CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

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FROM: The Secretariat

Consultative Group Meeting

November 8 - 12, 1982

Agenda Item 3

Attached is a copy of the transmittal letter from the TAC Chairman to the CGIAR Chairman, covering a statement made by TAC on crop protection (AGD/TAC:IAR/82/24). This statement is based on the relevant report prepared by Prof. J.M. Hirst, TAC Member, and entitled "Crop Protection - A Policy Proposal" (AGD/TAC:IAR: 82/19 Rev. 1).

The above documents and the question of crop protection will be included under Agenda Item 3 at the Consultative Group Meeting in Washington in November. Agenda Item 3 is the TAC Chairman's report on the 28th Meeting of TAC.

Attachment

Distribution:

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TAC Chairman
TAC Secretariat
Center Board Chairmen
Center Directors

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH
TECHNICAL ADVISORY COMMITEE
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August 12, 1982

Dear Mr. Baum:

Crop Protection

When the CGIAR decided at its November 1980 meeting in Manila, to follow the recommendation made to it by the 24th TAC not to admit the "International Center for Insect Physiology and Ecology" (ICIPE) into the System, it recommended, however, that "there should be a thorough review by TAC of the priority to be given by the CGIAR to insect and pest management". The TAC Secretariat subsequently prepared background material to this effect, and at its 25th meeting (February 1981), TAC requested one of its members, Prof. J.M. Hirst, to prepare an expanded version of this initial study which would aim at a more comprehensive coverage than the one implied by the word "pest management".

Prof. Hirst subsequently started a process of consultation with the IARCs concerned which contributed to two revisions of a policy paper on crop protection. Joint discussions with Centre Directors took place during the 26th TAC meeting at Ibadan and the 28th TAC meeting at El Batan. Prof. Hirst following the 28th TAC meeting included some additional suggestions made by the Centre Directors on the report presented to them at this meeting. The report which has been widely and warmly praised and endorsed by the Centre Directors at the 28th TAC meeting, includes, besides a section on policy issues, a well detailed annex which contains valuable and original information on the importance of crop protection, the policy applied and resources devoted to it by IARCs.

I submit herewith, for consideration by the Group, both a statement made by TAC on crop protection, based on Prof. Hirst's report and the discussions which took place during the 28th TAC meeting, and the report itself.

Mr. Warren C. Baum
Chairman
Consultative Group on International Agricultural
Research (CGIAR)
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These documents underline the fact that crop protection is an important and integrated component of the various crop improvement and farming systems research programmes of the IARCs and that such a situation should be maintained. The Centres, as evidenced by Prof. Hirst's report, marshall already an impressive array of interdisciplinary competence to work on the pests affecting their commodities, making full use of a wide range of genetic material. There is scope, however, for the Centres drawing on the experience accumulated by and the expertise available at Centers of excellence outside the System.

I consider that the attached documents contribute usefully to improving the Group's knowledge on the present state of crop protection research at the IARCs. They will also help to build up relevant research strategies responsive to future needs.

Yours sincerely,

Guy Camus
Chairman TAC

AGD/TAC:IAR/82/24
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THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

TAC STATEMENT ON CROP PROTECTION

TAC SECRETARIAT
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
August 1982

TAC STATEMENT ON CROP PROTECTION

1. After reviewing the activities of the IARCs and other institutions, the Committee confirms its opinion that research for an improved protection of food crops in developing countries is not a neglected field and does not warrant a new initiative by the CGIAR. Crop protection research is and should continue to be an important facet and an integral part of the diverse crop improvement programmes and farming systems research activities at the IARCs. It should remain distributed among Centres as a component of their multi-disciplinary programmes at their Headquarters and off-campus. The close interaction of researchers in crop protection and those in other fields at the IARCs and in national programmes is considered as mutually beneficial in the development of integrated methods of crop protection and other improved technologies for specific crops, and production systems in diverse agro-ecological zones. TAC considers that this strategy is sound and effective, and it would not favour the development of a specialized international institute covering the multiple aspects of crop protection research. TAC recognized, however, that the IARCs should continue to rely on specialized centres of excellence such as ICIPE to address some aspects of fundamental research and to seek highly specialized services, such as for example those of the reference laboratories for the identification of races of pathogens. TAC, therefore, encourages the members of the CGIAR to facilitate this cooperation by providing adequate support to the IARCs and the other institutions concerned. The Committee expresses serious concern at the possible decreases in the expertise available at the reference and identification centres on pests affecting tropical food crops. A similar threat may affect the development and testing of chemicals appropriate to some tropical food crops.

2. As regards the present programmes of the IARCs in crop protection research, TAC notes that the introduction of new technologies and the overall development of agriculture in developing countries modify the nature and the priority of research needs in crop protection towards more specialized and diversified research fields, which are difficult for the IARCs to cover in the present conditions of scarcity of funds. Beside the above-mentioned cooperative arrangements, TAC would recommend to examine the possibilities of establishing at the IARCs, where it is most needed, specialist units with a recognized role in providing expert services and specialized training for the CGIAR as a whole.

3. TAC wishes to draw the attention of the IARCs and of the CGIAR to the major gaps which exist in the development of appropriate technologies and practices for weed control, whereas weeds are becoming an increasingly important constraint in many agro-ecological zones. TAC recommends that increased emphasis be given to the development of integrated methods of weed control in the context of the research programmes on land development and farming systems at the IARCs.

4. As the enforcement of quarantine measures is a national responsibility, TAC fully supports the initiative taken by several Centres in developing appropriate arrangements and facilities on their campus or otherwise, so as to facilitate the effective control by the national quarantine authorities of the germplasm material which the IARCs distribute and receive.

5. The above general observations and recommendations are based on the attached report by Prof. J.M. Hirst, Vice-Chairman of TAC, which the Committee commends for consideration by the CGIAR. The Committee wishes to express its appreciation for this major contribution to the assessment of the research priorities in this field and its gratitude for the cooperation extended by the Centres for this study.

AGD/TAC:IAR/82/19 Rev. 1
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THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

CROP PROTECTION

A POLICY PROPOSAL

The issue of crop protection has been discussed by TAC at the 25th, 26th, 27th and 28th meetings. The paper authored by Prof. J.M. Hirst of TAC, has been revised several times in the light of the contributions received from the IARCs and the discussions held between TAC and Centre Directors. The present version has been finalized by Prof. Hirst taking into account such joint discussions during the 28th TAC meeting. For those who have been aware of earlier versions, they will note that the main body of the paper is now restricted to the policy issue, while general information on pests and on the crop protection programmes at the IARCs figure in annex.

The attached document should be read concurrently with the relevant excerpts of the 28th TAC meeting report (paras 292-305, pp. 77-79) and with the statement prepared by TAC on crop protection.

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

August 1982

POLICY PROPOSALS FOR CROP PROTECTION RESEARCH

The Importance of Crop Protection

1. In previous judgements of research priorities [1/] TAC has recognized crop protection as an important 'factor-oriented' subject. It now submits proposals for the consideration of the CGIAR which owe much to help from FAO and other organizations, but particularly to the Directors-General and staffs of the IARCs. In present circumstances TAC and the IARCs were conscious of severe budgetary constraints. While these certainly decreased the scale of the proposals, it seems unlikely that they altered their kind or relative importance.

2. Throughout this document and the accompanying Annex I, from which the proposals were developed, the word 'pest' is used as recommended by FAO to include all damaging animals, plants, micro-organisms and viruses. Few crops escape pest attack, although the severity differs greatly between seasons, soils and husbandry practices. Some crops are endangered before planting, most during growth, but some others not until the produce is stored after harvest. The forms of attack range from competition by weeds, through interference with metabolism or the regulation of growth or fruiting, the consumption of plants by rodents, birds, etc., to the spoilage or poisoning of the harvested produce.

3. To assess the extent of this damage or the cost of avoiding it is a task of notorious difficulty. While it may seem attractive to integrate all factors in monetary terms, this approach is ill-suited to the subsistence farmer, and is subject to the variability of national economics, while inflation quickly out-dates the estimates. More often, therefore, attempts are made to define the percentage of the potential crop lost. Such estimates usually omit the cost and effort expended in control, and to be accurate should be based on detailed and extensive estimates by experiments or surveys. Such studies may be helpful and justified in developed countries with ample research and extension services, but cannot be made the first call on the time of the very few crop protection specialists available in many developing countries.

4. Many crops escape serious damage and the worst effects result from the small proportion that become crop failures through pest attack. However, most estimates of damage seek to establish the average, and suggest it would be safe to think this may lie between 20 and 33%, even including the present use of pesticides. In addition, in money or labour spent, the actions taken to protect crops often form one of the largest variable costs of cultivation. Thus crop protection is and should be a major objective of research aimed to improve agriculture in the developing countries.

1/ AGD/TAC:IAR/79/1 Rev. 1

The Organization of International Crop Protection Research

5. The enormous diversity of crops, pests, soils, climates and economic circumstances implies that many problems of crop protection are location specific. Furthermore, the application of improved methods and necessary guidance and legislation must be the responsibility of national agricultural programmes. Because these still differ so greatly in resources and technical capability, there will long remain an essential role for international help to introduce and interpret the latest scientific advances to help the agriculture of developing countries.

6. TAC firmly supports the opinion of the IARCs that the multidisciplinary teams they have developed to study their mandate crops represent an essential component in the processes of acquiring, interpreting and transferring developments in crop protection. These teams have the ability to utilize the findings of the most sophisticated research into pest biology, the genetics and biochemistry of crop plants or the characteristics of crop protection chemicals, even though much of the initial work is best performed in sophisticated laboratories often in developed countries.

7. TAC is opposed to the concept of a single "Crop Protection Centre" because this would inhibit the action of existing multidisciplinary teams and the search for systems of crop protection that seek to integrate all the possibilities of pest control at minimal cost and with minimal disturbance in many different environments. Furthermore, TAC wishes to strengthen rather than weaken the relationship between crop mandate IARCs and the national programmes of the relevant nations. It sees the use of existing regional crop programmes as more economical and more effective than any attempt to establish a separate system for crop protection.

Major Scientific Issues

8. TAC recognizes both the past successes and future promise of breeding crop plants for pest resistance, and the special merit this approach has for the economy of low-input tropical crops. However, past successes in raising yield capability, problems with the maintenance of pest resistance and, hopefully, improving standards of living, will continue to modify the research needs. Several Centres have already modified programmes to emphasize agronomy, farming systems, weed control and crop nutrition. The greater these improvements become, the greater is the potential crop at risk from pests and the more their effects will be noted and felt.

9. The more widespread the cultivation of a few outstanding crop genotypes becomes, the more serious become the risks of catastrophic pest attack. History has shown that many pests are quickly able to evolve strains able to overcome single-factor genetic resistance. Such problems have induced much effort to produce more durable resistance based either on the complementary action of many genes or the action of a single gene proved unlikely to be circumvented by pest evolution. Unfortunately, the search is made difficult both by the genetic complexity of multiple action and by the lack of effective tests of durability other than long and extensive exposure. However, such efforts constitute a major component of many crop research programmes in IARCs.

10. Changes in pests very comparable to those that have circumvented single-factor plant resistance are now recognized as leading to the development of pest strains "insensitive" (resistant) to some previously potent pesticides, especially those where toxicity depends on single enzyme systems. Both for genetic resistance and for insensitivity to chemicals there is a worldwide need to explain how new pest strains arise, how they differ biochemically, and to study their population dynamics to seek ways to delay their increase.

11. The use of chemical pesticides is increasing in many developing countries, but faces serious difficulty because of increasing prices, the need for application machinery and the lack of skill in the use of chemicals or a sufficient public understanding of the hazards of their misuse. At present not all Centres recognize a need to develop strength in crop protective chemistry, with some preferring to leave it to industry, national programmes and laboratories in developed countries. If changes in developing country agriculture follow those elsewhere, this view may need reconsideration, with chemical pesticides first being used extensively for seed dressings, herbicides, rodenticides, protecting stored products and controlling pests against which resistance has not been found. However, the needs for change are not of great urgency, and so can reasonably be left for revision by Centres and Quinquennial Review Committees.

12. Very properly much interest and effort is currently devoted to combining resistance breeding and pesticides use with biological and cultural control practices, collectively referred to as "integrated crop protection", (almost synonymous with "integrated pest control" or "integrated pest management"). At least initially (and perhaps always) the development of such "integrated systems" requires for each crop specific attention and the existence of a team knowledgeable in all aspects of its production and pests. Even so, it is generally recognized that integrated crop protection systems will be difficult to establish,

need constant skill to maintain and at best will result in imperfect control. By contrast, integrated systems may be acceptable where "cosmetic quality" is not required (as with fruit for temperate zone markets), be cheaper and hence better adapted to low-input agriculture, maintain pest populations in more constant balance and hence create less environmental disturbance. Although success is far from certain, TAC believes the quest for integrated control systems must continue and supports the research and training in progress. For example, IRRI has recently completed the first six-month course on integrated crop protection.

Subsidiary Scientific Issues

13. The content of the foregoing paragraphs would probably be widely acceptable. However, TAC considered other aspects where less agreement could be expected, because of the diversity of programme and management practices of individual Centres, and because each has given much effort to developing long-term plans that attempt to define objectives and to optimize the application of scarce funds. There is much disparity in the degree to which Centres use specialized laboratories for fundamental or strategic studies by collaboration or contact. TAC considers such joint programmes should be encouraged as the best means of introducing necessary biochemical and cellular scale research; however, they would not wish to dictate their extent or placement, because success depends so much on personal compatibility. No CGIAR initiative is recommended, other than encouragement and a recognition of the great value of sabbatical and exchange placements.

14. In June 1981 Centre Directors expressed a wish for more formal effort to improve the dissemination of crop protection information. TAC agrees with the second thought that, although interchange is essential, ample mechanisms exist at least at some Centres, and can be copied elsewhere. TAC considers no CGIAR action is required. Similarly, TAC agrees that, while Centres must take the greatest care to prevent the spread of pests, the legislative aspects of quarantine are and must remain a national responsibility. TAC believes the Centres are aware of their responsibility to recognize pests in newly collected germplasm and to ensure the safe movement of this and planting material. In this regard it acknowledges the value of meetings between IARCs staff and national and international quarantine specialists such as the "International consultation on a system for safe and efficient movement of materials in global germplasm networks" held at CIAT, 15-17 June 1982. The results of this meeting were considered by the Centre Directors during the 28th TAC meeting.

15. Most Centres acknowledge the importance of specialist studies in crop protection, such as the mechanisms of pathogenicity and resistance, epidemiology, population dynamics, agrometeorology, pest attack forecasting and damage assessment, and of mycotoxins, stored product pests and pesticide residue analysis. There is a need to expand many such special studies which is at present prevented by shortage of funds. TAC recognizes that the importance of these topics differs between Centres, but believes they will increase in importance as crops and agriculture improve. Many principles discovered by research in developed countries will be transferable, but will need location-specific confirmation and application on crops in developing countries. Introducing such work to IARC programmes may require the transfer of other simpler responsibilities to national programmes in countries with the necessary competence. Alternatively, individual Centres might be assisted to develop specialist units offering a recognized training or advisory component. TAC and CGIAR should be sympathetic to such proposals.

16. TAC identified weed science and information about herbicides as topics needing much reinforcement, a conclusion with which most Centres agreed. They support the study of weeds as a component of crop agronomy, recognizing the importance of control by land management and cultivation. However, they believe that this together with knowledge of weed species and herbicide use will not be effectively deployed without much increased training of weed specialists followed by their placement both in Centres and in national programmes. There is a strong need for the establishment in a tropical environment, and perhaps in a University, of training courses in weed science, and it would be an added advantage if these could be associated with the facilities of one or more IARC. African farmers are said to devote 40% of their time to weed control. If this burden could be lifted, the farmers would have time to cultivate larger areas of better varieties, and so perhaps enable them to purchase the fertilizers and herbicides that are needed to take full advantage of higher yielding, pest-resistant crops.

17. Most Centres rely on identification and taxonomic services and culture collections in developed countries; especially those long devoted to tropical biology. Such services depend on irreplaceable collections served by highly specialized and equally precious staff. Most were established by former colonial powers who now find it difficult to justify the expenditure for services larger than national needs demand. Such institutions are also the natural repository for unique personal collections that justify continued curation after the death or retirement of the collector. Some such institutions offer abstracting services that are relied upon worldwide (e.g. the Entomology, Mycology and Parasitology Institutes of the Commonwealth Agricultural Bureaux). Others (such, in U.K., as the Tropical Products Institute, Centre for Overseas Pest

Research, ODA Tsetse Laboratory and Weed Research Organization) offer specialist advisory or liaison services which may be, or have already been, withdrawn. Although Centres pay some identification charges, the institutions have restricted these to token rates so as not to inhibit the inflow of specimens on which the continuing relevance of the collections depends and to provide authenticated duplicates for return to donor countries to establish national collections. TAC wishes to impress on donors the relatively small costs of ensuring continuation of such long-established services compared to the near impossibility and great cost of attempting to re-establish comparable collections and expertise afresh in IARCs or national programmes. The closure or impoverishment of such institutions would inflict serious and long-lasting damage on research and tropical agriculture.

18. Summary of proposals:

(a) Crop protection is and should be one of the more important objectives of factor-oriented research areas for crop Centres, where it currently concerns one-third of the total scientific complement of the system.

(b) TAC and Centre Directors are confident that crop protection should remain dispersed between Centres where the research can profit from the multi-disciplinary teams, regional programmes and relations with national programmes. They would not favour any centralized institute for crop protection.

(c) There are still good prospects for further improvement by breeding resistant plants but there is a strong need to study how these and other crop protection methods should be integrated within overall crop production systems.

(d) Because of the diversity of crops, pests and environments, TAC believes that crop protection programmes are best monitored through the Quinquennial Review system.

(e) IARCs are likely to continue to rely on research in specialist laboratories for advance in cellular and biochemical aspects of biology, resistance and pesticide action. However, appreciation of advances and feasible applications would benefit from increased sabbatical and exchange visits.

(f) The success of CGIAR research in improving agriculture will alter research needs. Specialist subjects (listed in para 15) will need more attention. At present scarce funds make this difficult but some progress might be possible by establishing, at IARCs of greatest need, specialist units with a recognized training role. When it considers the long-term plans of

Centres, TAC should pay particular attention to the strategic balance required in the future between the production of varieties in IARCs or national programmes, crop protection, improving agronomic practices, etc.

(g) Weed science is a subject which receives inadequate attention within IARCs and developing country programmes. One reason is the dearth of trained weed specialists who should be encouraged to work with agronomists and crop protection specialists. Donors are asked to consider ways in which training courses could be stimulated perhaps in universities in developing countries associated with the facilities of IARCs.

(h) TAC is seriously concerned at the possible loss or impoverishment of institutions (para 17) with special interests in support of tropical agriculture and which have proved of continuing value to many Centres. They wish to stress to donors that such services are indispensible, rely on decades of acquired experience and would be many times more costly to attempt to recreate than to preserve.

Introduction

1. 'Crop protection' is a useful collective term to embrace the variety of measures that producers may adopt to ensure the continued, cost-effective growth of healthy crops. It therefore comprises crop husbandry (agronomic methods), through suppressive techniques such as varietal resistance, chemical and biological control, to the sophisticated biochemical and genetical research needed to understand and control resistance to pests or insensitivity to chemicals. Within the CGIAR system all approaches are relevant to activities within the international research centres, but recommendations for use in developing countries must be tailored to fit the economics and practicalities of their national agricultural systems.

2. The history of discussion on this subject within TAC and the CGIAR is summarized in Appendix A. This document seeks to confirm the views recently expressed by TAC and the Centre Directors, and therefrom to distil a policy acceptable to the CGIAR as a whole.

Economic Importance of Crop Protection

3. While exceptionally serious damage may attract most attention, these effects are probably smaller than the aggregate of average losses. The complexity and variability of damage to crops, and the lack or inaccuracy of many statistics on production and loss, make it difficult to express them in terms of monetary values, let alone of human welfare.

4. One of the most comprehensive estimates remains that made by Cramer ('Plant Protection and World Crop Production', M.H. Cramer, 1967, Bayer). Table 1 illustrates conclusions (US$ equivalents based on 1965 values.

Table 1

Extent and Value of Losses

Caused by	As % of potential production				Total expressed as US$ (billions)
	Insects	Diseases	Weeds	Total	
Wheat	5.0	9.1	9.8	23.9	5.8
Rice	26.7	8.9	10.8	46.4	16.9
All cereals	14.7	8.9	11.2	34.8	34.0
All crops	12.2	11.8	9.7	33.7	71.0
All crops with polyphagous pests (rodents, locusts, termites, birds)	13.8	11.6	9.5	34.9	75.0

5. The order of magnitude of these estimated costs of pests, diseases or weeds has been confirmed by some more recent and specialized assessments. The decrease of crop yields worldwide due to weed infestation was estimated at 11% by Parker and Fryer (FAO Plant Protection Bulletin 23,83-95, 1975). CIMMYT, which has revised Cramer's estimates of losses of wheat and maize, from diseases alone, puts them at 33 million tons for each crop, representing monetary costs (1976 $) of $ 4.4 billion for wheat and $ 3.2 billion for maize.

6. Even allowing for the fact that these figures include data for all countries, not just those of primary concern to the CGIAR, it is plain that losses are many times the cost of the investment to improve food supplies. Before discussing how best to spend the limited resources at present available, it is necessary to clarify certain terms that may be confusing to non-specialists.

Terminology

7. 'Crop protection' in the wide sense used here comprises all the means available to avoid or limit damage to crops. It therefore includes the effects of weeds, polyphagous pests (rodent, locusts, termites, birds, etc.), with those of the pests and diseases of growing crops and of their products after harvest.

8. 'Pest': When used here in quotes 'pest' is meant in the traditional sense of any organism (or virus, etc.) that damages others and especially crop plants. 'Pests' therefore include vertebrates, insects, mites, nematodes, parasitic plants, weeds, fungi, bacteria, viruses, etc. Excluded are the excesses or deficiencies of chemicals in soil, water or air that damage plants naturally or as a result of pollution. Pest (without quotes) is sometimes used as a collective term for damaging animal infestations as distinct from diseases resulting from infections by microbial pathogens. In the 'policy proposal' pest is used in the first sense but without quotes.

9. Integrated crop protection (ICP) and integrated 'pest' management (IPM): These two terms express concepts introduced first as 'integrated pest control' that recognize that 'pests' may best be suppressed to less than economically damaging proportion by utilizing all suitable techniques (chemical, cultural and biological) compatible with cost, ecological and toxicological requirements. IPM is a term in common use (and some abuse), which was first proposed by entomologists; ICP is preferred because it stresses the involvement not only of the target crop, but also of adjacent or succeeding crops; however, IPM is in more common use.

Crop Protection Sciences

10. Integrated crop protection and integrated 'pest' management are much respected philosophies for attempting to protect crops and their products to the benefit of human welfare. However, neither includes all the scientific and agricultural endeavours on which their success depends. It is well, therefore, to summarize the scope of the scientific requirements:

(a) Scales of research:

Cellular and sub-cellular studies of the cytology, physiology and biochemistry of 'pests' and, where applicable, of their host plants and of the interactions between host and 'pest'.

Studies of whole organisms to reveal the biology of pests, pathogens and weeds, and of their natural enemies, with a view to control. The studies involved will differ with the class of 'pest', but will include taxonomy, life history and etiology, structure and function and mechanisms of resistance to 'pests' or sensitivity to pesticides.

Studies of populations of both 'pests' and crop plants, for example, epidemiology, competition, population dynamics and population genetics.

(b) Research on control agents and practices:

Conventional crop protection chemicals - chemical structure/activity relationships; modes of action; methods of formulation and application; persistence and degradation; effectiveness, selectivity and side-effects.

Novel methods or materials for control - new target systems or active compounds (e.g. pheromones and other behaviour controlling chemicals, plant growth regulators, phytoalexins and elicitors, etc.).

Natural enemies - the provision and maintenance of beneficial organisms; competitors, antagonists, predators, parasites, etc.

Plant breeding for resistance - the cytogenetics of resistance factors, breeding and selection methods, the mechanisms and durability of resistance.

Cultural controls - crop rotations, tillage practices and nutrition, provision and preservation of healthy seeds or planting material (including quarantine precautions, certification schemes, etc.).

(c) Development of crop protection strategies:

The prediction of damage and the timing of treatments; surveys of incidence and damage; increasing the durability of resistance to 'pests' or sensitivity to chemicals such as may be achieved by mixed cropping or rotation of crops or treatments.

The integration of crop production and protection to maximize yield most cost-effectively and practically to satisfy farmers, their food needs or markets.

Some Strengths and Weaknesses of Major Crop Protection Techniques

11. Breeding for resistance: Although usually a major factor in breeding programmes, 'pest' resistance is far from being the sole objective of plant breeders. Early experience showed that air-dispersed fungi and some insects can quickly evolve to circumvent single, 'specific', resistance genes, so that previously resistant varieties were attacked afresh. Now most breeding programmes seek more durable, 'non-specific', resistance. Although the mechanisms are still often very poorly understood, it is plain that resistance breeding can often almost keep pace with evolution or, if 'durable' even outpace it. It is evident that resistant varieties, of proved suitability to local environments and farming practices, constitute one of the easiest and most effective routes to agricultural improvement in developing countries.

12. The great emphasis on plant breeding in many of the international centres has been important in the contributions they have made, and has greatly increased national capabilities to continue the work. An awareness exists that to achieve the potential of some new varieties needs concurrent change in tillage, nutrition, weed control, etc. The emphasis on new agronomy to match new varieties or the synthesis of new farming systems should stimulate consideration of the balance between varietal and cultural improvement that is correct for individual international agricultural research centres during the next one or two decades. Where training has created a national competence in the simpler means of plant improvement, IARCs should perhaps divert more effort to agronomy, agrometeorology, 'pest' forecasting, pesticide residue analysis, and to improving understanding of 'pest' population dynamics and genetics? There would be little purpose in IARCs duplicating breeding programmes that developing countries could do for themselves, but much merit to be gained from changing emphasis to develop competitive advantages in different scientific aspects that national programmes will need help with as their competence increases.

13. Plant breeders have been prominent among those who have fostered the preservation of the world's plant genetic resources. In many important crops perhaps enough has been done to ensure that there are preserved at least small collections of most species, including wild progenitors and many local cultivars. In terms of the time scale of plant history, the need was urgent and the response was fast. However, we may not be entitled to be satisfied with current efforts, and should question what their inadequacies may be. Two questions may illustrate the point:

- The era of much increased genetic resource collection has been concurrent with an era of unrivalled genetic resource exploitation through the advent of scientific plant breeding and not least from within the CGIAR system. The period of short-lived 'boom and bust' cycles of varieties with hypersensitive resistance led breeders in developed countries to consider, and even to try to implement, strategies for the deployment of resistance factors. Few if any succeeded, but should we not study the use and deployment of the genetic resources that we have collected even more intensively than we encouraged the amassing of a new, perhaps irreplaceable resource?

- Natural populations are usually diverse, what size of sample (or better what number of collections) is required of each adequately to represent the full capability of the genome? How effectively do our existing collections equip us to preserve and extract characters that confer uncommon biochemical properties or resistance factors?

14. Chemical control: Since the 1940s there have been revolutionary changes in pesticides; natural products and simple inorganic chemicals have given place to more specific synthetic organic compounds. Many of these have proved enormously successful biocides, but some have properly led to serious environmental concern. Perhaps the most difficult have been the insecticides that persist in the air, soil or water, and are concentrated in natural food chains. Serious problems persist, for example, in the treatment of stored grain with organo-chlorine insecticides, where the amount consumed may be a very much larger proportion of that applied than in the case of a seed-dressing or a herbicidal application.

15. Recent developments may solve some problems but create new ones. For example, the enormous activity of some of the latest pesticides means that only 10 g/ha of active ingredient may be required, compared with 10 kg/ha for the first synthetic insecticides. But, applying uniformly materials of such activity will require full development of all the exciting advances in application techniques now appearing.

16. The agrochemical industry is estimated (Fig. 1) to have had world sales of almost $ 12 billion in 1980. Nevertheless, the current requirements for efficacy, toxicity, environmental safety and economic constraints are such that about 15,000 compounds may have to be examined for each one marketed at a research and development cost of perhaps $ 20-25 million. Therefore the launch of a new pesticide requires the prospect of worldwide sales on such major crops as cotton, maize, wheat, rice, vines, fruit and tropical plantation crops.

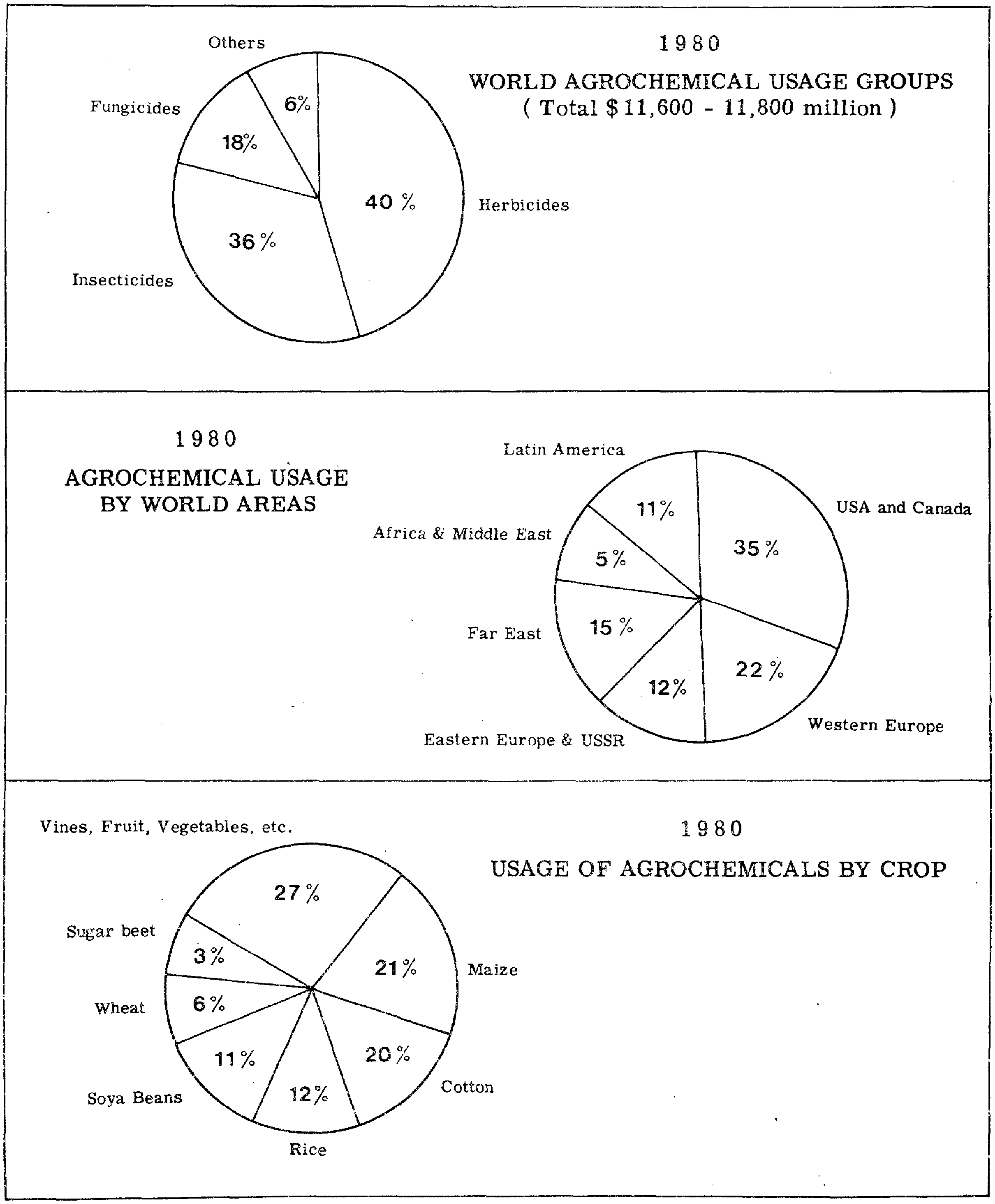
17. With such costs it is understandable that the agrochemical industry seeks to recoup its investment by pricing them so that their effect is profitable rather than necessarily reflecting the actual manufacturing cost. Nevertheless, as Fig. 1 implies, large amounts are used in the tropics and this can be expected to increase. Nevertheless, costs of the materials and their application will remain out of reach of most 'small farmers' until their incomes are greatly increased. This respite must be used to develop the means of educating farmers and the public in developing countries about the dangers of pesticide misuse and the precautions that must be taken to ensure safety.

18. Biological control: The possibility of setting unobjectionable organisms to suppress 'pests' is one of great attraction, considerable difficulty and some success. The rather small number of indisputable successes have deserved and gained a 'classic' status which has tended to obscure the difficulties. They have disproportionally concerned insect introductions, and particularly into protected environments or perennial crops. Efforts are certainly worth continuing because the chances of success seem greater on the scale of the small farmer, where a higher labour input is possible than in the large land clearances of mechanized arable cropping.

19. Information from visitors to the People's Republic of China suggests that they may have made important developments in biological control during their recent years of isolation. The facts would certainly merit examination on behalf of the developing countries that the CGIAR serves.

20. Cultural practices: Before the recent advances of breeding, biological control and pesticides, agricultural practices such as crop rotation, cultivation, adjustment of sowing date, plant nutrition, harvesting procedures and storage conditions formed the basis of efforts to protect crops. They remain important and effective methods and, although perhaps temporarily eclipsed by the attractions of new and labour-saving materials and techniques, they remain major pest control resources within the capabilities of poor farmers. Most are capable of considerable improvement through modest changes to equipment and careful education through collaborative improvement of farming systems.

Figure 1



Source: British Agrochemical Association, 1981

21. The integration of crop protection practices: Although ICP and IPM are new terms, they embody the very old concepts of good husbandry which aimed to incorporate any practice that would maximize healthy yield with least cost or harm to the land and its inhabitants. The word 'integration' implies an acceptance of the judicious use of plant resistance, biological, chemical and cultural practices to keep 'pest' incidence below amounts that cause serious loss. It therefore accepts a tolerable amount of damage in order to avoid the imbalance that can lead to catastrophic epidemics.

22. It is essential to remember that plagues, pestilences and famines were much more a feature of traditional agriculture than they are of science-based agriculture. Many diseases of crops and livestock are completely eradicable, others (e.g. many virus diseases of perennial plants) can be reduced to insignificance with little more than knowledge and care. Yet the new materials and techniques do require collaborative study between research scientists, national specialists and farmers to decide and explain which should be introduced to local practices and how this may best be done. Perhaps not infrequently such discussions may need to offer advice to developing countries on unaccustomed pressures from the seed, fertilizer, machinery and pesticide salesmen, who may each have vital contributions to offer if properly fitted into a schedule of education and development.

23. Three areas of crop protection seem at this time to merit particular mention and effort to integrate them into successful crop production, namely weed control, post-harvest damage and the often related development of mycotoxins.

24. Weed control: Weeds may exceptionally cause almost complete crop failures, but even more important is the fact that they form one of the usual dictates of farming practice. In a recent report, the FAO Committee of Experts on Pest Control (Draft 2nd Report, October 1981) have estimated that weed control occupies about 40% of the time and effort of many resource-poor farmers in developing countries. Parker and Fryer (1975, FAO, Plant Protection Bulletin 23, 83-95) estimated that crop losses from weeds averaged 11.5% of total production and, perhaps even more significantly, stated that with the application of existing knowledge only, this could be decreased to 8% within ten years.

25. The effects of weeds may often be greater in countries where water and nutrients are scarce than where large inputs are feasible. Not uncommonly the most productive new crop varieties have shorter stature which makes them less effective competitors with weeds. Even though weeds such as wild oats may be important worldwide, and their control would

benefit from effort among the world's 45 world science societies (12 in developing countries), they may behave differently in temperate and tropical zones. Others such as *Phalaris arundinacea*, *Striga spp.* and *Orobanche spp.* flourish most in warmer climates. The investigation of minimum tillage husbandry which may prove particularly suitable to some tropical crops, soils and climates, implies some weed control by herbicides. For reasons such as these there is a widespread opinion that more effort should now be devoted to the science and practice of weed control in the tropics, ensuring its relevance to local practice through establishing and cooperating with national specialists.

26. Post-harvest losses: Much of crop protection concerns attempts to realize the potential yield of crops in particular environments. By contract, post-harvest damage levies the full loss of a proportion of the yield already harvested and hence also of the effort and investment involved in gaining it.

27. Estimates range from insignificant in good storage (which may often be of traditional type), to over half destroyed or spoiled. The variety of products affected and of the damage and spoilage, make accurate assessment particularly difficult, but most estimates fall between averages of 5 and 15%. Deuse and Pointel 1/ are quoted as estimating the post-harvest losses in Africa (the continent of greatest need) as the annual food equivalent of 55 million people. Post-harvest damage takes many forms: physical damage by machinery; spillage from damaged containers; increased water loss; spoilage through ingestion and faeces, loss of seed viability or nutritive quality. Further damage may result from the production in the foodstuff of potent mycotoxins or allergens, which may make it dangerous to feed to humans or livestock.

28. In many countries there has been an unfortunate division in scientific and agricultural administration 'at the farm gate'; this separated those who grew crops from those who stored food. Although of less effect to the subsistence farmer, this interruption tended to obscure the fact that many spoilage fungi contaminate or cause latent infections on crops during growth. These develop fast if favourable conditions occur during storage. Most are suppressed by dry storage of dry products, except where metabolism by insect infestations releases water, which condenses locally, permitting mycelial growth causing spoilage and caking. Most insects infesting stored products are small

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1/ Deuse and Pointel 1974. Proc. 1st Intl. Conference of Stored Product Entomologists, Savannah, 85-93.

and fast breeding, so damage is related to population increase. Breeding rate is controlled by the rates of egg laying, the speed of development and the presence or absence of various resistance factors and as mechanical barriers to entry and oviposition or nutritive or toxic constituents in the stored product.

29. Experience in developing countries and research (e.g. by P. Dobie at the Tropical Products Institute, London) has shown that some of the worst recent problems have occurred in large stores of improved varieties. This is not surprising because local native cultivars arose from long unconscious selection for storage capability, as well as for yield and 'pest' resistance of the growing crop. Breeders in some IARCs are already aware of the problem and are instituting procedures to reject breeding lines subject to serious post-harvest loss. Plainly such co-operation should occur actively with all crops and be linked to education concerning the correct means of storage.

30. Mycotoxins: With few exceptions (e.g. mushrooms), fungi on foodstuffs have traditionally been regarded with suspicion. Russian workers were pre-eminent for many years, but interest widened greatly after the discovery in 1960 that the death of many young turkeys in U.K. was due to the presence of potent 'aflatoxins' in groundnuts infected with *Aspergillus flavus*. Subsequently some aflatoxins have been shown to be potent hepatocarcinogens, and other important toxic products have been associated with *Aspergillus spp.*, *Penicillium spp.*, *Fusarium spp.* and other microfungi. In common with thermophilic actinomycetes that grow fast in heated stored forages, these fungi can also cause important and debilitating respiratory allergies in humans and farm animals. Although much remains to be learnt about these organisms, the variety of the physiological effects of their product or means for their suppression, it is plain that they are often both unsuspected and particularly serious in warm, wet countries.

31. Although many IARC scientists are aware of these problems, few give them attention, probably because there is little evidence of variability within breeding material. However, the importance of these problems in some areas merits active cooperation with national scientists, and especially with post-harvest biologists.

Present Sources of Information and Action

32. The purpose of this paper is to develop a strategy for investment and effort in crop protection with the CGIAR system. It would be impractical and beyond this purpose to attempt to list the world activities, but equally difficult to justify a policy for the CGIAR without first giving some account of the activities of other agencies.

General:

33. The International Agricultural Development Service published a listing of 'Agricultural Assistance Sources' (New York, 1980); although it lacks any indexing of interests, it lists 13 multilateral and regional organizations, five private foundations and institutions and 16 national bilateral assistance organizations. All are relevant to the CGIAR system, and most are known to have supported crop protection projects. The International Society of Plant Pathologists, and comparable bodies for other disciplines, bring together the scientists involved in crop protection research.

34. National crop protection services vary enormously in extent and competence and their improvement must be a priority objective. Although help can be given to encourage development through teaching and demonstration, there are many roles that can only properly be discharged as national responsibilities, for example, plant health and quarantine services, pesticide residue analysis, seed certification schemes and many regulatory provisions. The few advanced institutions in developing countries (e.g. ICIPE) perhaps have an important special role in research training. FAO has taken a conspicuous role in organizing international collaboration in support of crop protection, e.g.:

- 'FAO/UNEP Cooperative Global Programme for the Development and Application of Integrated Pest Control in Agriculture'. (Concerns efforts in Africa, Latin America, Middle East and S.E. Asia, on cotton, rice, maize, sorghum, millet, etc.).
- 'FAO Plant Protection Programme'. (Concerns post-harvest loss, control and assessment of plant disease, plant quarantine, pesticide, WHO/FAO Annual Meeting on pesticides, weed management).
- 'FAO/International Agency for Atomic Energy'. (Techniques for use in breeding for 'pest' resistance, pesticide residue analysis and environmental consequences).
- The most recent and perhaps the most relevant effort is sponsored by both FAO and UNDP as an 'Action Programme for Improved Plant Protection'. It is the responsibility of the FAO Committee of Experts on Pest Control, which met first in 1980 (Rome) and again in 1981 (Eschborn, F.R.G.). This group has the important intention of defining the needs for strong national crop protection services to survey the capabilities and needs of individual national programmes. It hopes to collect data on crop loss, but because of the great cost of

widespread surveys , has decided to try to acquire data from experiments, small surveys, etc. It has also begun preliminary surveys of plant protection services in twelve African countries. The Committee inherited past interests in the Desert Locust, so it is understandable, if tantalizing, that it decided to give this problems some priority. When it has opportunity, and perhaps has strengthened the representation of experts in diseases to match those in animal pests, it will attend more to plant diseases; to weeds, where it recognizes a need for much more work and the training of more specialists (perhaps by establishing a weed science department in an African University); to birds, rodents, plant quarantine, the registration of pesticides and decreasing the incidence of post-harvest losses.
It is much to be hoped that this group can continue and extend its valuable work which has realistic aims. It recognizes the need to strengthen its resources, and it is necessary that this be supported.

Crop Protection within the IARCs

35. Centre Directors are thanked for supplying information here and elsewhere in this section. If there are inaccuracies or misinterpretations, the TAC Secretariat will be grateful for corrections. Tables 2a and 2b summarize the scientific effort involved in crop protection research. The total is quite impressive, but even so may not be adequate to the task.

CIMMYT

36. 'Pest' management in wheat. About 75% of CIMMYT's wheat programme is devoted directly or indirectly to plant protection, mostly against diseases. The effort has three main approaches: breeding for resistance, fungicidal control, herbicidal control of weeds.

(a) Breeding for resistance has concentrated particularly on major rust (stem, leaf and stripe) diseases, and provided wheat cultivars resistant worldwide to stem rust (*Puccinia graminis*). Limited effort is devoted to *Septoria spp., Fusarium spp., Helminthosporium spp.,* smuts and barley yellow dwarf virus. The search for and incorporation of resistance depends on:

(1) The traditional genetical and pathological analysis of particular gene action and their incorporation by conventional pedigree breeding.

Table 2a.

Crop Protection Personnel at IRRI, CIAT and CIP

	Entomology			Pathology			Weeds	Total staff engaged in crop prot.	Total workforce at IARCs
	Ecol.	Var. resist.	Insect. & IPM	Myc.	Bact.	Virol.			
IRRI									
Senior scientists	4	1.2	1.0	1	1	1	1.4	10.6	56
Visiting scientists	1.7	1.0	0	0	1	0	1.0	4.7	12
Research assistants	13.0	8.0	6.0	7	4	4	8	50.0	290
Tech. staff & labourers	44.0	31.0	19.0	24	23	15	18	174.0	1460
Post-grad./post-doc.	3.0	5.5	1.0	1	2	1	2	15.5	68
		Entomology			Pathology				
CIAT									
Senior staff		3			6		0	9	67
Visiting specialists		0			3		0	3	19
Professional support		7			15		0	22	185
	Entomol.	Nematol.	ICP	Myc.	Bact.	Virol.			
CIP*									
Senior staff	4	3	1	2	2	4	0	16	30
Scientific & supervisory	0	0	0	0	0	0	0	0	48
Other support	0	0	0	0	0	0	0	0	341

(*) Also has 7 breeder/geneticists.

Table 2b.

Crop Protection 1/ Personnel at other IARCs

	CIMMYT	IITA	ICRISAT	ICARDA	WARDA	Total
Pathology:						
Specialists	11	9	15(1)	6(1)	3	
Others 2/	7	-	-	6	-	
Total	18		15	12	12	
Entomology/Nematology:						
Specialists	4	11	12(2)	-	4	
Others 2/	-	?	-	4	-	
Total	4		12	4	4	
Weed Control:						
Specialists	-	3	-	-	2	
Others 2/	10	?	-	6	-	
Total	10	-	-	6	-	
TOTAL	32	23	27	22	18	

1/ Includes only staff in post. Excludes any staff engaged full-time in plant breeding, but includes seven breeder/pathologists (CIMMYT).

2/ Includes part-time crop protection workers, e.g. breeder/pathologists and weed control/agronomists (CIMMYT), also research fellows, associate specialists and technicians. IITA has in addition 17 breeders much concerned with crop protection.

Figures in brackets indicate staff included in total, but out-posted from Centre.

(2) Partly on growing very numerous acquisitions in areas where particular diseases are regularly severe, and selecting those showing the lowest average coefficients of infection (ACI), which usually prove to be those containing many resistance genes.

(3) Selecting for 'dilatory resistance' (slow-rusting, etc.), which may result from inefficient infection, limited growth, poor or delayed sporulation.

(4) Production of 'multiline varieties' comprising phenotypically similar plants which, because they contain different resistance genes, should produce more stable resistance. Collaborative work with Indian institutions in developing the exceptionally adaptable cross 8156, is the most advanced example.

(5) The results of ten years' study of results from intercontinental 'trap nurseries' for the three major rust fungi have indicated large areas where uniform wheat genotypes place crops at special risk from pandemics of such air dispersed pathogens. Such information should help CIMMYT develop a strategy for introducing varieties likely to avoid disastrous attacks.

(b) Chemical protection of wheat. While CIMMYT continues to believe that fungicides should only complement genetic protection, it does recognize that they could become more important where wheat cultivation may approach the present intensity in N.W. Europe. Currently its work aims:

(1) To evaluate new materials so that it can, from Headquarters or regional programmes, advise farmers on methods of controlling particularly serious attacks of diseases not yet effectively controlled by resistance. Currently this mostly concerns leaf rust, with head scab (*Fusarium spp.*) as another contender.

(2) At Headquarters, seed treatments aimed to eliminate seed-borne diseases (mostly smuts and bunts) are evaluated and applied to all samples issued; experimenters also use specific fungicides to eliminate diseases that might otherwise complicate or invalidate experiments.

(3) There is limited work on methods of fungicide applications (e.g. in irrigation water, granular side dressing, seed dressing and foliar sprays).

(c) Weed control investigations. Interest began through the need to control weeds in breeders' plots. Now that this is achieved by using herbicides, efforts have been extended as part of the crop's agronomy, to fields in Mexico and the regions. Emphasis was placed on wild oats (*Avena fatua*) and canary grass (*Phalaris minor*). While evaluation of new herbicides continues further work has shown that, by cultural methods alone, devastating infestations can be rendered unimportant in two years. Interestingly the effective methods differ from those attempted in temperate latitudes where a cold winter follows harvest. Different national practices may explain why weed control is a major factor limiting wheat yields in Pakistan, India and N. Africa, but not in Bangladesh, Nepal and the S. American Southern Cone Region.

37. 'Pest' management in maize.

(a) Breeding for disease resistance. Diseases are comparatively of less economic importance to the maize crop than to wheat, Polygenic resistance is uniformly used, and adequate field tolerance to *Helminthosporium spp.* and rusts exists other than in the highlands of equatorial Africa. Nevertheless, further improvement is proceeding, for example, against *Helminthosporium maydis* which is potentially serious in hot countries. The major needs are to improve resistance to:

(1) Streak virus, at present limited to lowland Africa, where a programme has been established to extend recent IITA successes.

(2) Corn stunt, where cooperation with Central American countries is making good progress, which could be extended should the disease occur in Asia or Africa.

(3) Downy mildew, in cooperation with regional staff in Thailand.

Other diseases receiving attention are tar spot (*Phyllachora spp.*), increasing in Central America, fungicidal controls are now known and genetic resistance is in prospect; stalk rots (*Fusarium spp.*) in Egypt; and ear rots, particularly in the Andean Highlands.

(b) Breeding for resistance to insects appears to take longer than to diseases, and now involves the mass culture in Mexico of larvae of fall army worm, sugarcane borer, Southwestern corn borer and ear worm. Thought is being given to how to develop methods for studying other damaging insects that do not occur in Mexico.

Collaborative programmes exist for measuring susceptibility of germplasm and new varieties to stored grain pests (with Tropical Products Institute, U.K.), and to aflatoxins in relation to genotype and climate (with USAID/USDA/University of Missouri). There is continuing selection for better and tighter husk cover, which decreases bird damage and entry of weevils into stored grain.

(c) Weed control. Weeds constitute one of the major limitations to maize production, but their control is usually specific to local environments and soils. Therefore trainees and regional staff are made aware of the problems and principles in traditional and limited tillage crops. They also have access to information from Headquarters and experiment station staff, who regularly conduct herbicide trials to ensure protection of experimental materials at CIMMYT experiment stations.

(d) Chemical control. Materials are tested regularly against pathogens and pests to attempt to ensure the reliability of the experiments it conducts or of the seeds it plants or exports.

(e) Stability of varieties. CIMMYT believes that its international testing programme is an extremely effective way to improve tolerance to the various stresses new varieties may meet. It is based upon the multilocation testing of many segregates, and subsequently recombining and retesting those that do best. It is thought that this progressive concentration of tolerance factors has shown measurable progress in a wide range of genetic material. CIMMYT considers its central effort is adequate, but recognizes a need for more regional investment against 'pests' that do not occur in Mexico.

IRRI

38. Rice diseases. Breeding for resistance has been given much priority, through studies of etiology and screening methods to identify sources of resistance. As a result, resistance has been identified to all thirteen diseases studied. Some resistance genes have been characterized and incorporated into newly developed varieties. The outstanding success was through incorporating a resistance gene from *Oryza nivara*, which greatly reduced the incidence of rice grassy stunt in the Philippines and elsewhere since 1974. Adequate resistance to sheath blight has not yet been found, and continued work is required where pathogenicity changes have occurred.

Chemical control is studied and applied where economically feasible. There have also been encouraging results from epidemiological studies of rice tungro disease, which have resulted in the Philippines in cooperative work leading to the ability to identify 'low risk crop seasons'.

39. Rice pests. Screening the germplasm collection (50,000) for resistance to eight major pests revealed 2,600 varieties with single or multiple resistance. National programmes have provided cooperation enabling screening for insects (e.g. gall midge) not occurring in the Philippines. Insect resistant varieties are now important in integrated control schemes in Asian countries. This is especially true of action against the brown plant hopper, where moderately resistant rice varieties have been shown useful in increasing the effectiveness of bio-control agents and insecticides. The mechanisms of resistance are also being identified.

40. Insecticides against rice pests are studied more at IRRI than anywhere else in the world. The programme embraces both application methods; the role of bio-control agents (including fungal pathogens) in suppressing pest populations; sex pheromones; insect migration; biologically active plant constituents and the biochemical bases of resistance. This work is done largely in conjunction with the world's foremost specialist laboratories and agro-chemical companies. Work on insect ecology is conducted in the Cropping Systems Program at IRRI, in which pest incidence is studied on rice and succeeding or preceding crops in relation to cultural and control practices, and the cropping system. Collaborative basic support work is provided by various institutions, e.g. on mechanisms of resistance to blast, as well as insect pests, and the use of pheromones in insect traps.
The Department of Entomology annually updates (to 2,000 scientists) a literature survey (600 articles) concerned in the management of insects in rice-based cropping systems. Besides contributing to scientific journals, IRRI distributes newsletters and results to over 16,000 rice scientists throughout the world, and produces tape-slide programmes for use in training at IRRI or elsewhere.

41. Weed science has received attention at IRRI since its inception. IRRI's current research involves development of relevant weed management technology for different rice cultures (transplanted, direct seeded flooded, direct seeded bunded, rainfed, and upland). Effectiveness of low cost herbicides in combination with other weed management practices is determined. Studies of weed ecology and weed management techniques for controlling perennial weeds in wetland and dryland rice are included as an intrinsic part of the research programme. IRRI has trained a number of young weed scientists from national programmes for M.S. and

Ph.D. degrees and has conducted non-degree research training. IRRI's weed science group participates in a joint training course on integrated pest management. Weeds are a major constraint to the improvement of rice yields in rainfed conditions, where establishment is by dry seeding. A meeting of the International Weed Science Society was recently held at IRRI, giving major attention to weed problems of rice production. The need to train more weed scientists for work in the national programmes is very apparent.

IITA

42. Although the mandate covers cassava, sweet potato, yam, cocoyam, rice, maize, cowpeas and soybeans, IITA restricts attention to African problems on those crops where the global mandate lies elsewhere. Weeds are seen as a major production threat, but they cannot be considered in isolation from land management any more than can research on pests and diseases be divorced from the locations where they occur or from the breeding programmes, which must acknowledge marked consumer preferences.

43. Weed research therefore emphasizes weed ecology, effects of tillage, smothering cover crops and the screening of herbicides for use in single or mixed species crops, or for the persistence of their residues in soils and water. Virus research has included studies of etiology, purification and serology to assist virus indexing and to understand the mechanisms of virus transmission (especially through seeds). It is recognized that few farmers can afford agrochemicals, so pest management studies aim especially to integrate pest, disease and weed control with resistant varieties and agronomic practices.

44. Legumes. Insect damage is most serious on cowpeas, which succumb to leaf hoppers, aphids, thrips, pod-borers and pod-sucking bugs against which breeding is directed as well as against fungal, bacterial and virus diseases. Stink-bugs and viruses cause major problems in soy beans, where breeders seek to find resistance or to limit seed transmission. The use of trap crops is also being investigated.

45. Cereals. Of three important African virus diseases of maize, the most serious is maize streak. Sources of resistance have been found by using mass infestations with the leaf-hopper vectors and serological virus detection. The elite resistant selections of the TZSR series are now extensively used in Africa. Less, but increasing attention is devoted to resistance to downy mildew, stem borers and cob rots. In rice, the other mandate cereal crop, attention has to be given to blast which is serious on upland varieties (the most important in Africa) against which

varieties with durable resistance are in prospect. Otherwise research has been concentrated on African problems, particularly rice yellow mottle virus, stalk-eyed fly and *Maliarpha* borer. Sensitive serological identification of rice yellow mottle virus has aided the identification of very resistant rice collections that are now used in the breeding programme.

46. Root and tuber crops. Cassava germplasm with marked resistance to bacterial blight and cassava mosaic is now in wide use in Africa, so attention has been turned to two pests spreading quickly after introduction from East Africa. Introducing hairy plant characters and biological control offer quick improvement. Recently sweet potato germplasm resistant to weevil and viruses has been identified and distributed to many African and Asian countries. Preferred varieties of cocoyam (*Colocasia spp.*) are being displaced because they are susceptible to cocoyam blight (thought to be caused by *Pythium spp.*). It is hoped that they can be preserved by incorporating recently identified sources of resistance.

CIAT

47. The CIAT mandate covers cassava, beans (*Phaseolus vulgaris*), rice and tropical pastures (grasses and legumes). Active crop protection programmes based on host plant resistance, biological control, and improved cultural practices are in progress with all crops.

48. Cassava: An integrated control programme is being developed for the major cassava pests and diseases.

49. Host plant resistance to three mite species, *Moncnychellus tanajoa*, *Tetranychus urticae* and *Oligonychus peruvianus* and several insects, mealybugs (*Phenacoccus herreni*), lace bugs (*Vatiga illudens*), and white-flies (*Aleurotrachelus socialis*), and stemborers, are being studied. Some resistant lines have been identified for all these pests. Biological control programmes are being developed for the cassava hornworm (*Erinnys ello*), mites mealybugs and lace bugs. Cultural practices that aid in reducing pest populations have been identified.

50. Cassava germplasm resistance to cassava bacterial blight, superelongation (*Sphaceloma spp.*), Choanephora leaf blight, anthracnose and post-harvest physiological deterioration is being studied and resistant lines have been identified.

51. Cultural practices to reduce disease incidence and severity are being developed for Frog-skin disease, Diplodia Root Rot, cassava bacterial blight and post-harvest deterioration.

52. Rice: Priority fungal diseases receiving concentrated attention are rice blast, sheath blight, brown leaf spot, leaf scald and the pathogen complex causing grain spotting. Insect research concentrates on the Sogatodes plant hopper and the hoja blanca virus which it transmits. Weeds continue to be a major yield constraint in all production systems.

53. Beans: Breeding for disease and pest resistance remains the bean programme's most important priority. Resistance to bean common mosaic virus is required in all the breeding lines developed at CIAT. Rust, common bacterial blight, anthracnose, angular leaf spot and bean golden mosaic are also given priority in the breeding for multiple disease resistance scheme developed by the bean programme. Among the major insect pests of beans, the leafhopper *Empoasca Kraemeri* continues to receive the most emphasis. Other bean pests for which higher levels of tolerance or resistance are being sought are spider mites and the bean pod weevil, *Apion godmani*.

54. Tropical pastures: Several species of legumes genera including *Stylosanthes spp.*, *Desmodium spp.*, *Zornia spp.* anthracnose and other diseases and insects. Resistance to the stemborer *Caloptilia spp.* has been observed in *S. capitata*. Resistance to the budworm, *Stegasta bosquella* is being investigated in *Stylosanthes spp.* and *Zornia spp.*

55. Research in grasses is concentrated on resistance to spittlebugs; results show that *Andropogon gayanus* is resistant and *Brachiaria humidicola* is tolerant to spittlebug attack. A programme for biological control of the spittlebug with the entomogenous fungi, *Metarhizium anisopliae* is underway. The grass diseases *Rhynchosporium* leafspot and "Crazy top" are being studied.

CIP

56. It is important and unusually difficult to maintain the health of potatoes through vegetative propagation cycles which may pass on degenerating virus diseases and other 'pests'. CIP continues a vigorous programme to evaluate 'pest' resistance on the greenhouse and field, and to incorporate through breeding resistance to late blight, bacterial wilt, leaf roll virus, cyst and root-knot nematodes and tuber moth. Depending on the 'pest' both monogenic and polygenic sources of resistance are used. Integrated crop protection involving biological control of root-knot nematode, tuber moth trapping by pheromone attractant and agronomic and chemical control practices are routine.

ICRISAT

57. Screening germplasm for major 'pests' is a priority objective on all the mandate crops (sorghum, pearl millet, pigeonpea, chickpea and groundnut). There is also work on other elements of pest management, including natural and biological control, cultural practices and the use of pesticides.

58. There is a concern for the total 'pest' complex of the crops which involves biological and ecological studies of insect pests (especially *Heliothis spp.*, pigeonpea podfly, sorghum shootfly, stem borers, and on groundnut, thrips, jassids and leaf miner), and among diseases (wilt complexes or pigeonpea and chickpea, viruses and leaf spots on groundnuts, head moulds and charcoal rot on sorghum, ergot and downy mildew on millet). Mycotoxins, particularly aflatoxin, are of prime importance to the groundnut pathologists. *Striga spp.* are the weeds receiving particular attention, both in India and in Africa.

ICARDA

59. Disease problems.

(a) The cereals programme aims to identify and use durable resistance to the diseases most important in the ICARDA region. This is done by identifying regions where particular pathogens occur in annual epidemics, to analyse the occurrence and role of various resistance genes, to incorporate the best into breeding programmes and to distribute them to national programmes.

(b) Non-cereal forage pathology is everywhere notoriously difficult and neglected, and only began in ICARDA in 1980-81. Therefore it has not passed the survey stage, but initial attention is directed to *Ascochyta spp.*, powdery mildew, downy mildew and common leaf spot (*Pseudopeziza spp.*).

(c) Among food legumes the major problems are: in faba bean (*Vicia faba*), rust, chocolate spot and *Aschochyta spp.*; in lentils, wilt and root rots; in chickpeas, Ascochyta blight.

60. Work has begun on the biology and epidemiology of *Ascochyta spp.* and *Botrytis spp.* (chocolate spot). Resistance screening procedures have been developed for laboratory and field use. At present ICARDA staff are unable to tackle virus and bacterial diseases or the root rot complex, so there is a temporary reliance on help from research in developed countries in the temperate zone.

61. Insect problems. Sources of resistance or natural enemies are being identified; among cereals, to stem sawfly (*Cephus spp.*) and aphids; among food legumes to aphids, stem borers, Sitona weevils and storage insects.

62. Weed control. Although there is a general awareness of the value of agrochemicals in integrated crop protection, most work has so far been devoted to herbicides. In cereals and forages this involves identifying best compounds and dosages for different agro-ecological zones, crop vigour and to match cultivar susceptibility. For weed control among food legumes attention has been given to both selective and broad-spectrum herbicides, and international trials have been established for faba bean, chickpeas and lentils.

63. The parasitic flowering plants receive special attention both to discover tolerance to *Orobanche spp.* among food legume genotypes and, in Syria, the possibility of controlling *Cuscuta spp.* with alfalfa seeds.

WARDA

64. Most of the crop protection staff work in the special projects in mangrove swamp rice (Sierra Leone), irrigated rice (Senegal), floating and deep-flooded rice (Mali) and upland rice (Ivory Coast). Besides screening for resistance to pests, the WARDA specialists have included insecticides and herbicides in coordinated variety trials.

65. The Centre has recently agreed to extend its work on rice stemborer in conjunction with ICIPE. It recognizes the need to begin a regional programme for integrated 'pest' management in rice, also involving training, applied research and demonstration, but at present lacks the funds to begin.

Needs for Tropical Crop Protection Research

66. The record of the 26th Meeting of TAC (AGD/TAC:IAR/81/29, p. 85, para 302) specifically requested IARCs to answer the questions posed in para 50 of AGD/TAC:IAR/81/6 Rev. 1. For convenience the questions are repeated below with a summary of the replies.

(a) *At present the cellular physiology and biochemistry of 'pests' is mostly studied in developed countries. Is there a need for increased effort by IARCs?*

Several Centres recognized a need and dependence on this type of work, but with only occasional mention of exceptions, e.g. ILRAD, ICIPE, thought it best left to collaboration or contract with specialist laboratories unless (as with ILRAD and ICIPE) they possessed the specialist expertise and facilities.

(b) *Most study of 'pests', natural enemies, etc., is presently located with study of the commodity affected. Do the crop and location specificities make it unwise to attempt centralization?*

A strong and unanimous opinion against centralization of crop protection research. Supported by the need to decentralize some work from individual Centres to their regional or national programmes. Also stress placed upon the necessity to preserve multi-disciplinary teams devoted to <u>all</u> aspects of crop improvement at mandated Centres.

(c) *Taxonomy and culture collections are essential facilities that are best centralized, but often poorly funded. Should the CGIAR system have more formal links with such institutions (USNCC; Commonwealth Mycological Institute, Kew; Bureau voor schimmelcultuure, Baarn, Netherlands; etc.)?*

Almost without exception IARCs recognized their continual dependence on such institutions. Five of eight Centres questioned wanted more formal links, several commented on present generosity, none complained of unwillingness to help. Few seemed to realize the threats to the continuation of such facilities in their home countries.

(d) *Quarantine is a national responsibility, but important to IARCs for seed health and dispersal of vegetative propagating material. Is there any possibility of improvement or economy by centralization?*

There was a recognition of national responsibilities, and most Centres were opposed to centralization. Comments included the need for individual Centres to improve standards and to assist in identifying unrecognized causal agents; the need for central agreement on standards (with FAO assistance); the success of some regional centralization (WARDA); no central station could handle the necessary diversity; third country quarantine was often valuable.

(e) *The certification of healthy propagating material seems well suited to tropical agriculture, but relatively little practised. Should certification schemes be encouraged?*

Almost complete unanimity in favour of developing certification schemes (CIMMYT felt it could benefit more by improved seed storage). Comments included: the need to develop schemes in relation to the development of national programmes and a fear that schemes might succeed only where dispersal or vectors are rare. (There is much evidence that such fears are exaggerated where infection rates are slow, or replenishment with fresh certified material is frequent and affects much of the crop).

(f) *Are facilities adequate for studying or seeking help with: natural enemies, epidemiology, loss assessment, increasing the durability of plant resistance and/or 'pest' sensitivity to pesticides?*

Most Centres recognized inadequacies in these capabilities, but in general considered present spending was right within financial limitations. Several agreed they relied for such special needs on contract or special assistance. IITA recognized that need differed much with different 'pests', but thought any apparent over-commitment to resistance breeding was not an element of faith, but a recognition of the reality that it was the least expensive, widespread way of controlling pests for tropical farmers (and simultaneously increasing yields).

(g) *Accepting that integrated pest management is a desirable objective, are the IARCs adequately staffed and equipped to study the component of chemical control that it implies?*

A majority of Centres thought they were adequately prepared for the need for agrochemicals. Several recognized a role for chemicals (most often herbicides) where other methods had not succeeded. Two admitted to having no competence at present; others would add more if funds permitted, or were prepared to leave it as a national responsibility.

(h) *Is the present effort on weed science adequate? Must it be crop and location specific?*

All Centres considered the present effort inadequate and that increases must be crop and location specific; plainly replies to which CGIAR should listen and respond. Comments included: recognition that often the ecosystem/water regime was more specific than location or crop species; that weed control was a major labour demand on tropical farmers; that trained weed specialists were urgently needed (an opportunity for a university?); recognition of dependence on the Tropical Weeds Programme of Weed Research Organization, U.K., which has recently been closed, but had supplied unbiased evaluation of herbicides.

(i) *Should the IARCs devote more effort to post-harvest losses and/ or mycotoxins? If so, how should it be increased?*

One Centre considered increasing yield more important than preventing loss or toxicity. Most recognized a general need for more awareness and action, but thought that, in general, adequate help was obtainable from laboratories in developed countries (Tropical Products Institute, U.K., American Universities, etc.). Several recognized a need to incorporate screens into breeding programmes to exclude very susceptible products. ICRISAT acknowledged a major concern with aflatoxins in relation to groundnut breeding, but no Centre offered to develop this as a specialist or training responsibility.

(j) *Are the other damaging agents thoroughly studied as we can at present afford? If not, what change of priority is proposed?*

Acknowledged to be not a plainly worded first question. Possibly because of this, few Centres acknowledged great need to change priorities. In any event, it was thought changes would seldom be common to all Centres. ICRISAT did see needs to emphasize work on birds, nematodes and parasitic weeds. IITA noted that changing crop practices could affect pest, disease, or weed problems.

(k) *Do IARCs have sufficient capability in or access to agro-meteorological research concerned with the effects of weather and climate on crop protection?*

The majority of Centres thought there should be more work done. Only ICRISAT had a specific programme. IRRI had received WMO and special fund assistance, but wanted it to be a core activity. One Centre had difficulty in obtaining national/regional data, but this seemed unusual. CIAT has shown how useful agroclimatic zoning can be. The subject merits more attention within IARCs.

(l) *The CGIAR has supported work most likely to bring quick improvement to crops and food in tropical countries. As national research develops, should the IARCs prepare to exercise their competitive advantage to assist national programmes with more fundamental studies, for which they now rely on developed countries?*

Most Centres agreed, but thought the needs must be studied case by case; could be met by the long-term planning exercises; must await considerable development of national programme competence; would be a long time before it became urgent.

Additional question - ICRISAT thought the following should have been asked:

> *Is the breeding/selection work in the IARC geared to the farmers' current and short-term future needs, particularly with regard to insect pest threats? This question has to be asked, for in general much of the breeding, selection and testing in the IARCs and in most national programmes appears to be conducted under insecticide umbrellas. ICRISAT has set aside two unsprayed areas, 86 ha on the black soil and 29 ha on the red soil, for testing and research. Plant breeders are starting to conduct projects in these areas.*

APPENDIX A

1. At its 5th Meeting TAC in 1973 considered papers from UNDP/FAO and FAO/International Agency for Atomic Energy Division, seeking better identification of gaps in pesticides residue research. Another paper by FAO introduced the subject of integrated pest control, and proposed a network of cooperative multi-country research projects. At the 6th TAC Meeting, FAO papers proposed worldwide coordination of research on *Fusarium spp.*, and a worldwide coordinated programme of research on horizontal resistance to wheat diseases. TAC did not support these proposals, considering that 'pest' control should be an integral part of the research programmes of the primary commodity research centres.

2. The question of pest and disease management and control was mentioned at the 21st meeting in the TAC Review of Priorities for International Support to Agricultural Research (AGD/TAC:IAR/79/1 Rev. 1). TAC recognized the problems that the development of pathogen biotypes created for plant breeders. They identified both the hazards of dispersing new biotypes and the delays that strict quarantines would cause to breeding programmes. The Committee supported the continued search for durable resistance and for more study of epidemiology and physiology to assist the development of effective integrated control practices.

3. In reviewing factor-oriented research ('Factor-Oriented Research under the CGIAR' AGD/TAC:IAR/80/5), TAC concluded that it had identified water management and plant pest and disease physiology, ecology, management and control, as high priority areas for consideration of possible new institutional arrangements under CGIAR auspices.

4. At intervals TAC has considered the contributions that could be made to pest management by ICIPE, especially if it were to be admitted to the CGIAR system (see Chapter III of the TAC mission report to ICIPE - Review of TAC and CGIAR discussions on ICIPE. At its 24th Meeting, TAC recommended against the admission of ICIPE chiefly on the ground of its place among the relative priorities of the CGIAR system and factor-oriented research, as well as of its possible complementarity with the commodity programmes of the IARCs. (Report of the 24th TAC - AGD/TAC:IAR/80/28, paras 171-182, pp. 51-54).

5. In Manila in November 1980, the CGIAR accepted TAC's recommendation concerning the non-admission of ICIPE; it also asked the World Bank to act as secretariat and fiscal agent to a consortium of donors for ICIPE. The CGIAR also asked TAC to review the priority to be given by the CGIAR to pest management, a task that was begun at the 25th Meeting of TAC (Addis Ababa, Feb./March 1981). The Secretariat produced a valuable introductory paper (AGD/TAC:IAR/81/6), which stimulated much discussion and a decision to request a committee member to revise the document (AGD/TAC:IAR/81/6 Rev. 1), to serve as the basis for a discussion with

the Centre Directors at the 26th TAC Meeting. This is summarized in the Report of the 26th Meeting (Ibadan, Nigeria, June 1981, paras 42-43, and 290-302. Ref.: AGD/TAC:IAR/81/29.

6. The present document seeks to incorporate the Ibadan discussions and subsequent correspondence with Centres involved in crop protection towards a policy for crop protection which TAC may wish to recommend to the CGIAR in November 1982.