Background Document

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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

# STUDY ON CROP PROTECTION RESEARCH AT THE INTERNATIONAL AGRICULTURAL RESEARCH CENTRES

## PHASE I REPORT

A Consultant's Report to the TAC

by

Dr. David R. MacKenzie

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION ORGANIZATION OF THE UNITED NATIONS

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## Contents

# PREFACE

The Technical Advisory Committee (TAC) to the Consultative Group on International Agricultural Research (CGIAR) has commissioned this study of crop protection research activities at the International Agricultural Research Centres (IARCs). This is the first report of three covering a three-phased evaluation, analysis, and recommendation to the TAC.

The purpose of dividing the study into three phases was to accommodate other TAC planning activities and meetings while permitting broader input into the study from diverse sources.

The importance of crop protection research to the missions of the IARCs is enormous. The delicate balancing of priorities against limited resources and tremendous responsibilities is a difficult task. In spite of these constraints, the IARCs have made major research contributions in the area of crop protection and those contributions are appreciated globally.

This is an appropriate time for the Centres to reassess their accepted priorities given their current extensive activities in strategic planning, the recent emergence of strong National Research Programmes Systems (NARS) in agricultural research and the growing global concerns for the sustainability of the major agricultural production systems.

The research opportunites identified for crop protection must be judged against realistic assessments of the available theory, knowledge and the likelihood for practical applications to real world problems. This Phase I report will attempt this evaluation with the understanding that the judgments will be subjected to responses, corrections and restatements in a Phase II effort to better serve the best interest of science, the International Centres, their partners and their clients.

# STUDY ON CROP PROTECTION RESEARCH

## Phase I Report

### 1. Concepts in Crop Protection

The complexity of most biological systems has been a scientifically well-established fact for many decades. This appreciation has grown as a consequence of research that has repeatedly demonstrated the capacity of living organisms to respond to changing conditions and to new opportunities. This understanding has been applied in the development of solution to problems in production agriculture by recognizing that in many instances, a single tactic for a complex problem may prove to be inadequate.

This axiom has proven all too true for agricultural crop protection. Reliance on a single control factor, such as host plant resistance, chemical sprays or other singular activities underlies some of the major failings recorded for crop protection. The capacity for genetic variability within biotic agent species has been repeatedly demonstrated as a biological fact, and an economic reality.

Appendix I of this report elaborates some of the details in the historical development of crop protection in agriculture that have led to the present reliance on certain approaches to crop protection. In this section information is developed on the conceptual components of integrated crop protection along with some of the reasons why research on these topics is making major changes in research directions and programmatic emphasis.

Crop protection is made up of classes of activities that can be, for editorial purposes, divided into: mechanical; chemical; cultural; and biological.

Mechanical practices in crop protection are best exemplified by the cultivation of weeds, ploughing to bury crop residues that may harbour pest, and similar practices common to agriculture that are intended to reduce the amount or numbers of biotic agents.

Chemical protection practices are well-known to agriculture, especially the use of pesticides, which retard or kill biotic agents. Herbicides are commonly used in production agriculture to control weeds. Insecticides, fungicides, antibiotics and similar chemical substances are also used against targeted biotic agents. Fertilizers can also affect the susceptibility or resistance of a crop and in that vein, they also serve as la chemical protection practice by adjusting the quantity of fertilizer applied to the crop. Thus, chemical control may be direct or indirect and related to other crop management practices.

Cultural practices can also be used to protect crops from biotic agents. The timing of a planting, adjustments in plant spacing, and similar management practices can contribute significantly to the development and consequent impacts of biotic agents on a crop production systems.

Biological practices may also significantly affect crop protection and represent important pest management strategies for commercial agriculture. Included in this category are host plant resistance (including strategies to deploy genes for resistance), the use of biological control agents, and similar strategies.

The growing concern for the sustainability of agricultural production systems, the evidence for the excessive use of some pesticides, and the growing cost of crop production systems that often leave farmers with little or no profit, have caused reevaluation of how to mix and match the components of crop protection. These are, of course, all within the domaine of integrated crop management. Crop protection research should not be considered in isolation from crop management.

The concept of Low Input Sustainable Agriculture (LISA) is an important issue which is directly related to these considerations and concerns. The philosophical approach of LISA is to greatly reduce agriculture's dependency on chemicals by selecting those approaches that would yield a long-term, environmentally stable agricultural production system that would be sustained for future generations.

More traditional crop protection researchers have approached their responsibilities from a different direction which is, perhaps, best exemplified by Integrated Pest Management (IPM). The IPM strategy is to mix component activities for a more dependable crop protection system. The proper mix of components depends on biological and economic choices based on a thorough understanding of the dynamics of the system and the likelihood of future developments such as weather changes, pest movements and similar information.

IPM and LISA are philosophically at odds. Underlying the current debate is the question of how best to provide adequate and dependable crop protection. The significant difference in the two approaches is the degree of acceptance of agricultural chemicals in the final mix. There is no argument between the two groups over the desirability of integrating multiple practices. The issue is, when and how much chemical control to use.

This is a significant consideration for the International Agricultural Research Centres (IARCs) inasmuch as there must be a balance between scientific need and public acceptance of the research approach. Some Centres are said to reluctantly accept modest research funding from multi-national chemical companies, while others reject such support in any form whatsoever.

This dilemma is a critical issue for crop protection research in the IARCs. And it has for too long gone unaddressed. The primary dependence of the IARCs on host plant resistance, their modest contributions to research on cultural control methods, and the relative infancy of biological control research have further contributed to the present situation. Some Centre programmes have overcome these limitations out of necessity and/or by design.

Other crop protection problems have gone less than completely addressed. Meanwhile the global use of pesticides accelerates in

commercial rice production and without much attention by the IARCs to the alternatives to this pesticide use. For instance, the expense of pesticides in Latin America rice production are not typically 20% or more of the cost of production (R. Zeigler, personal communication).

Now is the time for the IARCs to thoroughly reevaluate this situation for all crops and begin to make new decisions on how best to approach crop protection research. The emergence of biological control as a bio-rational method for crop protection is exciting and definitely warrants research attention. A new understanding is also emerging on the value of cultural control methods representing more than just the old ways of agricultural production. The opportunities in biotechnology to genetically engineer more durable host plant resistance, or novel biological control agents are other new and exciting avenues in crop protection research. How will chemical control practices fit into this new crop protection matrix? How will the IARCs participate in designing these integrated crop protection systems?

This Phase I report explores these questions by looking at current activities and possible research opportunities that should be considered by individual IARCs through a reprioritization of efforts, reprogramming of projects, and a rethinking of current policies.

## 2. Study Plan

As mentioned previously, this study has been divided into three phases. Phase I offers preliminary evaluations of the ongoing research activities in crop protection by IARCs. These evaluations consider individual Centre mandates, current research activities, strategic planning proposals and some of the related policy issues.

The Phase II report will be derived from a workshop of agricultural scientists selected for their experience through past employment at one or more IARCs and by their scientific discipline in crop protection. The workshop will be convened for a two day period. It will use the highly structured group meeting methods of Andre Delbecq which he terms the Nominal Group Technique. This procedure will be used to extract multiple items in response to specific target questions regarding agricultural crop protection research at the IARCs. It will then build by consensus some recommendations for continuing and/or for changing various crop protection research programmes at the IARCs.

The Phase III of the study will also be a workshop. It will be an open form to allow responses by senior scientists currently employed as crop protection specialists at the IARCs. These discussions will be scientific and programmatic responses to the early recommendations presented in Phase I and Phase II of this study. The timetable calls for completion of Phase I by the end of April, 1989. Phase II will be completed by the end of July, 1989. Phase III will be completed by the end of September 1989. This three phase approach to this study should permit critical scientific evaluation balanced with realistic research expectations.

## 3. Sources of Inputs for Phase I

The evaluations and conclusions presented in this Phase I report have been derived from multiple sources. The CGIAR Library was of tremendous assistance in providing annual reports, strategic plans and related documents for review and analysis. The TAC Secretariat provided several important studies including the 1982 Crop Protection document prepared for TAC.

Direct involvement of the author in several recent planning programmes at IARCs has also contributed useful information. The author served as a CIMMYT External Programme Review panel member in 1988. On that assignment he travelled throughout Latin America, attended a CIMMYT Board of Trustees meeting and spent three weeks in August reviewing CIMMYT research programmes and preparing the panel's report. In April 1989, the author served as a CIAT panel member to review the rice research programme at that Centre. He also served as an author and consultant in crop protection to the 1985 Anderson study entitled: "Agricultural Research Centres: Achievements and Potentials".

Additional information was derived from direct interviews conducted with several IARC staff and ex-staff members. This was useful in gathering opinions and views on crop protection research at the various Centres. Other sources of information included the author's membership on the FAO Panel of Experts on Crop Protection: ongoing study of scientific reports of research in professional journals and more critical semi-technical treatments of IARC research (e.g. Bruce Jennings).

## 4. IARC Crop Protection Research Activities

Table 1 presents summary information on Centre research activities by commodity. Inspection of Table 1 shows the existence of some overlaps between "mandates" that are often further complicated by "geographic mandates". These accepted assignments of research responsibilities are said to contribute a portion of the problem of identifying and coordinating some research areas. This is particularly true for crop protection research.

Table 2 presents aggregate subjective evaluations on crop protection research activities by the components of crop protection. The crop protection components were adapted from the Anderson study (cited above) with the recognition that other divisions of crop protection research could have been made, but these seemed suitable for this study. The evaluations of the level of research activity for the crop groupings range on a scale of 0 to 4 (with 4 representing very high levels of research activity). When no information is presented in the table, that particular item is still under evaluation. These preliminary evaluations will be reviewed by the participants in the Phase II workshop and the final evaluations will be included in the Phase III report to TAC.

Many of the Centres have earned high marks for their significant contributions to the enhancement of host plant resistance through crop improvement. Several of the Centres have also given tremendous energies

to pest surveillance projects through mechanisms such as international nurseries, trap nurseries, and similar approaches. Some very significant activities in integrated pest management are also well recognized. Some progress in biological control is also noted.

The International Centres should be rightfully proud of the research contributions that they have made to crop protection through past efforts and ongoing research.

More difficult to evaluate are the indirect contributions of IARCs as partners with National Agricultural Research Systems (NARS). It can be asserted that the IARCs have not received justifiable recognitions for the many contributions they have made through their NARS partnerships. This is a recognized weakness of the information in Table 2 and this fact must be noted.

The overlapping responsibilities for crop protection research by IARCs can best be exemplified by selecting one commodity for more indepth study. For this purpose rice research, as conducted at the various Centres, will be used as the demonstration example.

Four international Centres presently assert their responsibilities for rice research. These Centres are: International Rice Research Institute (IRRI), International Centre for Tropical Agriculture (CIAT), the West African Rice Development Association (WARDA), and the International Institute for Tropical Agriculture (IITA). IITA's responsibilities will, over the next several years, be transferred to the WARDA programme (to be completed 1991) and IITA will collaborate with WARDA on resource and crop management research. IITA will also continue to collect and preserve genetic resources of rice in Africa and "conduct pre-breeding research on African rice".

The participating Centres have obviously overlapping interests and responsibilities. In some cases, coordination seems to be lacking as demonstrated in WARDA's "Strategic Plan: 1990-2000". The plan identifies on page 42 mostly "specific complementary activities" with IRRI and virtually "no direct activity" with CIAT or IITA. Given the announced disengagement of IITA from rice research, this may prove reasonable. However, given CIAT's Strategic Plan (now in draft form) which gives emphasis to high-rainfall savanna rice, IARC research in rice production and especially crop protection needs better inter-Centre coordination.

Rice has also been targeted by TAC as one of the commodities for reduced resource allocations in the future. The announced decision will likely contribute to increased levels of competition between the Centres for limited resources for rice research. This may especially impact crop protection research in rice, particularly when viewed as traditional research activities, vis-a-vis the need for new research initiatives in crop protection. This expected shortfall in resources is reflected in some of the IARC current strategic plans and has apparently contributed to programmatic decisions that will work to the disadvantage of crop protection research in rice.

The implications for overlapping responsibilities for commodities and/or geographic region is differentially significant for some areas of

IARC research. Efforts by some of the Centres to negotiate memoranda of agreement (e.g., CIMMYT and IITA, CIMMYT and ICARDA) have met with mixed success. At issue in resolving these understandings are the complexities of crop protection research which often get lost in the documents which tend to focus on general aspects of crop improvement and germplasm distribution. As noted above, this is only a portion of the domaine of crop protection research.

Another programmatic factor must be also considered. Discipline research in crop protection tends to become isolated and fragmented when it is a component of a plant breeding programme. "Upstream" research in areas such as biological control, cultural practices, and similar crop protection studies are said to have met with limited acceptance at the IARCs. In some cases such research efforts have faced open discouragement by the leadership in commodity research programmes. There is a big challenge for the Centres to redefine the dimensions of crop protection in light of new directions in research, an ever expanding horizon for technology and in to response to newly recognized environmental, economic and social responsibilities.

## 5. Identified Needs

An analysis of the ongoing crop protection research at the IARCs has identified areas of needs that should be addressed. This section identifies those needs in the following categories:

- research
- programmatic
- policy

The IARCs would benefit collectively by increasing research efforts in biological and cultural methods of crop protection. Particular research emphasis should be given to biological control and host plant resistance through increased efforts allocated especially through biotechnology. It is truly unfortunate that so little biological control research has been conducted that is appropriate to the tropics. The diversity of tropical organisms and the opportunities to assess attributes such as antagonism, competition and similar traits useful to biocontrol agents easily justifies significant increases in such research efforts.

Major portions of this research will be truly "ground breaking" inasmuch as new knowledge will be needed to develop viable commercial practices. This task would seem to be an appropriate responsibility for the IARCs. Many of the Centres profess throughout their strategic plans a desire to move their research efforts "upstream", to conduct more strategic research. The alternative is to place greater reliance on developed countries, such as the USA, Japan, or the European countries to produce the needed crop protection technology appropriate to tropical agriculture. This approach seems to be flawed. The protection of intellectual property derived from biological research in more developed economies may mean that the discoveries may not be shared with developing economies, or only at a price.

Dependence on NARS to develop biological and cultural control technology for crop protection also seems unwise. The complexity of the

researchable problems and the long-term nature of this type of research weighs against relying on NARS. Thus, the IARCs are squarely at centre-stage in the expectations for strategic research in crop protection for the tropics.

A second crop protection research need of the IARCs is in the area of technology transfer. Technology transfer as a mechanism for the IARCs is not well developed and this deficiency needs to be researched. The expected (and planned for) shifts of the IARCs away from plant breeding (and hence improved seed distribution) to knowledge dissemination and the handling of biological agents is a far more complex task. New technologies will require new approaches to an extension system that must be developed through direct research investments. This need will become critical to the success of new crop protection technology inasmuch as to be useful. The technology must be extended to production agriculture. Surprisingly, this issue is treated incompletely in most of the IARCs' strategic plans, but remains a major concern.

Programmatic deficiencies in crop protection research are also evident by studying the IARCs' strategic plans and annual reports. The planning process for research in crop protection is often lost in the broader programme issues of a Centre. The Centres with programmes for multiple commodities rarely if ever look longitudinally at crop protection across commodities. Most often they give preference to commodity programmes at the expense of a discipline topic such as crop protection. This has had the undesirable effect of splintering a Centre's efforts in crop protection which would otherwise benefit from indepth, coordinated planning of its discipline research efforts.

Related to this observation, are the consequences of research programmes' structures and the distribution of support (including funding) by commodity rather than by research objective, identified problem, or specific research need. The allocation of resources within the Centre is, of course, traditionally the prerogative of the Centre's administration. However, the assignment of resources to a commodity programme may have the effect of lessening some of the opportunities for crop protection research.

The commodity programme structures within the Centres may also lessen the chances for identifying research leadership in crop protection research, not only within the IARC system but with the NARS as well. To give greater emphasis and visibility to crop protection research within the IARCs would require significant programmatic readjustment to allow the development of strong crop protection research programme leadership. If encouraged, this would facilitate better communication between Centres and with the national programme partnerships. It would also greatly improve research linkages with institutions in developed countries. This would yield many direct and indirect benefits for the Centre's research programmes.

There are policy needs that should be addressed by individual IARCs that would work to facilitate new approaches to crop protection research. Primary among these is the need for a clearer definition of the mandates (and directions of research) between the Centres and better clarification of responsibilities with partner NARS. In many of the

current IARC strategic plans, crop protection research becomes a lost entity, homogenized into various commodity research programmes. By directly addressing crop protection research needs, by setting out intended objectives, and by giving clear statements of policy to the Centre scientists, their collaborators, colleagues and critics, all would know better where they intend to go and what they intend to accomplish in crop protection research.

Finally, it is imperative that a decision be made, either collectively or individually by the IARCs on the appropriate (or inappropriate) role of agricultural chemicals as a tool in crop protection. Avoidance of the policy issue has left open the arguments from both supporters and critics of the IARCs. And this does not well serve the good interest of any of the Centres.

## 6. Phase II Activities

The next step in this evaluation study will be to assemble a panel of scientific experts with past International Agricultural Research Centre employment experience to review historical and current problems in crop protection for the IARC commodities and to lay out the current needs for research on those problems. A two day workshop with approximately ten participants (see Appendix 3) will address the general problems common to all commodities (e.g. instability of host plant resistance, pest resistance to pesticides, crop loss documentation, germplasm preservation). Attention will also be given to current research constraints in crop protection (i.e. site specificity, experimental design flexibility, needed quantitative methods for experimentation). The problems and constraints of crop protection research will be then addressed by the workshop. Some of these topics include manpower needs; requirements for fundamental knowledge in basic biology and biotechnology; systems research; climatology and meteorology; biological monitoring techniques; and seed health/quarantine considerations. The necessary resources (budget) to conduct this research to obtain the needed knowledge will be evaluated.

Other topics of interest that are indirectly related to crop protection will also be discussed. These will include the safety of experimentation with certain biologics (e.g. the importation of plant pests for research purposes) and the environmental, economic, social and ethical impacts of crop protection technology and how these might be assessed. The Phase II participants will also take a look at issues in intellectual property protection as they may affect the availability of technology and germplasm useful to IARC and NARS crop protection research.

However, the primary assignment for the Phase II workshop participants will be to study the options for the IARCs wishing to expand crop protection research. Some of the topics likely to be discussed include the internal restructuring of programmes (e.g. create departments); expand activities in contract research; developing "regional research projects" with sister institutions and/or NARS; negotiate memoranda of understanding to establish designated lead centres for targeted research topics; identify and designate funding for crop protection research; and somehow establish a braoder network for collaboration in crop protection research.

To accomplish one or more of the above items will require some choices among the alternatives. To initiate this discussion for the Phase II workshop participants, the following list of proposed choices will be presented to stimulate additional alternatives and begin exploration of the consequences of making certain choices. The tentative list of choices includes:

- Programmatic Restructuring
- A New Research Management Plan
- Directed Funding as:
  -- Special Grants
  -- Formula Funding
  -- Designated Research Appointments
- Quasi-Competitive Grants Programme
- Informational Networking for Targeted Disciplines
- Creating or Restructuring a Centre for Crop Protection
- Establish a Secretariat on Crop Protection

When the Phase II document has been prepared (early August, 1989) an invitation will be extended to the Directors General of the approriate IARCs. The invitation will ask for representative Centre senior staff scientists to attend the Phase III workshop. This effort will initiate the drafting of the Phase III document that will:

- Verify earlier evaluations of IARC research activities in crop protection.

- Provide verification of specific examples of IARC accomplishments in crop protection.

- Develop specific needs statements for future crop protection records.

- Formulate specific needs statements for future crop protection records.

- Formulate specific activities to enhance crop protection research efforts.

- Proposed structural changes to programmes and policy changes for Centres that would facilitate crop protection research.

This phase of the Study will be completed by October 1, 1989.

APPENDIX I

This century has witnessed some very significant changes in crop cultivation practices. New technologies have been developed in ways to replace labour. These changes have come as new varieties, mechanization, and chemicals which have all contributed to increased crop production. Farmers today use far less labour than their parents or grandparents to produce a crop. The following data are the hours of labour required in the years 1915, 1950 and 1985 in the United States to produce 1 unit of selected crop commodities. (Source: United States Department of Agriculture Statistics, 1986. US Government Printing Office: Washington, DC, p. 395).

| | Year | | |
|---|---|---|---|
| Commodity | 1915 | 1950 | 1985 |
| Corn* | 132 | 53 | 3 |
| Wheat* | 98 | 34 | 7 |
| Soybean* | 143 | 41 | 12 |
| Potato** | 26 | 12 | 3 |
| Cotton*** | 299 | 146 | 6 |

* = 100 bu; ** = 1 ton; *** = 1 bale

The reduction in labour in US farming this century is striking and similar patterns can be found throughout the world.

The substitution of mechanical and chemical cultivation practices for labour is now being closely scrutinized as many types of farming systems appear not profitable and some others are seen as not sustainable. This century has witnessed tremendous surges in mechanical and chemical cultivation practices that have not been paralleled with new technology in cultural and biological control practices.

Agricultural researchers are now looking to develop new technology that will make use of the new biological knowledge for a more rational and profitable system of integrated practices for better protection of crops.

APPENDIX II

## CGIAR-Supported International Agricultural Research Centres

| | |
|---|---|
| CIAT | Centro Internacional de Agricultural Tropical, Cali, Colombia |
| CIMMYT | Centro Internacional de Majoramiento de Maiz y Trigo, El Batan, Mexico |
| CIP | Centro Internacional de la Papa, Lima, Peru |
| IBPGR | International Board for Plant Genetic Resources, Rome, Italy |
| ICARDA | International Center for Agricultural Research in the Dry Areas, Aleppo, Syria |
| ICRISAT | International Crop Research Institute for the Semi-Arid Tropics, Hyderabad, India |
| IFPRI | International Food Policy Research Institute, Washington, D.C., U.S.A. |
| IITA | International Institute of Tropical Agriculture, Ibadan, Nigeria |
| ILCA | International Livestock Centre for Africa, Addis Ababa, Ethiopia |
| ILRAD | International Laboratory for Research on Animal Diseases, Nairobi, Kenya |
| IRRI | International Rice Research Institute, Los Baños, Philippines |
| ISNAR | International Service for National Agricultural Research, The Hague, Netherlands |
| WARDA | West Africa Rice Development Association, Bouaké, Côte d'Ivoire |

APPENDIX III

## Proposed Phase II Workshop Participants*

| | Name | Disciplinary Experience | Institutional Experience |
|---|---|---|---|
| 1. | E. Heinrichs | Entomology | IRRI |
| 2. | M. Shepard | Entomology | IRRI |
| 3. | P. Teng | Pathology | IRRI |
| 4. | R. Theberge | Pathology | IITA |
| 5. | R. Williams | Pathology | IITA, ICRISAT |
| 6. | H. Kauffman | Pathology | IRRI |
| 7. | R. Coffman | Plant Breeding | IRRI, WARDA |
| 8. | P. Jennings | Pathology & Breeding | IRRI, CIAT |
| 9. | D. MacKenzie | Pathology & Breeding | CIMMYT, IRRI, AVRDC |
| 10. | Not named | Weed Science | ------ |

* Other observer/participants will be invited from key institutions including CGIAR, TAC, FAO and others.

Note: None of the proposed participants have been contacted. Please treat this information as confidential.

None of the proposed Phase II participants are, at this time, employed by any of the IARCs and they should therefore serve as independent, non-vested information resources.

TABLE 1: Mandated and implied commodity research activities for the 8 IARC's with crop research responsibilities.

| | CROP COMMODITY | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CENTER* | Wheat** | Barley | Rice | Maize | Millet & Sorghum | Potato & Swt Potato | Cassava | Yams | Fava Bean & Lentils | Phaseolus Beans | Pigeon & Chick Peas | Ground-Nuts | Vigna and Soya | Forages |
| CIAT | | | X | | | | X | | | X | | | | X |
| CIMMYT | X | X | | X | | | | | | | | | | |
| CIP | | | | | | X | | | | | | | | |
| ICARDA | X | X | | | | | | | X | | X | | | X |
| ICRISAT | | | | | X | | | | | | X | X | | |
| IITA | | | X | X | | (X)? | | X | | | | | X | |
| IRRI | | | X | (X) | | | | | | | | | | |
| WARDA | | | X | | | | | | | | | | | |

* The Centers listed above conduct crop commodity research. Other centers within the CGIAR-supported center network include IBPGR, IFPRI, ILCA, ILRAD and ISNAR which do not have active research programs for crop commodities, especially in crop protection. (Please note that most Centers have strong collaborative programs in germ plasm collection and preservation with IBPGR.) See Appendix 2 for the complete Center names.

** Includes bread, durum and triticale types.

TABLE 2: Evaluations of the degree of research activity on the components of crop protection within the CGIAR supported IARC network. Commodity groupings reflect direct mandates of Centers and the research activities using the classifications of Anderson (1985) in "International Agricultural Research Centers: Achievements and Potential - Part IV." Evaluations are scored on a scale of 0 to 4, with 0 being no activity and 4 being very high research activity. The assigned scores are solely the responsibility of the author, are based on multiple sources of information and do not imply any judgement on the quality of the research activities.

| | CROP COMMODITI | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESEARCH ACTIVITIES | Wheat | Barley | Rice | Maize | Millet & Sorghum | Potato & Swt Potato | Cassava | Yams | Fava Bean & Lentils | Phaseolus Beans | Pigeon & Chick Peas | Ground Nuts | Vigna and Soya | Forages |
| INTEGRATION OF PRACTICES | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| Mechanical Control | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | |
| Chemical Control | 1 | | 2 | 0 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 2 | |
| Cultural Control | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | |
| Biological Control | 0 | 0 | 3 | 2 | 0 | 3 | 2 | 1 | 0 | 1 | 0 | 0 | 1 | |
| H.P. Resistance | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 2 |
| IPM | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | |
| Biotechnology | 2 | | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| INFORMATIONAL | | | | | | | | | | | | | | |
| Surveys | 2 | 1 | 3 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | |
| Monitoring | 3 | 1 | 3 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Forecasting | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | |
| Loss Assessment | 2 | 0 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | |
| Economic Thresholds | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | |
| OTHER TOPICS | | | | | | | | | | | | | | |
| Modelling | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| Population Dynamics | | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Ecology | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | |
| Basic Pest Science | 0 | 0 | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | |
| Sustainability | 1 | | 2 | 2 | 2 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | | |

## Addendum

Research with pesticides for crop protection strategies extends beyond efficacy studies to include:

- Safer handling of pesticides and technology to safely deliver small amounts of pesticide with little or no exposure to the applicators.

- Pesticide application technology that increases the efficiency of the pesticide applied thereby reducing the amount of pesticide needed.

- Timing of pesticide applications based on biological developments and meteorological events rather than by predetermined schedules.

- Complementary and synergistic effects of pesticides with other crop protection tactics (e.g. W. Fry's work with host plant resistance and fungicide protection for potato late blight disease management).

These and similar topics on pesticide use suggest broad areas of investigation with chemical control practices that should be considered as part of any crop protection research agenda.