" weed control program, thus averting loss of soil due to wind and/or rain. Judicious use of pesticides in integrated crop protection programs will have less adverse effect on the environment than pest control based on extreme use of agricultural chemicals.

In the foregoing discussion we have been concerned with the small farmer and his farming system involving food crops. Not to be overlooked is the importance of cash crops, such as tea, coffee, tobacco, as well as surplus food crops. Cash crops, some of which are perennial, are important to the well being of the farmer and his family. Many times cash crops provide the farmer his only "real income", which influences his standard of living, health practices, home construction and adornment, animal ownership, food storage capability, production potential, communications, social participation and attitudes. Also, income from these crops often provide the cash flow necessary to purchase agricultural inputs such as seed, fertilizer, and to a lesser extent pesticides.

However, various cash crops often add another degree of complexity to the farming system and crop protection tactics. For example, fertilizer is typically used on coffee but not on the intercrops of the system. In response to the additional nitrogen, maize, taro or other intercrops may produce plant growth more favorable for insect attack. Thus, crop protection practices will need to be changed accordingly.

Integrated crop protection concepts apply equally well to the cash crops, whether or not food crops. Inclusion of cash crops in the ICP research program is mandated by their overall importance to the farmer's cropping system as well as his well being.

INTEGRATED CROP PROTECTION AS RELATED TO FARMING SYSTEMS RESEARCH

Limiting Factors of Agricultural Practices

Agriculturists world wide must successfully integrate physical, biological, economic, and sociologic components into a systems approach of management (Duckham and Masefield, 1970). They have suggested five main types of factors limiting the possible occurrence of different types of agricultural practices found in any actual farm system.

Ecological factors determine the different types of production which are possible and which species can be cultivated under the existing climatic, soil and biological conditions, including species interactions within a specific single systems.

Infrastructural features concerning such things as land tenure, supplies of off-farm inputs such as water, power, expertise, advice, and material inputs further restrict the choice of combinations which can arise from ecologically suitable situations.

External economic constraints will profoundly influence the choice of attractive possibilities through such factors as location, communications, marketing systems, credit, subsidies and a whole host of features that affect the attractiveness of different systems of farming.

Internal operational factors such as farm size, labor force, and fixed improvements are also determinants.

Personal acceptance of an adopted system can have some influence in those types of agriculture where a range of possibilities allows personal choices to be made.

Within the structure of successive limitations of this type, development paths can be observed for different major types of ecological situations.

Most traditional agricultural research has tended to address isolated variables within the total management system, leaving the decision and applications of the results to the individual farmer operating within the framework suggested above. In the past, quality agricultural research has been conducted with an awareness of the production environment in which the

results were to be applied, while the formal concept of applying agricultural research to the overall farming system is relatively new, and with much of the methodology to be yet worked out. It is essential that farming systems should be evaluated rather than an evaluation of a single technological innovation in the abstract (NRC, 1977).

Multiple Cropping Systems

Multiple cropping for food production is in wide spread use by farmers in the warmer parts of the world and at all levels of agricultural technology and is one type of cropping system. Multiple cropping can be partitioned into various cropping patterns. One of the two major subdivisions is sequential cropping where two or more crops are grown in sequence on the same field per year. The succeeding crop is planted after the preceding crop has been harvested and the only crop intensification is in a time dimension. In this system there is not intercrop competition and management is for only one crop at a time within the same field. Sequential cropping may take the form of growing two crops a year, three crops a year in sequence, or growing four crops per year in sequence. Ratoon cropping is the cultivation of crop regrowth after harvest, but not necessarily for grain, e.g. sugarcane.

The second major subdivision of multiple cropping is that of intercropping. Intercropping is the growing of two or more crops simultaneously in the same field. Crop intensification is in both time and space dimension. There is intercrop competition during all or part of the period of growth and farmers manage more than one crop at the same time and in the same field. Intercropping may be subdivided into mixed intercropping in which two or more crops are grown simultaneously in strips which allow for independent cultivation but the strips are narrow enough that the crops interact agronomically, relay intercropping where two or more crops are grown simultaneously during only part of the growing cycle for each and where a second crop is planted after the first crop has reached its productive stage of growth but prior to the stage which it may be harvested.

The complexity (type) of the multicropping practices influences the

other biological entities of the farming system. Qualitative differences in pests or beneficial species, as well as differences in the abundance of species are observed. Manipulation of the multicrop farming system may significantly alter the economic balance in a positive or negative way with regards to the farming enterprise.

More than ninety percent of all tropical farms are less than five hectares in size. In Asia averages are often less than three hectares, as in the Philippines, or between one and two hectares as in Bangladesh. These are considered small farmers of the tropics. Poor crop protection, poor soil structure and low fertility, poor seed, and water shortages all limit the capacity of the small farmer of the tropics and sub-tropics to produce food.

With such multiple limitations, each a significant problem, agricultural assistance programs have tended to concentrate their efforts on the single factors which appear to be most crucial to production. Advances from these efforts, e.g. high yielding varieties of key grain crops such as rice have helped developing countries keep food production in step with rapidly expanding demands due to population increases. So far these production increases have come from the most favored farming areas (Harwood, 1979) where constraints are least influential on yields. However, the small farmers have not benefited from the transfer of the new technologies and because of the continuing need for additional food the small farmer contribution to productivity, as well as his general well being, has been the focus of our planning.

In addition, traditional agricultural development programs have often been aimed at a single commodity (Harwood, 1979). The small farmer more often than not finds such programs irrelevant or unacceptable because they are not useful in his typically varied cropping practices characteristic of the multiple cropping system. For this reason research planning efforts should be based on the agricultural systems actually used by small farmers in tropical areas.

Farming Systems Research

The quest for an efficient way of developing more relevant strategies for small farms is by determining what the "consumers" want. The farming systems research (FSR) approach provides a link between the small farmer

("consumer") to the research institution and the funding agency, thus counter-balancing the conventional experiment station research approach. It provides the farmers with a means of communicating their needs to both researchers and funding agencies (Gilbert et al., 1980).

Farming systems research has the following characteristics (Gilbert et al., 1980):

(1) The farming systems research approach views the farm, or production unit, and the rural household or consumption unit—which in the case of small farmers are often synonymous--in a comprehensive manner.

(2) The choice of priorities for research reflects a holistic perspective.

(3) In undertaking the research program, research on a sub-system can be considered as part of the FSR process if the connections with other sub-systems are recognized and taken into account in the research on the sub-system under consideration. (An example of a sub-system is integrated crop protection.)

(4) The results of the research are evaluated not only in terms of the sub-system, or sub-systems under consideration, but also with respect to the farming system as a whole.

An increase in the overall productivity of the farming system within the context of the entire range of private and societal goals is the ultimate aim of the FSR approach (Gilbert et al., 1980). Such an analysis recognizes the interdependencies and interrelationships within the natural and human environment in which the farming system is operated.

The farming system is the result of a complex interaction among a number of interdependencies and interrelationships within the natural and human environment at the center of which is the farming household. Norman (1976) divides the total environment in which the farming household operates into two parts: technical element (environment) and the human element.

As already pointed out earlier, the types of livestock and crop enterprises will be determined by the ecological conditions (technical) that delineates what the potential farming system can be. The technical element has received the greatest attention and in some cases improvements

in the potential of the farming systems has been increased. The technical element includes two factors: physical and biological (the latter embracing integrated crop protection).

The farming system that actually evolves, however, is a subset of what is potentially possible as defined by the technical element. The determinant that provides the sufficient condition for the presence of a particular system is the human element, characterized by two types of factors: exogenous and endogenous (Gilbert et al., 1980).

The exogenous factors which largely influence the farming systems in any given community are the social, economic and political institutions which are present in the area, largely outside of the control of the farming household, but directly influencing it. Community structures, norms, and beliefs, input supply systems and markets are examples of exogenous factors.

Endogenous factors are those over which the individual farming household has some degree of control. These are the four basic types of inputs mentioned earlier--land, labor, capital and management.

The farming system obviously is complex, which explains why some technology thought to be relevant has often not been adopted, or when it has, why the degree of adoption has varied widely. A lack of consideration of the human element in agricultural research has contributed to the lack of relevancy of many so-called "improved" technologies (Gilbert et al., 1980).

FSR recognizes that the farmer must be an integral part of the research process, and it also recognizes the value of the farmers experience as well as their traditional experimentation.

The Advantages of Integrated Crop Protection and Farming Systems Research

As already mentioned the agriculture research scientist needs to take advantage of the practices and experience of the farmer and his traditional practices; knowledge can be built using the established technology utilized by the farmers. The fact that farmers in many tropical regions of the world employ an intercropping system should not be considered as primitive, but explored further, and in the case of ICP, for the effects of intercropping on pest problems. Mixed cropping has been shown to be more profitable and to yield with a more dependable return than sole cropping. In addition, the same survey in Northern Nigeria indicated that intercropping was a more rational approach if they were faced with shortage of either land or labor (Norman, 1974).

FSR stresses the holistic approach; this implies taking everything into account, but in practice the comprehensiveness is limited by the state of development of methodology (Gilbert et al., 1980). ICP also stresses the holistic approach - to crop protection - and therefore is considered a sub-system of FSR (Norman, personal communication). ICP as a sub-system of FSR results in a farming system technology (FST) which considers not only the technical, but also the human element of the farming systems. ICP, as in the case of FSR, does not ignore the reductionist approach, i.e. the discipline or the commodity approaches. Effective programs of FSR require close linkage with the commodity and/or discipline oriented agricultural research. The effective ICP programs have similar requirements.

Farmers of developing countries have inherently and traditionally utilized integrated crop protection in their farming systems. Integrated Crop Protection is therefore in tune with traditional approaches with strong risk avoidance tendencies and the research results are more likely to be accepted by the small farmer community. The large, somewhat commercialized farm practices have gotten away from this approach and have not recently relied on practices such as cultural controls, etc. which were formerly employed by large farmers and still utilized by traditional

farmers for crop protection. Thus, research in ICP will result in a crop protection strategy which is more evolutionary in approach and therefore understood to be somewhat more valuable than the much more revolutionary type of technology, e.g. herbicides used for weed control which affects the employment of local labor, which has been shown to be quite problematic. In general, development strategists are now searching for, and promoting evolutionary approaches, and Integrated Crop Protection is consistent with this planning.

Research on ICP strategies takes into account those crops which are important in the multiple cropping systems as used in the developing countries. There is a decided advantage in the approach because it considers important crops which are nutritionally important, e.g. vegetables and fruits, which may play a secondary role if the crop protection research is based on a reductionist approach. ICP increases the potential for the expansion of these nutritionally important crops through appropriate crop protection strategies.

ICP is applicable in high and low income farm situations and the "spill over" effects of the research conducted on small farms to larger operations have already been pointed out. In addition, it compares favorably in regard to cost/benefits and relevancy to those tactics which may be developed under alternative approaches.

The judicious use of pesticides is one major advantage of ICP. The developed countries have relied heavily on the use of pesticides to bring about increased productivity and only recently has there been a wide scale impetus for the judicious use of pesticides through integrated management approaches. Reduction in the use of pesticides has been brought about by many factors such as resistance on the part of pests, development of new pests, toxicological and residue problems, economics, etc.

Little or no pesticides are used by farmers on crops in LDC's and therefore the farmers have not had the pesticide problems of developed countries. A major constraint to the use of agrichemicals in LDC's is the farmer's lack of capital inputs for purchase of pesticides and fertilizer and it is unlikely that the situation will change in the near future. Because ICP relies on multiple tactics, which in some cases may require minimal use of pesticides, the development of a crop protection strategy

will benefit the LDC farmer through a cost effective means by which pest control may be implemented. The means by which cost effectiveness in pest control practices can be put in place have already been discussed and will not be reiterated here. It should only be stated that ICP is a rational, ecologically and economically sound means by which pest organisms may be controlled.

Integrated crop protection research fills a niche not currently occupied by ongoing development projects, many of which deal only with reductionist approaches. ICP therefore offers an unique opportunity to research a severe agricultural problem through a farming systems approach. In addition, ICP necessitates the collaborative and interdisciplinary efforts to satisfactorily study the multiple technical and human factors involved in the management of pest problems extant in the developing countries or other agroecosystems.

REGIONS, COUNTRIES, AND CROPPING SYSTEMS

Because of the diversity of global agroecological zones, and the resulting diversity of crops in the tropics of the major geographic areas, we divided our attention between the Near East, Africa, Latin America, and Southeast Asia regions. Attempt was made to take into account differences in commodities grown, and cropping practices of the small farmers in each geographic region.

In describing priority countries of each of the regions we utilized the International Agricultural Development Service (IADS) documentation on "Agricultural Development Indicators" and the World Bank, "World Development Indicators" in determining the relative agricultural-economic status of one country as compared to another.

The criteria for our ranking Developing Countries were derived from a number of sources and compiled IADS. They are: (1) Least Developed (2) Most Serious Affected (3) Food Priority and (4) Food Priority Deficit Countries. In addition, we included GNP data for low middle income countries as well as a consideration of other statistics in less clearly defined instances.

We have identified the significant cropping systems in each of the countries targeted in the analysis described above. Data obtained by the Food and Agriculture Organization (FAO) and reported in the Supporting Papers: World Food and Nutrition Study, Vol. II, 1977, NRC, were used with IADS indicators to determine cropping systems important in each region.

The details of the study, analysis and results were presented in the Planning Study Interim Report, dated 15, March 1980.

As a result of the described procedures the countries of each region were ranked in a priority system and on this basis were selected for visit by study teams. The ranking indicated the regions and countries with the most significant food deficits as well as an indication of their state of economic development.

It is recognized that non-AID, medium income countries also need additional research on pest related production constraints and that these countries probably offer as great or greater opportunity than LDC's for significant collaborative research because of their better developed

research and administrative infrastructure. The inclusion of non-AID, and/or medium income countries in ICP research programs will be considered during Phase II of the Planning Program. Phase I was focused on analysis of the problems as they occur in the poorer nations.

After recognition of the priority countries was accomplished they were then related to cropping systems based on the predominant system for the particular region. This resulted in the collation by region, cropping system and countries as presented in Table 1.

A summary of study team findings is presented and the reader is directed to the Team Reports for each of the regions for the details concerning specific crop pests, controls, etc.

Of the four countries, Egypt, Sudan, Tunisia, and Tanzania, the site visit team agreed that Sudan offered the best opportunity for establishing a successful collaborative research program on ICP. In addition, the chance of successful implementation of an adapted ICP program is very high in the irrigated schemes. The major cropping system includes sorghum, groundnut, vegetables, and wheat in a cotton-base rotational system. Sudan has a high potential for agricultural production and an ICP program will definitely improve productivity. The facilities at Wad Madani are adequate and there are a good number of well trained collaborative counterparts who have enthusiasm and commitment to ICP philosophy.

Tunisia and Tanzania have sufficient needs and could benefit by an ICP research program. However, due to the lack of an adequate number of trained counterparts in crop protection, the team did not feel that it is possible to establish an ICP program at the present time. What is needed currently is a fully staffed multidisciplinary team to conduct research at the small farm level. A training component should also be included in such a program to insure successful implementation and continued research efforts.

In West Africa, only Cameroon was included for a team visit and the team visited IITA on return to the U. S. Cameroon is ecologically diverse and as a result the crops grown vary accordingly from humid tropics to semi arid areas of the Northern province.

In the West and Northwest Provinces of Cameroon maize is intercropped with groundnuts, beans, cassava, taro, yams, beans and/or coffee in similar

Table 1. GEOGRAPHIC REGION AND DOMINANT CEREAL CROP(S) BASE USED TO DESCRIBE CROPPING SYSTEMS OF THE COUNTRIES INDICATED

REGION	CROPPING SYSTEM	COUNTRIES (EXAMPLES)
Africa	Sorghum-Millet-Cotton/Groundnut Based	Mauritania, Mali, Niger, Senegal, Upper Volta, Sudan, Nigeria, Zambia, Chad
Africa	Maize-root crop Based	Kenya, Tanzania, Malawi, Cameroon, Berundi, Ghana, Guinea
Latin America	Maize Based	Costa Rica, Guatemala, Honduras, Colombia, Peru, Ecuador
South Asia	Rice Based	Sri Lanka, Bangladesh, Thailand, Indonesia, Philippines, Malaysia

plantings. In the Center South Province the predominant crops are groundnuts, maize, cassava, tannia and plantains. Root crops other than cassava and tannia are also included. In the North Province sorghum millet, groundnuts and cowpeas are grown on 80% of the tilled land. Vegetable crops are grown in conjunction with the crops of each system.

Cameroon, although ecologically diverse and a potential collaborating country, apparently lacks adequately trained counterparts to conduct the research in a CRSP project.

Because rice is the primary crop in Southeast Asia wherever water is available, rice-based cropping systems, with ICP emphasis on the rotational crops, must be the cropping system of choice. Although primary emphasis should be placed on the rainfed rice cropping systems, it will be necessary to consider irrigated rice cropping systems in some instances where pest problems are important constraints.

The rice based rotational crops are those in which production constraints due to pests are extreme. Moreover in Sri Lanka, Indonesia and the Philippines the pests of rotational crops have a basic commonality.

An ICP research program in Southeast Asia should not be restricted to rice alone because rice already received more research attention than any other crop or combination of food crops. Therefore, to extend crop production capabilities and yield stability in these countries, the rotational crops, e.g. vegetables, should receive more attention. On the other hand, consideration of some aspects of rice ICP will be required because rice is the principal commodity in the cropping systems of Southeast Asia.

In the event that the collaborative research program must be restricted to a single country, Sri Lanka offers the best choice because: (a) its climatic, edaphic, and topographic diversity within a small area permits research on a variety of rice based cropping systems, (b) its needs are greater than either Indonesia or the Philippines, (c) the government aggressively supports agricultural programs, and (d) other aspects of the total agricultural system are in place. Technology developed in Sri Lanka could be transferred to other countries via the IRRI outreach program or other mechanisms.

Generally throughout Latin America, crops can be separated by the

climatic zones in which they are grown: cotton, rice, plantain, sugar cane, cacao, coconut, citrus, mango, pineapple, peanut, sorghum, soybean, and cassava are found in the warm climates; beans, coffee, some vegetables and fruit trees, and plantain are found in the moderate climates; wheat, barley, potato, and vegetables are grown in the cool climates. Perennial crops are found principally in the warm-humid climatic zones while the annual crops are grown predominantly in the climatic zones with an adequate distribution of rainfall and with a dry period during which the crop can mature and be harvested. Corn and beans are the only crops that are grown commercially in diverse climatic conditions. In fact, corn was a major crop in all zones of all countries visited. Sorghum and some grain legumes (e.g. cowpeas) have been adapted to climatic zones low in precipitation. On the flatter lands in the valleys, highlands, and coastal plains, mechanized farms of large size dominate, and crops such as cotton and sugar cane are grown. On steeper slopes, perennial crops such as coffee predominate, but some corn and beans are also grown under weed-free conditions. This often leads to the erosion of valuable top soil. In the highlands that traditionally grow wheat, barley, corn, and potatoes, there is a displacement of these by vegetable crops near larger communities where a market exists.

The coastal area of Peru is somewhat unique, for though it is at sea level, it is cool and everything is raised under irrigation. Potato forms a major crop under that system, as do a variety of fruit trees, cotton, sugar cane, and rice. Many of these crops are grown in cooperatives, especially cotton, sugar cane, citrus, and rice, and as such are not really grown at the small farm level.

Many of the crops in all of the cropping systems discussed serve a double purpose, subsistence and cash.

Of those Latin American countries visited, the team recommended Peru as a primary collaborating country and Colombia in a secondary role in a CRSP.

It should be emphasized that the countries visited by the Study Teams were based on country and mission interest as a result of contact with each potential country. Final consideration for inclusion as potential collaborators shall be given to all of the countries indicated in our

original classification mode. Such consideration is reserved for Phase II of the Planning effort.

AGRICULTURAL PRODUCTION CONSTRAINTS

As previously described, the environment in which farming households operate can be divided into two components, the technical element and the human element.

Technical Element

The biological factors of the technical element are those which are dealt with in control of pests, while such variables as water, soil, temperature, solar radiation are categorized as physical factors of the technical element. The biological factors, in addition to others, act as constraints on pre- and post-harvest production of agricultural commodities.

Pests cause damage to their hosts in many ways, some of which are obvious to the casual observer, e.g. the wormy apple recently purchased at a roadside stand, or the backyard rose bush which has been severely defoliated by infection with mildew. However, pest damage and the losses sustained to agriculture may be much more subtle than the direct injury so easily noted by the consumer or the home gardener. In addition, the injury and subsequent loss may be very difficult to quantify, particularly in a complex farming system with the interactions of more than one pest with the crop. In the characteristic monoculture farming systems of the developed countries these problems are probably less complex than in the traditional intercropping system which many times involves cropping of more than one or two food crops, each with its own pest complex.

The indirect effect of insects acting as vectors of viruses, which cause severe diseases in food crops and which may result in practically total crop loss, is an example of a pest problem requiring a multidisciplinary approach for solution; the plant-insect-virus relationship emphasizes the multidisciplinary nature of crop protection problems.

Soil pests, unless controlled, continually damage the below ground parts of plants, some of which cause significant losses which may go almost completely unnoticed unless controlled experiments are conducted to assess

the damage. Other losses may become visible only at the time of harvest when the below ground crop, e.g. tubers and roots, are processed. Many times severe damage to the host may occur prior to occurrence of densities or incidence of the pests which are easily observed. Coincidence of unnoticed low pest densities (or incidence of disease) with a highly susceptible physiological state of the host plant may result in significant damage.

Key Pre-Harvest Pests

Four major pest groups, insects, pathogens, nematodes and weeds, cause severe loss of production in farming systems. Vertebrate animals are also responsible for considerable losses. Diseases and insects present a serious problem because they destroy not only the plant growing tissue, but many times they also attack the edible and reproductive parts, thus completely destroying a potentially productive harvest. Nematodes are known to be serious pests in some parts of the developing world, but in many tropical regions the full impact of these pests on crop production has not been determined. Presumably they are more severe pests in the tropics than in temperate environments.

Weeds are cosmopolitan and serious pests of agricultural production throughout the tropics and are judged by many as the most serious threat to productivity when not kept under reasonable control.

Integrated crop protection is concerned with the key pest problems of farming systems. Key pests are those which are perennial and cause damage above the economic injury level in the absence of control and therefore they are of high priority when considering crop protection strategies. Listed below are some key pests which have been identified from CRSP Planning Study Team reports and the State of the Art documentation. Many of the key pests are important production constraints on intercropped or rotational food crops of the farming system. They cause significant losses of these crops and are considered to be serious pests to overall food crop production. It should be understood that there are other potential key pests, i.e. species not included here that may, under some circumstances be regarded as key pests.

We have identified some examples of key pests of commodities grown in the cropping systems indicated above, i.e. the African sorghum-millet/cotton or groundnut based system, the African maize-root crop system, the maize based system of Latin America, and the rice based system of Asia (Table 2). It is recognized that there are not only pest species differences between regions but also a variety of crop difference when considering the intercropped or rotational crops grown in each of the cropping systems. However, the pests comprise species or genera which are important to all of the systems and which cause similar damage to their hosts, thus the stem borers form a significant group which is considered damaging to maize, rice and sorghum-millet production. Another example of commonality is in Heliothis armigera which is a serious insect pest of practically all major food crops as well as cotton. As a result of heavy pesticide applications on cotton a serious problem of resistance has developed in H. armigera as well as in other species of cutworms. In addition, these insecticide applications have created pest problems in crops succeeding cotton in the rotation scheme, or in those grown contiguous to cotton. Cotton production and pest control practices on that crop cannot be easily divorced from the pest problems of food crop production.

Table 2. EXAMPLES OF KEY PESTS
IDENTIFIED BY STUDY TEAM VISITS AND IN LITERATURE CITATIONS
DEMONSTRATING COMMONALITY OF PESTS IN
IMPORTANT TROPICAL CEREAL BASED CROPPING SYSTEMS

KEY PESTS	SORGHUM/MILLET-COTTON OR GROUNDNUT	MAIZE-ROOT CROP	MAIZE	RICE
INSECT/MITES				
Stemborers (*Chilo*, *Sesamia*, *Busseloa*)	+	+	+	+
Cutworms (*Heliothis*, *Prodenia*, *Spodoptera*)	+	+	+	+
Leafhoppers (*Nephotettix*, *Cicadulina*)		+	+	+
DISEASES				
Downy mildew (*Sclerospora*)	+	+	+	
Leaf blight (*Helminthosporium*)		+	+	+
Virus diseases (leafhopper vectored)		+	+	+
Virus diseases (Aphid and whitefly vectored)	+	+	+	+
Nematodes (Meloidogyne)	+	+	+	+
WEEDS				
Perennial grasses (*Imperata*, *Cynodon*)	+	+	+	+
Annual grasses (*Rottboellia*)			+	+
Annual dicots (*Amaranthus*)	+	+	+	+

The relationship of commonality between leafhopper species, although the species are geographically isolated, is based on their role as vectors of agents causing virus diseases in rice and maize. Virus diseases are serious production constraints in many farming systems and are not easily controlled. Furthermore, the fact that these insects feed on weeds (ex. Amaranthus spp., and some of the grasses) which may act as virus reservoirs is common to many virus disease transmission cycles and more firmly emphasizes the need for multidisciplinary research on weed and vector controls to reduce crop losses due to diseases. Aphis craccivora is a cosmopolitan key insect pest due to its mere abundance and feeding activities, but it too is an important insect capable of vectoring the virus causing rossette of groundnuts. Rossette is a disease problem of groundnuts throughout the plants' growing range. In addition, cowpea mosaic virus and eleven other plant viruses are transmitted by A. craccivora. Other aphids common to the tropics are important because of their efficiency in transmitting the casual viruses of plant diseases.

Some of the key fungal and bacterial pathogens identified are cosmopolitan in distribution and damage the same host species. Others of the same genera are found as key pathogens of different hosts but have a similar etiology and present very similar problems regarding control.

Weeds, and their interactions with pathogens and insects, are important key pests, but in addition they are a group of noxious plants constituting a major constraint to agricultural production through competition with food crops for one or more environmental factors such as light, water or nutrients. The fact that the same genera of weeds present problems throughout the tropics, and require significant farmer input for control, stresses the common problem to the small farmer of the tropics.

The root knot nematode and the root lesion nematodes are important pests of most tropical grown crops of the world and as research progresses their impact on agricultural production in LDC's will become better documented. Nematodes can cause strict limitations on the production of certain vegetable crops such as tomato.

From the above we can see a commonality between pests as well as between the crops of the farming systems. Many similarities exist which allow the implementation of integrated crop protection strategies based on

similar tactics but developed in different regions of the world.

Key insect pests of the maize, rice, or sorghum-millet based cropping systems include the stem borers of the genera Chilo, Sesamia, and Busseola, the cutworm and armyworms belonging in the genera Heliothis, Prodenia, and Spodoptera, and the leaf- and plant hoppers, as well as aphids, both of which are doubly damaging because of their role as plant virus vector species. Planthoppers of the genus Nilaparvata, and leafhoppers of the genera Nephotettix and Cicadulina, as well as the aphid, Aphis craccivora, are all important in this respect. The pyralid, Maruca testulalis, and the flower thrips Megalurothrips sjostedi are among the most important pests of cowpea, the latter frequently responsible for complete loss of the crop of West Africa. The green spider mite Mononychellus tonajoa and the cassava mealybug, Phenacoccus manihoti are considered as key pests of cassava. Both of the pests are recently introduced into Africa and have spread rapidly from the point of original infestation. Much concern has been voiced regarding these two organisms as a serious threat to cassava production.

The downy mildew diseases caused by fungal species of the genus Sclerospora and leaf blight diseases caused by Helminthosporium are key pests of maize, sorghum-millet, and rice production. Rice blast caused by Pyricularia oryzae can cause drastic reduction in the yields of rice.

Bacterial blights, wilts, and rots caused by the bacterial species of Pseudomonas, Xanthomonas, and Erwinia are key pests and can severely damage a variety of the plant species.

In addition there is a wide variety of viral and viral-like diseases which cause severe losses in the maize based cropping systems and in the rice based rotation system. Maize streak is vectored by insects Cicadulina spp.) and is a most serious disease of maize in Africa. A number of serious rice diseases (tungro, transitory yellowing, dwarf, and grassy stunt) of viral etiology are also spread by insect vectors (Nephotettix spp. and Nilaparvata spp.) and control of the diseases relies on suitable control of the vector species. Cassava mosaic is probably the most serious disease of this important root crop and the etiological agent can be vectored by white flies (Bemisia tabaci) or spread by the movement of diseased cutting. B. tabaci is also an important vector of viruses causing

tomato and bean (Phaseolus spp.) diseases. Many unidentified diseases of viral etiology undoubtedly cause serious crop losses and await assessment of their full impact on food production as well as their biology relation to host and vector species.

In general, cereals are not heavily infested by nematodes. However, maize, beans, groundnuts, vegetables, and root crops sustain high losses due to the attack of root knot nematodes of the genus Meloidogyne. It has been estimated that root knot nematodes cause a 13% loss of tropical agricultural production and in many cases nematodes are a limiting factor in agricultural production. As in the case of unidentified diseases caused by viruses, many parasitic nematode infestations have gone undetected, and this group of plant parasites may be responsible for greater losses than currently realized. Of the nematodes, the root knot nematode (Meloidogyne sp.) is most important.

Annual and perennial weeds as well as parasitic weed species such as Striga are key pests in the small farmer agricultural enterprise. Losses can vary greatly due to cropping practices, weed species and density, climate, irrigation, and control technology.

Of major importance to rice, maize, sorghum-millet production are species of perennial grasses, Imperata cylendrica, Cynodon dactylon, and species of annual grasses in the genus Echinochloa. Rottboellia exaltata is a serious annual grass problem in some areas of Southeast Asia and Latin America. The sedges, Cyperus sp., both annual and perennial, are also serious pests of cereal production in the tropics, as are the annual dicotyledons of the genus Amaranthus.

Vertebrate damage in agriculture involves a variety of crops and species of animals, particularly birds and rodents. Pre-harvest losses occur at planting and continue through the growing stage of the commodity and until harvested. Direct losses result from the feeding activities, but indirect damage is mechanical, the result being lodging of crop.

Damage resulting from birds is seasonal, and sporadic due to the mobility of the birds. In localized situations rodents may be a limiting factor of crop production; more often rodents unobtrusively remove a share of pre-harvest production (DWRC, 1978).

Without quantitative loss data it is difficult at best to assess the

relative importance of the described pest related production constraints. It should be reiterated that in many cases a true knowledge of the impact of pests on crops has not been obtained.

In addition, there are inherent difficulties in establishing the relative importance of pests. What is important as a pest over one wide geographic area may be replaced by some pest species on a more narrow geographic range. Thus, the listing of pests are groupings of organisms generally accepted as serious pests throughout the tropics.

Human Element

The human element within the context of the farming household environment is divided into two sets of factors: exogenous and endogenous. Factors such as politics, input supplies, and markets are exogenous. Factors which are endogenous are those over which the individual farming household has some degree of control. These are land, labor, capital, and management.

Of the exogenous factors, a number act as severe constraints on the production of the small farming unit. Agricultural policy with an emphasis on export crops results in many instances of price fixing as well as the government required fixed production of crops such as cotton.

The individual farmer cannot in some cases compete with imports because of fixed prices for his/her commodity on the local market. As an example, imported rice in Cameroon sells for less than that which is grown locally, thus affecting the farmers' incentive to produce rice. Similar examples of contraints on incentive exist in many of the developing countries.

Technical assistance to the farmer favors the export crops; salary structure for technologists is more favorable for those involved with export crops thus discouraging capable people from entering the disciplines concerned with crops other than those for export.

Additionally, other factors such as restricted input supply, lack of markets and cooperatives, lack of transportation and storage facilities, and foreign exchange problems may act as constraints to the production system of the small farmer.

Of the endogenous factors which act as production constraints the lack of adequate capital is one of the most important factors. The availability of capital resources either from the sale of cash crops, or from credit sources, directly impacts on the farmer's ability to put into place the technological developments which are available to him. Thus, crop protection using pesticides is not, in many instances, an available option. Similar problems involving capital resources and the implementation of agronomic practices such as the use of hybrid seed and fertilizer have been identified as severely limiting production.

Labor availability is another problem which influences the productivity of the farming household. The farmers of LDC's are many times faced with problems of under- or unemployment which affects pest control tactics such as weed control. Serious problems of labor shortages sometimes occur during peak periods of planting, cultivation, and/or harvest.

Acceptance of new technology, whether a farming operation such as crop protection or the use of new cultivars, or a variety of sociological reasons have acted as constraints to production. The acceptance of a new cultivar may be linked to the problem of capital resources even though the new cultivar (e.g. hybrid maize) seed is provided for the farmers use. For example, new high yielding maize varieties were not widely accepted by the farmers of Guatemala because of the required fertilizer inputs for production. Acceptance or rejection of a new crop or cultivar may be based on risk avoidance, color, taste, cooking quality or a host of other criteria which have no direct relationship to the beneficial attributes.

INTEGRATED CROP PROTECTION RESEARCH

Advantages of Collaborative Research Support Program (CRSP)

Developing countries used to be overly dependent upon imported, and often inappropriate, technology. It has been stressed that new R & D projects should be conceived, designed, and executed by scientists of the more developing country(ies).

A Collaborative Research Support Program for the conduct of agriculture meets these philosophical demands and will in the long run provide appropriate means for increased food production through the concept, design, and implementation of research on food crops. In addition, the training of agricultural research scientists in connection with the ICP-CRSP will alleviate the serious shortage of trained personnel experienced by some of the LDC's.

The CRSP research mode is unique because it promotes a joint interdisciplinary research activity on the part of a reasonable number of interested scientists in U. S. institutions through the creation and management of a programmed and coordinated research effort over the extended period of time required to establish a program of integrated crop protection. Crop protection problems in developing countries require a sustained research effort over a long period of time, at the minimum five years and undoubtedly much longer.

Research on the complex crop protection problems will be best designed by a group of interested U. S. institutions in collaboration with the scientists of developing countries and international centers. As a group they have the available multidisciplinary expertise which can best accomplish the required research effort. Crop protection viewed in the holistic sense cannot be as effectively dealt with as a short term commitment under an USAID contractual arrangement with single institutions.

The unique nature of CRSP-ICP research utilizing a holistic, and therefore interdisciplinary approach, is a feature which is not inherent in centrally funded or other USAID sponsored research. Similarly, much of the ongoing research at international centers, including farming systems research, is commodity or discipline oriented while national commodity

programs are limited to crop improvement programs with little or no effort on pest control. The proposed ICP-CRSP offers a more comprehensive research program based on farming systems and should result in management strategies which will significantly benefit the small farmers of LDC's.

Each partner of the interdisciplinary effort stands to benefit from the relationship through translation of ideas and implementation of research results in the solution of major problems. The minimum of interdisciplinary action of the past can be overcome if a collaborative research effort is put in place. U. S. institutions will benefit from a CRSP mode through the discovery of new interdisciplinary technology, some of which may be applicable to U. S. agriculture. U. S. agriculture research seeks new management systems, whether in pest control or in a more general application in farming systems. Much is to be learned from understanding and modifying traditional farming systems, some of which may benefit the small farmers of the U. S.

In addition, there are other advantages to the CRSP mode. One in particular is the comprehensive nature of the CRSP undertaking. Research in integrated crop protection can not be confined to a single multiple croppirg system in a single ecological situation, but will have to involve study of varied multiple cropping systems for food crops, many times dealing with the same key pests, but under differing geographic, ecological and population parameters. Research results obtained in one ecological area can be utilized in developing management strategies for similar pests in other agroecosystems. Therefore, much improved management programs will be the ultimate outcome. The CRSP mode using farming systems research approaches, i.e. evaluation of promising tactics under small farm conditions and farmer testing of tactics, should produce results, in a form which will be clear and immediately compatible with the form in which information is needed in outreach programs. The CRSP approach also increases the potential for exchange of biological materials, scientific information and the development of strong interdisciplinary relationships among scientists of developing countries in different geographic regions.

A CRSP will be implemented only if involved U. S. institutions can and are willing to make a long term commitment of personnel and matching funds as required under Title XII CRSP arrangments. The matching of funds on the

part of the U. S. institutions demonstrates genuine interest and potential mutual benefits in a long range collaborative effort in the research program.

The Collaborative Research Support Program will alleviate some of the serious shortages of trained scientists experienced by the LDC's, and, at the same time provide means for increased food production through the concept, design, and implementation of agricultural research. The assistance of a group of U. S. institutions and scientists in the program provides the "on the job" training so desperately needed by the young and/or otherwise inexperienced scientists of developing countries. Trained personnel without practical research experience need the added advantage of guidance from experienced, qualified senior scientists. One contemplated outcome of the program is a cadre of well trained agricultural scientists with the development of a "crop protection response capability".

Institution Participation and Linkages

U. S. Institution Interest in Participation -

There are adequate numbers of scientific personnel working on integrated pest management and affiliated with eligible Title XII institutions to undertake and implement a collaborative program in integrated crop protection. Due to the breadth of problems embraced in such a program it is envisioned that a group of institutions would form the U. S. input into an ICP project, as in the case with the other ongoing Collaborative Research Support Programs. Already functioning is a consortium of nine institutions, the Consortium for International Crop Protection (CICP), which is involved in international programs, and which is funded through USAID. The institutions involved are the University of California, Oregon State University, University of Hawaii, Texas A & M University, University of Florida, University of Miami, North Carolina State University, Cornell University and the University of Minnesota. The consortium is incorporated and may include other member institutions as a part of the corporate body. CICP has indicated a strong interest in the ongoing planning activity. The corporation has brought together some of the institutions with ongoing programs in integrated pest management, and it is assumed that more than a few of the nine would be interested in participation in an ICP project(s) in developing countries.

In addition, there are other interested universities such as Illinois, Kansas State, Michigan State, Purdue, Pennsylvania State, Ohio State, Oklahoma State and Wisconsin, to name a few, with strong programs in integrated crop protection and demonstrated willingness and participation in international programs as well as participation in IPM programs at the national level.

Contacts have been made with individual scientists at various U. S. institutions and strong interest in a CRSP-ICP program has been indicated on an individual scientist basis.

There are no foreseeable problems in developing U. S. institutional support for a program in ICP nor would there be significant problems in acquiring the needed scientific expertise to conduct a viable program.

L. D. C. Interest in Collaborative Participation -

It is apparent from ICP study team reports, and the reports of others, that in general the small farmer does not, and for a variety of reasons, use many modern technological practices in his/her farming system. There is a general awareness of integrated crop protection at the research and administrative levels in the LDC's. Furthermore, the study teams were impressed by the willingness of LDC's to participate in collaborative research on integrated crop protection. It was apparent from contacts made during the team visits that an ICP approach to solving pest problems is indeed a viable and acceptable approach. It is apparent that a lack of trained scientists with expertise to conduct the required ICP research is a shortcoming in the countries visited, and that situation is worse in some countries than others.

There is, however, a great deal of variation in the number of potential collaborators in the developing countries. Based on Study Team visits, Tanzania, even though interested and willing to receive assistance with crop protection problems, does not have the necessary number of counterpart scientists to conduct a productive ICP program, whereas in the case of Sudan, Indonesia, Sri Lanka, and Peru, for example, each has an adequate number of trained counterparts. Selection of the country(ies) to be involved with an ICP project should be based on the availability of counterpart personnel and non-AID, medium income countries may offer the advantage of having the necessary expertise to conduct the research needed. The presence of an outreach program should likewise be considered in the de-ision making process, but should not be used as a definitive criterion for inclusion.

In general, there appears to be a genuine interest on the part of the developing countries to expand their research efforts in integrated crop protection. Some of these countries have been identified and during Phase II Planning others will be identified according to their level of interest and capabilities as potential collaborators.

Potential Linkage -

The International Agricultural Research Centers (IARC's), through support of the Consultative Group on International Agricultural Research

(CGIAR), have made significant progress in developing dramatic increases in yields of cereal grains, many of the varieties carrying resistance factors to the ravages of pests. Programs supported by CGIAR now embrace the major food crops in most ecological zones and address the major problems of tropical agriculture. While the centers are still involved with improving varieties, some are becoming more involved with research on intergrated pest control.

Recent ICP Planning Team visits to IITA, ICRISAT, IRRI, CIAT, and CIP have identified potential linkages with these centers in the event that CRSP research mode is put in place in the countries of the ecological area encompassed by specific IARC research. A CRSP on integrated crop protection has the advantage of being able to use technological materials and the advice available through the individual center programs dealing with regional problems. ICP programs are more location specific and are more broadly spread with regard to specific locations than is possible with IARC programs yet ICP research requires the application of the knowledge base made available through the research programs of each of the centers.

As an example, the development of ICP technology is based on a thorough understanding of farming systems. Farming systems research at IRRI, IITA, and ICRISAT offer the opportunity to gain valuable research information on the traditional farming systems as well as those that are under current development. The programs do not include a well defined ICP-FSR approach. ICP research will add an additional dimension to farming systems research at IARC's. An integrated crop protection program benefiting small farmers deals mainly with farming systems of multiple crops and the development of a crop protection strategy requires the information available through collaboration with the IARC's.

Although it is not possible for CGIAR to respond to national research programs, the linkages that can be developed between the IARC's and national research institutes through international research networks is recognized as being of great importance. Through training activities, library and documentation facilities, organization of meetings and seminars as well as outreach programs, a direct linkage with potential CRSP's is of utmost importance to the success of these collaborative programs.

Ongoing and planned research through Collaborative Research Support

Programs offers potential linkages to specific commodities involved in the farming systems of developing countries. It was pointed out above that ICP will rely on the information and materials developed from research conducted in these programs. ICP can benefit substantially from cooperation with such projects because as is in the case of the INTSORMIL program on sorghum-millet, as well as the beans-cowpeas CRSP, there is a pest management research component dealing with resistant cultivars and biological control of pests. Presumably, a CRSP program concerned with groundnuts and/or a roots and tubers project will have similar crop protection components and a linkage to these projects is envisioned when they are in place. Discussion to date has resulted in anticipated cooperation and the development of complementarity between ICP-CRSP and the ongoing CRSP's.

An ICP-CRSP will have direct significance to the objectives of the INTSOIL program. The overall objective is to increase food production while conserving the natural soil resource base through improved soil management practices. In order to achieve potential yields through soil management practices requires management of pests; ICP as a part of the farming system offers the potential solution to these problems. Soil types have direct influence on the biology of soil invertebrate pests and weeds as well as the degradation of pesticides and the information obtained from the interdisciplinary research effort will have significance to the strategies developed in ICP.

Other USAID support projects offer potentially viable linkages with the planned ICP-CRSP and each can play a significant role in the development of integrated crop protection strategies. The UC/AID Pest Management and Related Environmental Protection Project, the Oregon State Weeds Control Systems Project and the North Carolina International Meloidogyne Project all have direct relatedness to the functioning of a CRSP program on integrated crop protection. Closely defined linkages are envisioned with each, particularly with the UC/AID project which is active in providing training and outreach programs in pest management through workshops, seminars, etc. in developing countries. An ICP-CRSP will add the necessary research dimension to the UC/AID pest management project to provide an effective management program. The other two programs can be of

great assistance with definitive background material on pest importance, distribution and control methodology in a number of developing countries as well as training through workshops, etc. which can benefit an ICP-CRSP program with regard to nematode and weed pests.

There are other USAID support programs in LDC's which have varying efforts on pest control and which may present opportunities for linkage with an ICP-CRSP. These programs are not designed as integrated crop protection programs and are a single component approach, such as plant breeding, to agricultural problems of the LDC's. An example of such a program which deals with pest management is the National Cereals Research and Extension (NCRE) Program (USAID 631-0013) in cooperation with the Republic of Cameroon. The NCRE project is designed to develop the institutional capacity to provide quality research on maize, rice, and sorghum-millet through training and the establishment of adequate physical plant and equipment to carry out a research program in Cameroon. The program is based on the development of suitable agronomic practices and varieties of maize, rice, and sorghum-millets. The suitable, or improved, varieties presumably will be selected for resistance to pests. The program relies on technical expertise of agronomists and plant breeders, but with no apparent input from crop protection specialists.

Vertebrate animals constitute a serious constraint to the production of cereals in the tropics. USAID has funded a research program at the Denver Wildlife Research Center (DWRC), U. S. Fish and Wildlife Service, to develop means of controlling vertebrate depradations to agricultural crops. The overall objective is to increase the available food supply in LDC's and to reduce the risks of severe losses to these pests. The ultimate goal is to develop safe, effective, and economical means of control methods suitable for the small farmer. Because of the nature of vertebrate pest problems, i.e. localized and/or seasonal, sporadic nature of the problem, and due to the mobility of birds, a program on integrated crop protection will rely heavily on a cooperative linkage with DWRC for input regarding vertebrate control.

Approach to Implementation of Integrated Crop Protection Research

As defined, integrated crop protection research is approached much in the same manner as farming systems research - the approach is "holistic" - therefore an all inclusive analysis of the system. ICP emphasizes the technical elements of the farming system, but at the same time it seriously considers the influences, as well as the reciprocal effects, of the technical research on the human element.

A means by which the individual problems, both technical and human, of the complex farming system may be best addressed, the solutions to which can be integrated into a successful implementation program, is required to provide a working framework for ICP research. The scheme employed in FSR (Gilbert et al., 1980), and which is similar to that suggested elsewhere for integrated crop protection research, involves a framework of four stages which delineate the research. They are as follows:

(1) The descriptive or diagnostic stage. In this initial stage the actual farming system is examined in the context of "total" environment as a means of identifying constraints faced by the farmer. Also considered is the flexibility of the system with regard to timing of planting, available resources, etc. An effort is made to understand the goals and motivations of farmers insofar as they may influence their efforts to improve the farming system.

(2) The design stage in which a range of tactics (cultural and biological controls, resistant cultivars, pesticides) are identified as relevant to deal with the constraints delineated in the descriptive stage.

(3) The testing stage in which a small number of promising tactics identified in the design stage are evaluated under farm conditions to determine their feasibility for inclusion in the development of an effective strategy which is suitable in the existing farm system. This stage should be a two stage process: initial trials with joint participation of the farm and

researchers and secondly, the farmer's testing totally under his control.

(4) The extension stage in which the strategies which have been identified through the design and testing stages are implemented.

It is suggested that this scheme be utilized in the development of collaborative projects dealing with integrated crop protection research.

In practice it is expected that overlap between stages will exist and that no clear boundaries between stages exist. Design studies for example may overlap with descriptive stages and they may also extend into the testing stages.

The described approach incorporates the farming family directly into the design and testing process and views the farmers as individuals as well as members of the community and society. It also recognizes the farmer as an integral part of the research and it provides a means by which multidisciplinary research teams can examine problems of the small farming system including the interrelationships between resources and enterprises.

The methodology as described is based on an appraisal of farming systems research (Gilbert et al., 1980). However, Glass and Thurston (1978) and Smith (1979) have suggested similar approaches to exploring crop protection problems and the transfer of modern technology into farming systems of the developing countries. We have suggested the approach as one which is compatible with the implementation of development programs in the LDC's and is capable of assisting the LDC farmers in a logical solution to pest problems.

RECOMMENDATIONS

The Grantee makes the following recommendations based on team visits, State of the Art, and advice from Advisory Committee as well as Phase I Assessment of the potential and significance of Integrated Crop Protection research and the potential benefits of a Title XII Collaborative Research Support Program for the conduct of an ICP research program.

1. That the Integrated Crop Protection Planning Program be continued with initiation of Phase II Planning Activities which constitutes the development of a CRSP Proposal:
   a. That research programs should be established in each of the following regions: Africa, Latin America and Southeast Asia,
   b. That priority research be conducted on the following cereal based cropping systems:
      (1) African sorghum/millet-cotton or groundnut system
      (2) African maize-root crop system
      (3) Latin American maize system
      (4) Asian rice system

2. That the following countries, as well as others which were ranked according to priority (see Interim Report), be considered as potential primary and secondary collaborating countries:

Region	Primary	Secondary
Africa	Sudan	Tunisia, Cameroon
Latin America	Peru	Colombia
Southeast Asia	Sri Lanka	Indonesia

The recommended countries are based on Study Team visits and no intent is made to discriminate against other LDC's. Final consideration of potential countries will be made in Phase II Planning.

3. That a Title XII Collaborative Research Support Program be adopted by USAID/DS/AGR for an Integrated Crop Protection research program on small farmer food (and related cash) crops.

4. That linkages be initiated between CRSP-ICP collaborators and International Agricultural Research Centers in order to assist and facilitate training of nationals and to make available the IARC's knowledge base and resistant plant cultivars to the ICP research effort. Further, it is recommended that linkages with regional research centers such as CATIE be included at a similar secondary level of participation in the research program.

OBJECTIVES OF PHASE II

The Grantee will develop and recommend the ICP-CRSP research program to be undertaken, the identity of U. S. institutions to be involved, level and form of LDC, regional research center, and International Agriculture Research Center involvement, and the management structure/process to be utilized.

IMPLEMENTATION OF PHASE II

I. The Grantee, with concurrence of JRC/BIFAD/AID, will select a Steering Committee representing expertise in the area of Integrated Crop Protection and composed primarily of individuals from institutions which will not be participating directly in the research to be planned. The Steering Committee will participate in an advisory capacity and serve in peer review of solicited U. S. institutional research proposals. It is anticipated that the Steering Committee will assist the Grantee, AID and JRC/BIFAD until the submission and acceptance of the final report.

II. The Grantee will propose the specific LDC site(s) for the conduct of, and the magnitude and approach for ICP-CRSP research based on:

A. Consultation with AID and JRC/BIFAD staff

B. Interaction with key LDC personnel (Ministry of Agriculture, experiment station and universities) and International Agriculture Research Center (IARC) staff as well as USAID Mission officers through interdisciplinary team site visits

1. to develop final definition of overall scope and focus of total research effort including key pests, potential management tactics, etc.
2. to develop Letter of Intent to Collaborate with each potential country which shall include:

a. objectives of specific in-country research
b. justification
c. specific research location(s)
d. institutions and personnel
e. responsibilities of each partner

3. to define U. S. staffing required, long and short term scientists, for conduct of research.

III. With information developed from on-site visits and preliminary expressions of interest by LDC's, the Grantee will develop a research design into a Preliminary Integrated Crop Protection Technical Proposal. The proposal should include, but not limited to, the following:

A. State of the Art summary prepared in Phase I
B. A conceptual program of research based on
1. identity of farming systems and production constraints (key pests)
2. interaction with other CRSP projects
3. interaction with IARC's
4. an indication of the probability of success
C. Tentative indication of funding levels

IV. The Grantee will solicit pre-proposals, after JRC-AID concurrence, as an indication of manifest interest in an ICP-CRSP, by sending the Preliminary Technical Proposal and preliminary indication of LDC interest, and using appropriate techniques for public notice, to all previously identified U. S. institutions and other interested agencies eligible to participate in CRSP research programs. The pre-proposals shall include (1) the executive agency within the institution and potential principle investigator(s), (2) portion of the CRSP of interest to the institution, (3) justification for such interest, (4) potential participants, (5) complementarity with domestic programs. A reasonable deadline date for submission of U. S. pre-proposals indicating manifest interest will be established, (6) particular interest or experience with one or

more potentially involved LDC's. Copies of the Preliminary Technical Proposal with letter of request for comment will be forwarded to those AID Missions and countries having expressed interest to collaborate.

V. The Grantee will solicit specific research proposals, transmitting copies of study team reports on countries visited, State of the Art document, Phase I Assessment document, Letters of Intent from LDC's, directions for preparation of proposals, requests for budget estimates, and indication of reasonable closing date for receipt of final proposals, to all eligible institutions indicating a manifest interest in program participation.

VI. The above described Steering Committee shall review submitted proposals and select the strongest participants for recommendation to JRC and AID. The evaluation committee will review each proposal for strengths and weaknesses as well as relevancy to the alleviation of specific LDC crop production constraints. Each submitted project shall be ranked on the basis of scientific merit and relevancy to problem solution. A critique of each proposal shall be made available to each institution upon written request.

VII. The Grantee, with the assistance of the Steering Committee and JRC and AID, will delimit the number of projects and participating U. S. institutions to a level consistent with budgetary constraints, available primary host country work sites, and compatibility of LDC/U. S. institution interests.

VIII. Following JRC and AID approval of the draft CRSP plan, regional workshops, meetings, or conferences will be held in LDC settings whereby the specific proposals by the U. S. institutions can be discussed in detail with potential LDC collaborators and program details developed which are mutually acceptable to AID, JRC, the LDC(s) involved, and the U. S. institutions(s).

IX. The Grantee will develop a final detailed plan for the collaborative research program to be submitted to JRC/BIFAD and AID. The plan will describe in detail the following:

- Background
- Rationale
- Goals
- Beneficiaries
- Strategy
- Program Inputs
  1. Financial
  2. Institutional (including worksites)
  3. Personnel
- Interactions between individual projects and program subentities
- Socioeconomic impact predictions

The Grantee will also propose a management process and Management Entity for the proposed ICP-CRSP which will define the functions and operational procedures of the management entity including staff, policy body, technical control body, external evaluation mechanism, financial and reporting arrangements. The proposed management entity and process will be determined by joint effort with the institutions selected to participate in the CRSP effort.

ADDITIONAL CONSIDERATIONS

The Grantee will, during the entire planning process, maintain close relationships with the JRC, making periodic reports to this committee. The Grantee will consider the apparent conflict between the need to prepare a collaborative program having a manageable number of principal institutions involved and the need to draw on potentially valuable contributions of a large number of individuals in less involved institutions. The Grantee will also consider, in the development of its recommendations, the desirability of substantive relationships between research which supports development assistance efforts and the technical assistance activities which are conducted in the related problem area.

The Grantee recognizes that the funding likely to be provided for ICP

research will be limited relative to the extent of the problem areas defined. A major concern in the Phase II planning process will continue to be careful selection of the problems to be addressed and of the research efforts to be applied to them. In the process, the long run interests of the U. S. universities, AID's overall program, and the need of LDC small farmers must be kept in proper perspective. Problems and approaches which are included in other CRSP programs, in other donor programs, in IARC efforts and which do not draw heavily on the unique strengths of an integrated crop protection methodology, should in general be excluded from efforts proposed in this planning exercise.

The Grantee will attach as appendixes to the final Activity Report:

1. Final ICP Collaborative Research Support Program Proposals
2. Copies of preliminary and detailed research project proposals submitted by potential participants
3. Minutes of all meetings leading to definitive action.

In addition to distribution of reports, mentioned above, three copies of all reports listed as a product of the planning process shall be submitted directly to the Documentation Coordinator, DS/DIU, Agency for International Development, Washington, D. C. 20523.

PROJECT STAFFING

The Grantee will assign one staff member full time to the planning effort required in Phase II to serve as planning program coordinator.

Staff will be obtained on a short-term basis to compose teams required for in-country visitation. These staff will be drawn from other universities, USDA and other organizations and to a lesser degree from grantee staff.

Through a sub-grant agreement, an 1890 land-grant institution, Alabama A & M, will be asked to continue to participate in the planning process and to furnish a portion of the short-term staffing needs of the project. The Grantee has had an excellent relationship with this institution during Phase I and they have provided significant input as members of the Phase I Advisory Committee and as contributors to the State of the Art document.

REQUEST FOR APPROVAL

Purdue University International Programs in Agriculture requests the Joint Research Committee, Board for International Food and Agricultural Development, and AID/DS/AGR consider acceptance of the Assessment Document and approval of the Recommendations and Proposals for Phase II Planning of a Title XII Collaborative Research Program on Integrated Crop Protection.

J. D. Paschke, Planning Coordinator

J. L. Collom, Associate Director
International Programs in Agriculture

LITERATURE CITED

Brader, L. 1979. Integrated pest control in the developing world. Ann. Rev. Entomol. 24:225-254.

Cramer, H. H. 1967. Plant protection and world crop production. Pflanzenschutz-Nachrichten. 20:1-524.

Duckham, A. N., and G. B. Masefield. 1970. Farming systems of the world. Chatto and Windus, London. 542 p.

Elias, D. J. (Ed.). 1978. Vertebrate damage control research in agriculture. Annual report. Denver Wildlife Research Center, U. S. Fish and Wildlife Service. 129 p.

Gilbert, E. H., D. W. Norman, and F. E. Winch. 1980. Farming systems research: a critical appraisal. In Draft. Prepared under AID grant "Alternative Rural Development Strategies", Office of Rural Development and Development Administration, AID, Washington, given to Michigan State University.

Glass, E. H. (Ed.) 1979. Pest management strategies in crop protection I. Summary report. Report to the Senate, Office of Technology Assessment. U. S. Govt. Printing Office.

Glass, E. H., and H. David Thurston. 1978. Traditional and modern crop protection in perspective. Bio Science. 28:109-114.

Harwood, Richard R. 1979. Small farm development: understanding and improving farming systems in the humid tropics. Westview Press, Boulder, Colorado. 160 p.

Levins, Richard, and Mark Wilson. 1980. Ecological theory and pest management. Ann. Rev. Entomol. 25:287-308.

Norman, D. W. 1974. The rationalization of a crop mixture strategy adopted by farmers under indigenous conditions: the example of Northern Nigeria. J. Development Studies, 11:3-21.

Norman, D. W. 1976. The social scientist in farming systems research. Paper presented at "Workshop on farming system research in Mali". Institut a Ecomie Rurale, Bamako, Mali. November, 1976.

N. R. C. 1977. Supporting papers: world food and nutrition study. Vol. II. p. 7-63.

Ruesink, W. G. 1976. Status of the systems approach to pest management.

Ann. Rev. Entomol. 21:27-44.

Smith, R. F. 1979. Transfer of North American crop protection technology to the Third World. p. 86-94. In Proc. Symposium "International Endeavors in Entomology, the Canadian Contribution". 1978. Entomol. Soc. Can. Ottawa.

World Bank. 1979. World development indicators. The World Bank. Washington, DC. 71 p.

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Appreciation is expressed to the members of the ICP Planning Program Advisory Committee for their helpful recommendations and suggestions made during 1979-80. Their able assistance has been essential and very beneficial to the Planning Program.

The Assistance of the Study Team consultants is also gratefully acknowledged. Objective recommendations for collaborative research in Integrated Crop Protection could not be made without their expertise and diligence in evaluation of potential countries for inclusion in the program.

Thanks also to Mrs. Patricia Porter who so ably assisted the program in many ways, particularly in making travel arrangements for the Advisory Committee and the Study Team members.

APPENDIX I

STUDY TEAM MEMBERS
AND
COUNTRIES VISITED

INTEGRATED CROP PROTECTION

STUDY TEAM MEMBERS AND COUNTRIES VISITED

Dr. Jack Drea - USDA - Paris, France Dr. T. T. Hebert - North Carolina State University Dr. Barbara Yates - Illinois Dr. J. D. Paschke - Purdue University	Cameroon Nigeria
Dr. George Abawi - Cornell University Dr. Gerald Wheelock - Alabama A & M University Dr. George A. Schaefers - Cornell University Dr. Larry Burrill - Oregon State University Dr. Stan Miller - Oregon State University	Egypt Sudan Tunisia Tanzania
Dr. W. G. Yendol - Pennsylvania State University Dr. R. M. Riedel - Ohio State University Dr. F. H. Tschirley - Michigan State University Dr. Mark Smith - DS/AGR/FCP	India Sri Lanka Indonesia Philippines
Dr. Michael Irwin - University of Illinois Dr. James McGrann - Texas A & M University Dr. Richard Stuckey - University of Kentucky Dr. G. F. Warren - Purdue University Dr. Delmar Broersma - Purdue University	Guatemala Costa Rica Colombia Peru

APPENDIX II

AGENDA AND MINUTES OF JULY 15-16, 1980 MEETING AT PURDUE UNIVERSITY

0800 - In depth analysis of Southeast Asian countries as potential collaborators in a CRSP. Identity of researchable problems, counterparts, and rationale for recommendations.

Dr. Yendol

0930 - In depth analysis of West African countries as potential collaborators in a CRSP. Identity of researchable problems, counterparts, and rationale for recommendations.

Dr. Hebert and Dr. Paschke

1030 - In depth analysis of East African countries as potential collaborators in a CRSP. Identity of researchable problems, counterparts, and rationale for recommendations.

Dr. Schaefers

1200 - Lunch

1300 - In depth analysis of Latin American countries as potential collaborators in a CRSP. Identity of researchable problems, counterparts, and rationale for recommendations.

Dr. Michael Irwin

1430 - Summary of recommendations to go forward to Joint Research Committee

Dr. J. Fulkerson
Dr. Woods Thomas

1700 - Adjourn

TENTATIVE

AGENDA ICP PLANNING PROGRAM

Review of Study Team Reports
and
Development of Recommendations
Regarding
Potential Countries for
Collaborative Research Support Programs

July 15-16, 1980

Purdue University

Entomology Hall Conference Room

July 15, 1980

0830 - Introductory Remarks

J. D. Paschke
Mark Smith

0900 - Report of the Latin America Study Team

Dr. G. F. Warren or Dr. D. Broersma
Brief discussion of findings and recommendations

1000 - Report of the East African Study Team

Dr. George Schaefers
Brief discussion of findings and recommendations

1100 - Report of the West African Study Team (Cameroon)

Dr. T. T. Hebert and Dr. B. Yates
Brief discussion of findings and recommendations

1200 - Lunch - John Purdue Room, Stone Hall (across State St. from Entomology Hall

1300 - Report of the Southeast Asia Study Team

Dr. W. G. Yendol
Brief discussion of findings and recommendations

1400 - Critical review of results of team reports, recommendations and discussions

Dr. R. F. Smith

1700 - Adjourn

July 16, 1980

MEETING FOR REVIEW OF ICP PLANNING PROGRAM
STUDY TEAM REPORTS
July 15-16, 1980
Purdue University, West Lafayette, Indiana

Present: Drs. Barbara Yates and Teddy Hebert, West African Team
Dr. George Schaefers, East African Team
Drs. William Yendol and Mark Smith, Southeast Asian Team
(Dr. Smith also representing USAID)
Drs. Michael Irwin (7/16 only) and G. F. Warren, Latin American Team
Dr. Ray F. Smith, Planning Program Advisory Committee Member
Drs. Woods Thomas and J. L. Collom, Purdue, IPIA
Dr. J. D. Paschke, Coordinator ICP Planning Program and Chairman

July 15 - 0830 hrs.

Meeting called to order by Chairman Paschke. Chairman introduced members and made comments regarding travel expenses, luncheon and dinner arrangements.

Chairman called on Dr. G. F. Warren in absence of Dr. Irwin to present preliminary remarks on Latin American (LA) Team visit.

Dr. Warren commented that the team had excellent USAID Mission support in countries visited.

Dr. Warren commented on the team visit to Central and South America. Also brought in the potential to link with CATIE, CIAT, and CIP for training and for research affiliation. Peru was ranked as the most likely as the country to be included in a CRSP. A number of reasons for the ranking including number of counterparts, agricultural needs, government and university philosophy regarding ICP and willingness to collaborate. Also mentioned some severe weed problems as production constraints in traditional agricultural systems. AID Mission supportive of ICP program if integrated into their programs. Slides were shown demonstrating severe weed problems of Latin America.

Dr. George Schaefers reported on team visit to Tanzania (Schaefers, Burrill and Miller) and subsequent visit to Egypt, Sudan, and Tunisia with Drs. Abawi and Wheelock. Discussed the situation in Tanzania, the

diversity in crops and areas of rainfall. Maize is number one crop along with beans, intense mixed cropping systems. Sorghum-millet replaces maize in dry areas. Very little crop protection. Not interested in ICP. Ministry of Agr. not very strong and poorly financed. Chance of success not very good. No collaborators of significance. The country has high agricultural productivity potential. Indicated serious pests of maize as borers, maize streak (virus), bean fly, green mite on cassava. Striga serious weed.

Egypt - Many well qualified crop protection people. One third of land in cotton production. Much AID support, PL 480 money, as well as FAO. Egypt does not need a CRSP-ICP program because the scientists are well aware of the concepts and there are the necessary personnel to do the work if and when approved by administration. Too much liaison between pesticide people and those people in the universities. Do not recommend Egypt for CRSP program in ICP.

Sudan - Varied ecology from dry north to humid tropics in south. Sudan biggest producer of groundnuts in Africa. Cotton is center of attention and all crops revolve around cotton production in a rotation system. Farmers have to plant cotton production in a rotation system. Farmers have to plant cotton. Growing vegetables is part of award system for good cotton production. Lots of talent in terms of interested crop protection people. "Package deal" of Ciba-Giegy, Shell for insecticides has caused havoc in pest problems in cotton - finally returning to more traditional approaches after white fly has practically ruined cotton production.

Tunisia - Olives most important crop for export. No research for small farmers; not much in the way of crop protection by small farmers. Very little talent. Crop protection in MOA as is crop production and extension. Essentially interested in pesticides for crop protection. IRRAT agriculture research group with 8-10 people in crop protection. Recognize need for cooperative research and are interested by administrators feel staff is already over extended. Tunisia badly needs additional trained people and therefore need considerable outside talent to take on collaborative program. Something could develop in Tunisia in future.

Drs. Hebert and Yates discussed visit to Cameroon and IITA, Ibadan,

Nigeria. In general, good attitude in Cameroon regarding cooperation and assistance to small farmers. Technical personnel capabilities weak. AID supported programs are additionally supported well by Cameroon government. Diverse ecology with cropping system designed for humid tropics to Sahel type environment with intergradation which offers good opportunity for ICP in different farming systems. One drawback is the fact that country is mainly French speaking, the other major drawback being the impression of a lack of trained scientists in the field. The latter may be a misconception and attempts are being made to substantiate or reject the belief. Dr. David Perkins, USAID Regional Food Crop Protection Program, acted as host and did an outstanding job of assisting team in their visit.

IITA - Short visit but team impressed with physical set up as well as training and research programs. A good institution to link with from both research and training aspects. Good basic research program to backstop applied work. A divergence of staff opinion regarding the possibilities of success for IPM(ICP) programs in the developing tropical countries. Not currently involved with multidisciplinary integrated crop protection.

Dr. Yendol reported on Southeast Asian team visit.

ICRISAT and India - AID Mission officer, Fletcher Riggs, discouraged any direct link with ICRISAT. In general, India is not currently viable for cooperative program. ICRISAT programs impressive and CRSP could link to their training programs.

Sri Lanka - team ably assisted by Dr. Tom Wilson. Government has positive attitude regarding collaborative effort. Dr. Yendol discussed specific research stations and cropping problems of Sri Lanka. Scientists have positive attitude regarding cooperation. Country needs assistance in research and training of researchers but has talent to work with.

Indonesia - Average farm size 0.5 hectare, major food crop rice, 2.3 million tons imported. Met with Dr. Ida Oko, Bogor (TRI). Have a number of agreements with other countries; Japanese, German, FAO, and IRRI with possibilities for IPM program through USAID. Brown plant hopper serious pest of rice. Indonesia considered one of the OPEC countries therefore not an AID country.

Recommend study on rice base (rainfed) cropping rotation systems for Sri Lanka and Indonesia.

Philippines - Visited the university and IRRI. Each should have linkage with CRSP from training standpoint. IRRI has pest management program. Good possibilities for cooperation with each group. Philippines is already in receipt of outside support so that Mission is overburdened.

Recommend collaboration with university and IRRI for training component of CRSP.

Dr. Ray Smith then reviewed the discussion which evolved during the day, and he made some significant observations concerning the planning process. Significant points are as follows:

Do not have great concern over lack of enthusiasm on the part of some countries and USAID Missions. Pick countries with strong positive response and don't spread program thin. A few successful demonstration programs of IPM concept is more important than spreading thinly to more countries.

Should have concern for other sponsored programs under FAO, bilateral programs of the U.K., Germany, etc. Enter into cooperation with other programs and IARC's. Design of program with the national program people - design based on their concepts of problems and solutions.

Cannot leave out cotton! Too much influence on other cropping systems to be ignored. Cotton is a food crop too.

Research and training of advanced students go hand in hand. Set up guidelines for how much research and training.

Some discussion of U. S. counterpart activity and length of time spent on overseas assignments. Conclusion was that it is dependent upon problem and the ecological situation of the area.

Recommend Sudan as highly desirable African country for collaboration program, with Jordan as a possibility for future contact in Mid-East.

In general, there is an interest in ICP projects which has developed over the past five years and countries and USAID have changed their attitudes regarding projects.

July 16 - 0830 hrs.

Meeting was reconvened by Chairman Paschke.

Discussion of Southeast Asia centered on Sri Lanka and Indonesia. Recommend ICP work with rice based rotation crops, stressed rainfed rice, but will need to include paddy rice too. Rotation crops include maize, soybean, groundnut, potatoes, pulses, sweet potatoes and vegetable crops. New expanded irrigated lands will allow expansion of farming programs. Pointed out that single crops, eg. rice, cannot meet the nutrition requirements of developing countries.

General discussion on farming systems and key pests. Generally agreed that a "key pest" concept changes with changing ecological parameters and that final decision will have to be made by collaborating incountry scientists and CRSP Phase II team.

Sri Lanka has talent in university and experiment stations to work as collaborators. Considered relationship with IRRI.

Sri Lanka 1st choice of place to work because of inputs by other donors and ongoing programs in Indonesia and Philippines. Linkage for training with U. of Philippines and IRRI strongly recommended.

Short discussion of inclusion of Cameroon - because of apparent lack of scientific talent should not be considered for primary role. French speaking country is drawback. Will attempt to find out more about available talent in Cameroon because the country in many other respects offers opportunity for CRSP success.

Latin America - Discussed countries - deleted Guatemala, needs great but no counterparts. ICTA poorly staffed with one Ph.D. Organized to info to farmer through extension. 4 million small farmers.

Costa Rica - Doesn't really need help - has funds from bilateral agreements. CATIE good, but lacks funds - farming systems program being pulled out. Potential for collaborative linkage arrangement. Bilateral monies from U.K. and Germany. Swedish in Costa Rica. Stable government. Attracting good plant protection people. Extension not good except coffee, parastatal arrangements.

Could link Latin American countries with CRSP and CATIE, thus covering Honduras, Guatemala, Costa Rica, Panama. CATIE big in training with link to University of Costa Rica - good possibility for link with training component of a CRSP.

Main crop in Latin America - corn-beans always intercropped. Corn

with other commodities including cash crops eg. coffee and/or vegetables. Highland wheat dominates in Guatemala mountains.

Colombia - Variable ecology - high mountains, coastal plains. Potential for collaborative effort - USAID Mission leaving - possibly to work in Colombia because of AID groundwork. Counterparts available with financial backing. Set up by David Scherer. Funds earmarked for Title XII collaboration. Extensive research organization (ICA) in Colombia. Approximately 137 BS, 145 MS, 39 Ph.D's working with Agriculture Research (1979) 42 BS, 24 MS, 2 Ph.D's Tech. transfer 222 BS, 17 Ms. ICA employees going down in number, salaries, etc.,a problem. Corn, beans, cassava, vegetables, root crops. Virus problems good research area. Need help.

Recommend limited program dealing with virus problems. Probably should follow up on Colombia.

CIAT - Where does Title XII fit with CIAT? Breeding program mission of center. Training budget cuts potential problem - (1) can work with Title XII - people could work at CIAT - through National Institutions. (2) circulate germ plasm through Title XII pest management program and national collaborators.

Peru - Baseline study discussed. Identified INIA and university as potential collaborators. INIA-USAID linkage dictates Title XII research to affiliate with INIA. Peru strong in ICP programs, primarily on cotton but also other crops. Scientific talent available. New government and policy to assist small farmer, assistance badly needed to solve food problems. AID attitude very good for putting a CRSP into place, very viable from country and ag scientists collaboration. Very good potential for Title XII and successful program. Small ruminant CRSP and Tropical Soils CRSP working with Peru.

Discussion of potential funding and number of countries which can logically be included as primary collaborative research sites. Concern voiced their program should not be spread too thin. Need to narrow program to the most likely for success.

Meeting adjourned for lunch.

Reconvened by Chairman 1330 hours.

Discussion of Sudan - Sudan is largest country in Africa and with a diverse ecology from semi-arid condition to those of the humid tropics.

Sudan is the potential granery of the Arab world. Sudan is a viable country for inclusion and it was agreed that it was best location in Africa in which to work as based on our background. Sudan has an adequate number of trained people with whom to collaborate. They also have an interest in ICP. Many acres are intended to be put under irrigation. There is available underground water sources. Sudan also gets water from Aswan high dam and there are many arable acres provided water becomes available.

The cotton based rotation crop system offers an important cropping system on which to concentrate. Sorghum-millet and vegetable production are the important rotation crops. Farmers required to grow cotton for which they receive assistance but they receive little assistance on the basic food crops. Humid tropic area offers potential to work on African maize.

Meeting adjourned 1600 hrs.