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PROBLEMS OF PEST CONTROL IN DEVELOPING COUNTRIES

IN RELATION TO MANAGEMENT OF THE ENVIRONMENT

(Item 9)

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TO: Technical Advisory Committee on International Agricultural Research

FROM: Ray F. Smith, Chairman, Department of Entomological Sciences, University of California

SUBJECT: Crop Protection in Developing Countries

Peter Oram has asked me to prepare an overview of the crop protection situation in developing countries for your consideration at the TAC meeting in Rome later this month. It was originally intended that this statement be distributed with the usual cover for agenda items. However, this has not reached me yet, and I am sending my statement directly to you so it will be in your hands prior to the Rome meeting. I shall be present in Rome for a portion of the TAC meeting to amplify this statement as needed and as would be useful.

Attachment
Critical Need in Developing Countries for Increased Crop Protection Response Capability

The world has seen in recent years an amazing change in the race between food production and human population increase. Tremendous gains in food production have occurred in many parts of the world and this trend is expected to continue. This widely publicized phenomenon, often termed the "Green Revolution," has resulted from a combination of many factors; the chief among them are: (1) the introduction of new high-yielding crop varieties, (2) the availability of purchased production inputs, e.g., fertilizers, pesticides, tractors, (3) new crop management technology (including double and multiple cropping), (4) improved irrigation capability and (5) the long-term cumulative effect of development efforts by national governments and international agencies. It should, of course, be recognized that a part of the gains in food production in some years have also been the result of favorable weather.

The system of traditional agriculture, which is characteristic of many areas in developing nations, is beginning to give way to modern agricultural technology. Traditional agriculture with its labor intensive, small fields sparsely planted with seeds of mixed genetic types is not as readily exploitable by endemic plant pests as are modern " monoculture" systems. The mixed culture also provides some protection against climatic adversity and attack by new pests because of its inherent heterogeneity. Furthermore, plants grown under the tillage system of traditional agriculture are generally not as susceptible to some pests as those developed under more favorable conditions for growth.

Pressured by a multitude of ubiquitous pests over many centuries, man's crop plants have become adapted through natural selection to the selective pressures of these traditional agricultural systems (agroecosystems). This state is stabilized by an array of genetic factors for high yield combined with tolerance to low fertility, pest attack and other environmental stresses. Moreover, these traditional systems usually represent an efficient allocation of man's available resources and rarely respond to additional investment of resources without accompanying introduction of new technology for increased production. This means that if modern pest management practices are imposed on traditional agroecosystems without also increasing the basic production potential, the investment will not be profitable; on the other hand, new crop protection inputs may be needed most critically where the
traditional agriculture has been modified by introduced technology, e.g., new varieties and fertilizers.

As contrasted to traditional agriculture, modern agriculture is a more intensified system that integrates capital inputs with management technology to maximize production per unit of area at minimum cost per unit of production, hopefully on a continuing basis. Many of the practices developed to achieve this goal contribute significantly to increased plant pest problems and thus may prevent achievement of the goal. For example, plant introduction and exchange has resulted in varieties with higher yields, resistance to pests and other desirable qualities; but this plant movement may carry with it new pests and disease pathogens and the introduced plant types may be susceptible to indigenous pests and diseases. Modern monocultures frequently involve only a single plant variety with a very narrow genetic base thus enhancing their vulnerability to devastation by pests and disease. Plant breeding and selection often place major emphasis on a single or very few qualities, consequently history records many examples of new varieties highly susceptible to previously innocuous pests or to new pest strains. Vegetative propagation, e.g., bananas and potatoes, has the real disadvantage of disseminating serious pathogens through infected or infested stock.

In addition, many cultural practices of modern agriculture may enhance susceptibility to disease or attack by insects. These include (1) fertilization which produces larger and more succulent plants that are often more susceptible to disease or insect damage than plants grown at lower nutritional levels; (2) irrigation which favors many disease and insect pests as contrasted to the fluctuating soil moisture levels under natural rainfall condition; (3) tillage and other soil manipulations are often an important factor in increasing the incidence of disease as compared to no-tillage or limited tillage cultures; (4) double and triple cropping which promotes rapid increase of pest populations; and (5) more dense plant populations with resulting micro-environment changes that favor the development of some pests. These same cultural practices may at times inhibit certain other pests, but in general, the balance is one favoring increased pest and disease incidence.

The "Green Revolution" has introduced many of these practices into the developing nations at a very rapid rate, and the pace of the process promises to quicken in the future. The rapidity by which these practices have been adopted and the increased production which resulted have been both surprising and gratifying. Motivated by the increased production with the new practices, many developing countries and international organizations have placed increased emphasis on the development
and introduction of new agricultural technology. These modernizing practices, which also enhance the potential for destructive pest attacks, are being introduced without proper attention to crop protection as a component of agricultural development programs. This is not to question the validity of these developments—there is now no other alternative. The fact remains that the changed agroecosystems resulting from the introduction of new methodologies produce shifts in and very often an intensification of pest and disease problems. This proven hazard is not today properly reflected in most of the development programs around the world. There is mounting evidence indicating that pest and disease problems in the developing countries are becoming more severe, indeed in some cases devastating, as the modern practices are introduced. Unless bold measures are taken to protect the food crops of developing nations against the ravages of pests and diseases, the production gains realized recently could vanish and hope for the future could be lost. Along with the introduction of new production technology, the introducers and the recipient developing nations must assure the development of an adequate crop protection response capability in order to protect the food production gains. This must involve significant effort in the training and retraining of crop protection and pest management specialists, the organization of new types of programs for research at the adaptive and implementation levels, and the education of the general public and farmers as to the significance of crop protection to their welfare.

Hazards to Environmental Quality and Other Unwanted Secondary Effects from Crop Protection Activities

As part of modern concern with the quality of the environment, we must take into account crop protection activities as they may have direct and indirect impact on the environment. This is true if for no other reason than that it is almost impossible to do anything within an environment—whether this environment be the entire biosphere, a restricted agroecosystem, a lovely home garden, or a quiet living room—without having a secondary and often unexpected impact on that environment. Some pest and disease control activities, especially those involving use of pesticide chemicals, may have a significant impact on environmental quality or stability in an agroecosystem. However, we should not become obsessed with these disruptive influences on environmental quality resulting from pest control activities for they are relatively minor as compared to other disruptive aspects of man. It would be better if these negative aspects of pest control would be examined as just one of the many considerations as better methods of managing the environment, including improved pest control, are sought. This more positive approach can contribute
to an enhanced environment and at the same time to the improved nutrition and health of man in all parts of the world.

The insertion of a chemical pesticide into an agroecosystem has as its objectives a change in the living conditions of at least two components of the system. Usually insecticides are applied for the purpose of bringing about a drastic reduction in numbers of one or more species of pests so that more favorable conditions can be provided for the growth and development of a crop species. Thus, the environment is changed and as a consequence there occur reactions and adjustments among other components of the agroecosystem. Chain reactions of enormous complexity may be set in motion by the application of biologically active pesticides such as the organochlorine, organophosphorus, and carbamate compounds used during the last quarter-century. These interactions are so complex that it is doubtful that even the most simple has ever been described completely or understood fully.

The environmental disruptions resulting from use of the synthetic organic pesticides have resulted in substantial alteration of the faunal composition of our agroecosystems, especially those that have received intensive treatment, deciduous fruits and cotton, for example. Some of the changes that have been most frequently observed following applications of pesticides have been severe outbreaks of secondary pests and of normally minor species and the rapid resurgence of treated populations. The severe and long-lasting depressions of natural enemies compared to pests following exposure to pesticides often is the result of the denial of adequate food for the natural enemies brought about by destruction of the prey species (i.e., the pests).

Considerable field experimentation in recent years has produced strong evidence to support the proposition that natural enemy suppression by pesticides is a major cause of change in pest status and resurgence of treated populations. Nevertheless, some evidence is available that shows factors other than the destruction of natural enemies are also involved in these population phenomena. Species-specific response to other mortality factors can be expected to occur just as it does to intoxication by pesticidal chemicals. Therefore, it is likely that other factors often operating in intricate complexity are also responsible for some of the pest "upsets" that have been attributed to the adverse effects of pesticides alone. A better understanding, than now exists, of the complex interactions taking place in agricultural ecosystems is needed. The interactions between pests and their hosts, natural enemies, and competitors and between the natural enemies and their natural enemies and competitors must be better understood in the development of effective pest management systems.
A Broad Ecologiclal Approach is Required for Stable Pest Management and Control

The revival of the old era when pest control was to a great extent ecologically-oriented is now firmly established today. This has come about largely as the result of public reactions to problems associated with pesticide chemicals combined with failure of complete dependence on chemicals to give adequate crop protection. There are numerous well-documented examples of the inadequacy of a unilateral chemical approach in both developed and developing countries. Unless a broad ecological approach such as emphasized by "integrated control type" programs is initiated, additional "pesticide abuse" situations will arise. Complete dependence on hazardous, broad spectrum pesticides over a period of time not only fails to control the pests in question but actually aggravates pest problems, endangers human health and threatens environmental quality. Furthermore, pesticide misuse imposes an additional real cost on food production.

The integrated control strategy employs the idea of maximizing natural control forces and utilizes other pest management tactics with a minimum of environmental disturbance and only when crop losses justifying action are threatened. Adverse weather factors, while a powerful repressive force for pests in agroecosystems, are not consistent enough to be a reliable suppressor of major pests. Use of natural enemies and plant resistance are basically compatible and supportive in the integrated control strategy. Cultural control, a third basically compatible tactic, is commonly used in ways to expose the pests to adverse weather, to disrupt their natural development, to increase the action of natural enemies, or to increase the crop's resistance. Chemicals, although not always compatible with the use of natural enemies, often can furnish a reliable immediate solution to a problem. Thus, pesticides are an important and necessary element in integrated control programs. Finally, a basic fund of ecological and biological knowledge is needed to guide decision-making in the integrated control strategy.

It is mandatory that scientists, in seeking better crop protection, explore the potentials of pest control with broader perspective than looking to single uncomplicated solutions. The search should include the broadest array of possibilities for control with emphasis in utilizing those forces which nature itself has put foremost; that is, the use of natural enemies, of plant resistance and of manipulations which expose pests to adversities of the environment.

The attainment of resistance in our crop plants to all major pests and diseases is an unrealistic goal. Nevertheless, resistance to key pests and diseases
or even partial resistance to some of them can be most useful in integrated control programs and at times is an essential element.

In the utilization of natural enemies, consideration must go far beyond the techniques of classical biological control, i.e., introduction of parasites and predators into new areas. Attention should also be given to assessing and understanding the role of natural biological controls, manipulation of the environment to increase efficiency of existing natural enemies, periodic colonization of natural enemies, supplemental feeding of natural enemies, and utilization of the invertebrate pathogens such as viruses.

The horizons suggested by introduction of new invertebrate pathogens and utilization of indigenous ones, such as insect viruses, have hardly been touched. It is highly probable that pathogens selective for certain species or groups of insects and innocuous to vertebrates abound in nature, but too little effort has been made to find them, characterize them, and develop them for practical use. Pathogens have many of the advantages of chemical insecticides and they lack many of their disadvantages; furthermore, the available pesticide application technology is adaptable to them. Some of the known pathogens are quickly and highly effective, specific in activity, safe and biodegradable. In some cases, they can be readily stored. Their cost, lack of proved reliability, patentability, and problems of registration clearance present some of the disadvantages and the barriers to their development. FAO and WHO are now making progress in establishing protocols for determining safety to humans for these microbial control products.

Pesticide Chemicals Serve a Special and Essential Need in Crop Protection

Chemical pesticides remain in many situations a most powerful and dependable tool for the management of pest populations. They can be more effective, dependable, economical, and adaptable for use in a wide variety of situations than many other proven tools for maintaining pest populations at subeconomic levels. Indeed, use of chemical pesticides is the only known method for control of many of the world's most important pests of agriculture and public health. No other tool lends itself to such comparative ease of manipulation and none can be brought to bear so quickly on outbreak populations.

Narrowly-selective chemicals appear to offer an almost ideal means of pest control. However, only a very few such chemicals have been discovered and developed for commercial use. Future prospects for additional developed chemicals have become
very dim. Historically, the chemical industry, for the most part, has had little interest in finding and developing this type of compound. The financial return upon investments in research and development of truly physiologically selective insecticides is small when compared with that for the broad-spectrum compounds now so widely used for insect control. Except for a relatively few key pests of major crops, e.g., boll weevil, rice stem borer, and codling moth, the chemical industry would be hard pressed to recover research and development costs of monotoxic compounds for pest control.

It is highly unlikely that the chemical industry will be willing to make unaided any substantial effort to discover and develop new selective compounds. This results from the problems involved with development of resistance to insecticides in many pest species with resultant rapid obsolescence of the chemical, unwanted side effects, high costs of securing tolerances and registrations for use, and a society that has become increasingly critical, perhaps unreasonably so, of chemical pesticide use. In fact, the prospects are so unattractive it is unlikely that industry will attempt to market such compounds previously synthesized and known to possess interesting selective properties but which are now sitting on the shelves of their chemical laboratories. This dilemma is one of the major obstacles blocking the development of adequate crop protection for the future.

Fortunately, it is not always necessary to rely upon the physiological selectivity of chemicals to obtain some of the specific effects required in integrated control and other pest management systems. Ecological selectivity obtained by the discriminating use of even the most broad spectrum insecticides can be employed in many cases for the development of effective, economical, and ecologically sound pest control programs. Development of such programs is presently limited to some extent by a lack of knowledge of the ecology, biology and behavior of pest/natural enemy/crop complexes. A more seriously limiting factor is a shortage of properly trained, imaginative, and capable applied crop protection specialists dedicated to the development of pest management systems based on the principles of integrated control. Nevertheless, there are some encouraging examples of progress along these lines in both developed and developing countries.

While it is recognized that pesticide chemicals have been and will continue to be an essential part of crop protection, current practices in pesticide use have not always been sound, not only in terms of food production, but also from the standpoint of human health and environmental quality. There is substantial need for trained personnel to assist and guide the "pesticide management process," i.e.,
the proper selection, procurement, formulation, packaging, shipment, storage, marketing, application, and disposal of pesticides.

The New Pest Control Technologies on the Horizon Cannot be a Full Solution

Insect hormonal chemicals, a variety of biochemical determinants of behavior, notably pheromonal type chemicals, and genetic interferences with reproduction have stirred imaginations of entomologists looking for a third horizon of insect control. These developments have not progressed far enough, however, to establish their probable utility or possible adverse consequences. However, there is now considerable evidence that none of these new technologies will be panaceas and problems of resistance, residues and undesirable ecological side effects will also be associated with many of them. For the foreseeable future, these new technologies must be looked upon as potential weapons which may be added to the crop protection scientists arsenal. Furthermore, the systematic gathering of qualitative and quantitative information on pest ecology and behavior is essential if many of the newer, as well as the older, non-pesticidal control techniques are to find their proper place in systems of crop protection.

Integrated control or pest management schemes will not arise automatically from neither research emphasizing the new pest control techniques nor from long term basic research alone. Practical integrated control programs available today have arisen only from pragmatic research directed at finding solutions for the real crop protection problems as they exist in farmers' fields. In nearly all cases integrated control programs come about as the result of a gradual evolution in which new technology has been introduced in a step-by-step process rather than through the introduction of a complete fully-formed system.

Crop Protection in the International Agricultural Research and Training Centers and a Multi-Country Research Project Approach to Strengthening Programs and Solving Critical Crop Protection Problems

The Consultative Group has been giving considerable attention to the development of international research and training centers as a basic element in a worldwide agricultural research network. Significant accomplishments have already been achieved by these centers and more are anticipated. However, in the crop protection field it is widely recognized that their scientists are but a "thin line" in the battle against pests and disease. Moreover, these international centers must, in addition to their own research programs, form vital linkages with programs in both
developed and developing countries if they are to reach their full potential for contributing to improved agricultural technology. The international centers have and will continue to produce new technology applicable to the problems of the developing nations, but that is not enough. There must be a mechanism to join the efforts of developing nations with those of the centers and other applicable institutions such as agricultural universities and institutions in developed countries and certain international organizations. The coordination of efforts on common crop protection problems through cooperative multi-country research projects could form such a set of linkages for an international research network subtending the network of international agricultural research centers.

These linkages must go beyond the "program collaborator concept." Under the "outreach" program of the International Rice Research Institute, for example, genetic materials are made available through a system of collaborators in many parts of the world. The collaborating countries or institutions have and can benefit from this participation by screening these genetic materials for adaptability to local conditions. But that system does not go far enough in assisting with the development of viable local programs. The "multi-country research project concept" would establish a more intimate relationship with collaborating institutions by involving their personnel in the processes of problem identification, project planning, project implementation, and project review. This should enable the developing countries to utilize more effectively their own scientists and the new technology flowing from the international centers and elsewhere.

At the present time there is very little collaboration between developing countries faced with the same pest or disease problem. Most developing countries have very limited scientific or other resources to bring to bear on such problems. The cooperative multi-country research projects would be a means of maximizing the utilization, on a collective basis, of these scarce program resources, of minimizing research results applicable to the real problems of each participating country.

Two elements would be critical to the success of these cooperative multi-country research projects: (1) a source of "international" funding to defray the truly "international costs" of the project such as the cost of meetings for planning and reviewing research and perhaps project initiation and modest operational costs of in-country project components; and (2) a management institution which would provide leadership in developing, implementing, and carrying out the project activity as well as managing the financing for the project. This management institution could be, for example, one of the international centers, or another appropriate
international organization, or an agricultural university in a developed country.

Other important characteristics of cooperative multi-country research projects on crop protection problems might be as follows: (a) a collaborative research relationship between two or more research and/or educational institutions in developing countries and one or more "common interest" international institutions or agricultural universities from a developed country; (b) a "common crop protection problem" which is subject to a multi-country approach and which will benefit from the broader perspective than can be gained by confining research efforts to a single country; (c) financial support by the collaborating institutions (including both developing and developed country institutions) to the extent of local funding availability and by other "international" sources; (d) a focus on high-priority crop protection problems in each collaborating country; (e) a technical committee of the active researchers from each collaborating institution. This technical committee would have responsibility for developing the project outline which would ascribe the research role to each collaborating institution. This approach would avoid unnecessary duplication of effort, expedite research progress through pooled resources and enhance communication between scientists of common interest in different countries so that each can benefit from the results and experiences of his international peer group; and (f) have the goal of strengthening crop protection programs in the developing countries commensurate with their long-term needs to insure against catastrophic crop losses from pests and diseases.

An important justification for "internationalizing" crop protection research is the fact that many of the most serious pest problems are very widespread in distribution and importance. These problems must be studied and understood on an international scale to permit development of ecologically and economically sound, long-term control strategies. On the other hand, many pest problems are location-specific in that certain varieties perform differently between areas as a result of differences in strains or races of the pests or different environmental factors. We must know and understand the common elements of different locations which account for problem similarities but just as importantly we must know the factors which produce problem dissimilarities between locations because these may provide the basis for control procedures at other locations.

In summary, the cooperative multi-country research project approach enables a group to accomplish collectively objectives that cannot be realized working independently with limited resources.
It is clear that enhanced crop protection response capability is an essential requirement for increased food production in the developing countries. This enhanced capability will assist both in securing the gains achieved and to be achieved through the "Green Revolution" and by reducing the severe food losses to pests and diseases. To improve significantly crop protection response capability, an immediate and broad attack on the problem must be made including, a) training and retraining of crop protection and pest management specialists; b) education of farmers and the general public in crop protection matters; c) in-country institution building; d) development of implementation technology for crop protection systems; and e) adaptive research approached on a collaborative, multi-country basis to develop crop protection solutions suitable for farm-level usage.

Training. Many crop-protection administrators, researchers, teachers and extension workers in developing countries received their formal training during the fifties and early sixties when an over-reliance was placed on pesticide chemicals for crop protection. In addition, many of these same scientists were trained in sophisticated university laboratories quite unlike the ones usually available to them in their home countries. Many of these crop protection personnel are becoming increasingly aware of the importance of a broad ecological approach to crop protection and the significance of an intensified attack on practical problems threatening food production. Their earlier training is inadequate to meet these new goals and much additional training will be needed. A great variety of tactics are available to achieve these training objectives, including short courses, workshops, conferences, short-term consultants, and most importantly, active participation in collaborative research projects in the developing countries. Future training of additional crop protection specialists for the developing countries should be focused on the special needs within their own agricultural systems and should also emphasize locating the training in the developing areas.

Education of General Public. Substantial efforts should be made to inform the general public as to the severe food losses caused by pests and diseases and the significance of an ecological approach to crop protection and the preservation of environmental quality. An informed public (including farmers) is an essential step in the implementation of adequate and effective crop protection programs.

Institution Building. Although some progress has been made toward development of in-country crop protection capability in local institutions, this must be
expanded and reinforced with emphasis on a multidisciplinary approach to crop protection. Again, participation in multi-country research projects should assist in this goal.

Implementation Technology. To implement these crop protection programs, changes in farmer and consumer attitudes and also of government regulations are needed along with increased awareness and knowledge of the complexity of agroecosystems. We need especially to alter our pattern of pest control advising. Not only are the biological aspects of crop protection complexities involved in the program implementation but also the political, social, regulatory, and educational avenues will have to be developed if the real food production potential is to be attained and protected.

Adaptive Research. In the first place, adaptive research derived in large part from existing knowledge and aimed at the problems as they exist in farmers' fields is needed. This adaptive research should include a) learning how to use chemical pesticides to the best advantage, b) understanding the ecology of the pest in its agroecosystem for purposeful manipulation of pest populations, c) comprehending the significance of the non-crop elements of the agroecosystem and their limitations on various control methods, and d) solving the incompatibilities among various control technologies. A reasonable balance of strategic or long term research should be included to provide the framework of understanding on which improved crop protection measures of the future will be based. The strategic research could provide ecological knowledge to improve the background of new control measures, predictive modelling, better understanding of processes involved in agroecosystems, etc., which should lead to improved crop protection.

Berkeley, California
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This statement was prepared by Ray F. Smith, Professor of Entomology, Entomologist in the Agricultural Experiment Station, and Chairman of the Department of Entomological Sciences, University of California, Berkeley. He is also currently Project Director of the University of California/USAID Project on Pest Management and Related Environmental Protection and has been the Rapporteur for the FAO Panel of Experts on Integrated Pest Control since 1967.