CIMMYT's Approach to Systems-Based Research

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The past decade has seen a rapid growth in the development of farming systems, or systems-based, agricultural research. This expansion has been so broad that it is at times difficult to recognize commonalities among the various research approaches grouped under this rubric. A meeting of the IARCs to discuss activities in systems-based research is therefore most opportune. This paper attempts to outline CIMMYT's approach to systems-based research, which we call on-farm research (OFR).

OFR can be considered a class of systems-based research because it takes into account the biological and economic interactions that determine the appropriateness of new technologies for particular groups of farmers. CIMMYT's work in OFR differs in some respects, however, from other types of systems-based research. OFR takes a restricted view of systems and focuses research on one or two enterprises at a time. As well, CIMMYT sees its role in OFR as one of providing research procedures and training, not in developing technologies themselves. Finally, CIMMYT's clients in this work are the national agricultural research services (NARS). It is the purpose of this paper to make explicit these characteristics of CIMMYT's approach to systems-based research, and to describe the activities of CIMMYT agronomists and economists that are related to this approach.

The paper is divided into four parts. The first part describes CIMMYT's rationale for a systems approach. The second part outlines the elements that are taken into consideration in developing the research procedures of OFR. The third part summarizes this set of procedures. The fourth part points to some issues in the institutionalization of on-farm research.

The treatment is best seen in the context of CIMMYT's

sense of its role in the process of technology generation. For historical and other reasons, CIMMYT's role is to provide germplasm, training, and research procedures--along with information and counseling--to its clients, the NARS. NARS are responsible for developing technologies for farmers which raise the productivity of resources committed to maize and wheat. The work of CIMMYT agronomists and economists in OFR is consistent with this role.

While CIMMYT staff recognize the importance of extension services, improved infrastructure, and more congenial policies in increasing resource productivity, our energies in OFR are concentrated on strengthening the research process which generates improved technologies. For the purposes of encouraging a discussion among IARCs regarding alternative approaches to systems-based research, this paper focuses on the contribution of OFR to near-term technology generation. This does not imply, however, that CIMMYT scientists are concerned only with the near-term in their work with NARS. Indeed, OFR often serves as a valuable base for CIMMYT's collaboration with NARS on longer term research issues. In addition, it should be emphasized that the activities of CIMMYT's agronomists and economists are in no way confined to OFR-related activities.

A. The Rationale for a Systems Approach

CIMMYT's work in OFR can be traced to the early 1970's, when it became obvious that the adoption of higher yielding wheat and maize varieties, and improved management practices, was proceeding at an uneven pace. In many areas new technologies were being taken up and used by farmers, but in other cases they were not. CIMMYT sponsored a series of studies to examine these differences in adoption patterns. The results showed quite clearly that new technologies are adopted only when they are consistent with

the agroecological and socioeconomic circumstances of farmers. Although other factors, such as the efficiency of the extension system, may at times be important, the overwhelming conclusion was that adoption of new technology is mostly a question of assuring that recommendations fit farmers' conditions.

Given this evidence, CIMMYT staff reviewed the then conventional process of technology generation with the hope that it could be made more cost-effective, more efficient at developing recommendations which would be widely used by farmers. Through experience with NARS colleagues it became apparent that four elements were critical to an efficient research strategy.

The first was careful identification of the farmer clients for whom recommendations were to be derived. The concept of recommendation domain has proven to be useful in this regard. A recommendation domain is a group of farmers whose circumstances are similar enough that they will be eligible for the same recommendation. The concept of recommendation domain enables researchers to efficiently direct their programs towards specific groups of farmers and well-defined research goals.

A second element was the critical importance of recognizing how interactions -- concurrent and over time, biological and economic -- shape farmer response to alternative technologies. The majority of farmers in developing countries make decisions about technology for a very complex environment. Some of the sources of that complexity are: i) long growing seasons, often permitting more than one crop per year and at times encouraging dependence on a wide variety of crops ii) the importance of risk, due to low farm incomes, uncertain climate and unreliable markets iii) the multiple objectives of farm

families, who often consume a considerable proportion of their own production iv) high dependence on family labor, characterized by competing opportunities and seasonal bottlenecks, and v) heterogeneity of resources employed (e.g. various types of land, labor). These considerations heighten the importance of interactions for developing country farms.

A third element, related to system complexity, is the importance of involving both biological and social scientists in the research process. Their collaboration from the early stages of the research is the most efficient way of addressing system interactions.

Finally, there is the advantage of carrying out much of the research on the farms of representative clients and under their circumstances. These elements have become the hallmarks of the approach which CIMMYT calls on-farm research.

B. A Strategy for On-Farm Research

In framing an approach to on-farm research, several considerations were critical. First, because the development of technologies is seen to be the responsibility of NARS, procedures for implementation must be consistent with NARS resources--staff, physical, and financial. Second, because of the high discount rates on investment in agricultural research characteristic of developing countries, early improvements in technologies are strongly preferred to later improvements, often even when the latter promise relatively large increases in resource productivity. Third, evidence from adoption studies shows that farmers tend to make few changes at one time as they adopt improved technologies.

These considerations convinced CIMMYT to concentrate on a class of systems-based research which treats one, sometimes two, enterprises (e.g. wheat, or a maize-bean intercrop) as variable, but recognizes competitive and complementary relationships with other activities, ensuring that these are integrated into the design of technology for the enterprise under investigation. This contrasts with work on the entire system, which treats many enterprises as variable. As well, in pursuing improved enterprise technology, CIMMYT staff advocate consideration of only a few high priority components. This contrasts with a strategy in which many components of a given enterprise are reviewed for simultaneous change. These characteristics of OFR address, in a cost effective manner, the considerations of the preceeding paragraph: they provide procedures within the reach of NARS resources, they encourage emphasis on near-term results, and they are compatible with farmer adoption behavior.

If research is to proceed efficiently, researchers need to be able to eliminate irrelevant solutions from consideration early in the process. A distinguishing feature of CIMMYT's procedures for planning an on-farm experimental program is the screening of possible solutions for compatibility with the circumstances of representative farmers. This characteristic is a consequence of a research approach that insists on careful identification of client groups, an awareness of system interactions which affect farmer reactions to new technologies, and collaboration between biological and social scientists. These attributes of well-focused diagnosis and planning are additional sources of cost-efficiency, facilitating the early elimination of less relevant potential solutions to priority problems.

On-farm research is closely linked to other research activities of NARS which CIMMYT staff endeavor to strengthen. Training in crop agronomy, for instance, emphasizes a practical, problem-oriented approach. Collaboration with NARS disciplinary scientists encourages participation in OFR, not only in order to bring the expertise of such researchers to bear on near-term solutions to farmer problems, but also to help set priorities for longer-term research programs. Similarly, CIMMYT collaboration with NARS economists on agricultural policy issues stresses the role of on-farm research as a basis for relevant policy studies. Moreover, effective on-farm research by NARS requires strong connections to extension services, and CIMMYT encourages the participation of extension personnel throughout the OFR process.

As with all such choices, our strategy has advantages and disadvantages. We believe that, as compared with other strategies, it raises the probability of formulating useful improvements which will be widely utilized by farmers in the near term. Its major disadvantage is that its narrow focus might miss significant, complex improvements, resting on changes in several dimensions of the system and so profitable in the context of existing infrastructure and policy as to be widely accepted by representative farmers.

It was said earlier that CIMMYT itself does not develop technologies for farmers. CIMMYT staff always participate in on-farm research with national program scientists. The work is always part of a conscious strategy of national program development. It consists of gaining experience with OFR techniques by working alongside colleagues in national programs; synthesizing these experiences in procedures; and training national program personnel in their use. CIMMYT is assisting a growing number of NARS scientists to use these on-farm research procedures in approximately 20 countries.

The experience gained through this type of work with national programs provides the material for continuing refinement of the procedures. National programs, in turn, modify the procedures to better fit their own needs. Experiences in the NARS also provide the basis for the development of materials used in training.

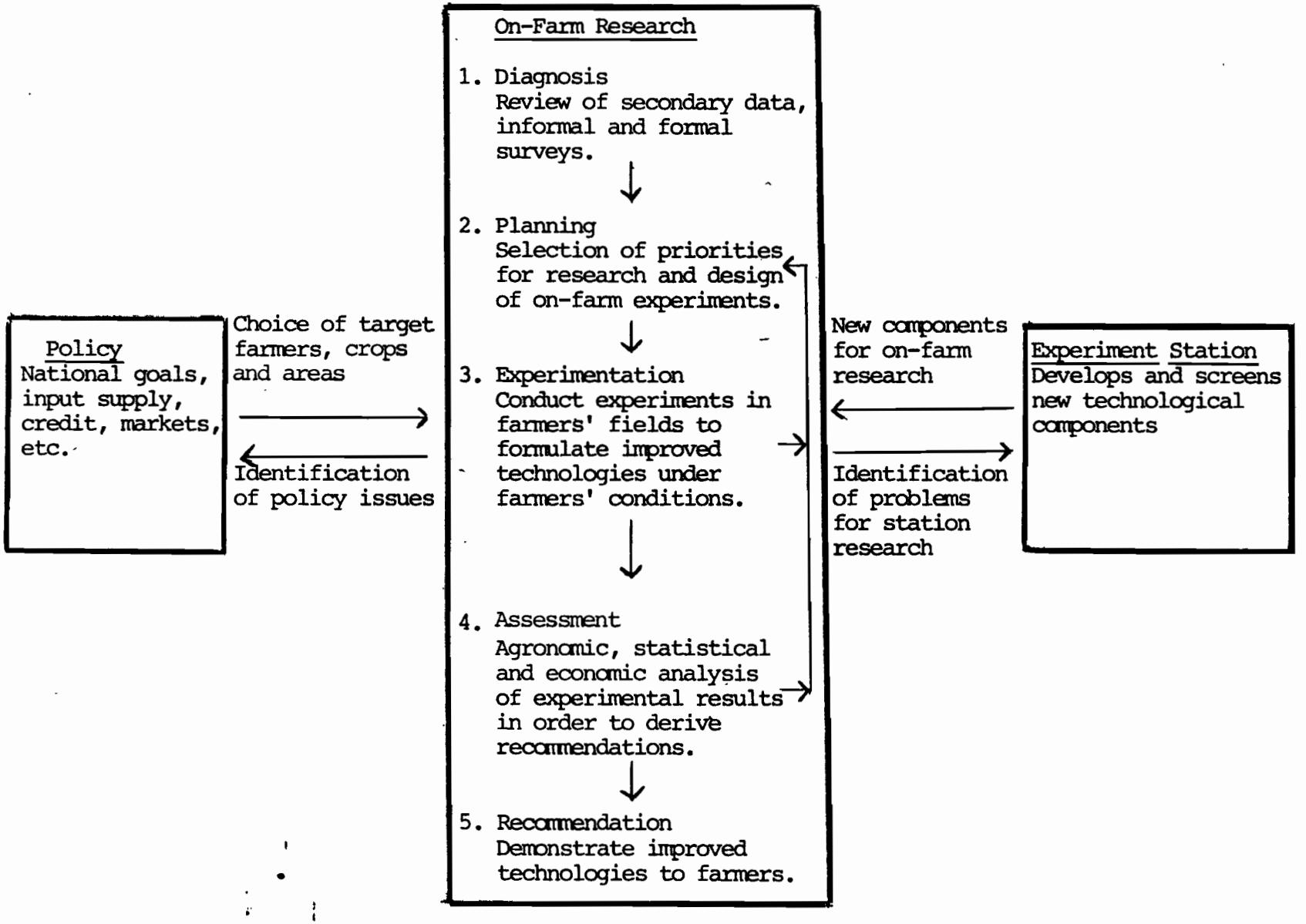
C. Procedures of On-Farm Research

The OFR procedures that CIMMYT staff develop and teach are based on a decade of experience with national research programs. They are designed to be used with the limited resources that characterize national program research. They are flexible enough to encourage adjustment and refinements as local situations dictate, but formulated so that researchers with little experience have firm quidelines that they can follow. While CIMMYT's staff work with NARS staff on issues related to maize and wheat, the procedures can be applied to a wide variety of crops.

The procedures promote a sequential approach to data collection, in which a rapid overview of the farming system guides further data collection on a smaller number of variables. This information is in turn translated to research priorities which form the basis of an on-farm experimental program. The collaboration of biological and social scientists is emphasized throughout the process. Although the iterative nature of the data collection process is emphasized, it is helpful to describe OFR in five stages: diagnosis, planning, experimentation, assessment, and recommendation (Fig. 1).

1. Diagnosis is both the initial stage of OFR and a continuing activity throughout the research process. Initial diagnostic work should be sufficient to develop a set of priority problems and potentially appropriate solutions that

Figure 1
Stages of On-Farm Research



form the basis of the first year's experimentation. During experimentation there are additional opportunities for various types of diagnostic activities. Diagnosis serves to make the experimental stage more efficient, and is not an end in itself.

For the diagnosis that forms the initial stage of OFR, the procedures advocated by CIMMYT include a review of secondary data (including relevant experimental data), an informal survey, and (often) a formal survey. The review of secondary data is fairly straightforward. The informal survey is the keystone of the diagnostic stage, and is absolutely essential. Biological and social scientists visit target areas, observe farmers' fields and talk with farmers, merchants, and others about practices and problems. Each succeeding day of the survey finds researchers focusing more closely on problems of key enterprises. Depending on the situation, the informal survey may be carried out at more than one time during the crop cycle.

The timing and extent of more formal survey activities is determined by the resources available to the national program and the nature of the research area. Choice of survey methods should be determined by the most efficient way of providing: a description of key elements of the system; an identification of problems that limit productivity; an explanation of these problems in the context of the system; and an exploration of the compatibility of proposed solutions with the system.

2. The planning stage of OFR takes place each year, before the cycle's on-farm experiments. It involves translating the information from diagnosis and from previous cycles' experimentation to a set of on-farm experiments. Researchers review the problems which limit the productivity of resources committed to major enterprises. For the most

important problems, researchers must decide if the problem is well enough defined so that possible solutions can be proposed for testing, or if the problem requires better definition. In the case of possible solutions, these are screened e.g. for likely profitability, risk considerations, compatibility with the farming system, and research time and cost. Those possible solutions that clear the screening process, and those factors required to better define priority problems, form the experimental variables from which a set of on-farm experiments are designed. The planning stage specifies the types of experiments, the experimental design, the number and characteristics of the fields where experiments will be planted, and the type of data to be taken.

The concept of recommendation domain is useful throughout the planning process. Specification of the number and type of farmers that share a particular problem, and that are eligible for the same solution, helps set research priorities. Specification of the characteristics of the farmers' fields where experiments should be planted contributes to an efficient use of research resources.

3. Experimentation is, of course, the central part of the on-farm research process. Not only are the experiments themselves the source of the information that will be used in formulating recommendations, but the observations and insights on the farming system gained by the scientists conducting the experiments provide additional information, characteristic of the interative nature of data management in on-farm research. The on-farm experiments look at a small number of experimental variables (generally 4 or less) and usually leave all non-experimental variables at the farmers' level. This underlines the importance of ascertaining the management practices of representative farmers before beginning experimentation.

Although there are a variety of experimental designs appropriate for on-farm research, the experiments can be grouped into three broad categories: i) there are experiments of an exploratory nature which attempt to characterize and further define problems (e.g., is there a response to phosphorus? Is poor plant stand caused by inadequate seedbed or by soil insects?); ii) there are experiments which test solutions to well defined problems (e.g. given that weed control is a problem, which of the potentially relevant solutions is the most appropriate control in this situation?); iii) and there are experiments which verify particular solutions and may be used as demonstrations. In the progression from exploratory to verification experiments, the degree of farmer involvement and management, the number of sites, and the size of individual plots all tend to increase. Other design characteristics will depend on the type of intervention being tested.

4. The assessment of on-farm experiments involves a review of the agronomic responses observed throughout the cycle, a statistical analysis of the results, and an economic analysis. The most important task is to ensure that the trial results can be interpreted agronomically. A statistical analysis gives researchers an idea of the degree of confidence they might place in the differences observed. Finally, when researchers have some assurance that the results of the experiments are reliable and understandable, an economic analysis of the pooled results for one recommendation domain is carried out. CIMMYT staff teach a method of economic analysis which involves partial budgets and marginal analysis. Risk associated with any treatment is estimated by looking at the variability of results across sites and across years and doing a minimum returns analysis. Formal assessment is complemented by continual review of the compatibility of proposed solutions with the farming system,

in particular by seeking farmers' opinions and observations throughout experimentation.

5. The principal goal of on-farm research is to develop recommendations that farmers will want to adopt. The recommendation may be quite specific (e.g. a new variety) or more general (e.g. advice on storing the crop). In any case, it is realized that farmers, being experimenters themselves, will make adjustments and adaptations to most recommendations in the light on their own particular circumstances. The objective is to provide them with the most useful information possible in the context of scarce research resources.

Follow-up on farmers' experiences with new recommendations is an essential part of on-farm research. As was mentioned earlier, the information generated by on-farm research is also useful to scientists involved in station-based agricultural research, and to policy-makers. And the relevance for diffusion is apparent, as extension workers cooperate with researchers through the entire process, contributing insights and coming to know the characteristics of the technology as it develops.

D. The Institutionalization of On-Farm Research

The major thrust of CIMMYT's work in on-farm research is the development and diffusion of a set of research procedures, with the aim of strengthening national program capacity to do this type of work. The procedures serve as guides only, and CIMMYT staff encourage each national program to elaborate its own research models, vocabulary, etc. as local circumstances dictate. CIMMYT staff utilize national program experience in refining the procedures, and encourage the formation of formal or informal networks among national programs so that they can contribute more

directly to each other's progress.

Although CIMMYT sees its role as the provision of OFR procedures for strengthening national programs, it is aware that there are several other important types of systems-based research activities in which other IARCs participate. In order to ensure that the IARCs and national programs understand the purpose of these activities it would be helpful if each IARC identified the principal clients of its systems-based research (the IARC itself, the NARS, or farmers) and the type of output expected (technology, farmer recommendations, information, procedures, or training).

The IARCs that are participating in systems-based research activities primarily for developing procedures and training national personnel have a particular responsibility to coordinate their efforts. If they do not, contradictory and confusing messages will be brought to the very national programs we seek to strenghten.

In addition, it is evident that such research cannot be carried out in an institutional vacuum. Research philosophies and procedures have implications for the organization and management of research institutions. Whether systems-based research should be organized on a commodity basis or on a regional basis; whether it should be carried out by a separate program or a liason mechanism among existing programs and departments; whether it demands full-time practitioners or can be integrated into current research activities; what mechanisms will ensure interdisciplinary cooperation; and what way to involve extension institutions in the work, are all issues crucial to the success of a systems-based approach in a national setting. No one of the IARCs has the expertise to completely resolve these questions, but discussions must be opened which involve IARCs and, most importantly, NARS in

order to better respond to the crucial problem of organizing and managing systems-based research.