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ON-FARM RESEARCH TO DEVELOP TECHNOLOGIES APPROPRIATE TO FARMERS

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It is now widely accepted that technological change is a necessary although by no means sufficient condition for agricultural development. It is clear that despite the widespread diffusion of new wheat and rice varieties, many new technologies are not being widely used by farmers because they do not fit the particular circumstances of farmers for whom they are intended. This is despite the fact that considerable public expenditures are often made to provide the infrastructure such as credit and markets to enable the farmer to adopt these technologies.

This paper attempts to synthesize our experiences with national research programs and with CIMMYT's wheat and maize programs in developing research methodologies to ensure that agricultural technologies generated by scarce research resources are consistent with the circumstances of target farmers. It emphasizes *ex ante* collaboration of technical and social scientists in on-farm research - both in diagnosing farmers' problems and demands for technology and in the development and testing in farmers' fields of those technologies which appear to meet these problems.

Traditional Approaches to Agricultural Research: Agricultural research is generally characterized by the gap between the researcher and the farmer[1/]. On the one hand much research has been guided by disciplinary interests. Although the importance of the problem to the farmer is sometimes advocated in determining research priorities, no explicit means of identifying priorities is employed. On the other hand, even research aimed at farmer problems has traditionally used a top-down approach - that is, it is conducted on research stations under conditions quite different to those of farmers and then passed to extension for promotion to farmers. Although the problems of extrapolating these results to farmers have been recognized (e.g. Swanson), the movement of research to farmers' fields has been slow. An exception is experimentation on fertilizers which has long been conducted on farmers' fields in many countries; but practices under which these experiments are conducted (e.g. weed control, land preparation) are often quite different from those of local farmers.

The economist in this process has usually been a late actor. Large scale involvement began with production function analysis of agronomic (usually fertilizer) experiments. In some cases this led to the collaboration of agronomists and agricultural economists in the *ex ante* design of fertilizer experiments (e.g. Hoffnar and Johnson). More recently in developing countries, the economists and other social scientists have been even later participants through *ex post* studies of technology adoption. Increasingly these studies reflect the fact that recommended technologies are not appropriate to particular farmer circumstances[2/]. However, these adoption studies have largely been conducted by economists outside of agricultural research institutions and as a result there has been little immediate feedback to decision-making on research priorities for developing improved technologies.

Toward Integrated On-Farm Research Programs: There is now increasing emphasis on collaboration of technical and social scientists in on-farm research to bridge the gap between researchers and farmers. The general approach embraced in various degrees by various institutions (e.g. Norman, CIMMYT, Dillon *et al*,

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[1/] The assertions in this section arise from our experience in many countries. There are of course many exceptions to these generalizations.

[2/] See for example the Perrin and Winkelmann review of several such adoption studies.

Hildebrand (ICTA, Guatemala), Navarro (CATIE) has three important components:

(a) The approach emphasizes solving farmer problems specific in time and location. It begins with an ex ante identification of current farmer problems and possible technological solutions to these problems that are feasible under the natural and socio-economic circumstances faced by farmers and that are consistent with national policy goals.

(b) Technologies appropriate to farmers are then developed and evaluated by experimentation in farmers' fields under farmers' conditions.

(c) Farmers' experiences with the new technology are monitored and this information fedback to research decision-making.

There is now growing support for the central role of on-farm research in national agricultural research programs. However the actual methodologies for implementing this type of research vary quite widely. In searching for such a methodology we have been conscious of the need for several basic criteria;

a) The research should be well focused to enable quick payoffs to relatively limited research resources. This means research is highly location specific and focuses on technology for an important or potentially important crop or crop mixture (in our case wheat or maize) rather than considering all crops and crop technologies in the system as variables. However, the identification and evaluation of potential technologies for a single crop must be made in the context of the farming system. Often small farmers operating in imperfect factors markets in an uncertain environment will operate highly complex systems to meet an overriding food security objective. While yield increasing technologies are important, technologies for the target crop which have total system benefits are also necessary (e.g. an earlier variety to allow two crops per season).

b) The farmer's decision-making with respect to technology is conditioned by natural circumstances such as soils and climate and by economic circumstances such as resource endowments and access to markets. To understand this complex of factors a multi-disciplinary research team usually consisting of an agronomist and an economist is needed to plan research with farmers.

c) Technological adoption by farmers is a learning by doing process that proceeds in small steps. The on-farm research should therefore set as an objective the generation of a few best-bet technological components. Furthermore, it is not possible to provide precise recommendations to each farmer but recommendations can be made which are generally relevant to representative groups of farmers.

d) On-farm research sould be part of a broader program to improve crop production and farmers incomes and therefore must be closely linked to experiment station research, policy making and extension.

e) The methodology of on-farm research should be practical and replicable in the context of scarce research resources of developing countries. It should be relatively cheap in implementation and enable a fast turn-around in results.

The remainder of this paper summarizes the methodology we have found to meet these criteria. Figure 1 shows the specific steps in the methodology.*

Choice of Target Region and Crop: Initially the choice of the crop and region for on-farm research program must be justified against the objectives of national policy and the resources and logistics available for the research. If national policy dictates that low income farmers should be priority beneficiaries of research expenditures, then the on-farm research will focus on a region where low income farmers are concentrated and where technologies are available with

* This methodology is described in detail in our Manual "Planning Technologies Appropriate to Farmers; Concepts and Procedures".

potential to increase production of a crop which is important in the farming system of these low income farmers. In this process researchers will want to also consider the future perspective as well as the present - for example, will there be an adequate market for the increased production. This initial matching of the likely outcome of the research with national development priorities helps in allocation scarce research resources.

Collecting Information on Farmer Circumstances: The research then focuses on an understanding of farmer circumstances in the target region. This phase has both diagnostic and descriptive objectives. The primary objective is of course to diagnose the problems and constraints to crop production in the area in order to "prescreen" from a wide range of possible technological components a few "best-bet" components for experimentation in farmers' fields. Information from this diagnostic stage can also be used to guide experiment station research such as the development of new technological components, particularly varieties. The diagnostic effort also uncovers particular constraints at the farm level which are the result of policy decisions or problems in policy implementation (e.g. problems of input availability, product marketing and credit). Secondly a description of farmer circumstances enables farmers in the target region to be tentatively classified into relatively homogeneous groups or recommendation domains for which the same recommended technology will be generally applicable. Also this description of current farmers' practices and fields is important to establish representative farmers' practices and sites for on-farm experiments.

In the context of this paper, farmer circumstances are all those factors which bear on farmers decisions with respect to technology for the target crop. These include natural factors such as climate, soils and pests and socio-economic factors including the environment of markets, infrastructure and land tenure and the farmers' own goals and resource constraints. Often these factors influence the farmer's choice of a crop technology through interactions within the farming system, i.e. resource competition, crop rotations and multiple cropping, risk management, and food preferences. To the extent that these interactions are important, information must be obtained on other activities of the farming system.

Three sources of information on farmer circumstances are used: (a) background information on the farmers' environment, usually from secondary sources, (b) interviews with farmers, and (c) observations in farmers' fields. Typically available background agro-climatic and socio-economic data are first collected and analysed. For example, in dryland areas rainfall data from several sites are checked for important differences across the region and for periods of major rainfall uncertainty. A team--usually an agronomist and an economist--will then spend one to four weeks touring the region in an exploratory survey of farmers and other persons linked to the farming community such as merchants, inputs suppliers and extension agents. At this stage informal interviews of farmers and visits to farmers' fields are conducted. A questionnaire is not used although the data is collected in a systematic manner against a mental "checklist" of issues and problems. Efforts are made to talk to traditional leaders who can often explain traditional practices, to innovative farmers who may or may not be working closely with the extension service and to farmers encountered by chance on the tour. The researchers begin by trying to obtain a broad perspective on the farming system. As the exploratory survey proceeds, the interviews become more focused on specific problems and hypotheses to explain farmers' practices for the target crop within the context of the larger farming system. Also at this stage tentative definitions of recommendation domains are formulated and potential technological components are identified.

The primary role of this exploratory survey is to place the researcher in the farmers' fields in direct communication with the farmer and to help design a sharply focused formal one-contact survey of farmers in the region in order to quantify and verify what has been learned in the exploratory survey and investigate some critical problems in more depth. Because a random sample of farmers is interviewed, the use of certain practices can be quantified and hypotheses on the reasons for these practices formally tested. Furthermore relatively little emphasis is placed on quantifying farmers' resource use and allocation in order to infer technological needs. Rather the questions aim to exploit the farmers own intimate knowledge and experience of his environment in order to identify these needs. As a result, many questions (again based on exploratory survey information) elicit subjective types of information such as preferences about specific varietal characteristics.

The implementation of the formal survey - the training of enumerators, sampling and field work - generally follows standard procedures for this type of work (e.g. Collinson). Farmers are stratified as far as possible by the tentatively defined recommendation domains and about 30-60 farmers are interviewed in each recommendation domain. The questionnaire is designed to be completed in 45 to 90 minutes.

Data Analysis and Prescreening Technologies: Data are analysed quickly after the survey (with a maximum of 3 months) usually using hand tabulation sometimes supplemented by computer analysis. Descriptive tabulations of farming systems and cultural practices with respect to factors such as rainfall and farm size, are used to refine boundaries of recommendation domains. These recommendation domains will only be broad classification of farmers and much heterogeneity will still remain within each domain. The descriptive tabulations also provide a profile of representative farmers' practices and fields in each domain for the design of on-farm experiments.

The diagnosis of research priorities is made in the following steps: a) Important reasons for farmers using current technologies are listed, b) Priority problems and constraints in the target crop are identified on the basis of these reasons, results of field observations and farmers' opinions and perceptions, c) Possible solutions to these problems and constraints are noted on the basis of practices of innovative farmer, on-station research and results and agronomic-economic expertise, d) All changes in the farming system implied by each solution including associated costs, labor needs and risks are listed. Based on researchers' understanding of the current farming system, those changes which are subjectively felt to be inconsistent with farmers' circumstances are eliminated (e.g. cash costs too high, unacceptable risks, conflicts with present multiple cropping systems), e) Partial budgets following Perrin et al are constructed assuming a priori best guestimates of yield responses for these technological components, f) In each recommendation domain a few best-bet components arising from this "prescreening" exercise are chosen for on-farm experiments.

This prescreening process emphasizes identifying technologies which use resources and inputs available to farmers and have short run pay-offs. However, experiments may be included with a longer run horizon. For example, such experiments may provide information on the desirability of making a new input available.

On-Farm Experimentation: Space limitations prevents a detailed discussion of on-farm experimentation here. It serves three purposes. First, it enables technology to be developed and tested under farmers' conditions. Most experiment stations are managed in such a way that over time, soil structure, fertility, weeds, pests and diseases are quite different from those in farmers' fields. Second, the technology can be developed and tested over a variety of environments and cultural practices representing a region. Finally, the farmer and extension can be actively involved in the process of developing and demonstrating technological components.

Several types of on-farm experiments are implemented by the same multidisciplinary team responsible for the surveys in order to test the three to four priority technological components arising out of the diagnostic studies (Violic et al, Winkelmann and Moscardi). Exploratory experiments are 2^n factorials with levels of each factor set at the farmers' level and at substantially higher levels to look at main effects and first-order interactions of each factor. On the basis of these experiments, experiments with one or two factors (depending on interactions noted in the exploratory experiments) are designed to find recommended levels of these factors in terms of income and risks[3]. Finally factors are combined to verify tentatively recommended technologies in comparison to the farmers' technology. These verification experiments often serve as the basic design for extension-run demonstrations. To ensure relevance all these experiments are conducted under conditions determined in the formal survey to be representative of local farmers.

Dynamics of On-Farm Research: On-farm research is a continuous learning process. After each cycle of on-farm research, information from surveys and experiments are integrated and analysed and strategies for the following cycle formulated. Special purpose surveys may be organized, particularly to monitor how farmers use the recommended technologies when they themselves must pay all costs and accept the risks. This provides important feedback to the research program. If cooperating farmers are accepting the technology then it can be promoted through extension and demonstrations, and new technological components, previously of lower priority, can be incorporated into the research program. On the other hand where farmers reject, or significantly change the recommended technology, an understanding of why this is so could influence the design of future experiments. Likewise, experimental results may help modify recommendation domains or identify new technological components not previously considered important.

Linkages of On-Farm Research, Experiment Station Research and Policy: Effectiveness of on-farm research can be greatly strengthened by maintaining close linkages with research on experiment stations. Experiment station research focuses on developing and screening new technological components - that is, research that usually requires greater control (e.g. development of new varieties) or would be risky when done on farmers' fields (e.g. screening new herbicides). Promising new technological components arising from station research are then submitted to experimental evaluation in farmers' fields. The results of on-farm research also help establish priorities for station research. For example, a knowledge of farmer circumstances can guide plant breeders in deciding between yield, earliness, specific disease resistance, grain type, and storability in varietal development.

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[3] Procedures for analysing experimental data and making recommendations are described in Perrin et al (1976).

On-farm research is also conducted in a specific policy context that might guide the selection of target farmers and technologies consistent with national goals. In addition, in most countries there is a shortage of micro-level information for policy analysis. The detailed information on farmers' circumstances and technological responses under farmers' conditions generated by on-farm research can be important for identifying changes in policy and policy implementation that would complement the introduction of improved technologies (e.g. increasing the availability of specific inputs).

Finally, the impact of on-farm research is increased if researchers responsible for on-farm research are institutionalized within the agricultural research establishments with appropriate incentives and logistics to work in a multi-disciplinary team on priority farmer problems. This will require agricultural research programs to include economists as an integral part of the research staff. Our work initially focused on demonstrating to research administrators the value of these on-farm research procedures and the potential contribution of economists (e.g. Collinson, 1978). The emphasis has now shifted to assisting national research programs to develop their own capacity for on-farm research. It has been shown that well trained four year agricultural graduates are capable of implementing these on-farm research procedures in a target region.

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FIGURE 1. OVERVIEW OF AN INTEGRATED RESEARCH PROGRAM