Tetlay, K. A., Heisey, P. W., Ahmed, Z. and Munir, A. (1991), *Seed Sci. & Technol.*, **19**, 123–138

Farmers' sources of wheat seed and wheat seed management in three irrigated regions of Pakistan

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(Accepted June 1990)

Summary

Cereal farmers in developing countries often have three major sources of seed: seed purchased from a formal seed industry, seed obtained from other farmers, and seed retained from the previous year's grain crop. This paper reports the results of a survey of nearly 400 farmers in three different wheat cropping areas in Pakistan. The most common seed source was retained seed, followed by seed from other farmers. Half or fewer of all farmers appeared to manage retained seed to maintain seed quality. When farmers first obtained seed of new varieties, the most common source was other farmers. Use of the formal seed industry for seed of new varieties was much greater in the Punjab than in North West Frontier Province. Literacy and extension contact were the variables most commonly associated with farmer awareness of the nearest seed depot. Short run solutions to the problem of wheat varietal turnover in Pakistan require a better seed distribution system. When seed is not purchased every year, but rather bought primarily when the farmer wants to change varieties, the planning to meet seed demand requires considerable care.

Introduction

Seed is the most basic input in crop agriculture, yet one that has often been overlooked, perhaps because it usually comprises a minor portion of farmers' production costs. The 'Green Revolutions' of hybrid maize in the developed countries and wheat and rice in developing countries have led to greater interest in seed of cereal crops. This generalization concerning 'Green Revolutions', of course, oversimplifies the position. Impressive advances in wheat yields have been recorded in developed countries, and hybrid maize has achieved success in some developing countries.

A great amount of information on seed production and quality control is available, as well as on seed legislation that guides production and marketing. Less is known about the economics of seed industry development (Kelly 1989), although some guidelines for organizing the supply of seed are available (Kelly 1989; Douglas 1980; Gregg

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1983). These questions are particularly crucial in developing countries with large agricultural sectors but relatively young seed industries. Deciding how much and what kind of seed to supply also depends on an ability to predict farmers' demand for seed.

This article reports the results of a survey of farmers' sources of wheat seed in three irrigated regions in Pakistan. In Pakistan, the Green Revolution in wheat has made a well-known impact on yields and production. In recent years, however, new wheat varieties have not spread as fast as is desirable, given their superior yield potential and rust resistance compared to older varieties (Byerlee 1989).

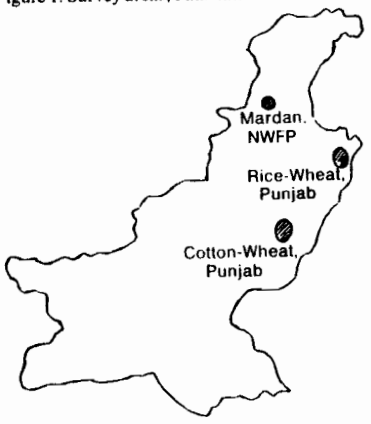
The wheat seed market in Pakistan provides a good example of the issues involved in attempting to promote the use of new varieties in a cereal. The major usable product of cereal crops, the grain, is also the seed. In regions with a government-sponsored or commercial seed industry, cereal farmers can choose between buying seed, retaining grain from one season's crop for planting in the next, or obtaining seed from other farmers. Because seed can be retained from a grain crop, it is in some ways more similar to a capital item than to a variable input.

When a farmer does decide to get new seed, it can either be new seed of a variety he currently grows, or seed of a new variety to replace an old variety. In the former case, the farmer may purchase seed because seed retained from the grain crop has deteriorated in production potential. This is largely true for a crop like hybrid maize, for which farmers typically buy replacement seed each season. Loss of production potential is also a major reason for farmers changing seed of a cross-pollinated crop like maize. Even the seed of self-pollinated crops like wheat can deteriorate if it is mixed with seed of other varieties or species or loses its germination potential during storage. When farmers change the seed they use to change varieties, improved yield potential in the new variety is an important additional consideration. Furthermore, the old variety may have lost disease resistance. Besides improvements in production potential of new seed and deterioration in seed retained from the grain crop, seed and grain prices, base yield levels, interest rates, learning costs, and risk premia may all affect the costs and benefits of the farmer's changing seed (Heisey and Brennan 1989).

Material and methods

In 1986 wheat scientists and social scientists from the Pakistan Agricultural Research Council (PARC), the International Maize and Wheat Improvement Center (CIMMYT), and the Pakistan Economic Analysis Network (EAN) project collaborated in a series of four studies designed to analyze the wheat seed system in Pakistan from the breeding of new lines to adoption by farmers. These studies analyzed measures of assessing the progress of a wheat breeding program; methods of determining the extent to which different varieties are grown by farmers; seed multiplication and marketing in the Punjab by the Punjab Seed Corporation (PSC); and farmers' seed sources, seed management, knowledge of wheat disease, and adoption behaviour. They are summarized in Heisey, ed. (1990).

Figure 1. Survey areas, Pakistan.



As part of these studies, PARC social scientists administered detailed questionnaires concerning wheat technology to: 1) 146 farmers in 30 villages selected randomly in Ferozewala, Gujranwala, and Daska *tehsils* in the rice-wheat zone in the northern part of the irrigated Punjab (a *tehsil* is an administrative unit comprising very roughly 500,000 to 1,000,000 people. Ferozewala, Gujranwala, and Daska *tehsils* are contiguous units located in Sheikhupura, Gujranwala, and Sialkot Districts, respectively, of Punjab Province); 2) 149 farmers in 30 villages randomly selected in Lodhran, Mailsi, and Bahawalpur *tehsils* in the cotton-wheat zone of the southern Punjab (Lodhran, Mailsi and Bahawalpur *tehsils* are contiguous units located in Multan, Vehari, and Bahawalpur Districts, respectively, of Punjab Province); and 3) 99 farmers in 20 villages randomly selected in the irrigated portion of Mardan District, which lies in the Peshawar plain of Northwest Frontier Province (NWFP).

Survey locations are depicted in figure 1. Data collected from these surveys are the basis of this article. They refer to the wheat crop grown in the 1985-86 season. The article presents summary statistics describing, by survey area, wheat seed sources for all varieties taken together; wheat seed sources for individual popular varieties; initial sources of seed when farmers acquired recent wheat releases; the relationship of farm size to seed depot use; farmers' knowledge of and visits to seed depots; characteristics of farmers who served as seed sources to other farmers; and farmers' management practices for grain retained as seed.

In addition, the article analyzes the factors related to correct knowledge of seed depot location and to actual visits to the seed depot. Many variables can influence whether or not a given farmer knows the location of the nearest seed depot or visits it. These include human capital variables, such as literacy; farm size and tenure variables; information sources, such as agricultural extension; or distance from the depot. Since these variables are unlikely to operate independently of one another, variable-by-

Table 1. Independent variables for probit analysis of farmers' knowledge of and visits to a seed depot.

Variable	Definition
AGE	Farmer's age in years
ASQ	AGE squared
LIT	Dummy variable = 1 if farmer was literate
LNSIZE	Natural logarithm of farm size in hectares
OWN	Dummy variable = 1 if farmer owned some or all of the land he farmed
STATUS	Dummy variable = 1 if farmer was a village official, owned a shop, etc.
EXT	Dummy variable = 1 if farmer met with agricultural extension personnel in year previous to the survey
RADIO	Dummy variable = 1 if farmer listened to agricultural programming on the radio in month previous to the survey
DEMO	Dummy variable = 1 if farmer had visited or hosted a wheat demonstration plot in year previous to the survey
DIST	Distance to the nearest seed depot in kilometers

variable analysis of relationships with knowledge of seed depots or visits to them are likely to be misleading (Feder, Just, and Zilberman 1985). Instead probit analysis, which uses a number of independent variables, is used to predict the probability of whether or not a given farmer knew the location of the seed depot and also to predict whether or not the farmer had visited a depot. The coefficients in a probit equation can be interpreted as a change in probability caused by one variable given constant levels of the other explanatory variables. (See, for example, Maddala 1983 for a discussion of probit models.)

Independent variables used in the probit analysis are listed in table 1. Several equations were estimated for each of the three zones. Results of one of the better equations for each zone (better in terms of goodness of fit as determined by the regression chi-squared statistic) are presented below. Results of the equations presented were also checked for consistency with the other estimated equations. Estimation of single equation probit models is not entirely satisfactory in the present instance because there

Table 2. Seed depot density.

(Retail seed outlets* per 100,000 ha of wheat)	
Sheikhupura, Gujranwala and Sialkot districts (Rice zone)	8.8
Multan, Vehari and Bahawalpur districts (Cotton zone)	22.6
Mardan district	2.1
ALL PUNJAB	15.1
ALL NWFP	3.3

* Cooperative Bank Outlets are not included in the Punjab since they handle very little wheat seed.
Source: calculated from data obtained from the Punjab Seed Corporation, Lahore, and presented in Chaudhry and Heisey (1988); and from data obtained from the Agricultural Development Authority, Peshawar.

Table 3. Wheat seed sources varieties currently planted.

	(percentage of farmers)		
	Rice zone	Cotton zone	Mardan*
Own	55	62	59
Other farmers	21	22	27
Seed depot	10	8	9
Research/Extension	-	-	4
Shopkeeper/Grain merchant	3	2	1
Other**	11	6	-

* Percentage of fields.
** The 'other' category for the Punjab rice and cotton zones refers to farmers who got seed from a variety of sources. In Mardan, the analysis was done by fields, so sources did not overlap.

are likely to be causal relationships between some of the explanatory variables. However, the results help determine which variables are more likely than others to predict farmers' contact with the seed depot.

In this article, 'new varieties' at the time of the 1986 surveys are those released in 1979 or thereafter, since these varieties were in most cases in the initial stages of adoption. When the survey was taken, Punjab 81 had already been banned north of Faisalabad because of stripe rust susceptibility (that is, banned in the rice zone, where it is grown, and in Mardan, where it is not). We nevertheless classify Punjab 81 as a new variety since the factors influencing its adoption resemble those influencing the adoption of other new varieties. In recent years, Punjab 81 has been declining in area in the rice-wheat zone both because the PSC no longer makes its seed available there and because it has proven to be particularly susceptible to shattering (Chaudhry, Asi, Niaz, and Khan, 1985).

Results

Data from the three survey areas are broadly similar but nevertheless reveal certain contrasts. Some differences relate to the fact that the seed system is more rudimentary in NWFP than in the Punjab. Others relate to contrasts between the two cropping areas in the Punjab. Seed production and distribution in the Punjab is particularly concentrated in the cotton zone. Seed depot density cannot be calculated exactly for the three survey areas because data on depots are only available at the district and not the *tehsil* level. However, if we calculate density of seed outlets for the districts where the survey areas were located, the results confirm high density in the cotton zone and low density in Mardan (table 2). Another difference among the areas is that newer wheat releases were more widely diffused in the rice zone than in the cotton zone at the time of the surveys, largely because WL-711, a high-yielding, well-adapted, but rust-susceptible variety, was dominant in the cotton zone.

Farmers' Sources of Wheat Seed: All Varieties Currently Planted

In all three areas, the most common source of wheat seed planted in 1985-86 was seed retained from the last year's crop. This was used by 55 to 60 percent of the farmers (table 3). Roughly one-fifth to one quarter of the farmers got their seed from other farmers, and some 10% or fewer purchased seed at a depot.

An examination of some of the more popular varieties in each zone clarifies the pattern of seed acquisition. At the time of the surveys, popular new wheat varieties, by our criterion, were Pak 81 in the rice zone and Mardan; Punjab 81 in the rice zone; and Bahawalpur 79 in the cotton zone. Popular old varieties were Blue Silver in the rice and cotton zones; WL-711 in the cotton zone and Mardan; Yecora in the rice zone; and SA-42 in Mardan. In Tables 4–6 we also include the varieties Sandal in the rice zone and 'Mexipak' in Mardan. Sandal is a sister line of Yecora, and therefore phenotypically quite similar. Many farmers in Mardan did not know the names of their varieties and used the generic term 'Mexipak', the name of the original semidwarf variety in Pakistan to refer to any semidwarf wheat. Wheat breeders indicate that there is very little of the actual Mexipak variety planted anywhere in Pakistan.

Obviously, farmers planting older varieties were more likely to have been planting them longer and to be using retained seed. On the other hand, farmers planting new varieties were more likely to have obtained their seed from a seed depot. Some evidence indicates that for new varieties in the Punjab, notably Pak 81, other farmers were more often a source of seed than they were for older but still popular varieties (tables 4 to 6).

Initial Seed Sources for New Wheat Varieties

Patterns of seed acquisition become more evident if we look at sources of seed for new varieties *the first time* farmers plant them. As expected, seed depots were a major initial seed source for farmers in the two zones in Punjab but were much less important in Mardan, where the seed system is less developed. Looking at all three zones together, it is apparent that other farmers were the source of seed for about half the farmers when they started growing a new variety (table 7).

Some farmers in Mardan first got seed of new varieties from research or extension. The 'other' category in Mardan usually refers to cases in which farmers said they got seed at a depot, but did not know the depot's correct location; it is likely that some of that seed also came from research or extension.

Farmers who first acquired seed of new varieties from the depot tended to have larger holdings (table 8), whereas farmers with less land more often got seed of new releases from other farmers. In Mardan, because of the smaller numbers involved, research and extension are grouped with the seed depot as an initial source of seed, as they are both formal institutions apart from the informal, but powerful, mechanism of farmer-to-farmer seed transfer. In Mardan, farms are quite small so the 10 ha division between 'small farms' and 'large farms' is less appropriate than in Punjab. Forty-six percent of all farmers with more than 4 ha initially got seed of new varieties from

Table 4. Wheat seed sources new varieties and other popular varieties currently planted rice zone.

	(percentage of farmers)				
	Pak 81	Punjab 81	Blue Silver	Yecora	Sandal
Own	17	39	76	85	56
Other farmers	39	21	5		12
Seed depot	20	15	5		4
Shopkeeper/Grain merchant	7	6	5		
Other	17	18	9	15	28

Table 5. Wheat seed sources new varieties and other popular varieties currently planted cotton zone.

	(percentage of farmers)				
	Pak 81	Punjab 81	B79*	BS**	WL-711
Own	37	52	48	67	70
Other farmers	26	19	39	12	20
Seed depot	32	24	4	8	
Shopkeeper/Grain merchant	–	-	4	2	
Other	5	5	4	10	10

* Bahawalpur 79
** Blue Silver

Table 6. Wheat seed sources new varieties and other popular varieties currently planted Mardan.

	(percentage of farmers)			
	Pak 81	Blue Silver	SA-42	'Mexipak'*
Own	35	53	56	81
Other farmers	35	35	37	19
Seed depot	15	12		
Research/Extension	15	-		
Shopkeeper/Grain merchant			7	

* 'Mexipak' tends to be a generic name for semidwarf wheat in Mardan; it usually refers to an older HYV that the farmer has been growing for a considerable amount of time.

a seed depot, research, or extension, while 24 percent of the farmers under 4 ha got new wheat seed from these sources. It seems likely that in Mardan it is primarily the very largest farmers who have contact with formal seed sources.

Farmers who supplied seed of new varieties to other farmers tended to have larger than average farms. Still, 50% or more of the farmers who initially obtained new varieties from other farmers said their source was a farmer with less than 10 ha (table 9).

Table 7. Initial sources of seed: new varieties.

	(percentage of farmers)		
	Rice zone	Cotton zone	Mardan
Other farmers	56	47	46
Seed depot	37	52	14
Research/Extension		-	18
Shopkeeper/Grain merchant	5	2	
Other	2	-	21

Table 8. Farm size and use of seed depot in the acquisition of new wheat varieties.

	(percent farmers using new varieties who first acquired them from seed depots)		
Farm size	Rice zone	Cotton zone	Mardan*
< 10 ha	22	43	19
≥ 10 ha	63	65	71

* Source includes both seed depots and research/extension.

Table 9. Type of farmer from whom seed of new variety was obtained.

	(percentage of farmers)		
	Rice zone	Cotton zone	Mardan
< 10 ha	66	47	58
≥ 10 ha	32	46	42
Landlord	2	7	-

Table 10. Distance to farmers providing seed of new varieties.

	(percentage of farmers)		
	Rice zone	Cotton zone	Mardan
Same village	52	54	69
< 5 km	32	29	15
5 10 km	3	13	8
> 10 km	13	4	8

Table 11. Knowledge of seed depot location and seed depot visits.

	(percentage of farmers)		
	Rice zone	Cotton zone	Mardan
Knew correct location	51	46	52
Stated other location	14	11	38
Did not know location	35	44	10
Visited depot*	38	36	21

* Only includes those farmers with correct knowledge of depot location.

Source farmers were also close to the farmers they served; over half the farmers who got seed from other farmers contacted someone within their own village and over 80% received seed from a farmer within a 5 km radius (table 10).

In all three survey areas, over 90% of farmers planting new varieties said they had no problems obtaining seed. Three-quarters or more financed the seed with their own money; the other significant way of obtaining seed was to exchange grain for seed with another farmer (one-sixth to one-fifth of the farmers got their new seed that way). Yet in both the rice and cotton zones, around half of the farmers who knew about new varieties but did not plant them said this was because seed was unavailable. In Mardan, this reason was also cited by nine of the 24 farmers who knew about new varieties but were not planting them.

Farmers' Contact with the Seed Industry

About half the farmers in all three zones knew the correct location of the nearest seed depot. Some farmers in each zone said they knew the location but identified it incorrectly, an occurrence much more common in Mardan than in Punjab (table 11). Mardan District has only two Agricultural Development Authority (ADA) depots, although there are other ways in which seed can be distributed. Significantly more farmers in the Punjab who were aware of new varieties (they were already planting them or had heard of them) knew the correct location of the depot nearest them. In Mardan, there was no relationship between varietal awareness and accurate knowledge of the seed depot.

Over one-third of the farmers surveyed in the rice and cotton zones had actually visited a seed depot whereas only one-fifth of the farmers in Mardan had done so (table 11). In the Punjab, farmers who were planting new varieties were more likely to have visited a seed depot than those who were not. In Mardan, there was no relationship between planting new varieties and seed depot visits.

Tables 12 and 13 summarize the probit regressions analyzing factors influencing farmers' knowledge of seed depot location or visits to the seed depot. The results in Table 12 for the rice zone could be employed to compare two hypothetical farmers to illustrate the use of the probit model to predict seed depot knowledge. The first farmer is a literate farmer who has no special social status, no contact with agricultural

Table 12. Factors related to correct knowledge of seed depot location probit analysis.

Independent variables*	Rice zone	Cotton zone	Mardan
AGE	0.0498	0.0347	0.220
	(1.10)	(0.653)	(2.96)***
ASQ	0.000590	0.000328	0.00224
	(1.27)	(0.558)	(2.97)***
LIT	0.582	0.393	1.12
	(2.13)**	(1.45)	(2.38)**
LNSIZE	0.225	0.153	0.330
	(1.69)*	(1.20)	(1.84)*
OWN		0.279	0.564
		(0.979)	(1.60)
STATUS	0.214	0.409	1.51
	(0.730)	(1.30)	(2.82)***
EXT	0.529	0.570	0.621
	(1.85)*	(2.05)**	(1.50)
DIST	0.0350	-0.0397	
	(-1.15)	(-1.80)*	
CONSTANT	1.51	1.07	4.71
	n = 142	n = 141	n = 92
	$X^2(7) = 36.3$	$X^2(8) = 20.3$	$X^2(7) = 25.3$

Note: Asymptotic t-values in parentheses; *** indicates significance at the 1% level; ** at the 5% level; and * at the 10% level.
[a] Dependent variable is KNOW; dummy = 1 if farmer knew the correct location of the seed depot nearest his village.

extension within the past year, and other continuous characteristics set at the medians for the sample. The second is a farmer with identical characteristics except for being illiterate. The probit equation predicts the literate farmer would have a 61% probability of knowing the correct location of the nearest seed depot; the illiterate farmer would have only a 38% probability.

The results of the probit regressions are consistent with our expectations, except for several anomalous relationships in the smaller Mardan sample. Literacy is the key human capital variable, positively related to seed depot knowledge and visits in the rice zone and in Mardan. In the cotton zone, literacy is not significant at standard levels but the coefficient does have asymptotic t-values significant at the .20 level. In Mardan, a quadratic age specification is also significant, implying that as a farmer's age increased up to the mid-40's, the farmer was more likely to know where the seed depot is or actually to have visited it; after that increasing age reduced the probability.

Extension contact is the main information source related to contact with the seed depot. In the rice and cotton zones, farmers who had seen extension personnel within the last year were significantly more likely to know where the seed depot was. In the rice zone and Mardan, extension contact was significantly related to visits to the seed depot. There is an anomalous result regarding information sources in Mardan, where

Table 13. Factors related to visits to seed depot probit analysis.

Independent variables[a]	Rice zone	Cotton zone	Mardan
AGE		0.0625	0.381
		(1.16)	(2.60)***
ASQ		-0.000602	0.00362
		(1.01)	(2.53)***
LIT	0.888	0.418	1.74
	(3.43)***	(1.56)	(2.60)***
LNSIZE	0.192	0.107	0.245
	(1.56)	(-0.809)	(1.21)
OWN			0.606
			(1.30)
STATUS		0.638	1.08
		(2.08)**	(1.67)*
EXT	0.623	0.337	1.12
	(2.32)**	(1.20)	(2.44)***
RADIO			-0.827
			(1.88)*
DEMO	0.343		
	(1.26)		
DIST	-0.0389	-0.0508	
	(1.24)	(2.16)**	
CONSTANT	1.18	-1.50	-10.7
	n = 146	n = 141	n = 87
	$X^2(5) = 42.2$	$X^2(7) = 21.3$	$X^2(8) = 30.3$

Note: Asymptotic t-values in parentheses; *** indicates significance at the 1% level; ** at the 5% level; and * at the 10% level.
[a] Dependent variable is VISIT; dummy = 1 if farmer had visited a seed depot.

farmers who had listened to agricultural programming on the radio within the last month appear less likely to have visited the seed depot.

Variables related to general status or resources base, such as farm size, tenure, or social status are mostly insignificant or anomalous. Increasing farm size did appear to increase the likelihood of seed depot knowledge in the rice zone, but the effect in Mardan was negative. All in all, farm size appears to have little predictable relationship to seed depot knowledge or contact. This finding does not necessarily contradict earlier indications that larger farmers planting a new variety for the first time were more likely to get seed of the variety at a seed depot. What the present results seem to indicate is that larger farmers have significantly higher levels of literacy and extension contacts and, once these other variables are taken into account, farm size does not have much of an effect one way or the other on their contact with the seed depot.

The most anomalous result is the highly significant negative effect of social status in Mardan. In Mardan, only 17 farmers had positive social status, which is a rather crudely defined variable. Nearly all of these farmers were literate. However literate farmers without 'social status' were significantly more likely to identify seed depot

Table 14. Farmers' seed management practices for retained seed.

	(percent of farmers using retained seed)		
	Rice zone	Cotton zone	Mardan*
Kept separate field, threshed and stored separately	17	7	15
Selected field at harvest, threshed and stored separately	20	4	36
Threshed and stored separately only	7	26	
Subtotal: Attempted to maintain seed purity	44	37	51
Stored separately only	4	3	3
Did not store separately	51	60	47

location correctly than literate farmers with status. Perhaps farmers with status were more familiar with *non-ADA* seed sources such as research farms or extension offices.

Social status also appeared to be positively related to depot visits in the cotton zone. When the social status dummy is left out of the estimating equation in the cotton zone, the coefficient for literacy becomes significant at the .05 level, suggesting that the 'social status' variable may be picking up some of the same influence as the literacy variable did in the other zones.

In the cotton zone, where retail seed outlets are most concentrated, farmers located farther from the depot were less likely to know where it was or to visit it. The relationships were also negative in the rice zone, but not significant at standard levels. There were no relationships in Mardan, where the formal seed system is a much less active agent of varietal diffusion.

Management of Retained Seed

From year to year, the most significant source of wheat seed is seed that farmers themselves retain from their previous crop. Farmers in the three surveyed areas were asked if they managed seed crops any differently from the rest of their grain: did they select a special field for seed, or thresh and store the seed separately from other grain?

Farmers in the rice zone and Mardan were somewhat more likely than cotton zone farmers to choose a separate field for seed, either before or at harvest. Over all three zones, 40–50% of surveyed farmers threshed and stored their seed separately from the rest of their grain (table 14). Threshing seed separately from grain was the criterion for determining if the farmer made special efforts to preserve seed quality. The few farmers who stored seed separately without threshing it separately were not included in the 'special seed management' group for further analysis.

Very few other characteristics of farmers could be related to whether or not they used special seed management practices. In both the rice zone and Mardan, seed management practices of farmers planting new varieties did not differ from those not planting them. Farmers in the cotton zone who planted new varieties were significantly

more likely to manage their seed to maintain quality.

With increasing farm size, the likelihood increased that farmers in the rice and cotton zones threshed seed separately. In the rice zone and in Mardan farmers who had contact with extension in the last year appeared more likely to thresh seed separately.

Discussion

The evidence presented in this article confirms that farmers' major source of wheat seed is seed retained from the previous year's crop. The next most frequent source of seed is other farmers. Less than 10% of farmers surveyed obtained seed at a depot. Fewer than half of the farmers who retained their own seed sought to ensure its purity by selecting or threshing it separately.

In 1985 Haider, Naiman, Tinsley, and Shang (1987) took wheat seed samples from ten farmers in the Sind, Pakistan. Although they found that four of the samples had high proportions of inert material caused by weevil damage or broken grain, all but one of the samples exhibited a percentage germination of over 90% after it was cleaned. Haider *et al.* argued that a longer term problem could be build-up of weed seed. Our own work leads us to speculate that slow losses over time caused by intermixtures or loss of germination are less important than actually experienced disease loss in inducing farmers to change wheat varieties (Heisey, ed. 1990).

When farmers change varieties, other farmers are the most important source of seed. In the Punjab, where the seed system is better developed, seed depots are almost equally important as a source of seed when farmers want to change varieties. In Mardan, seed depots are much less significant as an initial source of new seed, but research or extension personnel sometimes provide seed of new varieties to farmers. Another way of looking at the question of the importance of the formal seed system in spreading new wheat varieties is that in the Punjab farmers planting new varieties are significantly more likely to know where the seed depot is and to have visited it; in Mardan there is no relationship between planting new varieties and contact with the seed depot.

It is likely that dispersing seed distribution points more widely would hasten the spread of new varieties. Farmers who plant new varieties say they easily obtain seed; yet farmers who know about new varieties but do not plant them often explain that seed is not available. In areas where there are more depots, distance from a depot is negatively related to knowledge of its location or actual visits to the depot. Seed depot density is not the only factor influencing wheat varietal diffusion, however. There are more seed depots for a given wheat area in the cotton zone of the Punjab than in the rice zone, yet diffusion of new varieties had proceeded further in the rice zone at the time of our survey.

A number of associated farmer characteristics appear to influence whether farmers know about or have visited a seed depot and whether they manage seed and grain crops differently. In most cases, the significant effects are what one would expect, and the most consistent explanatory variables are literacy and contact with extension.

Farm size does seem to make a difference in one case-initial source of new seed.

When other variables such as literacy and extension contact are taken into account, farm size does not usually appear to be related predictably to contact with the seed depot. In other words, larger farmers are more likely to get seed of new varieties from a seed depot because they are more likely to be literate and to have contact with extension than simply because they have more land. Larger farmers may also be more likely to manage seed differently than grain. For seed policy planning it should be noted that new seed often enters a village when a larger farmer obtains it from the formal seed system. Seed then spreads from farmer to farmer within the village or spreads to an adjoining village. Farmer-to-farmer seed diffusion is highly localized, as fewer than 10% of farmers get seed from a village more than 10 km away. Despite the strengthening of the formal seed production and distribution system, informal, farmer-to-farmer seed transfer clearly remains a major means of diffusing seed, as in the early days of the Green Revolution (Lowdermilk 1972).

General patterns in the diffusion of new wheat varieties and reasons why farmers change varieties in these areas of Pakistan are analyzed further elsewhere (Heisey, ed., 1990). For example, a major constraint to the diffusion of new varieties is simple lack of awareness that these varieties exist. Once a farmer becomes aware of replacement wheat varieties, farmers' perceptions that they will yield more than their old varieties are very important. Other factors such as performance when planted late or resistance to shattering are important depending on the cropping system of a particular area or its current varietal mix.

Some preliminary conclusions about spreading the benefits of good seed can be drawn from evidence presented in this article. Possible long-term solutions to the problem of seed diffusion are identical to those recommended for a range of problems in post-Green Revolution agriculture (Byerlee, 1987): greater literacy and more widely dispersed, more effective extension. Shorter-term solutions include establishing a better seed distribution system with more seed outlets, even though individual farmers will not demand seed every year; and improving the coverage of varietal demonstrations. The challenge in the first case is to improve seed marketing so that the benefits of earlier spread of wheat varieties to more farmers are greater than the costs of an expanded marketing system.

A major problem in planning seed production and distribution systems is predicting farmers' demand for seed. Planning documents for the Punjab Seed Corporation assume, for example, that demand for high-yielding wheat varieties would be stronger in the irrigated areas; that larger farmers are more likely than smaller farmers to purchase seed; and that farmers would 'renew' their wheat seed every five years (World Bank 1976). However the World Bank appraisal does not appear to recognize that a major factor in seed renewal, particularly for a self-pollinated grain crop like wheat, is the farmer's desire to change varieties, not to buy new seed of the variety or varieties he has been using. As a result, planning of wheat seed demand requires particularly close analysis of the number and characteristics of new varieties coming out of the research system, as well as their likely acceptability to farmers.

Beyond the private benefits available to farmers from the more rapid adoption of

seed of new varieties, governments may have social reasons for encouraging more rapid varietal turnover. Not only may they wish to increase food supplies, but they may place greater social value than the individual farmer on preventing losses caused by disease (Heisey and Brennan 1989).

In addition to the general policy suggestions mentioned earlier for accelerating the diffusion of seed of new varieties, the 'mini-kit' system of varietal demonstration practiced in India and other countries might be effective (Kelly 1989). Douglas (1980), however, argues that in the long run the use of kits cannot replace the need to develop an effective commercial seed industry. Further studies from different countries of the practical organization of functioning seed systems, as well as of the factors influencing farmers' demand for seed, would be useful. These studies could help governments shape their seed policy and potential private seed suppliers determine the likely profitability of entering the seed business.

Acknowledgements

The authors wish to express their appreciation for the contributions and comments of the following individuals: M. R. Akhtar, the late M. M. Aslam, M. A. Bajwa, D. Beck, J. P. Brennan, D. Byerlee, K. Cassaday, M. A. Chaudhry, P. R. Hobbs, A. Khan, A. K. Khattak, J. Longmire, A. Majid, L. Morgan, M. T. Rasool, A. Sattar, M. Smale, R. L. Tinsley, G. Traxler, and F. Walters. Funding from the United States Agency for International Development under contract 391-0489, the Pakistan Agricultural Research Council, and the World Bank in conducting the study is also gratefully acknowledged.

Views expressed in this paper should not be construed to represent the views of The Aga Khan Rural Support Programme, the International Maize and Wheat Improvement Center (CIMMYT), or the Pakistan Agricultural Research Council (PARC).

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