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VARIETAL CHANGE IN POST-GREEN REVOLUTION AGRICULTURE: EMPIRICAL EVIDENCE FOR WHEAT IN PAKISTAN

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Yield gains may continue to be the most important factor affecting varietal change in post-Green Revolution agriculture, but they are often not as spectacular as in the initial shift to high-yielding varieties. A survey of nearly four hundred farmers was conducted to determine factors leading to slow varietal change in Pakistan, where disease vulnerability has been a particular problem. Farm-to-farm information transfer, and to a lesser degree literacy, were important in explaining varietal awareness. Farmers' opinions of general and specific yield characteristics were important in explaining varietal adoption. In contrast, formal extension appeared to have little effect on either awareness or adoption, and farmers' disease knowledge was also limited. Strengthening formal educational and extension systems may be crucial to continued agricultural productivity growth in post-Green Revolution agriculture.

1. Introduction

The 'Green Revolution' has resulted in an enormous amount of literature in many disciplines. Although no consensus definition may exist, the distinguishing feature of a Green Revolution might be a relatively dramatic change in the rate of increase of aggregate yield. The most apparent technical cause is a change in yield potential, intimately related to particular genetic characteristics such as dwarfing or hybridization. The relative roles of initial versus continuing genetic advance, and of complementary inputs such as fertilizer, tend to be specific to location, time and crop.

In contrast, relatively little attention has been paid to agricultural technical change in post-Green Revolution settings, as debate has centred on social and institutional impacts (Byerlee, 1987). Features of post-Green Revolution *technical* change include a shift to much greater reliance on formal agricultural

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research for improved crop technology, including varieties (Heisey, 1990); an increasingly important role for maintenance research aimed at preventing *declines* in productivity (Plucknett and Smith, 1986); increased intensification of input use, such as chemical fertilizer; and, eventually, increased input-use efficiency through improved managerial and information skills (Byerlee, 1990a).

This paper analyses factors related to the adoption of new wheat releases in post-Green Revolution Pakistan with data from a survey of nearly 400 farmers in three irrigated wheat-producing areas of Pakistan, in an attempt to explain the recent history of slow replacement of varieties. The next section describes the problem. The following section briefly surveys approaches to the economics of varietal replacement. The next three sections analyse factors affecting both aggregate and individual adoption in the three surveyed areas: first, by a description of the production zones; second, by noting farmers' stated reasons for changing varieties; and third, through a multinomial logit analysis of actual adoption behaviour. The final section presents conclusions.

Table 1 Indices of Wheat Varietal Replacement, 1977-86

Location	*Weighted Average Age of Varieties* (Years)*	*Area Planted to New Varieties† (%)*
Punjab, Pakistan		
All area	11.0	11
Area under semidwarf varieties	8.8	11
Punjab, India	6.5	30
Yaqui Valley, Northwestern Mexico	4.1	85

* $A_t = \Sigma_i p_{it}(t - \tau_i)$, where A_t = weighted average age of varieties in year t, p_{it} = proportion of wheat area covered by variety i in year t, and τ_i = year of release for variety i (Brennan and Byerlee, 1991). The figures in the table are the means of A_t for the 10 year period.

† Percentage of wheat area planted to varieties released in the previous 5 years. The figures in the table are the means for the 10 year period.

Calculated from data provided by:
Crop Reporting Service, Lahore, Punjab, Pakistan
Department of Agricultural Economics, Ludhiana Agricultural University, Punjab, India
CIMMYT data files, Yaqui Valley, Mexico

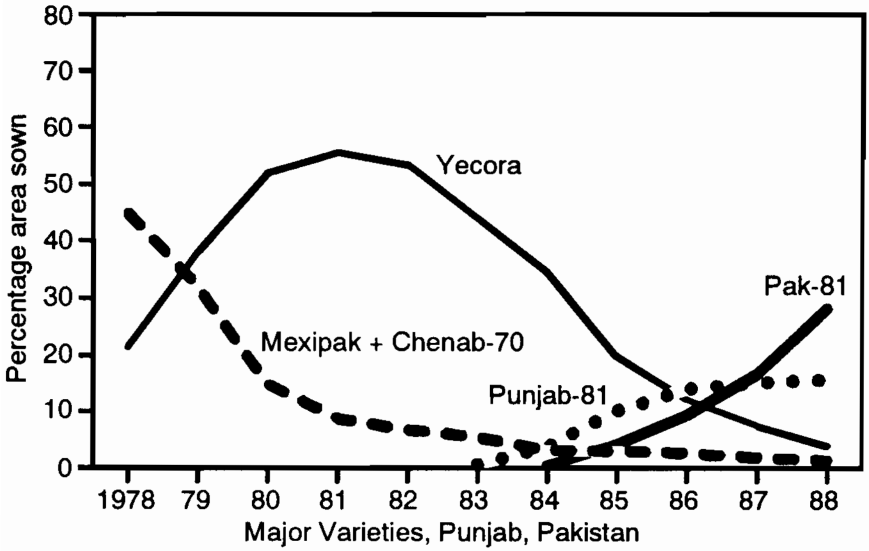
2. The Problem of Slow Wheat Varietal Replacement in Pakistan

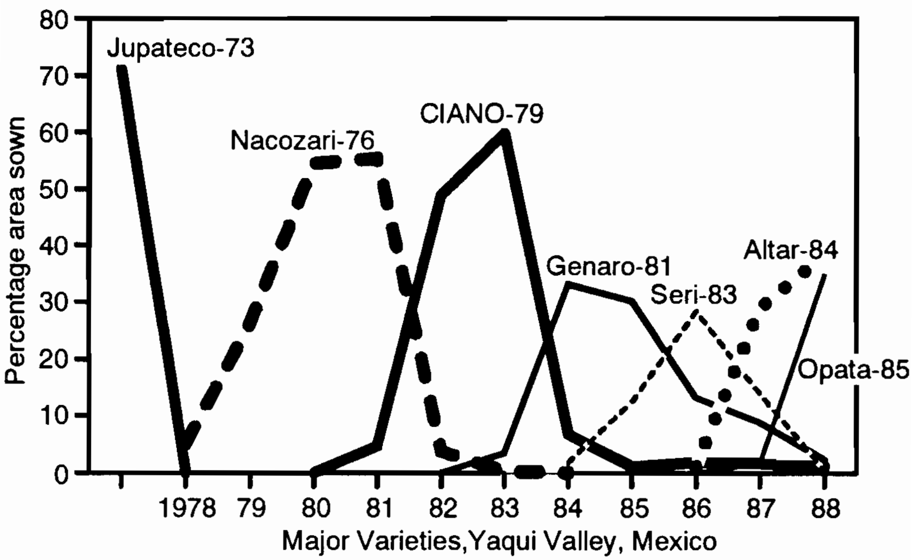
Several methods for summarising complex time-series data on varieties grown by farmers into a single measure of the rate of varietal replacement have been proposed (Brennan and Byerlee, 1991). By two of these measures, weighted average age of varieties and area planted to new varieties, the rate of replacement has been slower in Pakistan than in similar irrigated, post-Green Revolution wheat-growing environments (Table 1).* Though in both fast and slow replacement areas, a single variety may dominate in some periods, the period between peak area coverage by one dominant variety and the next has been about 10 years in Pakistan's Punjab, compared to only 2 to 3 years in Mexico's Yaqui Valley (Figure 1).

The yield potential of wheat varieties available to Pakistani farmers in the post-Green Revolution period has been increasing, so that slow varietal replacement has kept yields lower than they might be (Byerlee, 1990b).

* The rate of varietal replacement in Pakistan is also noticeably slower than in more dissimilar environments (Brennan and Byerlee, 1991).

Figure 1 Varietal Replacement in Pakistan and Mexico





Furthermore, genetic resistance to diseases continues to be an important problem, as the resistance of released varieties often breaks down within a few years because pathogens, especially of leaf rust (*Puccinia recondita*) and stripe rust (*P. striiformis*) are continually evolving.* The mean duration of resistance to resistance to leaf and stripe rusts for many of the post-1965 releases was 6.3 years (Khan, 1987), implying a useful life of many varieties shorter than actual life.

* Wheat scientists now believe they may have achieved durable resistance to leaf rust by incorporating 'slow-rusting' genes. The speed with which new varieties with durable leaf rust resistance reach farmers will still be related to some of the factors analysed in this paper.

Crude estimates of yield losses caused by the planting of susceptible varieties imply economic losses of approximately US$40-50 million in 1986-87, a non-epidemic year (PARC, 1987). In 1977-78, Pakistan's Punjab suffered a rust epidemic, resulting in losses of at least $117 million beyond normal losses in years without epidemics (Nagy, 1984). By contrast, India's Punjab was not seriously affected in the same season.

Byerlee (1990b) summarises the combined effect of farmers not planting the best-yielding and most disease-resistant varieties. If the weighted average age of varieties in Pakistan were reduced to a world average of seven years (Brennan and Byerlee, 1991), returns to wheat breeding research in the post-Green Revolution period would have increased from an annual average of 25 to 31 per cent.

3. The Economics of Varietal Adoption and Diffusion

Most variables expected to influence individual farmer varietal adoption in a given period, or varietal diffusion paths over time, can be given an economic interpretation. In theory, the price of the seed input, the price of the grain output, or their ratio, can be expected to affect profitability and thus individual adoption behaviour, year-to-year aggregate adoption changes, or the rate of varietal change as measured by standard parameters (Griliches, 1957; Knudson, 1991; Heisey and Brennan, 1991). In practice, limited cross-sectional variability in seed/grain price ratios constrain the use of these prices in studies of individual adoption. Additionally, single-year observations may not represent economic equilibria (Griliches, 1957) and longer planning horizons on the part of farmers may dampen the price effect (Heisey and Brennan, 1991). As a result, attempts to incorporate these prices into studies of varietal diffusion over time have often met with limited success (Griliches, 1957; Knudson, 1991).*

In diffusion studies, the greater fertilizer responsiveness of one type of variety may mean that fertilizer price does affect rates of varietal change (Knudson, 1991). The varieties studied in this paper are all fertilizer-responsive, semi-dwarf wheats, and there is once again little cross-sectional variability in fertilizer prices among the sample farmers.

The net result is that the primary variable defining differences in mean profitability will be differences in mean yield (Griliches, 1957). In the present study, several varietal characteristics affecting mean yield over a range of actual farmer circumstances are considered. Furthermore, total profitability from the perspective of a partial-subsistence farmer may include other varietal characteristics such as grain quality or straw yield.

Some of the costs of varietal adoption (e.g. information acquisition) may be fixed (Feder and Slade, 1984), and farmers may maximise utility over the distribution of returns rather than simply maximising profits. Just and Zilberman (1983) demonstrate that, under these conditions, the very smallest farms may not adopt. As farm size increases, partial or even full adoption can occur, but, as it increases further, the proportion of land planted to the new technology may then decrease. Farm size, sometimes thought unequivocally to raise the probability of adoption, to increase land allocation to a new variety on an individual farm, or to speed aggregate diffusion, can therefore have more complicated effects.

* The wheat seed/grain price ratio is higher in both northwest Mexico and the Indian Punjab than in Pakistan, yet varietal replacement is faster in Mexico and India (Table 1).

As noted, varietal change may be more accurately characterised as a disequilibrium process rather than one of classic economic equilibrium. If so, both the efficiency of sources of information and farmers' human capital, as reflected in their ability to analyse that information (Schultz, 1975), may crucially affect adoption.

4. The Three Surveyed Wheat Production Zones

In 1986, social scientists from the Pakistan Agricultural Research Council (PARC) initiated a study of the constraints to the rapid diffusion of new, disease-resistant wheats. They interviewed 146 farmers in 30 villages in three adjacent subdistricts in the rice-wheat zone of northern Punjab; 149 farmers in three adjacent subdistricts in the cotton-wheat zone of southern Punjab; and 99 farmers in 20 villages in irrigated areas of Mardan district in North West Frontier Province (NWFP). The survey areas, as well as the larger cropping systems they represent, are indicated in Figure 2. Characteristics of the study areas are summarised in Table 2.

Figure 2 Surveyed Wheat-Producing Zones of Pakistan

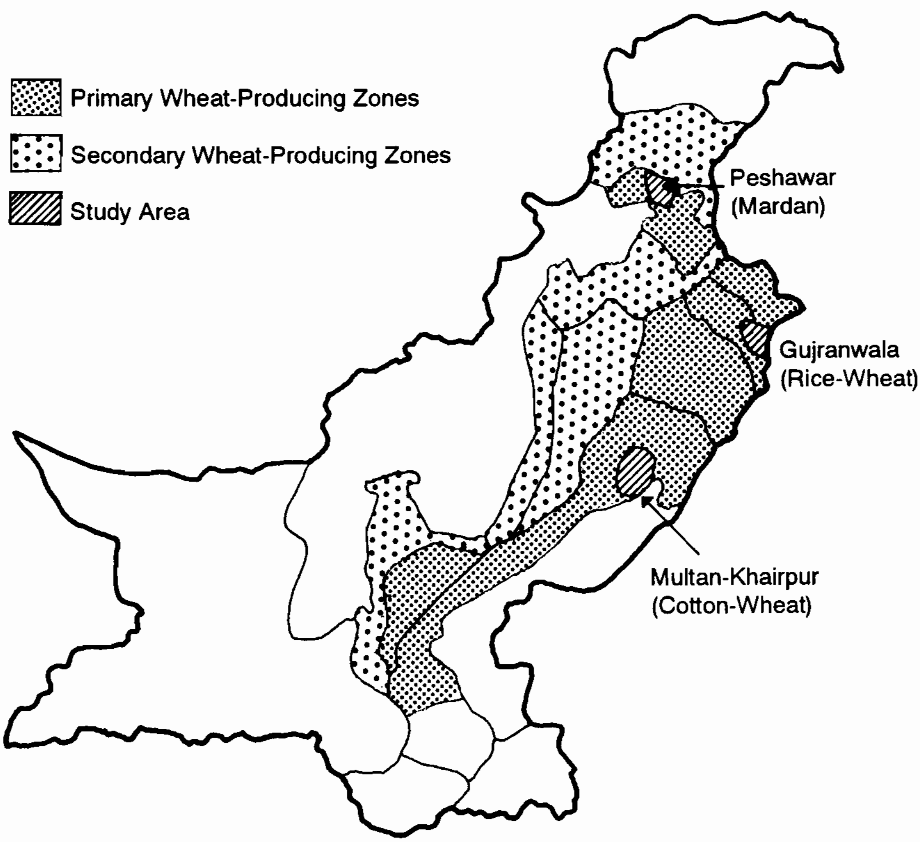


Table 2 Characteristics of Three Wheat Production Zones in Pakistan

	Zone		
	Rice-wheat	*Cotton-wheat*	*Irrigated Peshawar/ Mardan*
Irrigated wheat area* ('000 ha)	830	2065	120
Farm size (ha)†	10.1	10.5	5.3
% farmers < 5 ha†	49	40	83
% owners or part owners†	86	74	56
% literate†	54	43	35
% with extension contact, year previous to survey†	27	24	26
% area planted to post-1978 releases‡			
1985/86	49	31	24
1986/87	55	36	40
1987/88	76	43	47
1988/89	80	44	NA
% farmers plant only new varieties†	27	22	14
% farmers plant partial area to new varieties†	27	20	14
% farmers aware of but not planting new varieties†	13	16	29
% farmers unaware of new varieties†	33	42	42
Retail seed outlets/100,000 ha wheat§	8.8	22.6	2.1

* Source: CIMMYT (1989).

† From sampled farmers, 1985/86.

‡ Source: Agricultural Economics Research Units (AERUs)
Pakistan Agricultural Research Council (PARC)
Faisalabad and Tarnab, Peshawar.

§ Source: Heisey (1990).

Basmati rice is the major summer crop in the rice-wheat zone, wheat the major winter crop. Waterlogging, soil salinity, and poor soil structure following rice production limit wheat yields, and perhaps 40% of the wheat area was planted at later than optimal dates at the time of the survey. Both leaf and stripe rusts can cause major production losses (CIMMYT, 1989; Byerlee *et al.*, 1986). Among the sampled farmers, land ownership and literacy were the highest in this zone, but extension contact was no different from the other zones.

The cotton-wheat production zone is the major wheat-producing zone in Pakistan. Before the advent of the Green Revolution, summer-season cotton and winter-season wheat tended to be planted in separate fields. Since then, a variety of factors, including the earlier maturity of semidwarf wheats compared to the old tall varieties, have led to cotton and wheat being grown in rotation in at least half the wheat area. Largely as a result, at least 70-80% of the wheat area is planted at later than the optimal time. A related technical problem is heat stress during grain filling. Leaf rust can be serious, but stripe rust is not considered a major problem in this zone (CIMMYT, 1989; Byerlee, Akhtar and Hobbs, 1987). In the sample, literacy was somewhat less and tenancy somewhat higher than in the rice-wheat zone, but extension contact was no different.

Crop rotations are much more complex in Mardan than in the other two zones. Maize and sugarcane are the major summer crops. Though wheat is the major winter crop, sugarbeet, fodder crops, and tobacco are also important. Less wheat is planted late in this zone than in either of the cotton-wheat or rice-wheat zones. Leaf and stripe rusts are both major problems (CIMMYT, 1989;

Byerlee *et al.*, 1986). Farm areas in Mardan are in general much lower than in either of the other two study regions. Tenancy is more pronounced in the Mardan subsample, and literacy lower. Extension contact appeared to be quite similar to contact in the rice-wheat and cotton-wheat zones.

For the purposes of this study, 'new' wheat varieties have been defined as those varieties released in 1979 or later, after the 1977-78 rust epidemic. By this definition, and assuming a target cycle of seven years from release to replacement, the earliest 'new' varieties would have been near the desirable time for replacement at the time of the survey. In 1985-86, the two most popular recent varieties were Pak 81 and Punjab 81, both released in 1981.

From 30 to 40% of the sample farmers said they were not aware of any of the wheat varieties released after 1978 — a striking result that illustrates the slowness of varietal diffusion. Although Pak 81 and Punjab 81 were midway through their targeted cycle, they were near the beginning of the adoption-disadoption sequence in farmers' fields. In 1985-86, measured as either a percentage of farmers or a percentage of area, adoption of new wheat varieties was higher in the rice-wheat zone and lower in Mardan than in the overall sample (Table 2).

Wheat seed production for Pakistan is concentrated in the cotton-wheat zone, and seed depot density (defined in Table 2) is high there. There is no parastatal seed corporation in NWFP, and the density of seed marketing outlets is much lower in Mardan than in either of the other two study areas. Comparing adoption rates with seed marketing coverage suggests that seed availability may affect the spread of new varieties in Mardan, but alone it cannot explain the differences in adoption in the rice-wheat and cotton-wheat zones.

5. Farmers' Opinions of Desirable Varietal Characteristics

Surveyed farmers were asked a series of questions intended to elicit their stated reasons for replacing wheat varieties as well as their views of desirable varietal characteristics. Farmers in all three zones ranked resource reallocation within the entire cropping system ('better land preparation') and movements along the wheat response function ('more fertilizer') well ahead of a possible shift of the response function ('better variety') as most important for increasing wheat yields. Nonetheless, in all three study areas, over 70% of farmers who had adopted newer wheat releases stated that their reason for doing so was the higher yield of the new variety.

To sharpen the definition of 'better variety', farmers who were aware of post-1978 wheat releases (both adopters and non-adopters) were asked to compare a known new variety with a known old variety on several characteristics. These included general grain yield; factors affecting grain yield under specific circumstances (late planting performance, shattering resistance, and shrivelling resistance); and other desirable characteristics (straw yield, baking quality). As expected, farmers planting new varieties tended to give them a favourable ranking on most characteristics. Farmers not planting the new varieties were more likely either to rank the old variety as superior or say that they could not compare the varieties. Differences in opinion between those planting new varieties and those not planting them were significant for all characteristics in the rice-wheat and cotton-wheat zones, but only for grain yield in Mardan.*

* In two cases, baking quality in the rice-wheat zone and suitability for late planting in Mardan, a majority of farmers in both categories thought the old variety better.

Farmers' knowledge of possible reductions in yield caused by disease was limited. In all zones, 70-90% of the farmers identified rust as a major disease affecting wheat. In each study area, only one-quarter to one-half though some varieties were more resistant than others, and at most one-quarter thought that resistant varieties could lose their resistance.

6. A Multivariate Analysis of Awareness and Adoption of New Wheat Varieties

Econometric Model

A multivariate logit analysis of both awareness and adoption of new wheat varieties was done for two reasons. First, actual behaviour is as important as stated explanations in understanding adoption. Second, the effect of single variables thought to influence behaviour should be tested in the presence of other variables so that their true importance is not overstated.

Because such a significant proportion of the farmers in all three zones was unaware of new varieties, two separate analyses were done for each zone. First, a binomial logit model was estimated to explain awareness of new wheat varieties. Second, to predict the conditional probabilities of adoption (planting some area to new wheat varieties) and of full adoption (planting full area to new wheat varieties), a multinomial logit model was estimated using only data for those farmers aware of new varieties. The dependent variable for the second model was trichotomous: non-adopters aware of new varieties; partial adopters; and full adopters.

Variables used in the logit analyses are shown in Table 3, and hypothesized effects of the included dependent variables are indicated in Tables 4 and 5. These variables comprise human capital variables (age* and literacy), farm size and tenure variables, information variables (extension and radio contact), and

Table 3 Variables Used in Logit Analysis of Awareness and Adoption of New Wheat Varieties

AGE	Farmer's age in years
ASQ	AGE*AGE (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
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 year previous to survey
LNVIL	Natural logarithm of N+1, where N is the percentage of village wheat area covered by new varieties, from a related survey by wheat breeders
YIELD	Dummy variable = 1 if farmer thought new variety clearly superior to old variety in grain yield
CHAP	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for making *chapatis*.
LATEPL	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for late planting
SHRES	Dummy variable = 1 if farmer thought new variety clearly superior to old variety for shattering resistance

* The square of age was also included in the regressions to test the hypothesis that, past a certain age, the effects of greater farmer conservatism might outweigh the effects of longer farming experience.

Table 4 Hypothesized Effects of Independent Variables on Awareness of New Wheat Varieties

AGE	+
ASQ	–
LIT	+
LNSIZE	+
OWN	+
EXT	+
RADIO	+
LNVIL	+

a village information variable (village wheat area covered by new varieties). In the multinomial adoption regressions, dummy variables constructed from farmers' evaluation of certain varietal characteristics (grain yield, late planting performance, shattering resistance, and baking quality) were also used. These dummies had a value of 1 if the farmer ranked the new variety as superior on that characteristic; 0 if he ranked the old variety superior, ranked them equally, or was unable to make a comparison.

Tables 4 and 5 can be used to determine whether the appropriate asymptotic t-test for the significance of a coefficient should be one- or two-tailed. Where a particular direction for the effect is hypothesized, the test for significance of a coefficient should be one-tailed. Where no direction is hypothesized, the test is two-tailed. In some cases, a variable is hypothesized to have a directional effect on the probability of adoption but an indeterminate effect on full adoption.

Estimation Results — Varietal Awareness

One variable significantly explained varietal awareness in two of the three zones — proportion of village wheat area planted to new varieties — suggesting a simple but powerful demonstration effect (Table 6).* This conclusion is

Table 5 Hypothesized Effects of Independent Variables on Partial or Full Adoption of New Wheat Varieties

	Normalization on Non-Adoption		*Normalization on Partial Adoption*	
	Partial Adoption	*Full Adoption*	*No Adoption*	*Full Adoption*
AGE	+	+	–	±
ASQ	–	–	+	±
LIT	+	+	–	±
LNSIZE	+	+	–	–
OWN	+	+	–	±
EXT	+	+	–	±
LNVIL	+	+	–	±
YIELD	+	+	–	+
CHAP	+	+	–	+
LATEPL	+	+	–	+
SHRES	+	+	–	+

* Furthermore, another village variable, a dummy for location on a metalled road, appeared to be significant in the cotton-wheat zone when it replaced the village wheat area variable in that regression.

Table 6 Factors Affecting Awareness of New Wheat Varieties: Binomial Logit Analysis

	Rice-Wheat Zone	*Cotton-Wheat Zone*	*Mardan*
AGE	0.0967	0.0102	–0.158
	(0.0779)	(0.0824)	(0.120)
ASQ	–0.000972	0.0000340	0.00176
	(0.000787)	(0.000920)	(0.00134)
LIT	0.278	1.33*	0.871
	(0.484)	(0.439)	(0.702)
LNSIZE	0.236	0.106	0.684†
	(0.237)	(0.196)	(0.344)
OWN	1.18†	–0.172	–0.574
	(0.596)	(0.427)	(0.580)
EXT	0.909†	–0.405	0.690
	(0.535)	(0.453)	(0.685)
RADIO	1.41*	–0.163	–0.213
	(0.495)	(0.389)	(0.514)
LNVIL	0.901*	–0.00281	0.718†
	(0.292)	(0.223)	(0.346)
Constant	–6.40	–0.611	0.767
Log-likelihood	–72.7	–91.7	–52.1
	n = 142	n = 144	n = 88
	$\chi^2(7) = 34.3$	$\chi^2(7) = 12.8$	$\chi^2(7) = 16.7$

Dependent variable is a dummy variable = 1 if farmer was aware of new wheat varieties, 0 otherwise.

Asymptotic standard errors are in parentheses.

* significant at the 1% level, one-tailed.
† significant at the 5% level, one-tailed.
‡ significant at the 10% level, one-tailed.

supported by the facts that other farmers were most frequently cited as the source of information about new varieties by farmers actually planting them (Table 7); and that the most common initial source of seed (around half of all farmers in all three zones) for farmers planting new varieties was other farmers (Tetlay *et al.*, 1991). Village effects, related to farmer-to-farmer transfer of not only information but also the seed itself, can be important determinants of technological awareness.

On the other hand, the variables for formal transfer of agricultural technical information, extension contact and listening to agricultural radio programming, only appeared to affect varietal awareness in the rice zone where diffusion seemed faster. Note, however, that actual adopters in the other two zones were twice as likely as in the rice zone to state that extension was the source of information about new wheat varieties (Table 7). We speculate that, in regions where varietal replacement is relatively slow, extension contact may be important for varietal awareness among early adopters, but may not have a broader effect across the farming population until varietal diffusion has proceeded further.

Table 7 Farmers' Source of Information About New Wheat Varieties for Farmers Planting Them

		Percentage of Farmers	
	Rice-Wheat	*Cotton-Wheat*	*Mardan*
Other Farmers	69	48	57
Extension	14	30	28
Seed Depot	9	8	7
Radio	8	12	4
Other	—	2	4

The other variable that receives weaker support across zones as influencing awareness is literacy. This coefficient was highly significant in the cotton zone and just above the 10% level of significance in Mardan.* Farm size was only significant in explaining varietal awareness in Mardan, and land ownership was only significant in the rice-wheat zone.

Estimation Results — Varietal Adoption

Apart from farm size, village effects in the rice-wheat zone, and age in the cotton-wheat zone, the standard variables often thought to influence adoption did *not* appear to affect adoption of new wheat varieties by farmers already aware of them (Tables 8 through 10).

On the other hand, farmers' positive evaluation of varietal characteristics did appear to be related strongly to their adoption. In all three zones, positive evaluation of the relative grain yield of new varieties was significantly related to adoption, but not to full adoption. Late planting performance and shattering resistance appeared to be important in both the rice-wheat and cotton-wheat

Table 8 Factors Affecting Adoption of New Wheat Varieties, Rice-Wheat Zone Multinomial Logit Analysis

	Normalization on Non-Adoption		*Normalization on Partial Adoption*	
	Partial Adoption	*Full Adoption*	*No Adoption*	*Full Adoption*
AGE	−0.222 (0.187)	0.0118 (0.193)	0.222 (0.187)	0.233 (0.170)
ASQ	0.00277 (0.00206)	0.000177 (0.00215)	−0.00277 (0.00206)	−0.00260 (0.00182)
LIT	0.0532 (1.30)	0.730 (1.20)	−0.0532 (1.30)	0.676 (0.965)
LNSIZE	0.641‡ (0.480)	−0.0522 (0.453)	−0.641‡ (0.480)	−0.693† (0.344)
OWN	−1.02 (1.83)	1.03 (2.02)	1.02 (1.83)	2.05 (1.60)
EXT	−1.71 (1.02)	−0.520 (0.916)	1.71 (1.02)	1.19 (0.880)
LNVIL	0.904‡ (0.630)	0.759 (0.638)	−0.904‡ (0.630)	−0.145 (0.558)
YIELD	2.21* (0.931)	1.40† (0.813)	−2.21* (0.931)	−0.808 (0.849)
CHAP	−0.618 (1.21)	0.668 (1.03)	0.618 (1.21)	1.29‡ (0.937)
LATEPL	0.367 (1.12)	2.38† (1.03)	−0.367 (1.12)	2.01* (0.804)
SHRES	3.66* (1.30)	1.24 (1.35)	−3.66* (1.30)	−2.42 (0.880)
Constant	−0.288	−5.87	0.288	−5.88
Log-likelihood	−52.7 n = 75 $\chi^2(20) = 56.2$			

Dependent variable is a trichotomous categorical variable for farmers aware of new wheat varieties, dividing them into non-adopters, partial adopters and full adopters.
Asymptotic standard errors are in parentheses.
* significant at the 1% level, one-tailed.
† significant at the 5% level, one-tailed.
‡ significant at the 10% level, one-tailed.

* Recall too that across survey zones, literacy was highest in the rice-wheat zone where adoption of new wheat varieties was also highest.

Table 9 Factors Affecting Adoption of New Wheat Varieties, Cotton-Wheat Zone Multinomial Logit Analysis

	Normalization on Non-Adoption		*Normalization on Partial Adoption*	
	Partial Adoption	*Full Adoption*	*No Adoption*	*Full Adoption*
AGE	0.691†	0.642†	−0.691†	−0.0492
	(0.348)	(0.347)	(0.348)	(0.178)
ASQ	−0.00723†	−0.00648†	0.00723†	0.000749
	(0.00368)	(0.00363)	(0.00368)	(0.00190)
LIT	−1.76	−2.40	1.76	−0.641
	(1.69)	(1.74)	(1.69)	(0.876)
LNSIZE	1.54†	0.958	−1.54†	−0.587‡
	(0.759)	(0.769)	(0.759)	(0.436)
OWN	1.26	−0.352	−1.26	−1.61
	(2.03)	(1.91)	(2.03)	(0.995)
EXT	−1.39	−0.816	1.39	0.576
	(1.69)	(1.77)	(1.69)	(1.05)
LNVIL	0.153	1.05	−0.153	0.896
	(1.29)	(1.41)	(1.29)	(0.830)
YIELD	4.04‡	3.96‡	−4.04‡	−0.0858
	(2.48)	(2.48)	(2.48)	(0.803)
LATEPL	4.93*	4.98*	−4.93*	0.0514
	(1.98)	(2.00)	(1.98)	(0.882)
SHRES	2.06‡	1.81	−2.06‡	−0.246
	(1.60)	(1.60)	(1.60)	(0.789)
Constant	−20.3	−20.0	20.3	0.286
Log-likelihood	−34.8			
	n = 55			
	$\chi^2(18) = 50.1$			

Dependent variable is a trichotomous categorical variable for farmers aware of new wheat varieties, dividing them into non-adopters, partial adopters and full adopters.

Asymptotic standard errors are in parentheses.

* significant at the 1% level, one-tailed.
† significant at the 5% level, one-tailed.
‡ significant at the 10% level, one-tailed.

zones, but not in Mardan. Both of these results make sense in the light of the characteristics of the zones. We have noted that late planting is more common in both of the zones in Punjab, and particularly in the cotton-wheat zone, where this variable appears to be even more important than general grain yield. Note also that, in the cotton-wheat zone, opinion about late planting appears to influence adoption, but not complete specialisation in new varieties. In the rice-wheat zone, perceived late planting performance appears to be related to full adoption of new varieties. This suggests that in the cotton-zone *all* wheat varieties might be expected to do well at late planting dates, whereas in the rice-wheat zone late planting performance may be evaluated after grain yield. Shattering resistance is probably important in the Punjab and not Mardan because Punjab 81, a new variety more prone to shattering than other varieties (Chaudhry *et al.*, 1985), was grown in the Punjab but not Mardan.

The only other variable consistently affecting adoption across zones was farm size. In both the cotton-wheat zone and Mardan, where adoption of new wheat varieties was lower, farm size for partial adopters appeared to be significantly larger than farm size for both non-adopters and full adopters. Significance for the farm size variable in distinguishing between non-adopters and full adopters was just above the 10% level. In other words, in both zones farm size influenced the adoption of new varieties positively; but as farm size increased, it increased the likelihood farmers would diversify across new and

Table 10 Factors Affecting Adoption of New Wheat Varieties, Mardan: Multinomial Logit Analysis

	Normalization on Non-Adoption		*Normalization on Partial Adoption*	
	Partial Adoption	*Full Adoption*	*No Adoption*	*Full Adoption*
AGE	–0.475	–0.317	0.475	0.157
	(0.338)	(0.389)	(0.338)	(0.260)
ASQ	0.00545	0.00354	–0.00545	–0.00191
	(0.00398)	(0.00447)	(0.00398)	(0.00303)
LIT	–4.11	–5.41	4.11	–1.30
	(2.51)	(2.66)	(2.51)	(1.80)
LNSIZE	2.22†	1.21	–2.22†	–1.01
	(0.977)	(1.02)	(0.977)	(0.798)
OWN	0.333	2.96	–0.333	2.63
	(2.32)	(2.44)	(2.32)	(1.91)
EXT	–0.316	–0.517	0.316	–0.201
	(1.45)	(1.59)	(1.45)	(1.36)
LNVIL	0.862	0.615	–0.862	–0.246
	(1.12)	(1.30)	(1.12)	(1.17)
YIELD	3.65*	5.32*	–3.65*	1.67
	(1.55)	(2.07)	(1.55)	(1.86)
CHAP	–1.95	–0.478	1.95	1.48
	(1.53)	(1.52)	(1.53)	(1.40)
LATEPL	1.13	0.816	–1.13	–0.316
	(1.67)	(1.83)	(1.67)	(1.41)
SHRES	–0.117	1.17	0.117	1.29
	(1.58)	(1.75)	(1.58)	(1.43)
Constant	4.18	–0.342	–4.18	–4.52
Log-likelihood	–24.7			
	n = 41			
	$\chi^2(20) = 39.5$			

Dependent variable is a trichotomous categorical variable for farmers aware of new wheat varieties, dividing them into non-adopters, partial adopters and full adopters.

Asymptotic standard errors are in parentheses.

* significant at the 1% level, one-tailed.
† significant at the 5% level, one-tailed.
‡ significant at the 10% level, one-tailed.

old varieties. This finding is consistent with the Just-Zilberman model. In the rice-wheat zone, farm size distinguished partial adopters from both non- and full adopters, but did not differentiate between non- and full adopters. This suggests that in later stages of varietal diffusion, the influence of farm size on adoption becomes less important, but it does continue to affect the probability of varietal diversification.

7. Conclusions

Adoption of New Wheat Varieties in Post-Green Revolution Pakistan

The results indicate that the process of varietal replacement is usefully considered to be a process of information diffusion. Many farmers were simply unaware of recent wheat releases at the time of the survey. Slow diffusion of new varieties may be related to the relatively large role played by farmer-to-farmer rather than formal sector diffusion of information and seed.

Second, the most important variable affecting economic profitability of seed use is likely to be grain yield. In post-Green Revolution settings where yield differences among varieties may be small, farmers' perceptions of these differences are important. Yield under specific circumstances may be as important as general yielding ability, and understanding particular farming systems contributes to knowledge of these circumstances. Events which tend to occur every year (late planting) may be given greater weight by farmers than events which do not (severe disease attack).

Third, the analysis of farmers' individual adoption choices can be complex. Factors related to varietal awareness may differ from factors related to varietal adoption, and their influence on varietal adoption may differ from their influence on complete adoption. This is particularly noticeable for farm size.

Accelerating Varietal Replacement

Many policy alternatives for accelerating varietal replacement focus specifically on the supply side (Heisey, 1990) and do not stem directly from the analysis in this paper. On the demand side, since formal information channels seem considerably less important than informal ones in varietal replacement, faster replacement may depend in part on strengthening the role of one formal institution, agricultural extension. Furthermore, because better yields appear to be the most important characteristic inducing farmers to adopt new varieties, yet disease resistance was not widely understood by farmers, effective educational compaigns to increase farmers' knowledge of disease might pay off. The importance of yield indicates that if research-based increases in varietal yields slow down, promoting the diffusion of disease-resistant varieties might become increasingly costly. The significance of policy changes in seed supply would then become even more crucial. In summary, in post-Green Revolution agriculture, the informational and educational requirements of farmers become particularly important (Byerlee, 1987). Continued growth in agricultural productivity may depend on meeting these requirements more efficiently than at present.

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