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Integrating On-Farm Research with Disciplinary, Commodity and Policy Research: The Potential of On-Farm Wheat Research in Pakistan

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Although on-farm research (OFR) is aimed mainly at developing improved recommendations for specific groups of farmers, the results of this type of research can often have much wider and more important implications for the mainstream commodity and disciplinary research that is usually conducted on-station. OFR programmes are in a unique position to generate farm-level information that is not generally available to on-station researchers or to policy makers. This information includes an in-depth understanding of farming systems, quantitative information on farmers' practices and their variability, and agronomic and economic responses to improved practices measured under farmers' conditions through on-farm experimentation. The results from OFR can be particularly valuable where several OFR programmes are carried out in different locations representing the major farming systems, allowing aggregation of results to the national level. Despite this potential for wider use of OFR results at the regional and national level, few research systems have been able to capitalize on the rich set of data increasingly being generated by OFR programmes.

One of the principal reasons for this under-utilization of OFR results is that those who are engaged in this type of research are usually on the periphery of their research organizations, both in terms of location and profession. They tend to be relatively junior staff, assigned to field projects at some distance from research headquarters and from policy makers. As a result, they often do not have the support of their colleagues at headquarters nor the opportunity to contribute to setting directions for research and policy. This can be true even if the on-farm researchers are part of a commodity research programme.

This chapter summarizes OFR activities carried out on wheat in Pakistan over a 5-year period. It illustrates the potential for using OFR not only to improve the efficiency and relevance of recommendations at the local level, but also to contribute to making national level research in various disciplines more responsive to the needs of farmers, as well as to providing information for policy decisions.

The results of OFR on wheat in Pakistan are of national significance because wheat is the main food grain and the major winter crop throughout the country. In 1990, Pakistan produced over 15 million t of wheat on about 7.5 million ha of land, most of it irrigated. Since 1965, it has achieved one of the most remarkable increases in wheat production in the world, as part of what is commonly called the Green Revolution — that is, the rapid adoption of semi-dwarf wheat varieties and fertilizer use, accompanied by improved supplies of irrigation water. However, in the past decade, wheat production in Pakistan appears to have entered a stage of 'post-Green Revolution blues', as yield growth has slowed and evidence accumulates that yields are low given the level of seed, fertilizer and water now being applied. Indeed, there is growing concern about the sustainability of current yields (Hobbs et al., 1988; Byerlee, 1990). In addition, increased cropping intensity in the dominant irrigated systems has posed special challenges to developing improved technology for wheat grown as part of these evolving systems.

Against this background, an OFR programme, initiated by the Pakistan Agricultural Research Council (PARC) and the International Maize and Wheat Improvement Center (CIMMYT) and carried out in several major cropping systems, has attempted to suggest new directions for improving the efficiency of wheat production in Pakistan. While this programme was initially aimed at developing improved recommendations for each of those systems, it soon became apparent that the results had much wider implications for wheat commodity and disciplinary research programmes conducted on-station and even for price and input policy with respect to wheat. We describe here how that work was organized and discuss some of the principal results and their implications for setting wheat research priorities and analysing policies at the national level. We conclude by noting some of the challenges to more effective utilization of the results of OFR at national level.

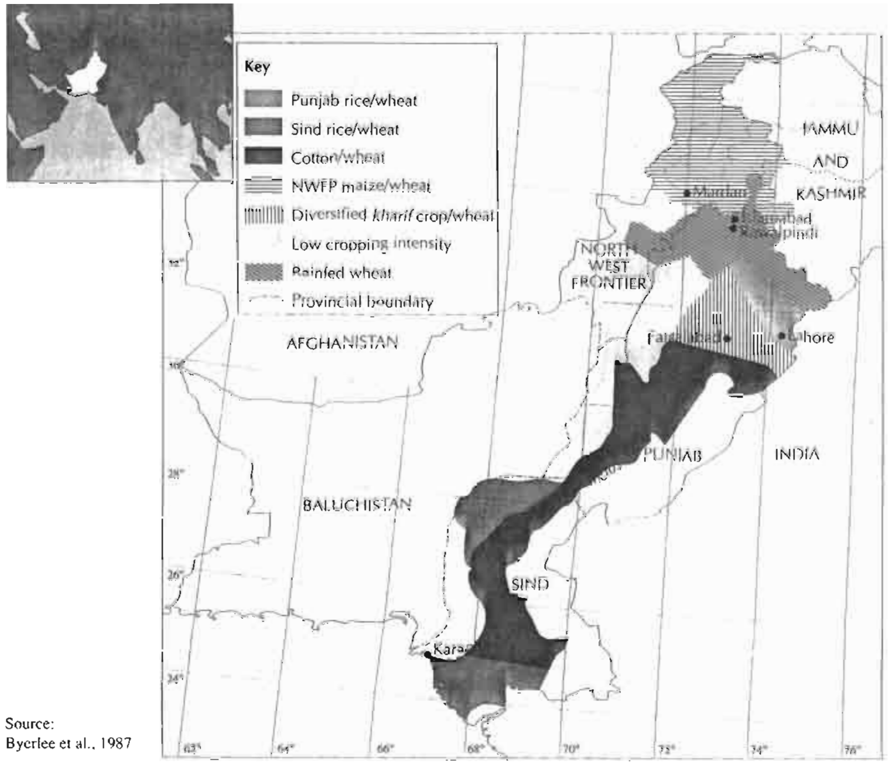
OVERVIEW OF THE ON-FARM RESEARCH PROGRAMME

Pakistan has a well-developed agricultural research system that includes a wide range of institutions. Wheat research is carried out both at the national level, by PARC, as well as at the provincial level, with each of the four provinces having a wheat or cereal crops research institute. However, OFR based on well-defined diagnosis and on-farm experimentation by a multidisciplinary team was not a part of the research tradition. In addition, and despite the trend towards wheat being grown as part of increasingly complex farming systems, the research system lacked a means to coordinate research across commodities produced as part of the system. An OFR programme was initiated in 1983 by agronomists from PARC's wheat programme, in collaboration with agronomists from the wheat programmes of provincial research institutes. Socioeconomists from PARC who were based in the provincial institutes also took part in the programme. The research focused on the major wheat growing province, Punjab, as well as North West Frontier Province (NWFP) (*see* Figure 16.1).

Wheat is grown in many different environments and conditions in Pakistan (*see* Table 16.1 *overleaf*). In order to address this diversity, it was decided to carry out work in a number of carefully delimited areas that were representative of important wheat-based systems. Among the factors which determined the choice of target research areas were the extent to which a particular system was representative and its proximity to a research station. The target areas included three major irrigated wheat systems (Punjab rice/wheat, Punjab cotton/wheat and NWFP maize/wheat) and one rainfed system (*see* Table 16.2 *overleaf*).

In the irrigated systems, wheat, the dominant food crop, is grown during the winter (*rabi*) season, after a summer (*kharif*) crop, usually a cash crop (*see* Table 16.3 *overleaf*). In the two irrigated systems in the Punjab the major *kharif* crops are rice and cotton, while in NWFP maize and sugar cane are the main *kharif* crops. In the rainfed (*barani*) system of northern Punjab, wheat is usually grown in the *rabi* season after one complete year of fallow, and a variety of fodder crops and pulses are grown in *kharif*. The number of years that wheat has been planted continuously as a *rabi* crop is also an important measure of crop rotation. In this respect, the rice/wheat area stands out with a high proportion of fields planted to wheat (and rice) every year.

Figure 16.1 Distribution of major wheat-based cropping patterns in Pakistan



Source:
Byerlee et al., 1987

Research focused not only on demonstrating the similarities and differences between these systems but also on showing the variability within them, even in the relatively homogeneous irrigated areas. Within each area, differences in cropping patterns tend to reflect farmers' resource base and access to markets. For example, in the maize/wheat area of Mardan, sugar cane is concentrated in areas closest to sugar mills. In the cotton/wheat area, larger farmers who produce more wheat than required for home consumption tend to emphasize cotton production and leave more land fallow in the *rabi* season.

The OFR included several methods of data collection. One of the key activities in each research area was an informal diagnostic survey, in which researchers spent about a week in the field during the wheat season talking with farmers and observing their fields. Each survey was conducted by 7-15 researchers, representing a wide range of disciplines and several research institutes (Byerlee et al., 1989). The informal surveys were

Table 16.1 Area, production and yield of wheat in different cropping systems in Pakistan, 1982-83

	Area (000 ha)	Production (000 t)	Yield (t/ha)
Irrigated systems:			
Rice/wheat	1313	2318	1.77
Punjab (Basmati rice)	(1010)	(1843)	(1.83)
Sind (IR6 rice)	(303)	(475)	(1.57)
Cotton/wheat	2559	5067	1.98
Maize/wheat	129	227	1.76
Diversified *kharif* crop/wheat	1062	2131	2.00
Low cropping intensity	420	660	1.57
Rainfed systems:			
Barani areas, northern Punjab and southern NWFP	1007	975	0.97
All systems	5483	10 403	1.90

Source: Byerlee et al., 1986

Table 16.2 Resource base of farmers included in on-farm research programme, Pakistan

	Punjab rice/wheat	Punjab cotton/wheat	NWFP maize/wheat	Punjab rainfed
Average farm size (ha)	8.4	8.2	2.7	2.9
% farms less than 5 ha	56	58	85	89
% fields tenant operated	41	37	59	10
% using tractor in wheat production	82	57	81	88
% using a tubewell in wheat production	81	93	13	0

followed by formal surveys using a short questionnaire and focusing on key practices and issues that had been identified in the informal surveys. An important feature of the formal surveys was that they included a yield sample from 3-5 plots in a specific field for each farmer at the time of harvest. In addition, several other special purpose surveys were conducted during the course of the research. These surveys varied according to the cropping system and were designed to follow up on issues of special relevance to particular systems.

The survey work was followed by an extensive programme of on-farm experimentation in each research area, except for the Punjab cotton/wheat area where resource constraints prevented the initiation of the experimental programme. The experiments were conducted in farmers' fields representing the dominant crop rotations in each research area. These experiments concentrated on a few priority research themes for the target system that had been identified in the diagnostic stage.

Table 16.3 Cropping patterns of areas included in on-farm research studies

System	Location	% cropped area under wheat in *rabi* season	% cropped area under dominant crop in *kharif* season	% fields with at least 3 years' continuous wheat in *rabi* season
Rice/wheat	Gujranwala/ Sheikupura	77	64 (rice)	72
Cotton/wheat	Multan	72	63 (cotton)	51
Maize/wheat	Mardan	66	63 (maize)	27
Rainfed wheat/ fodder	Northern Punjab	94	45 (sorghum/millet)	15

Source: Byerlee et al., 1986

SELECTED RESULTS OF THE ON-FARM RESEARCH PROGRAMME

In this summary of the results of the diagnostic and experimental work, the discussion is limited to results concerning choice of variety, land preparation and planting practices, fertility management and weed control.

Variety and planting date

From the diagnostic surveys, two major results stood out at almost all the sites with respect to varieties and planting dates. The first was that although nearly all the wheat varieties grown in the study areas were semi-dwarf varieties introduced as a result of the Green Revolution (with the exception of a few local varieties grown in the rainfed area), the rate of adoption of newer varieties was very slow (*see* Table 16.4 *overleaf*). This slow rate of adoption has continued and has put many of Pakistan's wheat growing areas at risk from leaf and stripe rust attack, as the older varieties become susceptible to new races of rust.

Yield performance of the newly released varieties was not an issue, as extensive on-farm experimentation had indicated that they were superior to current farmers' varieties. Over 50 experiments in the irrigated areas showed that the new variety Pak-81 gave an average 20% increase in yield over the farmer variety. Although Pak-81 was developed for irrigated areas, it also outyielded the farmers' variety in the medium and higher rainfall parts of the rainfed area. Only in the drier parts is the availability of appropriate varieties more problematic, as farmers need varieties that can be planted deeply into residual moisture. Interviews with farmers in these areas showed they were more interested in varieties that provided more fodder and higher grain quality.

A major follow-up study was conducted to establish the reason for this slow adoption of apparently appropriate higher-yielding varieties in all but the dry rainfed area (Heisey, 1990). Although the situation is complex, it would appear that the major explanation is farmers' unfamiliarity with new varieties and their lack of knowledge about the dangers of a rust epidemic, coupled with an inefficient distribution system for seed of new varieties. Neither the extension service nor the private sector has been aggressive enough in demonstrating and promoting new varieties, and the research service has not invested sufficient resources to monitor the movement of newly released varieties.

Table 16.4 Variety use in wheat areas, Pakistan

	% of fields			
Variety classification	Punjab rice/wheat 1984[1]	Punjab cotton/wheat 1985	NWFP maize/wheat 1984	Punjab rainfed 1985
1. New recommended (Pak-81, Punjab-81, etc.)	16	15	16	55
2. Old recommended (Sonalika)	18	24	37[2]	39[3]
3. Banned (rust susceptible)	66[4]	61[5]	47[2]	—
4. Local	—	—	—	6
5. Total	100	100	100	100

Notes: 1. Year of survey.
2. Variety classification for the maize/wheat area of Mardan is very approximate, as many farmers do not recognize variety names; also, a mixture of varieties is grown in many fields.
3. Lyallpur-73.
4. Mostly Yecora.
5. Mostly WL711.

Source: Byerlee et al., 1986

The second major finding from the diagnostic surveys was the prevalence of late planting in all the irrigated systems surveyed (*see* Table 16.5). This reflected the increase in cropping intensity and the tendency for more wheat to be planted after the dominant *kharif* crop rather than after fallow, as had traditionally been practised. Survey data have confirmed this increasing tendency to plant late (*see* Figure 16.2).

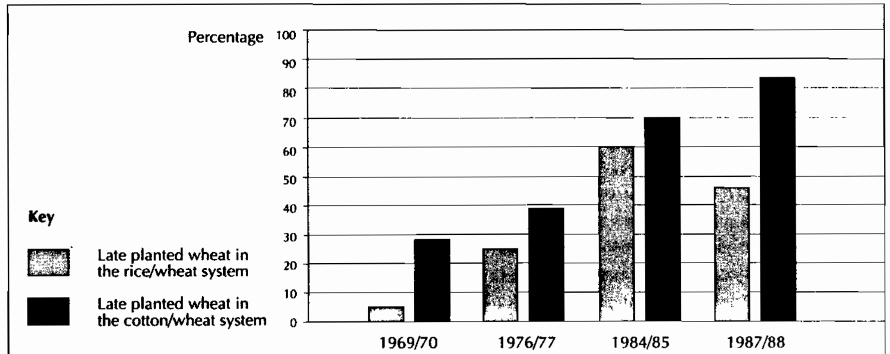
Wheat yields in Pakistan are very sensitive to date of planting because of the effect of high temperatures in the flowering and grain-filling stages. Both on-station and on-farm experiments indicated that each day's

Table 16.5 Distribution of planting dates of wheat in the irrigated areas of Pakistan

Planting date	Punjab rice/wheat (%)	Punjab cotton/wheat (%)	NWFP maize/wheat (%)
Recommended time (before Dec.1)	60	29	66
Somewhat late (Dec.1-15)	30	29	19
Very late (after Dec.15)	10	41	15

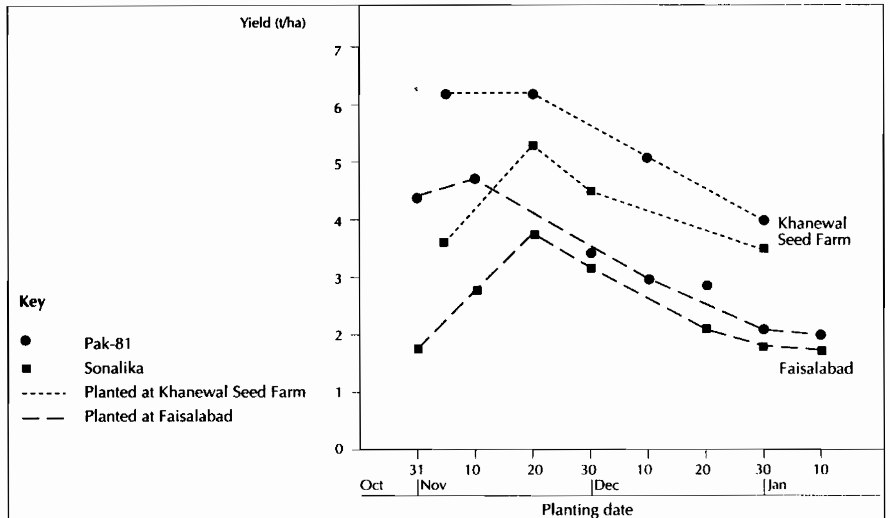
Source: Byerlee et al., 1990

Figure 16.2 Percentage of wheat planted late (after 1 December) in the Punjab of Pakistan



Source: Bashiruddin (pers. comm.)

Figure 16.3 Effect of planting date on the yield of Pak-81 and Sonalika wheat varieties at two locations in the Punjab (average from 1981 to 1984)



Source: Hobbs, 1985. Based on data provided by Punjab Agricultural Research Institute, Faisalabad and Punjab Seed Corporation, Khanewal delay in planting after mid-November decreased yields by 1% (Hobbs, 1985; Aslam et al., 1989). However, conflicts with the harvest of the previous crop often push wheat planting well beyond the optimal period, especially in the cotton/wheat system. The wheat planting date is also affected by the management and maturity date of the previous *kharif* crop. However, simple economic calculations show that, at present prices, the returns to one additional cotton picking are more than double the value of wheat lost to delayed planting, so farmers are behaving quite rationally in this respect (Byerlee et al., 1987).

The diagnostic survey data were important in establishing a priority for wheat varieties that performed well at late planting. Wheat breeders have traditionally given priority to evaluating yields at 'optimum' planting dates. Some research was in progress on developing early maturing varieties that were assumed to be most appropriate for late planting. However, an analysis of available experimental data on variety by date of planting showed that the recently released Pak-81 variety, although later maturing than the variety Sonalika recommended for late planting, yielded better at all planting dates (Hobbs, 1985) (*see* Figure 16.3). Also, farmers were found to be using one variety at all planting dates, rather than specific varieties for optimal and late planting.

On the other hand, in the rainfed areas, farmers would benefit from a wheat variety that could be planted earlier in the season, in order to take advantage of the monsoon rains. In drier areas, wheat must be sown deeply into residual moisture at planting time, and the available improved varieties have difficulty emerging vigorously from this depth.

Land preparation and planting practices

The land preparation and planting practices in the four wheat-based systems are shown in Table 16.6. In the irrigated areas, the turnaround time between crops is affected by the intensity of land preparation. This is particularly crucial in the rice/wheat area, where a seedbed for wheat must be prepared on the puddled, compacted soils left from the previous rice crop. Although the survey showed that farmers prepared land more intensively in this area, the resulting seedbed was often inadequate to achieve a good stand of wheat. Farmers sometimes took 3 weeks or longer to prepare the seedbed, and thus sacrificed considerable wheat yields because of the delay in planting. Experiments using a specially designed drill showed that direct drilling of wheat with zero tillage reduced turnaround time, with no loss in wheat yields (Aslam et al., 1989). In other areas, farmers have shown considerable imagination in managing turnaround time between crops. In parts of NWFP, for instance, they have developed an innovative method of relay cropping sugar cane into wheat.

Table 16.6 Land preparation and planting practices in wheat, Pakistan

	Punjab rice/wheat	Punjab cotton/wheat	NWFP maize/wheat	Punjab rainfed
Average number of tillage operations	6.1	4.8	3.3	8.2
Average seed rate	98	110	113	94
% broadcast seed	98	98	92	3

Source: Byerlee et al., 1986

Although research and extension had recommended and widely demonstrated line planting of wheat in the irrigated areas, the vast majority of farmers broadcast wheat seed. Extension loses credibility by persisting with the recommendation to plant in lines, especially when farmers usually do not have the time, draught animals or equipment to follow the recommendation and when experiments show little or no yield advantage over broadcasting.

The survey showed that land preparation and planting practices were very different in the rainfed area, where limited soil moisture near the surface restricts possibilities for broadcasting wheat seed. Instead, most farmers drilled their wheat using an animal-drawn planter or a tractor-drawn seeder. Turnaround time was not such a factor here, except perhaps on the more intensively cultivated *lepara* land (*see below*) near the village. Most of the rainfed wheat was planted on land that had been fallowed during the previous *kharif* season, where farmers ploughed following rain to conserve moisture and control weeds. This accounted for the high number of tillage operations observed. Nevertheless, most ploughing was done with a shallow-tyned cultivator, and repeated passes with a tractor contributed to soil compaction. On-farm experiments at more than 50 locations over 5 years showed a significant yield response of over 25% to the use of a mouldboard plough (Razzaq et al., 1990a). This difference can be attributed to several factors, especially the breaking of the soil compact layer to allow better rooting and water infiltration.

Fertilizer use

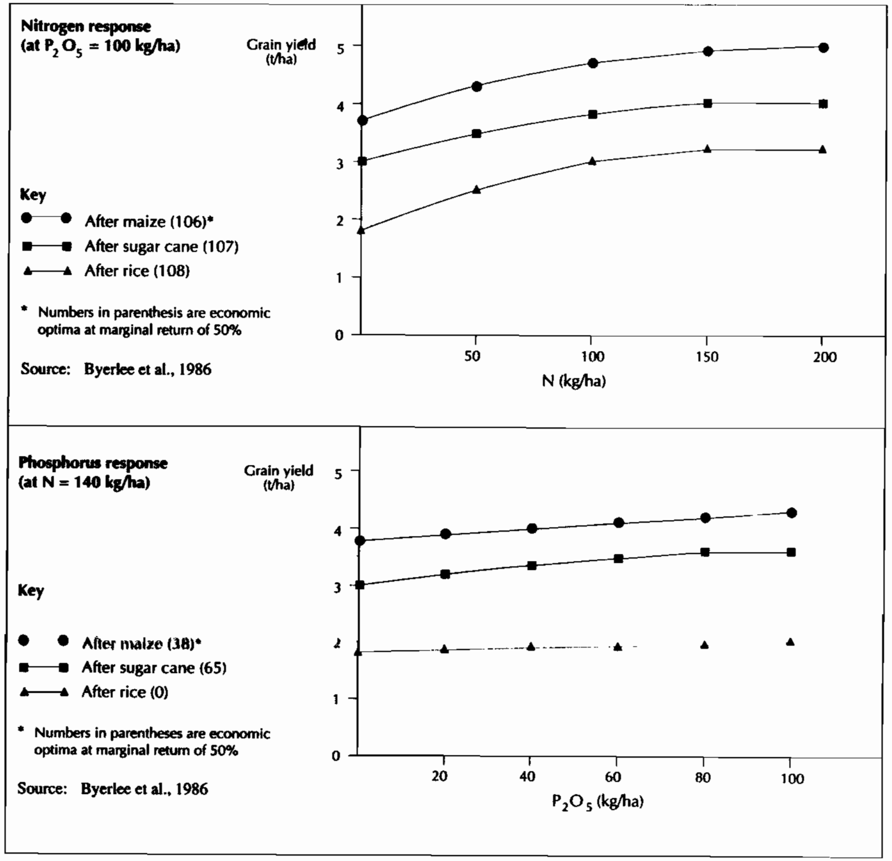
Almost all the farmers in the wheat systems studied used chemical fertilizer, but practices and problems varied considerably from one farmer to another and according to field conditions. As expected, in the rainfed area fertilizer use tended to be greater in the higher rainfall zone. But a more important factor in determining fertilizer use in rainfed areas, and in shaping future research, was the local land type classification. Farmers distinguished two types of land — *lepara* fields that are located close to the village and receive farmyard manure, and *mera* fields that are farther from the village and are not regularly manured. The use of farmyard manure was important for maintaining soil fertility and for improving soil structure and moisture retention capacity. *Lepara* land accounted for an average of only 27% of total farm area, but over half of the crop production. On-farm experiments showed that it was necessary to derive separate fertilizer recommendations for these two land types, particularly with regard to phosphorus.

In irrigated areas, few farmers (except those with very little land in the NWFP maize/wheat system) applied farmyard manure to their wheat crop, although almost all of them had considerable experience with chemical fertilizers.[1] Recommendations have traditionally given one fertilizer level for all irrigated wheat areas in Pakistan, but farmers have adjusted their fertilizer doses to reflect differences in cropping patterns, access to irrigation water and availability of resources. On-farm experimentation confirmed the rationality of many of the choices made by farmers and pointed the way towards the development more efficient fertilizer recommendations.

Experiments carried out in both the rainfed and irrigated areas emphasized differential response to fertilizer by crop rotation and land type, and produced recommendations for more homogeneous groups of farmers based on realistic estimates of farmers' total costs of applying fertilizer and acceptable rates of return on capital. Figure 16.4 (*overleaf*) shows estimated fertilizer responses for wheat after maize, sugar cane and rice.

The conventional wisdom in Pakistan has been that nitrogen and phosphorus should be combined in a ratio of 2:1, and indeed government policy reflected the objective of moving to this target ratio by placing a subsidy

Figure 16.4 Fertilizer response curves for wheat in different cropping patterns



on phosphatic fertilizers. Data from on-farm experiments showed little justification for this rule, and enabled more efficient fertilizer recommendations to be tailored to a variety of farming conditions. The research showed, for instance, that in some cases (for example, in the rice/wheat area) fertilizer use would be more productive if more nitrogen were applied relative to phosphorus, while in other cases the nitrogen : phosphorus ratio should be lowered. In the long run, however, more efficient fertilizer use will depend as much on complementary improvements in irrigation practices, weed control and stand establishment, as on fertilizer management *per se*.

Weed control

As expected, the importance and type of weed problems in wheat varied considerably among the systems studied. In the rainfed area, weeds did not appear to be a major problem. In addition, most of the wheat was intercropped with mustard, which was then harvested on a continuous basis and used for fodder. Although this may appear an irrational practice, experiments showed that mixing wheat and mustard in the same field was quite profitable (Hobbs et al., 1985).

In the irrigated areas, handweeding was practised in only a few fields, and very few farmers used herbicide on wheat. Handweeding was declining because of the increasing cost of labour, but farmers used several other weed control techniques, including crop rotation and pre-planting irrigation and cultivation. Rotation, particularly with the fodder crop Egyptian clover or *berseem* (*Trifolium alexandrinum*), was a common way of controlling grassy weeds, but was profitable only for farmers who had enough animals or were close enough to city markets to justify the fodder produced. Indeed, the diagnostic surveys in the three irrigated areas showed a strong correlation between grassy weed infestation and the continuous planting of wheat in the same field for 3 or more years (without rotation).

OFR identified two particularly important issues related to weed control. In the maize/wheat area, research showed that herbicides applied to control broadleaf weeds were relatively cheap and quite effective (*see* Table 16.7) and that farmers were very open to learning how to use them. In fact, some farmers had taken the lead in experimenting on their own with efficient methods for broadcasting herbicides mixed with soil or sand. The principal constraints appeared to be an inadequate extension effort and apathy on the part of private chemical suppliers. In the rice/wheat area, grassy weeds, particularly *Phalaris minor*, had become a serious problem, especially in fields sown continuously to wheat. Experimentation showed good returns to using herbicides for

Table 16.7 Economics of herbicide application in two irrigated wheat areas

	NWFP maize/wheat (20 sites)		Punjab rice/wheat (14 sites)	
	Broadleaf herbicide (Buctril M)	Grassy weed herbicide (Dicuran MA)[1]	Broadleaf herbicide (Buctril M)	Grassy weed herbicide (Dicuran MA)
Increase in yield (kg/ha)[2]	550[3]	700	0	1000
Gross benefit (Rs/ha)[4]	775	990	—	1420
Cost of herbicide (Rs/ha)[5]	240	525	—	575
Net benefit (Rs/ha)	535	465	—	845
Marginal return (%)	220	89	-ve	152

Notes: 1. Dicuran MA also controls many broadleaf weeds.
2. Experimental yield adjusted downward by 10%.
3. US$ 1 = Rs 17.
4. Net wheat price Rs 1.4/kg after subtracting harvesting, threshing and marketing costs.
5. Doses were 1.4 l/ha for Buctril M and 2.5 kg/ha for Dicuran MA. Costs include Rs 75/ha for application.

Source: Aslam et al., 1989

grassy weeds in this system, although the relatively high cash outlay associated with this practice suggested that further research was required on more efficient application methods, dosages and products.

IMPLICATIONS FOR COMMODITY AND DISCIPLINARY RESEARCH

The OFR results reflected a wide range of wheat production practices and problems in Pakistan. The contrasts and similarities between areas, and the ingenuity and dynamism of Pakistan's farmers, emerged clearly from the data. The challenge is how to integrate this rich set of data from several key systems in order to improve the overall research and policy strategy for wheat at the national level. Although the data derived from location-specific studies on wheat, the implications go well beyond recommendations for a particular location or for a single commodity. Possible courses of action for plant breeding, crop management research, extension, and socioeconomic research and policy analysis are discussed here. In some cases, these actions have been implemented, but in others the links between OFR and commodity or disciplinary research and policy are not well developed enough to utilize the OFR results effectively.

Plant breeding

A number of potential priorities for wheat breeding can be identified from the OFR data (*see* Table 16.8). Wheat breeding in Pakistan is carried out mainly at the provincial level in close coordination with PARC, which organizes national yield trials and sets up the committees for varietal evaluation and release. In the interests of efficiency, crop breeding programmes try to develop varieties that are as widely adaptable as possible. This effort has been particularly successful in Pakistan, as shown by the remarkably consistent performance of varieties such as Pak-81 across a wide range of environments. However, the threat of a rust epidemic continues to hang over the country unless farmers take up these new varieties more quickly than they have in the past. Although much of the responsibility seems to lie with extension in this case, a problem uncovered in interviews with farmers was that the breeding programmes often used similar names for their new varieties, which confused the farmers. As a result of this finding, new varieties now carry distinctive local names.

The OFR programme also identified the need for wheat breeders to more explicitly address the needs of Pakistan's rapidly evolving farming systems. Varieties were traditionally evaluated in variety by planting date trials in order to establish the optimum planting date for a given variety (assuming that the farmer had flexibility in planting time). Moreover, separate programmes were developed for optimum and late planting, with the emphasis on the former. Largely as a result of the OFR work, breeders now give attention to finding varieties for specified planting dates, dictated by the cropping system in which wheat is grown. In addition, instead of separate programmes for 'normal' and late planting, breeders now evaluate their materials over a wide range of planting dates, seeking those varieties that perform well at both normal and late planting, regardless of maturity period. A national-level variety by planting date trial has been implemented for this purpose. More opportunities need to be established for breeders to get early feedback from farmers regarding other characteristics of new varieties, such as chapati qualities, forage quality and shattering, that often slow the adoption of new varieties. This can be managed through more informal meetings between farmers and breeders, combined with occasional surveys and follow-ups of on-farm experiments.

The OFR work also highlighted the need for close communication between wheat breeders and breeders for other crops, especially cotton and rice, grown in rotation with wheat in irrigated cropping patterns. The

Table 16.8 Priorities for wheat breeding, Pakistan

Priority	Rice/wheat	Cotton/wheat	Maize/wheat	Rainfed
Stripe rust resistance	*		*	*
Leaf rust resistance	*	*	*	*
Varieties suitable for late planting	*	*	*	
Varieties with better emergence from deep planting				*
Varieties suitable for early planting				*
Better contact with other commodity programmes	*	*	*	

conflict between cotton harvesting and wheat planting can be resolved, for example, by using earlier varieties of cotton or varieties of wheat suitable for late planting. Likewise, changes in maturity of cotton or rice varieties, or even changes in the management or the price of these crops, can have important implications for wheat breeders (Byerlee et al., 1987). In some cases these conflicts may best be resolved by substituting other crops, such as oilseeds, for late planted wheat if development of appropriate varieties (especially early maturing ones) of these crops appears more likely than development of wheat varieties for late planting (Tetlay et al., 1990). Unfortunately, mechanisms for close coordination between commodity breeding programmes for crops grown in the same cropping system are virtually non-existent.[2] Indeed, several hundred kilometres separate the main cotton and rice breeding institutes from the wheat breeding institute.

Long-term crop management research

Despite the potential for further gains though breeding, it is obvious that much of the challenge of increasing the productivity of Pakistan's wheat-based farming systems must be taken up by crop management research, especially on issues requiring a longer time period to assess the implications for crop management and productivity.

Cropping intensity is increasing in all the systems studied, and researchers need to explore ways to help farmers gain experience with new options. In the rainfed areas, most wheat is still grown after fallow because of a perceived need for moisture conservation. New cropping patterns need to be designed so that farmers can take better advantage of available land and moisture. In the irrigated systems, where cropping intensities tend to be higher, there is much scope for exploring alternative crops and management practices. However, it will be necessary to examine the sustainability of these more intensive systems, paying particular attention to factors such as soil fertility (especially micronutrients), pest populations (for example, soil-borne pathogens), and irrigation water management (*see* Table 16.9 *overleaf*).

These issues require a fresh outlook on agronomic research and planning in order to deploy research resources in the most efficient manner on those issues most relevant to the future stability of major farming systems. Some agronomists may have to specialize in more strategic research to do justice to issues related to the sustainability of intensive cropping systems.

Table 16.9 Long-term priorities for crop management research, Pakistan

Priority	Rice/wheat	Cotton/wheat	Maize/wheat	Rainfed
Increase cropping intensity	*	*	*	*
Increase crop diversification	*	*		
Effects of long-term rotations on fertility and pests	*	*	*	*
Micronutrients	*	*	*	*
Irrigation water efficiency	*	*	*	
Effects of reduced tillage	*			*
Direct drilling of wheat	*	*		
Alternative tillage methods and soil structure improvement	*			*
Efficient herbicide application	*	*	*	
Soil health problems	*			*
Farmyard manure management and conservation			*	*
Fodder management and conservation			*	*

The future of effective agronomic research in Pakistan also depends upon the development of effective collaboration between commodity programmes and research institutes, and better integration of the various disciplines related to crop management, such as soil science, irrigation, water management, soil fertility, tillage and weed science. These disciplines have traditionally worked in isolation from each other, usually in separate disciplinary research institutes and often at different locations.

Most of the long-term issues in crop management research will be specific to a particular system, such as tillage in rice/wheat, direct drilling of wheat following cotton, or the management of mixed cropping in the rainfed areas. Some research may also be relevant across systems, such as the management of crop residues and organic manures in order to stabilize or build soil organic matter. This work will require the attention of multi-disciplinary teams that have one foot in the field and the other at the research station.

A good example of interdisciplinary collaboration stimulated by the results of adaptive research is provided by Inayatullah et al. (1989). In the rice/wheat system, after zero tillage on wheat had been shown to be feasible and cost effective, there was some concern that leaving rice stubble in the field would increase the problem of rice stem-borer damage in the following rice crop. Accordingly, the rice entomologist organized field surveys during the wheat season to examine the population of stem-borers in zero-tilled and conventionally tilled fields. On the basis of this work, he was able to devise a strategy for stem-borer control that allowed for zero-tillage.

This type of strategic crop management research suggests not only a need for better integration of crop management disciplines but also a longer-term perspective in research. Both long-term experiments in representative sites on experiment stations, as well as long-term monitoring of farmers' fields and practices, may be appropriate. The organization of long-term research that cuts across commodities and disciplines is especially challenging. In addition, while much of this research will be done initially under fairly controlled conditions, it should evolve as quickly as possible to adaptive research with the full participation of farmers.

In rainfed areas, an even more difficult challenge facing crop management research is the issue of fodder management and conservation and its interaction with wheat management. More efficient ways of producing and conserving fodder need to be explored (Byerlee et al., in press). This may require experimentation with speciality fodder crops and a closer examination of the trade-offs in intercropping fodder and grain in maize and wheat production. It may even involve OFR with animal production and collaboration with livestock scientists. In Pakistan there has been very little contact between crop and livestock scientists, despite the great importance of animals in many of the country's farming systems. The recent establishment by PARC of a coordinated farming systems programme has helped initiate better communication between crop and livestock scientists.

Extension services

The OFR programme has already contributed to strong adaptive research efforts in several areas. It has become obvious in the course of this research that an important priority is to improve the capacity of the extension services to transfer the results of the adaptive research. The extension services are organized at the provincial level and have recently adopted the Training and Visit (T&V) extension method. Nonetheless, coordination between research and extension, especially at the local level, remains weak.

There are a number of immediate opportunities for extension to make an impact (*see* Table 16.10). One of the most pressing of these is to organize better demonstrations of new wheat varieties and to make farmers more aware of the dangers of rust epidemics and the risks of a breakdown in rust resistance of wheat varieties. In those areas where chemical weed control has potential, the extension services could stimulate the private sector to acquaint farmers with products and equipment, teach safe application methods and help organize the availability of sprayers. In one case study in a Punjab village in the rice/wheat system where herbicide use had been widely adopted, it was found that the factors determining adoption were the presence of an extension agent who had made available a backpack sprayer for rental to farmers and a local farmer who then developed his

Table 16.10 Short-term priorities for adaptive research and extension, Pakistan

Priority	Rice/wheat	Cotton/wheat	Maize/wheat	Rainfed
Demonstration of rust-resistant varieties	*	*	*	*
Adjust fertilizer dose to higher N:P ratio	*			*[1]
Adjust fertilizer dose to lower N:P ratio		*	*	
Broadleaf weed control			*	
Grassy weed control	*			
Deep tillage			*	*

Note: 1. On *lepara* land.

own rental service (Ahmad et al., 1988). As the OFR programme moves into issues such as alternative tillage methods, long-term strategies to maintain fertility and integrated pest control, the extension services must play an increasingly important role in providing farmers with the information and skills to use these management-intensive technologies more effectively, as well as in organizing or encouraging the availability of inputs and machinery needed to implement the technologies where appropriate.

Given the large number of systems and the diversity within them, it is unreasonable to expect that the OFR teams currently in operation will be sufficient to provide the location-specific information required for further increases in the productivity of these systems. Increasingly, the extension services will have to carry the responsibility for adaptive research, with orientation and training from the research system.

Socioeconomic research and policy analysis

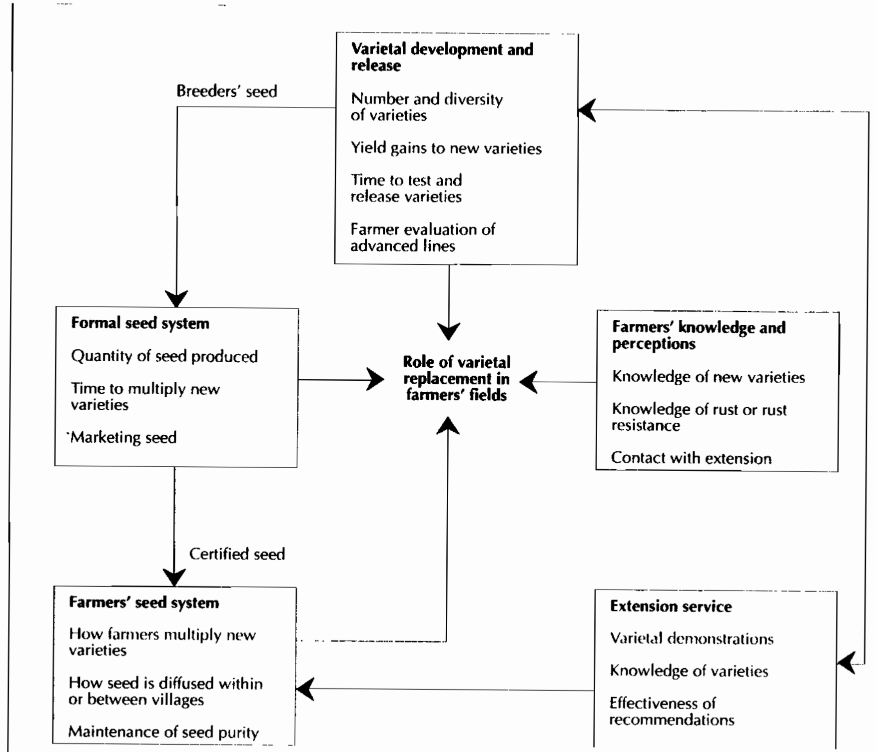
An important achievement of the OFR programme has been the strengthening of socioeconomic research units in the provincial research institutes. To improve collaboration with crop scientists, socioeconomists need to develop expertise in particular research areas (such as soil fertility) and systems (such as rice/wheat). Some of the priority issues for socioeconomists will require virtually their full-time presence in the field, often in association with an adaptive research and extension effort (*see* Table 16.11); other issues will require close interaction with research directors and policy makers. Although there will inevitably be some specialization among socioeconomists, leaders of socioeconomic research units should have a staff development strategy that allows researchers to develop confidence and familiarity with both the farmer's field and the policy maker's office.

A wide range of issues arising from the OFR programme require socioeconomic research. Some of them involve analysing trends and changes in national policy and interpreting the implications to crop researchers. These include analysing fertilizer response data, in the light of the expected removal of subsidies on phosphatic fertilizer, and studying the comparative advantage of oilseed crops with respect to wheat, in view of the growing demand for vegetable oil and government emphasis on oilseed production. Changes in the demand for and the importance of livestock products also has implications for setting research priorities in several of the wheat-

Table 16.11 Priorities for socioeconomic research, Pakistan

Priorities	Rice/wheat	Cotton/wheat	Maize/wheat	Rainfed
Seed distribution systems	*	*	*	*
Fertilizer subsidy	*	*	*	*
Comparative advantage of oilseeds	*	*		*
Costs of harvesting, labour displacement	*	*	*	*
Irrigation policy	*	*	*	
Demand for livestock			*	*
Monitoring technological change	*	*	*	*
Community decision-making in land use				*

Figure 16.5 Analysis of varietal development, seed system and information transfer in understanding slow wheat varietal replacement in Pakistan



Source: Heisey, 1990

based farming systems. A particularly complicated issue, related to wheat harvesting, is the trend toward mechanized harvesting and its implications for costs of production, labour supply and equity (Smale, 1987). In rainfed areas, intensification of cropping may require extensive research at the community level, on such issues as the nature of community decision-making regarding land use, fallowing and livestock grazing.

Socioeconomists should also take responsibility for developing an effective system for monitoring technological change and evaluating research impact. The OFR studies filled in some large gaps in researchers' knowledge about how new technologies are spreading (for example, mechanization) or stagnating (for example, wheat varieties). Such knowledge is crucial for research decision-making and for justifying research pay-offs to those who fund agricultural research. The Agricultural Economic Research Units (AERUs) have already initiated monitoring by conducting annual surveys of wheat, rice and cotton varieties. Recently, these surveys have expanded to include key management practices such as planting date and the use of fertilizers and herbicides. Given the size of these surveys (1000 farmers), socioeconomists must ask whether they should continue this work, or work with the crop reporting service responsible for crop statistics to collect the appropriate data and make it available in a timely manner to agricultural research institutes.

Clearly, much of the OFR work has important implications for policy, especially in improving the efficiency of input delivery. A major challenge for socioeconomists working at research institutes is how to make this information available to policy makers. The case study on the slow adoption of wheat varieties was aimed specifically at identifying the policy changes needed to accelerate varietal adoption. This study included analyses of the farmers' information system, the formal seed distribution system, the informal seed distribution system and the wheat breeding system (*see* Figure 16.5), and produced a number of policy recommendations, ranging from the procedure involved in naming varieties to commissions given to private vendors of certified seed (Heisey, 1990). Although meetings were held to discuss the results of the findings, the large number of agencies involved from the research, seed and extension system made it difficult to effectively reach all the relevant decision makers.

Another policy implication arising from the OFR programme concerns the subsidy on phosphatic fertilizer. The research results suggested that in some systems phosphate was a limiting nutrient, while in others, such as the rice/wheat system, farmers may have already exceeded the optimum dose. Thus, while the subsidy may have been appropriate in some situations, in others it may have led to inefficiency. The results were considered in the negotiations between donor agencies and the government that eventually led to the removal of the subsidy.

An important condition for fuller use of OFR results in policy analysis is the need for results to be synthesized and reported in a timely manner. In the Pakistan OFR on wheat, diagnostic surveys were usually reported within 6 months of completion. The results of the on-farm experiments have now been synthesized over 5 years at each site (Aslam et al., 1989; Razzaq et al., 1990a; Razzaq et al., 1990b). While reporting results does not guarantee that policy makers will read them, it is an important first step toward facilitating their use in policy decisions.

CONCLUSION

The main conclusion arising from this review of the OFR programme in Pakistan's wheat-based systems is that further progress demands better integration between disciplines, commodities and institutions, as well as integration between strategic research, adaptive research and extension. Without this integration there is little possibility of effectively addressing the issues identified in the OFR programme or of exploiting the potential for using OFR to set research priorities and guide policy decisions at the national level.

Take the case of the rice/wheat system. Crop breeding research needs to develop alternative varieties of rice and wheat that are able to minimize conflicts in the planting time of wheat. Extension and the private sector need to ensure that farmers know about these varieties and can judge their performance. Research is needed on alternative tillage and planting methods for both rice and wheat, and long-term rotation trials on reduced tillage, oilseeds and organic manures should be initiated to analyse the sustainability of these new systems. Many of these trials will initially be conducted on the research station through close collaboration between the rice and wheat commodity programmes, but they need to be based on an understanding of farmers' existing cropping systems and the problems inherent in those systems. There is thus an inevitable link to the adaptive research on fertilizer use or weed control currently in progress in the field.

The common thread through this complex research programme is the ability to understand and work under farmers' conditions. OFR provides the perspective and the methods to do this. The farming systems perspective gives researchers a framework for dealing with agricultural systems that are becoming increasingly complex. The perspective itself is not enough, however. High-quality research will be required, and it must be founded in a research strategy that goes beyond narrow disciplines or commodity interests. If the methods of OFR are understood and applied *throughout the research organization*, there is a chance of giving small farmers a 'voice' at all levels (Norman, 1980) and making sure that that voice is heard wherever research decisions are made. But simply working with farmers in their fields will not be enough either. Progress will still depend on providing better education and political organization to the farming population so that farmers can exert pressure more directly on research and extension organizations to meet their needs.

A strategy that demands that a considerable proportion of research be carried out in farmers' fields and requires coordination and communication among a variety of researchers and institutions is potentially expensive and beyond normal management capacity (a review of the management factors in OFR is provided in Chapter 15). It should be kept in mind that the research described here relates only to a few representative and important wheat-based systems in Pakistan. Extending this strategy to include all the major wheat growing areas, or to include other farming systems, represents a tremendous challenge.

Selecting priority farming systems and target groups for a research effort is a difficult task. Locations for strategic research must be representative of the conditions of important farming systems. Adaptive research must be organized so that it reaches large numbers of farmers. This is especially difficult in the rainfed systems of Pakistan that exhibit varying conditions and problems within a small area. Where possible, the selection of areas for strategic research and adaptive OFR should be coordinated to take advantage of the inevitable links between the two.

Staffing assignments represent an additional challenge. Most scientists would profit from the opportunity to move back and forth between farm-level and experiment station assignments. Adaptive research may at times demand full-time field presence, but there should be opportunities to rotate in and out of such assignments. Initially, it may be advisable to establish a small working group for an important cropping system with representatives of each major commodity programme. This group would be charged with designing strategic research and on-farm adaptive research that address important constraints in the system.

Lastly, the issue of better communication among all the agents involved in technology development and transfer is a fundamental issue which must be addressed if this strategy is to function. Rather than establishing new departments or programmes, a series of opportunities must be presented to researchers, extension agents and farmers in order to facilitate more effective communication between these parties. Working groups (whose lifetime is a function of their productivity), joint planning meetings and joint field activities are all possibilities. In the Pakistan case, where OFR was organized by wheat researchers, communication of the OFR results was most effective with on-station wheat researchers, especially breeders. This was facilitated by travelling seminars during which on-station and on-farm wheat researchers reviewed and discussed each other's work. Communication with other commodity programmes was more difficult, as was communication with the wide array of disciplinary research programmes. Communicating results to policy makers is undoubtedly the most challenging task, if only because of the tenuous links between researchers and policy makers.

Although it is easy to design communication systems built around planning meetings and workshops, perhaps the most effective technique for improving communication is through the informal diagnostic survey where teams representing different commodities and disciplines talk informally to farmers and observe their fields, and then meet daily to synthesize findings and come to a common understanding of problems and opportunities. This type of diagnostic survey has become well established in OFR programmes. The challenge now is to extend the method to setting priorities for on-station research, including varietal development and long-term crop management research, and even to guide policy making.

Notes

1. The use of farmyard manure has decline in irrigated areas, with tractors replacing draught animals and with competing non-farm uses of farmyard manure (for example, as cooking fuel).

2. Despite this, there has been some recent success in developing earlier maturing rice and cotton varieties (Akhtar et al., in press; Sharif et al., in press).

This chapter draws on the work of many scientists who participated in the joint PARC/CIMMYT research effort, including Munir Ahmed, Zulfiqar Ahmed, Ramzan Ahktar, Mohammed Aslam, Mohammed Azeem, Naeem Hashmi, Sajidin Hussain, Baktmand Khan, Bakht Roidad Khan, Abdul Majid, Mohammed Munir, Abdul Razzaq, Mohammed Shafique, Mohammed Sharif, A.D. Sheikh, and Khaleel Tetlay.

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