At the institutional level, the extension systems need to liaise more effectively with the relevant research organisations to design the programmes and technical packages that should be 'sold' to the farmers. It is actually expected that the extension systems should commission the development of technologies and innovations peculiar to specific environments or in answer to felt local problems.

The above suggestions, if implemented, should enhance the effectiveness of the Ministry-based extension systems pending the time a decision is made to make the provision of extension services the exclusive preserve of semi-autonomous institutions such as the Agricultural Development Projects (ADP) and the River Basin and Rural Development Authorities (RBRDA).

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From Adaptive Research to Farmer Recommendations and Extension Advice

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SUMMARY

Information from adaptive research programs is usually summarized into 'recipes' for crop production that do little justice to the increasing complexity of farmers' decisions or to the large amount of useful information generated by mature research programs. A major challenge for exploiting the benefits of adaptive research is to find ways to synthesize and simplify information generated by research, into a form that can be effectively used by farmers. The concept of farmer recommendations and farmer stratification for extension advice, and farmers' needs for increasing amounts of specific information and conditional recommendations are discussed. But even with specific recommendations, there always remains substantial opportunity for farmers to adapt technology to their own needs, and this calls for a wider array of auxiliary information, improvements in farmers' understanding of the technology and increases in farmers' technical and managerial skills. Some implications for the organization, methods and philosophy of extension systems are also briefly reviewed.

INTRODUCTION

A substantial share of agricultural research expenditures is devoted to adaptive research aimed at providing improved technical information to farmers for increasing their efficiency in using available inputs and resources. Much of this information deals with crop management

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decisions—research on cropping patterns, rotations, tillage, planting methods, plant nutrition, pest control and post-harvest operations. Information from adaptive research is usually synthesized and simplified for farmers in the form of '*recommendations*' for crop production.

In recent years, the farming systems perspective in adaptive research has received wide interest as an approach to ensuring that research priorities and farmer recommendations are oriented towards the needs of target farmers, especially small farmers.[29] While a great deal of attention has been given to the methodology for conducting adaptive research,[5,15,35] very few guidelines have been developed for efficiently synthesizing and simplifying the information generated by this research for use by extension workers and farmers. Typically, adaptive research teams meet annually to formulate production recommendations for extension workers and farmers, that represent the current state of the art with respect to the 'best' methods for crop production. This procedure of condensing the results of perhaps hundreds of experiments over several years into a single 'recipe' for crop production does little justice either to the resources invested in the research or the increasing information requirements of farmers in a technologically dynamic and complex agriculture.

It is the purpose of this paper to provide a simple framework for organizing information from adaptive research for use by extension workers and farmers. It is argued that as adaptive research programs mature and the quantity and quality of information generated increases, much of this information will be wasted unless methods are found to more efficiently organize its transfer to farmers. (This situation also seems to prevail in more developed agriculture.[18]) The paper distinguishes between *prescriptive information* that is usually transferred in the form of recommendations, and *auxiliary information* and information on *crop production principles and skills* to enable farmers themselves to adapt research and extension information to their own needs. This discussion of recommendations also helps clarify the closely related concept of a 'recommendation domain' (i.e. the stratification of farmers into more or less homogeneous subgroups) to increase efficiency of research and extension efforts.

PRESCRIPTIVE INFORMATION—FARMER RECOMMENDATIONS

Defining recommendations

Despite the widespread use of the term 'farmer recommendation', it is rarely explicitly defined in the agricultural research literature. Consequently,

different implicit meanings are often attached to the term. In this paper, we adopt a working definition of a good recommendation as '*that practice which farmers, given their objectives and resources, would employ if they had all the information available to the researchers.*' Note that the word 'would' is used rather than 'should' to emphasize that farmers' decision criteria rather than researchers' criteria (such as high yields or profits) are the basis for selecting recommendations. A recommendation aims to alleviate only one factor limiting productivity—the imperfect information situation of farmers. Hence, it assumes the current objectives and resource constraints of farmers. For example, if official bank credit is in short supply (which it usually is), a recommendation should take into account the existing capital situation of farmers, usually reflected in a high cost of capital. Likewise, a recommendation should only be made for inputs currently available to farmers. (In practice, availability of inputs runs a continuum from 'not available to any farmer any time' to 'available to all farmers all the time.' Scientists may sometimes aim research at policy makers and input suppliers to improve the supply of an input that is not currently available to farmers. However, results of this research would not be included in recommendations to farmers.)

From the above definition it will also be clear that a useful recommendation provides new information that promotes a *change* in current practices. If farmers, for example, generally use 100 kg/ha of seed for wheat and this is broadly appropriate, then seed rate would not be part of the recommendations. At the same time to be acceptable to farmers, recommendations should be restricted *to a few priority changes* that can be adopted by farmers in the short term, rather than promoting a 'package.' Due to capital constraints and a cautious learning-by-doing approach, farmers do not adopt packages but make improvements in a stepwise manner. True, packages often enable the exploitation of positive interactions between components, but they ca nearly always be disaggregated in to a series of discrete changes that are profitable when adopted alone *and in the appropriate sequence*.

Farmer stratification and intra-farm variability

The above definition of recommendations assumes a population of farmers who would all use the same production technology, given access to the same information. However, most farming populations are characterized by substantial heterogeneity between farmers and fields as well as variability over seasons. Hence, the relevance of a given recommendation requires that homogeneous subgroups of the farming population be delineated. A number of possible variables can influence this delineation. If it is assumed that all farmers have access to the best available information then choice of management would be determined by the following factors.

1. The response function

This is described by $Y_n = f(X_{in}, S_j, R_{jk})$ where Y_n is output of the nth crop, X_{in} are inputs that are managed by the farmers, S_j are site-specific variables (e.g. soil type, previous crop) not directly controllable by farmers but which are known or can be measured at the time of making a decision on X_i, and R_{jk} are uncertain variables of the environment (e.g. rainfall, pest incidence). (See Byerlee & Anderson[4] for a fuller discussion of this model). Variation in crop response occurs due to variability in S_j and R_{jk} and their interaction with X_i. Some of this variation is site-to-site variation (S_j and R_j, where R_j is the mean of R_{jk} for a site over years) and some is year-to-year variation at a given site (R_{jk}).

2. The prices of Y_n and X_i

These may vary between farmers, due, for example, to location and tenancy conditions.

3. The resources available to farmers and their objectives and managerial ability

In developing countries, these factors may result in large variability in farmers' management even within a homogeneous agro-climatic zone.[9]

These different sources of variation lead to (a) variation between farmers (from all sources), (b) variation within farms attributable to variation between fields (due to S_j and R_j), variation between seasons in a given field (from R_{jk}) and year-to-year variation in prices. Both variation between farms and within farms clearly have implications for organizing research and providing recommendations to farmers, since it is unlikely that one recommendation will be appropriate to all farmers in all fields in all years.

The first step in any research and extension program will be to identify more homogeneous sub-groups of farmers. These could be delineated by detailed analysis of the above categories of 'exogenous' variables that determine farmers' management (i.e. S_j, R_{jk}, prices and farmers' resources and objectives). In practice, variation in current farming systems, including production practices, reflects underlying variability in these exogenous variables.[28] Hence, study of variation in current systems and practices usually allows the most important delineating variables to be identified. Variability which is due to time lags in adoption (e.g. between small and large farmers) would not be considered if the time lag is small in relation to the time horizon of a research project.

For extension programs, it is important to recall that the main purpose of farmer stratification is to make extension more efficient. Hence, delineating variables should be readily identifiable in the field (e.g. soil type, ownership of draught power, access to irrigation, altitude). Variables such as family customs or preferences or capital constraints will not be very useful as delineators if extension workers cannot easily classify farmers by these variables.

There is always potential to stratify farmers into smaller, more homogeneous, groups in order to reduce between-farmer variability, especially that due to socio-economic factors. This process is initially limited by resources available to research and extension programs but this constraint is relaxed over time as research programs mature and research information accumulates. However, because many variables that lead to variation between farmers are difficult to delineate for the purposes of extension of the recommendations, further sub-grouping eventually defeats the main purpose of stratification. Furthermore, a point is soon reached where between-farm variability is less important than variability within farms and across years and the benefits of subgrouping rapidly diminish. To accommodate within-farm variability we introduce the concept of *conditional recommendations.*

Conditional recommendations

Farmers usually face substantial variation within farms and, in fact, traditional management practices reflect adaptation to this variation. They often have different soil or land types within a farm or the location of a field in relation to the village strongly influences management and base fertility levels. Differences in crop rotations often lead to quite different responses for a particular crop depending on its place in the rotation.[7] Decision-making for this field-to-field variation within farms (due to S_j) is sometimes referred to as '*strategic*' since farmers known, or can measure, this variation and accommodate it in their management strategy.[11,34] '*Tactical*' decision making, on the other hand, refers to decisions made to accommodate year-to-year environmental variability (R_{jk}), e.g. elimination of a second nitrogen application with early season drought or a decision to apply a pesticide based on observed pest incidence in a given field. Both of these types of variability—between fields and across years—offer opportunities for making conditional recommendations to farmers. That is, a recommendation is made conditional on the occurrence of a particular event (e.g. place in the crop rotation, pest incidence, etc.).

Both the conditioning variable (S_j, R_{jk}) and the final recommendation may be discrete or continuous as shown in Table 1. Examples of discrete

TABLE 1
Examples of Conditional Recommendations

Conditional variable	*Recommendation*	
	Discrete	*Continuous*
Discrete	1. Fertilizer level × crop rotation, soil type or land type (S) 2. Pest control × pest presence/absence (T)	NA
Continuous	1. Pest control × pest count (T) 2. Irrigation × soil moisture % (T)	Fertilizer level × soil test level (S)

S = strategic decision. T = tactical decision.
NA = Not applicable.

conditional variables are crop rotation, land type, soil type and pest presence (yes/no). These variables are usually known or are easily observable by farmers. For example, Fig. 1 shows phosphate response in wheat by land type in a rainfed area in Pakistan. Fields close to the village that regularly received farmyard manure and are more intensively cropped, show much smaller response to phosphate than fields more distant from the village.

Sometimes, and especially for tactical decisions, conditional variables may be continuous. These include measures such as soil tests, pest counts and recorded rainfall that usually require some effort and costs on the part of farmers to measure. A common example is the threshold concept in pest

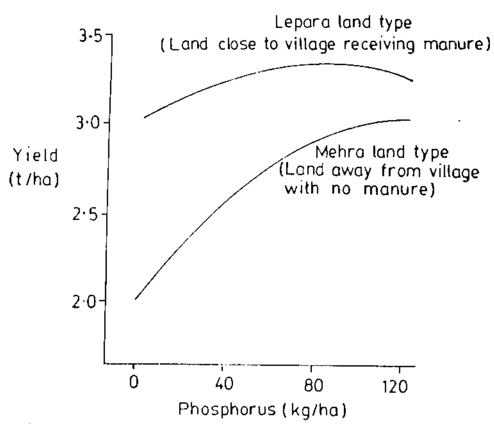

Fig. 1. Response to phosphorus in rainfed wheat grown on different land types, Northern Pakistan 1985. Source: Hobbs *et al.*[16]

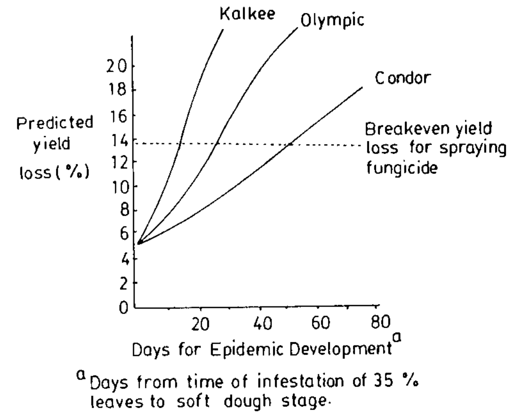

Fig. 2. Predicted yield losses for wheat varieties with different stripe rust resistance at different times for epidemic development. Source: Brown and Holms.[2]

management where pest scouting and a model are used to predict if the pest damage is likely to exceed the cost of pesticide application.[22] Figure 2, for example, relates the decision to spray for stripe rust in wheat to the variety and the stage of crop development at which rust infestation occurs. Continuous conditional variables may lead to continuous recommendations. The most common example is soil testing for fertilizer recommendations where a calibration curve is used to relate optimum fertilizer doses to soil test results.[8]

The appropriate level of recommendation specificity

On the basis of the above concepts, three levels of recommendations of increasing specificity can be defined:

- Type I —General recommendations. A single recommendation is made for all farmers in a recommendation domain.
- Type II —Recommendations conditional on discrete variables.
- Type III —Recommendations conditional on continuous variables.

An adaptive research program should invest in increasing specificity of recommendations until the value of the additional information exceeds the cost of generating and transferring the information. Increasing specificity of information entails higher costs to researchers, extension and farmers to be effectively utilized. However, returns to this additional information are potentially high. Several studies have documented the returns to soil test information,[8,26,30] Likewise, returns to integrated pest management based on pest scouting provide high returns through the substitution of better information for pesticide use.[17,21,25,33]

In developed agriculture, farmers increasingly employ more specific information often based on continuous conditional variables.[31] In developing countries, providing prescriptive information at high levels of specificity usually entails substantially greater costs. The greater variability in agroclimatic environment, especially in marginal and mountainous areas,[20,23] and the diverse socio-economic circumstances of farmers in developing countries,[9] means that specific information may be applicable to a smaller universe. In addition, the cost of transmitting more specific information to a farming population deficient in literacy and numeracy skills is substantially increased. Finally, institutional support services such as soil testing laboratories or pest advisory services required to utilize specific recommendations are not generally available or are unreliable. (Although soil testing laboratories are available in many countries, most researchers complain of long delays and inconsistent results. Hence, it will be a long time before small farmers have ready access to soil test results.)

Conditional recommendations can sometimes be simplified to fit these circumstances. For example, to overcome the problems of small farmers effectively using Integrated Pest Management (IPM),[12,19] farmers have been trained to subjectively assess or 'eye ball' pest damages to reduce the complexity of formal pest scouting techniques.[17] In Malawi, a simple peg board has been designed to enable farmers to judge when the economic threshold of insect infestation in cotton has been reached.[9]

Most developing countries still require considerable research to develop an appropriate stratification of farmers and broadly applicable Type I recommendations. In most research systems there is also a good deal of potential for developing Type II recommendations such as fertilizer doses by crop rotation or land type, especially as the capacity to transmit increased amounts of information to farmers is developed. Investment in more specific Type III conditional recommendations can only be justified when adaptive research, extension and other support services are well developed.

ADAPTING RECOMMENDATIONS TO INDIVIDUAL FARMER NEEDS

In most developing countries, the ability to provide specific recommendations that will be approximately optimal for most farmers is limited by the high cost of generating and transferring very specific recommendations, especially in a dynamic environment. Variability in socio-economic circumstances between farmers that cannot be easily captured by recommendation domains (e.g. in access to capital or subsistence food priorities) also reduces the general relevance of specific recommendations.

For these reasons, recommendations, whether general or specific, *are only guidelines which farmers must adapt to their own individual*

Adaptive research and extension can facilitate farmers' own adaptation through (a) provision of auxiliary information from adaptive research and (b) efforts to increase farmers' understanding of the technology and to improve their technical and managerial skills.

Auxiliary information from adaptive research

Adaptive research programs usually generate a good deal of information that is not incorporated into the recommendations but which would be valuable to extension and to farmers in their own adaptation of recommendations. Examples of this type of information are:

1. Economic data on costs and returns

For example, the expansion path or Net Benefit Curve[24] provides a set of efficient treatments at increasing levels of expenditures and at decreasing marginal rates of return. For example, Fig. 3 shows a case where, at expenditures of less than Rs250/ha, farmers should emphasize application of nitrogen fertilizer. At expenditure levels of Rs500/ha, application of a 2:1

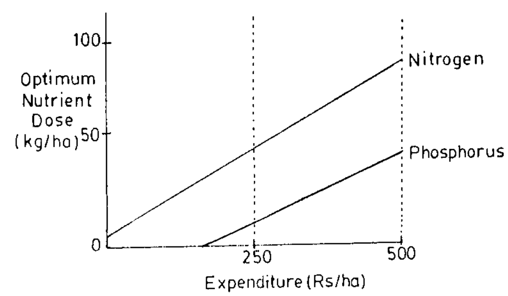

Fig. 3. Optimum doses of nitrogen and phosphorus at different expenditure levels. Based on response curve for rainfed wheat in Pakistan, 1985.

ratio of nitrogen to phosphorus would be appropriate. These curves are relatively easy to derive from fertilizer experimental data and provide valuable rules of thumb for extension and farmers. Researchers can also provide other types of economic data such as variability in net returns that might help extension workers and farmers assess recommendations.

2. Data on the sensitivity of the response of recommended technology to the timing and method of application

Prescriptive information generally emphasizes the type and level of inputs i.e., it aims to improve *allocative efficiency*. Yet there is growing evidence that there are potentially large gains to increasing *technical efficiency* through improved timing and methods of application of inputs.[3,14] In the course of conducting an adaptive research program, researchers learn a great deal from farmers about what factors affect the efficiency in using a given input under farmers' conditions, especially in the stage of farmer verification where farmers actively participate in trial management. Information on downside risks (e.g. phytotoxicity from late herbicide application) could be especially important in speeding adoption.

3. Information on feasible sequences for the adoption of two or more technological components

There are often interactions between technological components which indicate that one component should be adopted before another (e.g., weed control before fertilizer) while the reverse sequence might not be economic.

Improving farmers' understanding of the technology and developing technical and managerial skills

Beyond auxiliary information from adaptive research, farmers can more effectively adapt recommendations if they understand essential principles related to using the improved technology and have basic technical and managerial skills. For example, knowledge of nutrient composition, potential carry-over effects and symptoms of nutrient deficiencies should help farmers to adapt fertilizer recommendations to their own needs. Technical skills in calculating dosages, identifying pests and predators, calibrating sprayers, etc., will also enhance technical efficiency and indeed are often necessary for effective use of more complex recommendations such as Integrated Pest Management.

Improved understanding of scientific principles related to new technology is also often necessary in order to effectively use prescriptive information. For example, most farmers in Pakistan are not aware of the fact that rust resistance of wheat varieties is subject to breakdown as new races of rust evolve. Hence farmers are slow to change wheat varieties if the only advantage of the newer varieties is rust resistance which is revealed, on average, about one year in eight when an epidemic occurs. Likewise, Integrated Pest Management often involves counter-intuitive recommendations related to the build-up of pest resistance to insecticide use or encouraging beneficial insects.[12] Farmers who do not understand the logic behind such recommendations will be slow in adopting them or may not adopt them at all.

Finally, in a well-developed adaptive research and extension program, extension efforts should eventually seek to upgrade farmers' managerial skills. This will include the ability to seek out better information and utilize this information in decision making.

Providing auxiliary information from adaptive research and more emphasis on understanding the technology and on improving technical and managerial skills should be regarded as complementary to prescriptive information. Often the purchased inputs initially used by farmers are variety and fertilizer that are less management-intensive inputs than later innovations such as pesticides, micro-nutrients and precision plant spacing. In addition, farmers with a good understanding of new technology and basic scientific principles should be able to better adapt to changes in their environment.[27] These types of information and skills are less likely to become obsolete than specific production recommendations.[32]

The move from prescriptive recommendations to more general information aimed at enhanced understanding and improve skills in agricultural production has implications for extension. Upgrading the skills and knowledge of extension workers and close research-extension links are needed to enable extension agents to transfer this wider array of technical information. Also, extension agents will need to play more of an educational and advisory role rather than the traditional roles of message communication and exhortation.

Finally, to disseminate this broader array of information, research programs can adopt a two-tiered strategy. Initially, they might focus on providing a broader range of information and skills to extension agents to enable them to do a better job of working with farmers to adapt recommendations. As farmers' skills and experience with improved technology increases, emphasis would shift to providing farmers directly with this wider array of information and enhancing their understanding and skills regarding the new technology.

CONCLUDING COMMENTS

As adaptive research programs mature they will produce increasing quantities of better quality information that can be transferred to farmers through (a) more specific prescriptive information, (b) a broader range of auxiliary information, and (c) general principles and skills related to improved technology. A first stage in this process is appropriate stratification of farmers into more homogeneous groups or recommendation domains for the purposes of making generally applicable recommendations.[13] As information accumulates, emphasis should be changed from general recommendations for groups of farmers, to conditional recommendations to accommodate variability within domains and across years. Conditional recommendations may increase in specificity as more quantitative conditional variables such as soil tests and pest counts are employed and as the ability of extension agents to transfer additional information, and of farmers to use it, develop.

To date, however, too much emphasis has been placed on prescriptive information almost as recipes for crop production, relative to the transfer of more general information and skills on improved technology to enable farmers (a) to use increasingly specific recommendations, (b) to improve the technical efficiency with which these recommendations are used, and (c) to adapt prescriptive information to their own needs.

The framework of this paper has a number of implications for adaptive research and extension programs. Sustained increases in agricultural productivity require transfer of increasing amounts of prescriptive-type and principles-type information to farmers. This calls for a drastic upgrading of extension services in many countries, especially in 'post-Green Revolution' agriculture. While simple information messages do diffuse rapidly from farmer to farmer, farmers tend to rely on extension agents for more complex technical information and skills.[10] In addition, extension needs to be closely involved in adaptive research. Both the farming systems perspective in research and the Training and Visit system of extension[1] emphasize closer linkages of research and extension and also upgrading of the skills of extension agents through formal training. However, in both cases their major pre-occupation has been with generating and transferring prescriptive recommendations at the expense of developing farmers' own knowledge and skills to more effectively use improved technology.

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Agricultural Extension in the Less Developed Areas of Southern Africa

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SUMMARY

This paper is based on data obtained from studies aimed at evaluating the effectiveness and efficiency of extension services in the Ciskei, Transkei and KwaZulu areas of Southern Africa. Findings show that extension services have operated in a haphazard manner, with neither priorities specified nor plans drawn up and implemented. There were considerable deficiencies in the quality of staff, technical support, communication methods, administration and management at all levels. There were deficiencies in levels of technical and extension knowledge and the general morale and status of extension workers leaves much to be desired.

A relatively low percentage, mainly progressive farmers, were contacted by extension workers. Only a small percentage of farmers adopted recommended technology which was not always suited to the needs of farmers. Suggestions are made for improving the situation through development of more appropriate technological packages, greater farmer involvement in extension and research, improved training, management, communication, evaluation procedures and supporting services.

INTRODUCTION

The singular lack of success on the part of extension services in less developed areas of Southern Africa is shown in available agricultural production statistics.[5] Studies of the human potential in less developed areas

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