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Adoption of Recommended Varieties: A Farm-level Analysis of Wheat Growers in Irrigated Punjab

MUHAMMAD IQBAL, M. AZEEM KHAN, and MUNIR AHMAD

This study uses farm level data to analyse the determinants of adoption of recommended wheat varieties in irrigated Punjab, Pakistan. A notable proportion of wheat acreage is sown to non-recommended wheat varieties in the province. These cultivars had either lost (overtime) or did not have resistance against yellow rust. Farm size, education, and size of wheat enterprise on the farm are the important determinants of adoption of recommended wheat varieties while tractor ownership and irrigation source play a positive but insignificant role in the adoption decisions. Age and tenure proved to be less of a constraint towards adoption of the recommended wheat varieties. The likelihood of the adoption of recommended wheat varieties varied among tehsils, with the highest probabilities of adoption in Melsi and Arifwala tehsils of cotton-wheat zones I and II respectively.

I. INTRODUCTION

Pakistan is gifted with a wide range of agro-climatic regions suited for the production of a wide diversity of crops. Wheat is the major crop of the country and it is cultivated under irrigated as well as rainfed conditions in all the provinces. It accounted for 37.18 percent of the total cropped area of the country during 1999-2000. The share of wheat in total value-added in agriculture was over 12 percent during the same year. The province of Punjab is the main producer of the crop and contributes over 73 and 78 percent in terms of wheat acreage and production respectively. Despite the allocation of most of the land and other resources to wheat production, the country has been a net importer of wheat, excepting a few years in the past. Pakistan had to import wheat in a record amount during the year 1996-97, whereas it experienced a bumper crop production during 1999-2000 and had a

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notable amount of exportable surplus.

Evolution of new high-yielding/disease-resistant wheat varieties and development of other technological innovations play an important role in increasing wheat productivity. The wheat breeders at various research institutions of the national agricultural research system of Pakistan are continuously busy in developing new varieties with the required characteristics. Studies have shown that a steady progress in increasing wheat yields and improving disease resistance have been achieved [Byerlee (1993)]. However, large yield gaps exist among the farm-level yield of wheat and that obtained at the research stations [Iqbal, *et al.* (1994); Ali and Iqbal (1984)]. This yield gap is attributed to various biological and socio-economic factors, variety being one of the most important among them.

Since the release of Maxipak in 1965, more than 80 wheat varieties have been released by the national agricultural research system (NARS), and only 25 of them were commercially adopted [Farooq and Iqbal (2001)]. Historically, adoption of wheat varieties has been slow in Pakistan and involved long lags between the time of release of a variety and the time of its (wider) adoption at farmers' fields. The analysis of diffusion and adoption of new varieties and other interventions evolved for farm-level use has been an area of special interest to the economists.[1]

However, in Pakistan, efforts in this regard have been sporadic, scant, and limited in scope. The purpose of this paper is to document the extent of adoption of high-yielding wheat varieties in the irrigated Punjab and identify the determinants of adoption of these varieties. The marginal probabilities for various explanatory variables would also be estimated.

The paper comprises four parts. Section II deals with the description of data and the specification of the model to be estimated. The results regarding the composition of wheat varieties grown in Punjab and the estimates of the model are discussed in Section III. Section IV concludes the findings of the study.

II. DATA AND METHODOLOGY

The study is based on primary data collected through a formal survey of

[1]Harper, *et al.* (1990) analysed the factors that the influence adoption of insect management technology by rice producers in Texas. Alauddin and Tisdell (1988) studied the patterns and determinants of high-yielding varieties of cereals in Bangladesh. Soule, *et al.* (2000) examined the adoption of conservation tillage practices by U.S. corn producers. Shakya and Flinn (1985) analysed the adoption of modern varieties and fertiliser use for rice in Nepal. Sarap and Vashist (1994) investigated the adoption of modern varieties of rice in Orissa (India). Shiyani, *et al.* (2000) studied the adoption of improved chickpea varieties in the tribal region of Indian Gujarat. A comprehensive survey of more studies regarding adoption of agricultural innovation can be found in Feder, *et al*. (1985). The findings of adoption studies especially, regarding the effect of farm size, education, and tenure on adoption decisions of the farmers differ depending on the characteristics of the technology (soil conservation innovations vs. variety of a mono seasonal crop of 4 to 5 months duration) or institutional set-up in the respective societies.

wheat growers in the irrigated plains of Punjab, Pakistan. The universe of this study comprises wheat growers in mung-wheat zone, cotton-wheat zone I, cotton-wheat zone II, and mixed cropping zone of the province. A multi-stage sampling technique was used to select the sample wheat growers. At the first stage, three to five major wheat-producing districts from the above-mentioned zones were purposively selected. At the second stage, one to two tehsils from each district and four to five villages from each tehsil were randomly selected. Finally, from each village, eight to ten farmers were randomly selected for formal interviews. This gave a total sample of 660 wheat growers. Seven questionnaires had to be discarded due to incomplete and faulty information, and thus data for 653 observations were analysed. The sample included 338 small, 203 medium, and 112 large-size farms, which respectively constituted 52, 31, and 17 percent of the total sample size. The district-level composition of the sample by various zones is as follows.

Mung-wheat zone	Bhakkar, Mianwali, and Layyah districts;
Cotton-wheat zone I	Multan, Muzaffargarh, Vehari, Khanewal, and Lodhran districts;
Cotton-wheat zone II	Sahiwal, Pakpatan, Bahawalnagar, and Okara districts;
Mixed cropping zone	Faisalabad, Toba Tek Singh, and Jhang districts.

The adoption or non-adoption of recommended wheat varieties (RWV) was treated as a decision involving a dichotomous response variable. The variables representing farmer and farm attributes are likely to affect farmers' decision about adoption of RWV. These include age, education, farming experience, farm size, tenure, irrigation source, extension contact, access to credit, and location of the farm (distance of the farm from market, agricultural research institute/station, and/or seed multiplication center, etc). Different studies on the subject have used different sets of explanatory variables and, to some extent, with diverse definitions and/or measurements[2] of these variables. Most of these studies consider the total farm area as an important factor affecting farm-level adoption of technology. However, we consider the size of operational holding rather than the total farm size to be the more relevant variable. Moreover, in addition to the size of operational holding, the size of the concerned crop enterprise itself may also play a role in affecting the adoption decisions; and the inadequate enterprise size is expected to impede adoption of recommended varieties, especially if they are relatively of poor quality and the farmers grow wheat for family consumption. None of the adoption studies could conceive the probable role that the inadequate

[2]For example, education has been measured as schooling years in some studies while in others as a dichotomous variable (illiterate=0 and literate=1).

size of a particular crop enterprise can play in adoption decisions. This study uses the size of operational holding as well as the size of wheat enterprise along with other explanatory variables.

This study is based on a data set collected by Agricultural Economics Research Unit (AERU), Faisalabad, through a survey of varieties of selected crops in the irrigated Punjab during 1996-97. The information on variables like extension contact, access to credit, and distance of the farm from agricultural research institutions and seed multiplication centers, etc., are missing and are a limitation. The evidence on effectiveness of the extension system of Pakistan has not been proven in any of the studies known to the authors. Similarly, the use and need of credit for purchasing wheat seed is also expected to be minimal, as most farmers in Pakistan purchase a small amount of seed of new variety or varieties to start with, multiply it on their farm, and then use own-produced seed for several years. For capturing the effect of farm location, dummy variables representing various tehsils were included in the model.

As mentioned earlier, adoption of RWV is treated as a binary dependent variable. The researchers have very popularly used Qualitative Response Models (QRM) for analysis of the data sets involving such binary response variables.[3] Harper, *et al.* (1990) analysed factors that influence adoption of insect management technology by rice producers in Texas. Malik, *et al.* (1991) used probit analysis to study the role of credit in agricultural development in Pakistan. Hussain, *et al.* (1994) used it to study the impact of training and visit (T & V) extension system in the irrigated Punjab (Pakistan). Ahmad and Battese (1996) used the probit model to study the incidence of Cotton Leaf Curl Virus in Punjab (Pakistan). The probit model assumes that there is an underlying response variable y_i^* defined by the following relationship.

$$y_i^* = \beta' x_i + u_i \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

Actually y_i^* is not observable. What we observe is a binary variable y_i defined as

$$y_i = 1 \quad if\ y_i^* > 0 \qquad\qquad y_i = 0 \ \text{Otherwise}$$

The term $\beta' x_i$ is not E ($y_i |\ x_i$) as in linear model; it is E ($y_i^* | x_i$). The probability P_i of the adoption of recommended wheat varieties on *i*th farms is

$$\text{Prob}(y_i = 1) = \text{Prob}(u_i > -\beta' x_i) = 1 - F(-\beta' x_i) \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$$

[3]The qualitative response models are well-presented in Maddala (1986). Empirical estimation of qualitative response models, by using the LIMDEP programme, is well-described in Nagy and Ahmad (1993).

Where F is cumulative distribution function of u_i. In this case the observed value of y_i are just realisation of a binomial process with probabilities given by the above equation. The likelihood function can be written as

$$L = \prod_{y_i=0} F(-\beta' x_i) \prod_{y_i=1} [1 - F(-\beta' x_i)\ ] \quad \dots \quad \dots \quad \dots \quad \dots \qquad (3)$$

The functional form of the above equation depends upon the assumption made about the distribution of u_i. In probit model we assume that u_i are IN(0, σ^2). In this case

$$F(-\beta' x_i) = \int_{-\infty}^{-\beta' x_i/\sigma} \frac{1}{(2\pi)^{1/2}} \exp(-\frac{t^2}{2})dt \quad \dots \quad \dots \quad \dots \quad \dots \qquad (4)$$

The marginal probability of an explanatory variable "*k*" in the probit model is defined as the following partial derivative

$$\frac{\partial}{\partial x_{ik}} \Phi(x'_i \beta) = \phi(x'_i \beta)\beta_k \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (5)$$

Where $\phi(x'_i \beta)$ denotes the standard normal density function and β_k is the coefficient of *k*th independent variable.

The study estimated various indicators of adoption including crude adoption rate, intensity of adoption, participation index, and the propensity to adopt. The crude adoption rate is defined as the proportion of the farmers cultivating RWV and is applicable to measuring adoption in the aggregate. The intensity of adoption refers to the ratio of area under RWV to total wheat acreage and is a more relevant measure at the farm-level. Participation rate is the product of crude adoption rate and intensity of adoption. The propensity to adopt is the likelihood of a farmer to adopt RWV. The marginal probabilities related to various explanatory variables affecting adoption of RWV were calculated using the estimates of the probit model. For empirical estimation of the model, the dependent variable ADOPTION was defined as 0 if a farmer allocated all wheat acreage to non-recommended varieties and 1 otherwise.[4] The explanatory variables used in the model include the farmer and farm-related attributes like age (AGE), education (EDU), farm size (OPERHOLD), tenancy status (DOWNER), source of traction power (DOWNTRCT), irrigation source (DCANAL), size of wheat enterprise (DENTERP), and location of the farm (tehsil dummies DTEH1 through DTEH16). The location dummy for Bhakkar Tehsil (DTEH1) was

[4]The partial adopters were treated as adopters, assuming them to be in the process of adopting.

dropped from the list of explanatory variables included in the empirical model to avoid a perfect multicollinearity. The complete list of variables used in estimation of the probit model and their definitions are given in the following table.

Table 1

Definitions of Variables Used in the Adoption Models

Variable	Definition		
AGE	Age of the farmer in years.		
EDU	Years of schooling.		
OPERHOLD	Size of operational holding in acres.		
DOWNER	= 1 For the owner-operated farms.	0	Otherwise
DTRACTOR	= 1 For farm that owns a tractor.	0	Otherwise
DENTERP	= 1 If the farmer grows wheat on more than one acre;	0	Otherwise
DTEH1*	= 1 If the farm is located in Bhakkar Tehsil;	0	Otherwise
DTEH2	= 1 If the farm is located in Piplan Tehsil;	0	Otherwise
DTEH3	= 1 If the farm is located in Krore Tehsil;	0	Otherwise
DTEH4	= 1 If the farm is located in Layyah Tehsil;	0	Otherwise
DTEH5	= 1 If the farm is located in Multan Tehsil;	0	Otherwise
DTEH6	= 1 If the farm is located in Muzaffargarh Tehsil;	0	Otherwise
DTEH7	= 1 If the farm is located in Melsi Tehsil;	0	Otherwise
DTEH8	= 1 If the farm is located in Khanewal Tehsil;	0	Otherwise
DTEH9	= 1 If the farm is located in Lodhran Tehsil;	0	Otherwise
DTEH10	= 1 If the farm is located in Chichawatni Tehsil;	0	Otherwise
DTEH11	= 1 If the farm is located in Arifwala Tehsil;	0	Otherwise
DTEH12	= 1 If the farm is located in Bahawalnagar Tehsil;	0	Otherwise
DTEH13	= 1 If the farm is located in Depalpur Tehsil;	0	Otherwise
DTEH14	= 1 If the farm is located in Jaranwala Tehsil;	0	Otherwise
DTEH15	= 1 If the farm is located in Gojra Tehsil;	0	Otherwise
DTEH16	= 1 If the farm is located in Chiniot Tehsil;	0	Otherwise

*Tehsil was not included in the estimated model to avoid a perfect multicollinearity.

III. RESULTS AND DISCUSSION

The socio-economic characteristics of the farmers and attributes associated with their farms are likely to influence the farmers' receptivity of new innovations and the decision to adopt new technological interventions. The information on age, education, farm size, tenancy status, farm power and irrigation source was obtained and the socio-economic profiles of the sampled wheat growers are presented in Table 2. Average age of the respondents was about 43 years. There were no significant variations in the mean age of farmers across the cropping zones. Education among farmers of the area under study was very low and, on the average, farmers had about 6 years of schooling. The education level of the farmers operating small and medium size farms was significantly lower than that of farmers operating the large farms. Similarly, education among the tenant farmers was significantly lower than that among the owner and owner-cum-tenant farmers. The average size of the operational holding was 20.47 acres. The mean size

Table 2

Socio-economic Characteristics of the Sample Wheat Growers by Cropping Zones

Characteristics	Mung-wheat	Cotton-wheat–I	Cotton-wheat–II	Mixed Zone	All Zones
Age (Years)	41.76	41.98	42.91	44.15	42.57
Education (Years)	5.52	5.72	7.24	7.79	6.36
Farming Experience (Years)	21.02	20.65	19.88	21.65	20.73
Tenancy Status: (%)					
Owner	64.6	75.6	57.8	73.8	68.0
Renter	35.4	24.4	42.2	26.2	32.0
Power Source: (%)					
Own Tractor	48.8	36.8	46.4	56.6	45.9
Rent Tractor	51.2	63.2	53.6	43.4	54.1
Irrigation Source: (%)					
Canal Irrigation	17.7	24.5	12.1	13.3	17.6
Supplemented with Tubewell	82.3	75.5	87.9	86.7	82.4

of land holdings varied significantly among zones. The average size of holding in cotton-wheat zone-II was significantly higher than the average farm size in other cropping zones. Similarly, the farm size of the owner-cum-tenant farms was significantly higher than the owner- or tenant-operated farms.

Relationship of the operator farmer with land (tenancy status or tenure) is also expected to affect the decision-making process of a farmer especially for medium- and long-term investment at his farm and in the adoption of improved farming practices. According to relationship of land with the operator, the farms were categorised as owner and renter farms (owner-cum-tenant or tenant-operated farms). The owners operated majority of the farms (68 percent) and pure tenancy was the least common category, with tenants operating only 12.7 percent of the farms. The rest of the farms were operated by owner-cum-tenants.

The source of traction power on a farm determines the intensity and scale at which farm operations can be performed; it also assures the timeliness of the operations. Tractors were the major power source and the use of bullocks for ploughing was nominal. The majority of the farms (54.1 percent) used rented tractors for ploughing while 45.9 percent farms used owned tractors. The ownership of tractor varied across the farm sizes and among categories of farms by tenure. The use of own tractors on large-size farms was higher than its use on small-size farms.

The majority of the farmers (82.4 percent) had to supplement canal water with tubewell water (own or rented), and only 17.6 percent of them had sufficient canal water to irrigate their wheat fields. The recommended high-yielding varieties usually have more water requirements, and therefore sufficient supply of cheaper and quality water (canal water) is expected to help in the adoption of these varieties.

Farm Area under Wheat Crop

Generally, farmers allocated more than half (55.06 percent) of the farm area to wheat production. The farmers of the mixed cropping zone cultivated wheat on 35.8 percent area of their farms and were allocating the lowest proportion of their land-holding to wheat cropping. The proportion of farm area under wheat declined with an increase in farm-size. The tenant farms devoted larger chunk of farm area (60.2 percent) to wheat production than the owner-cum-tenant or owner farms, which respectively put 49.7 percent and 48.8 percent of the farm area under wheat cultivation.

Table 3

Average Farm Size, Wheat Acreage and Percentage of Farm Area under Wheat

Zone/Farm Category/ Tenure	Farm Size (Acres)	Area under Wheat (Acres)	Share of Wheat Acreage in Total Farm Area (%)
Cropping Zone			
Mung-wheat Zone	18.53	8.50	45.87
Cotton-wheat Zone-I	15.29	9.74	63.70
Cotton-wheat Zone-II	29.37	15.59	53.08
Mixed Zone	19.52	7.07	36.22
Farm Category			
Small	7.51	4.40	58.59
Medium	19.23	10.31	53.61
Large	61.85	28.80	46.56
Tenure			
Owner	17.51	8.81	50.31
Owner-cum-tenant	35.43	17.60	49.68
Tenant	13.11	7.94	60.56
All Zones/All Farms	20.47	10.42	50.90

Number of Wheat Varieties Grown

Mostly mono-varietal culture prevailed in the area wherein a single variety is spread over a vast acreage with most of the farmers planting it. About three-fourths of the farmers planted only one wheat variety on their farms whereas one-fifth of them cultivated two wheat varieties. However, percentage of the farmers who cultivated more than two wheat varieties was nominal. The farmers of the mung-wheat zone were relatively more inclined to grow more than one cultivar and 36.6 percent of them planted two or more wheat varieties on their farms. The farmers operating small-size farms and the tenants were relatively more inclined towards mono-varietal plantation of wheat.

Table 4

Number of Wheat Varieties Grown by Cropping Zone, Farm Size, and Tenure

(Percent of the Farmers)

Zone/Farm Size/Tenure	One Variety	Two Varieties	Three Varieties	Four or More Varieties
Cropping Zone				
Mung-wheat Zone	63.4	30.5	3.7	2.4
Cotton-wheat Zone-I	82.6	15.9	1.5	–
Cotton-wheat Zone-II	74.1	21.7	4.2	–
Mixed Zone	83.6	14.8	1.6	–
Farm Size				
Small	84.0	15.1	0.9	–
Medium	68.0	27.1	3.4	1.5
Large	65.2	26.8	7.1	0.9
Tenure				
Owner	76.4	20.0	2.7	0.9
Owner-cum-tenant	71.1	24.2	4.7	–
Tenant	80.2	19.8	–	–
All Zones/All Farms	75.8	20.8	2.8	0.6

Adoption of Recommended Wheat Varieties

More than 14 wheat varieties were being cultivated in the area under study during 1996-97. These cultivars are listed in Annexure (Tables A-1 and A-2) and are grouped as recommended and non-recommended wheat varieties. Among the recommended wheat varieties, Inqalab-91 was the dominant variety and accounted for about 70 percent of the total wheat acreage. The other major RWV included

Parwaz and Punjab-85; these were grown on 4.14 and 2.64 percent of the total wheat acreage, respectively. Wheat varieties Shahkar-95 and Punjab-96, released a short time ago, were in the initial stages of adoption. These varieties, wheat variety Faisalabad-85, and other recommended varieties, are summed up under the title "others" in Annexure Tables A-1 and A-2.

About one-fifth of the wheat acreage was allocated to non-recommended varieties. Wheat varieties PAK-81 and Wattan were the main non-recommended cultivars grown during the year under study. Wattan is a newly evolved high-yielding variety. However, it was not approved for cultivation due to its susceptibility to yellow rust.[5] Similarly, PAK-81 (once a very popular and recommended variety) has been withdrawn from the list of recommended varieties due to its loss of resistance against yellow rust. However, the farmers are continuing cultivation of these varieties on account of certain characteristic of these varieties, especially for quality of *chapati* and *bhoosa,* grain size, and white colour, etc. The common indicators of adoption like crude adoption rate, intensity of adoption, and participation index were calculated and are reported in Table 5. The marginal probabilities to adopt recommended wheat varieties were also calculated for various explanatory variables included in the model and are discussed in the relevant sub-section.

The crude adoption rate of 82.1 percent is quite encouraging. However, a notable proportion of farms (17.9 percent) cultivated non-recommended wheat varieties. The crude rate seems to be positively related to farm size as a higher percentage of large farmers (90.2 percent) adopted RWV than their counterparts operating medium (81.8 percent) or small farms (79.6 percent). Similarly, crude

Table 5

Adoption Rate, Adoption Intensity, and Participation Index

	Adoption Rate (% Farms)		Adoption	Participation
	Non-adopters	Adopters	Intensity (%)	Index
Zone/Farm Type	(1)	(2)	(3)	(2x3)

[5]The provincial and federal research institutions submit their best advanced lines of wheat for testing the yield, quality, and disease adaptability, etc., through the National Uniform Yield Trial (NUYT) in different agro-ecological zones of the country as well as international testing for disease and yield. The data of NUYT and the recommendations regarding the candidate varieties are presented for the approval of Variety Evaluation Committee (VEC). Only the varieties approved by the VEC are released by National Seed Council and are called recommended varieties.

Cropping Zone				
Mung-wheat Zone	27.4	72.6	63.20	0.4588
Cotton-wheat Zone-I	15.4	84.6	80.14	0.6780
Cotton-wheat Zone-II	7.2	92.8	91.00	0.8445
Mixed Zone	23.8	76.2	76.54	0.5832
Farm Size				
Small	20.4	79.6	78.33	0.6235
Medium	18.2	81.8	82.92	0.6783
Large	9.8	90.2	83.55	0.7536
Tenure				
Owner	18.5	81.5	77.74	0.6336
Owner-cum-tenant	16.4	83.6	73.23	0.6122
Tenant	17.3	82.7	86.16	0.7125
All Farms	17.9	82.1	80.34	0.6596

adoption rate varied among the cropping zones. It was the highest (92.8 percent) for cotton-wheat zone-II and the lowest (72.6 percent) in mung-wheat zone. The crude rate showed little variation across various categories of wheat growers by tenure. The overall adoption intensity was 80.34 percent, reflecting the fact that quite a notable proportion of wheat acreage (19.66 percent) is being planted to non-recommended wheat varieties and is prone to high risk of yield losses. The intensity of adoption was higher in cotton-wheat zones relative to the other zones. The intensity tends to increase (to some extent) with farm size. Intensity of adoption of RWV was the highest at tenant farms (86.16 percent) and the lowest (73.23 percent) at farms operated by owner-cum-tenants.

Factors Affecting Adoption of Recommended Wheat Varieties

Identification of characteristics that differ on adopter/non-adopter farms and ascertainment of the determinants of adoption are very important. A comparison of the characteristics of adopters and non-adopters is presented in Table 6. As defined earlier, farmers who allocated all wheat area to non-recommended varieties were termed

Table 6

Characteristics Associated with the Adoption of Recommended Wheat Varieties

Variable*	All Farmers	Non-adopters	Adopters	Significance
OPERHOLD (Acres)	20.47	13.91	21.91	0.020
AGE (Years)	42.57	42.65	42.55	0.946
EDU (School Years)	6.36	5.66	6.51	0.076
DOWNER	68.00	70.10	67.50	0.592
DCANAL	17.60	15.40	18.00	0.494
DTRACTOR	45.90	40.20	47.20	0.167

DENTERP	3.20	6.00	2.60	0.061
DTEH1	6.28	12.82	4.85	0.001
DTEH2	6.28	3.42	6.90	0.159
DTEH3	6.28	7.69	5.97	0.487
DTEH4	6.28	14.53	4.48	0.000
DTEH5	6.28	4.27	6.72	0.324
DTEH6	6.28	5.98	6.34	0.884
DTEH7	6.28	1.71	7.28	0.025
DTEH8	6.28	4.27	6.72	0.324
DTEH9	5.67	10.26	4.66	0.018
DTEH10	5.97	2.56	6.72	0.086
DTEH11	6.43	0.85	7.65	0.007
DTEH12	6.28	3.42	6.90	0.159
DTEH13	6.74	3.42	7.46	0.114
DTEH14	6.28	7.69	5.97	0.487
DTEH15	6.29	7.69	5.97	0.487
DTEH16	6.13	9.40	5.41	0.103

*Please see Table 1 for definitions of various variables.

as non-adopters, and others were called adopters. Among the continuous variables, education and farm size differ significantly between adopters and non-adopters at 5 percent and 10 percent level respectively. These variables may be the determinants of adoption of recommended wheat varieties. Similarly, using Cochran's and Mantel Haenszel "Chi Square" statistics, independence between the response variable ADOPTION and various dichotomous factor variables was also tested. The dummy variables for enterprise size and the dummies for certain tehsils are significantly different between adopters and non-adopters. The dummy variables representing farm ownership, tractor ownership, irrigation source, and some tehsil dummies show insignificant relationship with adoption. The scope of this kind of analysis has its limitations as it examines the relationship between two variables at a time. More information can be gained by investigating the multivariate relationships. Given the type of data involved in the study of adoption, we used a probit model for further analysis and the empirical results are discussed in the following sub-section.

Empirical Results of Probit Model

The model described in Section II was estimated by using the LIMDEP software. The probit estimates of the coefficients and corresponding marginal probabilities for various explanatory variables are presented in Table 7. The chi-square is significant at 1 percent and implies that the explanatory variables affect adoption of RWV. The McFadden-R^2 was low (0.114) as compared to the typical range of 0.2 to 0.4 for such models. Nonetheless, the model correctly predicted over 81 percent of the observations. The coefficient for continuous variables, like the size of operational holding (OPERHOLD), age (AGE), and education (EDU), is positive. For a one-tailed test, farm size and education were significant at 0.05 and 0.10 level of significance respectively. However, for a two-tailed test these variables were significant at 0.0556 and 0.1567 percent level respectively. A 20 percent confidence level has been used in similar studies when little was known about the relationship between the dependent and explanatory variables [Harper, *et al.* (1990); Ahmad and Battese (1997)]. There are contradictory findings about the effect of education on adoption of technology. Harper, *et al.* (1990) find education negatively affecting the adoption of insect management technology by rice growers in Texas. Alauddin and Tisdell (1988) report an insignificant effect of education on adoption of high-yielding varieties of cereals in Bangladesh. However, estimates of our model provide the evidence that farm size and education are importantly and positively associated with the adoption of RWV. This finding is consistent with Soule, *et al.* (2000) who conclude that farm size and education are significantly and positively related to the adoption of conservation tillage practices by the U.S. corn producers. The insignificant positive coefficient for age hints that age of the farmer is not a constraint to adoption of these varieties.

Table 7

Probit Estimates of Coefficients of Various Determinants Affecting Adoption of Recommended Wheat Varieties

Variable	Coefficients (β)	Standard Error (S.E)	Marginal Probability
OPERHOLD[a]	0.00987**	0.00516	0.00224
AGE	0.00182	0.00499	0.00041
EDU[a]	0.02452*	0.01731	0.00556
DUMCANAL	0.13842	0.20335	0.03013
DTRACTOR	0.03980	0.14306	0.00907
DOWNER	–0.12811	0.15752	–0.02855
DENTERP	0.66192*	0.41358	0.10549
DTEH2	1.00758***	0.34033	0.26224
DTEH3	0.43412	0.31187	0.14140
DTEH4	–0.11534	0.29684	–0.04319
DTEH5	0.92911***	0.33133	0.25017
DTEH6	0.72957**	0.31475	0.21331
DTEH7	1.36117***	0.40987	0.30199
DTEH8	0.61599*	0.34433	0.18815

DTEH9	–0.11724	0.38384	–0.04391
DTEH10	0.87139**	0.38395	0.24044
DTEH11	1.29408**	0.51104	0.29610
DTEH12	0.99908***	0.35815	0.26100
DTEH13	0.96198***	0.34452	0.25538
DTEH14	0.43795	0.34548	0.14247
DTEH15	0.44857	0.34280	0.14247
DTEH16	0.33934	0.33934	0.11393
Constant	–0.66175	0.50772	

[a]Tested for a one-tailed test.

*,**,***Significant at 10, 5, and 1 percent level respectively.

Log-likelihood Function	= –232.06	Log-likelihood (0)	= –261.97
Chi-squared	= 59.82401	Degrees of Freedom	= 22
Significance Level	= 0.000024	McFadden-R^2	= 0.1142
Percentage of Right Predictions	= 81.5		

The dummy variables representing tractor ownership and irrigation source show a positive effect on adoption of the RWV. However, the coefficients were not significant at any reasonable level of significance. Similarly, the dummy variable representing owner farmers (DOWNER) is insignificant and bears a negative sign. This may relate to the very nature of technology under discussion, i.e., the investment in high-yielding RWV is a short-term investment (usually meagre in amount also) and tenants have no less incentive for investment than the owners. Moreover, the pure lease tenants (pressed to be more competitive) are in no way less likely to adopt RWV. This is in contrast to Shakya and Flinn (1985) who find that owner farmers are more likely to adopt modern rice varieties in Nepal. Similarly, Soule, *et al.* (2000) report that cash renter U.S. corn producers are less likely than owner operators to adopt conservation tillage practices. However, our results show that tenure plays an insignificant role in the adoption of a short-term practice like RWV.

The coefficient for the dummy representing type of wheat enterprise (DENTERP) was positive and significant at 10 percent level, showing that the likelihood of adoption of RWV was higher at wheat enterprises of adequate size. It was observed that varieties like PAK-81, Wattan, and Yakora accounted for a large proportion of area under non-recommended wheat varieties. These varieties are high-yielding and are considered high-quality wheat cultivars.[6] However, wheat variety Wattan was not approved due to its susceptibility to yellow rust. The other two varieties have lost resistance against rust over time and have been withdrawn

[6]In terms of quality of *chapati* and *bhoosa.*

from the list of recommended varieties by the Department of Agriculture, Government of the Punjab. The area under these varieties is on decline but the farmers continued to grow them for their high quality grain and high yield.[7]

All the coefficients for tehsil dummies had a positive sign except for Layyah (DTEH4) and Lodhran (DTEH9). Most of them (nine out of fifteen) were significant. The results show that the probability of adoption of RWV is higher in tehsils of Piplan (DTEH2), Multan (DTEH5), Muzaffargarh (DTEH6), Melsi (DTEH7), Khanewal (DTEH8), Chichawatni (DTEH10), Arifwala (DTEH11), Bahawalnagar (DTEH12) and Depalpur (DTEH13) than in Bhakkar tehsil. The coefficients for the dummy variables representing thesils of Krore (DTEH3), Layyah (DTEH4), Lodhran (DTEH9), Jaranwala (DTEH14), Gojra (DTEH15), and Chiniot (DTEH16) were insignificant, showing that the likelihood of adoption of RWV in these tehsils is not more than that in Bhakkar.

Marginal probabilities were also estimated for various explanatory variables included in the model and are reported in the last column of Table 7. Marginal probabilities for OPERHOLD and EDU are 0.224 and 0.556 percent respectively. The marginal probability of the size of holding shows that an increase of 5 acres in farm size would increase the probability of adoption of RWV by 1.12 percent. Similarly, an additional five years of formal schooling would raise the probability of adoption by 2.78 percent. Inadequate size of the wheat enterprise reduces the probability of adoption of RWV by 10.55 percent. The likelihood of adoption of RWV by farmers in Piplan, Multan, Muzaffargarh, Melsi, Khanewal, Chichawatni, Arifwala, Bahawalnagar, and Depalpur tehsils was higher by 18 to 30 percent than that in Bhakkar. Variables like the general educational level, roads and marketing infrastructure, presence or non-presence of seed multiplication centre and/or agricultural research institutions, and variables related to weather may be responsible for these disparities in probabilities of adoption across tehsils.

The predicted probabilities that the recommended wheat varieties would be adopted were also calculated for an average farmer[8] possessing various combinations of other socio-economic characteristics and are reported in Annexure Table A 3. The probability that a farmer who has sufficient canal water, owns a tractor, has a title to the land (with an adequate size of wheat enterprise), and is located in Melsi tehsil will grow RWV is 0.97, while the probability of adoption by a farmer located in Layyah or Lodhran tehsils with all other attributes remaining the same is 0.64. The chance of adoption of RWV by an average farmer with insufficient canal water (who has to supplement irrigation with tubewell water) who rents a tractor, has title to the

[7]For home consumption especially in areas with low risk of incidence of rust.

[8]Farmer operating average-size farm (20.47 acres), having educational level equal to mean schooling years (6.36 years), and with an age matching the sample average (42.57 years).

land (with an inadequate size of wheat enterprise), and belongs to Layyah or Lodhran tehsil is only 0.32.

IV. CONCLUSION

The non-recommended wheat varieties are grown on about one-fifth of the wheat acreage in irrigated Punjab. The major part of wheat area under non-recommended varieties is being sown to cultivars which are susceptible to yellow rust. This implies that a notable proportion of wheat acreage is prone to a high risk of incidence of yellow rust especially during the years when favourable conditions for outbreak and spread of rust would prevail. Inqalab-91 is the most dominant wheat variety and accounts for more than 70 percent of the total wheat acreage. This variety is getting quite old and may degenerate or lose its resistance against yellow rust in the coming years. The spread of a single (old) variety over such a vast acreage presents a very risky situation as any probable loss in resistance of this variety against rust may result in huge losses to farmers and the nation. Hence, there is an urgent need to develop replacement/substitute wheat varieties for Inqalab-91 and to promote them.

The age and tenure of the farmer are less of a constraint on adopting the recommended wheat varieties. Farm size and education are important determinants of adoption. The widespread illiteracy or low education among farmers and the dominating number of small farms in the province may hinder adoption of recommended varieties in future years. Therefore, varietal technology needs to be made easily available for the small and illiterate or less educated farmers through enhanced extension services, better access to institutional credit, and an improved system of multiplication and distribution of certified seed. The wheat breeders should also focus on improving wheat quality along with yield improvements—or at least should not be unrestrained in trading off quality for quantity. In particular, more attention should be paid to maintain those crucial characteristics of wheat cultivars which are the most liked by the farmers and consumers. Finally, a regular monitoring of wheat varieties in the Punjab is suggested to assess the adoption patterns of the farmers and the yield performance of various varieties.

Annexures

Annexure Table A-1

Composition of Wheat Varieties in Selected Zones of the Irrigated Punjab

(Area in Percentage)

Characteristics	Mung-wheat	Cotton-wheat–I	Cotton-wheat–II	Mixed Zone	All Zones

Recommended					
Inqalab-91	52.18	71.67	77.84	70.51	69.87
Parwaz	2.55	3.04	6.99	0.70	4.14
Punjab-85	5.57	1.89	1.66	2.52	2.64
Pasban	2.72	2.58	0.04	0.70	1.43
Others[a]	0.18	0.96	4.47	2.11	2.25
Sub-total	**63.20**	**80.14**	**91.00**	**76.54**	**80.34**
Non-recommended					
Pak-81	22.48	11.82	1.39	12.31	10.10
Kohnoor-83	7.71	2.76	0.00	0.00	1.76
Wattan	6.17	1.99	4.83	6.43	4.49
Others[b]	3.44	3.29	2.78	4.72	3.31
Sub-total	**36.80**	**19.86**	**9.00**	**23.46**	**19.66**
Total	100.00	100.00	100.00	100.00	100.00

[a]Includes the Punjab-96, Shahkar-95, and Faisalabad-85 wheat varieties.

[b]Includes Yakora, Fakhar-i-Hind, and unidentified non-recommended wheat varieties.

Annexure Table A-2

Wheat Varietal Mix on the Sampled Farms by Size

(Area in Percentage)

Wheat Varieties	Small Farms	Medium Farms	Large Farms	All Farms
Recommended				
Inqalab-91	68.38	60.92	76.38	69.87
Parwaz	1.85	5.37	4.40	4.14
Punjab-85	4.53	4.31	0.68	2.64
Pasban	1.59	1.50	1.31	1.43
Others[a]	1.39	1.13	3.39	2.25
Sub-total	**77.74**	**73.23**	**86.16**	**80.34**
Non-recommended				
Pak-81	12.54	17.44	4.21	10.10
Kohnoor-83	1.13	2.58	1.52	1.76
Wattan	3.63	3.74	5.37	4.49
Others[b]	4.96	3.01	2.74	3.31

Sub-total	**22.26**	**26.77**	**13.84**	**19.66**
Total	100.00	100.00	100.00	100.00

[a]Includes the Punjab-96, Shahkar-95, and Faisalabad-85 wheat varieties.

[b]Includes Yakora, Fakhar-i-Hind, and unidentified non-recommended wheat varieties.

Annexure Table A 3

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Annexure Table A-3

Predicted Probabilities of Adoption of Recommended Wheat Varieties in the Irrigated Punjab

Canal Water:	Sufficient								Insufficient							
Tractor Ownership:	Own Tractor				Rent Tractor				Own Tractor				Rent Tractor			
Title to the Land:	Owner		Renter		Owner		Renter		Owner		Renter		Owner		Renter	
Adequate Enterprise Size:	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Farm Location									**Probabilities**							
In Piplan	0.93	0.80	0.95	0.83	0.93	0.79	0.94	0.82	0.91	0.76	0.93	0.79	0.91	0.74	0.93	0.78
Not in Piplan	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Krore	0.82	0.60	0.85	0.65	0.81	0.59	0.84	0.64	0.78	0.55	0.82	0.60	0.77	0.53	0.81	0.58
Not in Krore	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Layyah	0.64	0.39	0.69	0.44	0.63	0.37	0.68	0.42	0.59	0.33	0.64	0.38	0.58	0.32	0.63	0.37
Not in Layyah	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Multan	0.92	0.77	0.94	0.81	0.92	0.76	0.93	0.80	0.90	0.73	0.92	0.77	0.89	0.72	0.91	0.76
Not in Multan	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Muzaffargarh	0.89	0.71	0.91	0.75	0.88	0.70	0.90	0.74	0.86	0.66	0.89	0.71	0.85	0.65	0.88	0.69
Not in Muzaffargarh	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Melsi	0.97	0.88	0.98	0.91	0.96	0.87	0.97	0.90	0.96	0.85	0.97	0.88	0.95	0.84	0.96	0.87
Not in Melsi	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Khanewal	0.86	0.67	0.89	0.72	0.86	0.66	0.88	0.70	0.83	0.62	0.86	0.67	0.82	0.60	0.85	0.65
Not in Khanewal	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Lodhran	0.64	0.38	0.69	0.43	0.63	0.37	0.68	0.42	0.59	0.33	0.64	0.38	0.58	0.32	0.62	0.37
Not in Lodhran	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Chichawatni	0.91	0.76	0.93	0.79	0.91	0.74	0.93	0.78	0.89	0.71	0.91	0.75	0.88	0.70	0.90	0.74
Not in Chichawatni	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Arifwala	0.96	0.87	0.97	0.89	0.96	0.86	0.97	0.89	0.95	0.84	0.96	0.87	0.95	0.83	0.96	0.86
Not in Arifwala	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Bahawalnagar	0.93	0.79	0.95	0.83	0.93	0.78	0.94	0.82	0.91	0.75	0.93	0.79	0.90	0.74	0.92	0.78
Not in Bahawalnagar	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Depalpur	0.93	0.78	0.94	0.82	0.92	0.77	0.94	0.81	0.90	0.74	0.92	0.78	0.90	0.73	0.92	0.77
Not in Depalpur	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Jaranwala	0.82	0.60	0.85	0.65	0.81	0.59	0.84	0.64	0.78	0.55	0.82	0.60	0.77	0.53	0.81	0.58
Not in Jaranwala	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Gojra	0.82	0.61	0.86	0.66	0.81	0.59	0.85	0.64	0.79	0.55	0.82	0.60	0.78	0.54	0.81	0.59
Not in Gojra	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41
In Chiniot	0.80	0.56	0.83	0.61	0.78	0.55	0.82	0.60	0.75	0.51	0.79	0.56	0.74	0.49	0.78	0.55
Not in Chiniot	0.69	0.43	0.73	0.48	0.67	0.41	0.72	0.47	0.64	0.38	0.68	0.43	0.62	0.36	0.67	0.41