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# Determinants of Improved Wheat Varieties' Adoption in Punjab, Pakistan

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## ABSTRACT

*Pakistani farmers are reluctant to quickly adopt improved wheat varieties that are inevitable for increasing wheat yield. Majority use the previous year's farm produce as seeds to save the seed cost but incur opportunity cost in terms potential yield loss. Objective is to estimate the adoption and impact of improved high yielding wheat varieties on rural households' income food security and poverty levels in Punjab, Pakistan. The determinants of adoption and impact evaluation of IWV (Improved Wheat Varieties) can be assessed using Propensity Score Matching (PSM). The empirical results revealed that there were several constraints to adoption related to human capital, village assets, household assets, infrastructure and institutional support. Most important out of this long list were education, experience, land holding, wheat area sown, land rent, soil quality, land fragmentation, slop, use of laser leveler, agricultural extension services, metal road, availability of credit facility, variety rust resistant, irrigation cost, ZT Drill, seed rate, seed drill, highest education, female farm worker, male farm worker, family members, and location at distributary. Lack of knowledge, education, institutional support, agricultural extension services, as well as household assets drives the adoption of improved wheat varieties.*

***Keywords:*** *Impact Evaluation, Wheat, Punjab*

## INTRODUCTION

Wheat is essential to human beings as staple food for majority since long time. It was one of the first domesticated food crops and for centuries has played a critical role to feed human kind and ensuring food security worldwide. Approximately 20 percent of the dietary calories and protein needs of human are provided by this crop. Food requirements are increasing in the developing world by one percent per annum. Annual wheat demand ranges from 27 kg in Africa (East and South) to 170 kg in Asia (Central). Fifty percent of the world wheat production is harvested from the developing countries (including China and Central Asia) that have approximately 53 percent of the area used for this crop (Nayak, 2015). Wheat contributes 60 percent of the daily diet and this fulfils the 72 percent of daily caloric needs in Pakistan. Average wheat consumption is approximately 124 kg per capita per annum–which is quite high as compared to world average (Akhlaq et al. 2017; Williams and Raza, 2019). Extraordinary increase in the yield due to the introduction of the Green Revolution (GR) technologies in 1960s has significantly changed the wheat production globally. This has brought benefits for producers in terms of low production costs and consumers are happy due to falling prices of food items especially wheat. Economists are now of the opinion that agricultural research and development is now facing underinvestment (Swaminathan, 2017).

Farmers adopted improved wheat varieties more quickly as compare to any other agricultural technology in the known history. Developing countries have approximately 90 percent of the area under these varieties whereas Pakistan has about 95percent (Agricultural Statistics of Pakistan 2019-20). To sustain current production and yield levels or to further enhance, it is inevitable to replace present varieties with improved ones. With the passage of time agricultural productivity is increasing at very slow rate or static. To ensure the food security in present time productivity gains are required at the pattern of Green Revolution (Shiferaw, et al. 2013).

Pakistan produces more than 25.195 million tons of wheat per annum. Wheat contributes 8.9 percent value addition in agriculture and accounts for 1.6 percent of GDP of Pakistan (Pakistan Economic Survey, 2018-19).

In the present scenario increase of area for wheat crop is no more an option and it would remain same at round about nine million hectare. At the same time demand for wheat in Pakistan keep on increasing to feed the increasing population and it is estimated to be 34.25 million tonnes by the year 2030. This means that to produce 10 million tonnes extra wheat, yield must be improved from present 2.8 to 3.8 tonnes per hectare by the year 2030 (Shahid, 2019). Ministry of Food Security and Research has initiated the wheat productivity enhancement project to increase the yield up to 3500 kg per hectare under vision 2025 in next five years (Rattu, 2019).

**Table 1.1: Estimated requirements and projected area and yield for wheat (2010-30)**

| Year | Population (Millions) | Requirement (m. tonnes) | Area (m. ha) | Yield (kg/ha) |
|---|---|---|---|---|
| **2010** | 179.425 | 24.274 | 9.042 | 2688 |
| **2015** | 199.243 | 25.633 | 9.224 | 2779 |
| **2020** | 220.892 | 28.82 | 9.05 | 3184 |
| **2025** | 242.235 | 31.415 | 9.05 | 3471 |
| **2030** | 262.958 | 34.25 | 9.05 | 3785 |

Source: Agricultural Statistics of Pakistan 2017-18; Worldometers, 2019; Shahid, 2019, Pakistan Economic Survey, 2018-19; and Provincial Departments of Agriculture.

Pakistan is facing severe shortage of certified seed. Currently, less than half of the wheat growers obtain seed through formal sources, where as remaining majority use their own farm produce as seed or get it from other growers. It is expected that approximately 8.945 m.ha will be sown under wheat crop in year 2019-20 for which 1.07 m.tonnes of certified seed was required. Whereas total certified seed availability in the country was only 429341 tonnes. That is one of the major constraints causing low yields in the country (FSC&RD, 2019).

It is recommended to sustain yield, old varieties are required to be replaced after every 3-4 years by improved high yielding varieties that are resistant to pests and diseases. This seed replacement procedure is required to boost wheat productivity and ensure food security (Akhlaq et al. 2017; Nazli and Smale, 2016). About 152 wheat varieties have been released in Pakistan largely during last decade. Most of the varieties 'run out' in three to five years of their release due to rust susceptibility or other reasons (Ali, 2018). In order to have food secure future farmers should have access to seed of improved wheat varieties having high yield potential, disease, drought and pest resistance, early maturity, adoptability to saline and water logged areas and vigour to bear climate changes (Raza et al. 2019). Improved wheat varieties development and dissemination ensure food security of farm households. Thus is an essential element of the food security policy (Shiferaw et al., 2014).

There exist a wide range of variability is wheat yield that ranges from 0.8 to 5.5 tonnes per hectares. It is evident that the yield gap can be shrunken by improving wheat management leading to better food security (Ali, 2018). If Pakistan's fast growing population and growth of wheat productivity are analysed. It is evident that the productivity of wheat at the moment is not more than 2.883 tonnes per ha (Pakistan Economic Survey, 2018-19). Production need to be enhanced to 31.4.tonnes and correspondingly yields to 3.5 tonnes per hectare by the year 2025 to meet the increasing population food requirements of Pakistan that is estimated to be 242.234 million in years 2025 (Worldometers, 2019).

Agriculture professionals are also under criticism for less diversification in Rabi season, so that an area of at least 0.5 million acres (0.202 million ha) may be recovered in next 5 years to shift to oilseeds, pulses and fodder. Therefore, per unit rise in the productivity in all agro-ecological zones in this context at much faster pace is the only plausible solution to accomplish the task envisioned above. Robust research program for evolution of climate smart High Yielding varieties (HYV) of wheat can respond well to these problems (Ali, 2018).

Pakistani farmers are reluctant to quickly adopt improved wheat varieties that are inevitable for increasing wheat yield. As general practice large numbers of peasants use the previous year's farm produce as seeds to save the seed cost but incur opportunity cost in terms potential yield loss. Adopting improved wheat varieties keeping in view the cropping zones can increase the output up to 22 percent (Hina and Khan, 2015).

The main objective of this study is to estimate the determinants of adoption of improved high yielding wheat varieties in Pakistan and suggest policy recommendations for researchers and development planners for improving the wheat productivity, food security and alleviate rural poverty. The specific objectives of the research investigation are as under:

1. To explore the determinants of the adoption of improved wheat varieties by wheat growers in selected districts of Punjab, Pakistan.
2. To suggest policy recommendations for researchers and development planners for improving the wheat productivity associated with the adoption of improved wheat varieties.

## METHODOLOGY

In this chapter conceptual framework and analytical approaches used for empirical analysis are presented. The conceptual framework is built on the basic concept of the technology adoption. Here the technology in focus is the improved wheat varieties (IWV). The wheat farmers have dichotomous choice i.e. either they have adopted these improved wheat varieties or they have not adopted.

### Econometric Framework

Intuitively it is hard to calculate the contribution of a particular factor contributing in the decision of farmers to use the improved agricultural technology in an observational study. The reason of this is our limitation to know the level of counterfactual in case the technology was not adopted by that particular household. Such issues are addressed in experimental or non-observational studies by randomly assigning the households into two groups called treatment group and control group. Later on both groups are compared to know the statistically significant difference. Selection bias may cloud the results of an observational study if treatments are non-randomly allocated or if there is a problem of self selection and the estimates would not be the accurate estimates (Kassie, Shiferaw, and Muricho, 2010).

Conceptual framework and theoretical model for adoption of IWV (Improved Wheat Varieties) can be assessed using Propensity Score Matching (PSM), and continues PSM.

**Propensity score matching model**

Propensity score matching (PSM) is one of the most renowned non-parametric methods of adoption decision evaluation. It has two assumptions; 1) unconfoundedness and 2) common support. PSM is conditional probability of participation (IWVs adoption) when pre-participation characteristics are known (Rosenbaum and Rubin, 1983).

PSM advocate the use of two similar and comparable groups one as adopters and other as non-adopters. These groups are having only difference of adoption of technology and are compared using matching methods (Rosenbaum and Rubin 1983; Heckman et al. 1998; Caliendo and Kopeinig 2005; Smith and Todd 2005).

**Assumptions of Propensity Score Matching model**

Average treatment effects on the treated (ATT) can be calculated based on following two assumptions;

1. Unconfoundedness: means that only the observable features are the criteria for selection of treatment group. Propensity scores are calculated as conditional probability

$$(P(X_i) = P(d_i = 1/X_i\ )) \qquad (1)$$

Where as

$X_i$ = $i^{th}$ individual who is conditional adopter

$d_i$= 1 for $i^{th}$ individual as adopter,

and $d_i$= 0 for non-adopter

2. Common support: represent the area when treatment and control groups overlap for calculation of ATT.

**Propensity Score Matching Model**

Selection of most relevant variables that effect the adoption of improved wheat varieties is crucial and skipping of important leads to biased estimation (Heckman et al. 1997). Bryon et al. (2002) reported that including of irrelevant variables decrease common support. Rosenbaum and Rubin (1983), Dehejia and Wahba (2002), and Diprete and Gangl (2004) highlighted the importance of balance variable selection.

ATT is of major importance and can be mathematically stated as

$$\tau|_{I=1} = E(\tau|_{I=1}) = E(R_1|I = 1) - E(R_0|I = 1) \quad (2)$$

Whereas

= average treatment effect for the treated (ATT),

$R_1$ = outcome for adopters of the new technology and

$R_0$ = outcome for non-adopters (Caliendo and Kopeinig, 2008).

The key issue is that E ($R_0$ | I= 1) cannot be observed, while [ $^e$ = E ($R_1$ | I = 1) - E ($R_0$ | I = 0] can be estimated, that is likely biased.

Different matching methods such as **Nearest neighbour matching, Radius matching, Kernel matching, Stratified matching, and Mahalanobis metric matching** give almost same results with minor variation (Caliendo and Kopeining 2005). Two methods used **Radius matching and Kernel matching** has following features;

**Radius matching**

To overcome the incidence of bad matches a restriction is applied in form of clippers and comparison is made within that distance. The advantage of this method is that it uses all the units present inside of the clipper and thus give best matches (Dehejia and Wahba, 2002).

**Kernel matching**

In Kernel matching (KM) control group items are given weights and more weight is given to the closest item. Low variance is the benefit and disadvantage is selection of bad matches (Caliendo and Kopeinig, 2005).

**Limitation of PSM**

Limitation of PSM is unconfoundedness assumption. This assumption is no more restrictive as compare to IV approach for the analysis of cross-sectional data (Jalan and Ravallion, 2003). Michalopoulos et al. (2004) stated that PSM method provides the most accurate results in non-experimental studies where there is no random assignment. Whereas fixed effect models did not make the results better.

**Data source**

A comprehensive field survey was conducted in 2016 to collect the primary data from field to substantiate the secondary data. A multi-stage purposive sampling technique was followed to select the sample representative of actual on ground situation. A properly planned questionnaire was designed for the purpose of data collection during the survey (Questionnaire is attached as annexure III). Data were organized and tabulated before actual analysis. The data was analyzed using suitable statistical techniques like t- statistics and propensity score matching.

**Universe**

Under Agricultural Innovation Program (AIP), CIMMYT distributed wheat seed among the farmers with the help of national partners in order to improve the productivity by replacing the improved varieties with the poor performing varieties. AIP interventions were carried out in 17 districts of Punjab. These districts are the reference population for this study.

**Sampling frame**

The data for proposed study was gathered from eight districts of Punjab province. A multi-stage purposive sampling technique was used. Eight districts from Punjab province that is approximately 50 percent of total intervened area on the basis of generally food secure and moderately food insecurity level were selected for the study in hand (Annexure 2).

The mode of irrigation as irrigated or rain fed was also considered while selecting the districts. The proposed Rain fed districts of Punjab like Bhakkar is moderately food insecure while Attock, Chakwal and Rawalpindi are generally food secure. Generally food secure and irrigated districts of Sargodha and Mandi Bahauddin are having mix cropping system. Hafizabad has rice-wheat and Rahim Yar Khan wheat-wheat cropping system (Integrated Food Security Phase Classification, 2010; Pakistan Food Security Phase Classification, 2014). On average 10 percent of the beneficiary populations were interviewed from the above mentioned 8 districts. The beneficiary sample was consisting of IRD (Integrated Research and Development), mother trial and seed production farmers.

**Sample**

To have a fair knowledge of the population approximately 10 percent of the beneficiaries on average from each district were approached at random for data collection. In all 275 respondents were interviewed including 30 female respondents. To make a valid comparison an equal number of the non-beneficiaries were also enumerated.

**Table 2.1: Sample distribution of beneficiary and non-beneficiary farmers**

| District | Beneficiary | Non beneficiary | Total |
|---|---|---|---|
| **Attock** | 28 | 5 | 33 |
| **Bhakkar** | 28 | 4 | 32 |
| **Chakwal** | 28 | 13 | 41 |
| **Hafizabad** | 21 | 10 | 31 |
| **MB Din** | 21 | 6 | 27 |
| **Rawalpindi** | 26 | 8 | 34 |
| **Rahim Yar Khan** | 28 | 15 | 43 |
| **Sargodha** | 24 | 10 | 34 |
| **Total** | 204 | 71 | 275 |

### Questionnaire

A well-structured questionnaire was developed related to socio-economic characteristics, crop production and improved wheat varieties adoption. The questionnaire was pretested before the actual survey in the field and necessary changed were incorporated keeping in view of the field observations. Data was collected in collaboration with the International Maize and Wheat Improvement Center (CIMMYT). The questionnaire comprised of the questions regarding comparison of beneficiaries and non-beneficiaries, wheat varietal selection, yield, and cost of production.

### Collection of data

Individual interviews were carried out to collect information from beneficiary and non-beneficiary farmers. The beneficiary farmers are those who were provided with wheat seed during the wheat season of 2015-16 under one of the category of IRD, mother trial or seed production. The non-beneficiary farmers were those respondent farmers who belonged to the same area of beneficiary farmers without any wheat seed assistance. (Questionnaire is attached as Annexure-III).

## RESULTS AND DISCUSSIONS

This section presents the socioeconomic profile of the respondents of study area and major issues/ problems in wheat crop production. Lastly the empirical results are explained. The empirical analysis was conducted using the Microsoft Excel, STATA and SPSS software.

### Socioeconomic profile of sample respondents

In this section socioeconomic characteristics of respondents are presented. Socio economic characteristics include age, formal education, farming experience, family system, income sources etc as discussed below.

### Human capital

Human capital is the "productive wealth embodied in labour, skills and knowledge," (Pettinger, 2019). Productivity of the human capital can be enhanced through training and education especially in case of smallholder farmers. Human beings play a pivotal role in production, distribution and consumption in agriculture sector.

Increasing productivity and welfare especially of the small farmer are closely related to the development of human capital in term of education and skill training (Aslam, 2016). As presented in Table 3.1 mean age of the farmers was 44 years for beneficiary and 24 years for non-beneficiary with a t-value of 0.53 indicating a statistically non-significant difference in the age of respondents. During survey farmers of 88 years old and young gentleman of 18 years were met. Most importantly difference as per education status of the respondents is concerned, a great diversity was observed ranging from illiterate to master degree holders. Generally beneficiary farmers were more literate as compared to the non-beneficiary farmers and their difference is statistically significant at 5 percent level of significance. When asked about the farming experience of the respondents it was almost same with few exceptions that have only one year of farming experience in contrast to respondents having 66 years of farming experience. On average farmers, in the study area, have more than twenty-one years' experience of farming. The t value of 0.86 shows a non-significant difference among the farmers.

**Table 3.1: Socio-economic profile of sample respondents**

| | Beneficiary | Non-Beneficiary | Mean Difference | t-values |
|---|---|---|---|---|
| Age (Years) | 44 | 42 | 2 | 0.53 |
| Education(Years) | 7.59 | 6.57 | 1.02** | 1.97 |
| Farming Experience (Years) | 21.67 | 20.31 | 1.36 | 0.86 |

Note: ***, **, * indicate significance at 1, 5 and 10 percent correspondingly.

### Land holding information in the study area (Acres)

The land holding information is presented in table below. It was reported that on average beneficiary farmers were having about 8.13 acres of land, while non beneficiaries reported 6.13 acres of owned land. The difference is significant at 10 percent level of significance with a high t-value of 1.74 telling that the beneficiary respondents have significantly high land holding as compare to the beneficiaries. Land holding status of the beneficiaries depicted that AIP wheat component focused on comparatively small farmers. On average operational land holding of selected farmers in both categories were estimated at 8.75 acres and 7.70 acres for beneficiary and non-beneficiary farmers respectively. Majority of farmers have rented in land that average to 4.22 acres for beneficiary and 1.10 acres for non-beneficiary from absentee land lords while a small acreage was rented out by a small number of farmers in case of beneficiaries. Furthermore, area not available for cultivation was small and didn't differ much.

**Table 3.2: Land holding information in the study area (average in Acres)**

| Category | Beneficiary | Non-Beneficiary | Difference | t-values |
|---|---|---|---|---|
| Own Land of the farmer (Acres) | 8.13 | 6.13 | 2.00** | 1.74 |
| Land rented in by the farmer (Acres) | 5.29 | 4.09 | 1.20 | 0.93 |
| Land rented out by the farmer (Acres) | 0.80 | 0.00 | 0.80** | 1.96 |
| Land shared in by the farmer (Acres) | 4.22 | 1.10 | 3.12*** | 3.14 |
| Land shared out by the farmer (Acres) | 0.39 | 0.00 | 0.39 | 1.08 |
| Operational Land Holding of the farmer (Acres) | 8.75 | 7.70 | 1.06 | 0.84 |
| Area not available for cultivation(Acres) | 0.64 | 1.03 | -0.39 | -0.67 |
| Land Rent (per Acre per Year) | 26488 | 32472 | -5984*** | -4.07 |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

Land rent per acre/year was calculated in Pakistani rupees (PKR). If we compare the land rent paid by non-beneficiary farmers it Rs.32732 per acre per annum that is higher than the rent paid by beneficiary farmers that is only Rs. 26488 per acre per year. The land rent is being determined by the supply and demand forces. The land rent for non-beneficiary is higher by Rs. 5984 per acre as compare to beneficiary due to the fact that the demand for land to be rented in much higher for non-beneficiary. Contrary to that lot land is available with beneficiary farmers to be rented out that has dropped the land rent per acre. The difference in land rent is statistically

**Area location at distributary**

When asked about the location of land from the farmers, as shown in table below, about 7 percent beneficiary farmers have land on the head of the distributary, while a huge (46percent) percentage of beneficiaries cultivating their lands without canal irrigation water. About 40 percent non beneficiaries were cultivating their land situated on the middle of the distributary. Further analysis showed that 22 percent beneficiaries and 15.5 percent non beneficiaries respectively have land on the tail of the distributary. The t-value of 1.59 divulge that the difference between beneficiary and non-beneficiary were statistically non-significant.

**Table 3.3: Area location at distributary**

| Location | Beneficiary* | Non-Beneficiary* | Difference | t-values |
|---|---|---|---|---|
| Head | 14 (6.9) | 4 (5.6) | 10 | 1.59 |
| Middle | 50 (24) | 29 (40.9) | 21 | |
| Tail | 46(22) | 11 (15.5) | 35 | |
| No canal | 94 (46) | 27 (38) | 67 | |
| Total | 204(100) | 71(100) | 133 | |

*Figures in parenthesis are percentages

**Status and significance of laser land levelling in the study area**

Previous studies recommended the use of leveling devices to manage the uneven soils that have a direct positive relationship on soil moisture, crop yield and earnings of the farmer (Ali, Hussain and Erenstein, 2018). During field survey, when asked about the usage of laser land leveler, as revealed in Table 3.6, about 60 percent beneficiary and 56 percent non-beneficiary respondent have not used laser leveler on their land ever, however, more than 98 percent were of the view that if they will have level their land through laser leveler it will help to save the water. About 98 percent beneficiary farmers and 100 percent non-beneficiary farmers were convinced that laser land leveling can improve the productivity and decrease water usage. Similarly, 41.2 percent beneficiary and 44 non-beneficiary farmers answered that they have access to laser land leveler while others were deprived of this tool. Observation of t-value states non- significant difference between beneficiary and non-beneficiary.

**Table 3.4 Status and significance of laser land leveling in the study area**

| | | Beneficiary$^{\alpha}$ | Non-Beneficiary$^{\alpha}$ | Difference | t-value |
|---|---|---|---|---|---|
| Used laser leveler | Yes | 82(40.2 | 31(44) | 51 | 0.51 |
| | No | 122(59.8 | 40(56) | 82 | |
| Do land leveling saves water | Yes | 126(97.7) | 36(100) | 90 | 1.18 |
| | No | 3(2.3) | 0 | 3 | |
| Have access to laser land leveler | Yes | 84(41.2) | 31(44) | 53 | 1.07 |
| | No | 120(58.8) | 40(56) | 80 | |
| Total | | 204(100) | 71(100) | 133 | |

(Source: Primary data of Field survey)

$^{\alpha}$ Figures in parenthesis are percentages

**Village infrastructure**

A well-developed infrastructure in rural area not only provides the socioeconomic well being but also increases the rate of adoption of latest technologies (Ali and Erenstein, 2016). Analysis of the study found that about 86 percent beneficiary and 59 percent non-beneficiary farmers have easy access to the metaled road and the difference in availability of this facility between beneficiary and non-beneficiary respondents was significant at 1 percent level of significance. Only few answered in affirmative way when asked about agriculture extension office, commercial bank, pesticide dealer and post office in the village. Even worse condition was about the availability of implement repair, input dealer, output market, on farm water management (OFWM), agriculture research station and soil fertility laboratory that was merely to 1 percent respondents. Majority of respondents answered that they have boys school, girls school and electricity respectively in their village. About 82 percent farmers responded that they have easy access to transport facility. Only 9 percent farmers replied yes when asked about the facility of post office in their village. The difference in availability of facilities to beneficiary and non-beneficiary respondents is significant for girls school at 10 percent, for implement repair at 5 percent and for electricity, pesticide dealer post office and input dealer at 1 per cent level of significance.

The results presented here are consistent with the findings of earlier researchers. A dynamic extension department can play a critical role in Pakistan in order to increase the awareness and adoption of the agricultural technology that is crucial for increasing the productivities (Khan et al. 2020).

**Table 3.5: Village infrastructure**

| | | Beneficiary percent | Non beneficiary percent | Difference (percentage) | t-values |
|---|---|---|---|---|---|
| Facility of Metal Road | Yes | 59 | 86 | -27 | 4.56*** |
| | No | 41 | 14 | 27 | |
| | No | 86 | 86 | 0 | |
| Agric. Extension Office | Yes | 2 | 1.5 | 0.5 | 0.09 |
| | No | 98 | 98.5 | -0.5 | |
| School (Boys) | Yes | 93 | 94.5 | -1.5 | 0.52 |
| | No | 7 | 5.5 | 1.5 | |
| School (Girls) | Yes | 84 | 78 | 6 | -1.85* |
| | No | 15 | 22 | -7 | |
| Commercial Bank | Yes | 2 | 1.5 | 0.5 | 1.25 |
| | No | 98 | 98.5 | -0.5 | |
| Transport | Yes | 81 | 86 | -5 | 1.01 |
| | No | 19 | 14 | 5 | |
| Electricity | Yes | 97 | 100 | -3 | 3.89*** |
| | No | 3 | 0 | 3 | |
| Pesticide Dealer | Yes | 3 | 3 | 0 | 2.24*** |
| | No | 97 | 97 | 0 | |
| | No | 98 | 100 | -2 | |
| Post Office | Yes | 10 | 3 | 7 | 2.19*** |
| | No | 90 | 97 | -7 | |
| Implement Repair | Yes | 1 | 3 | -2 | 1.91** |
| | No | 99 | 97 | 2 | |
| Input Dealer | Yes | 1 | 3 | -2 | 3.18*** |
| | No | 99 | 97 | 2 | |

| | | | | | |
|---|---|---|---|---|---|
| Output Market | Yes | 0 | 0 | 0 | 0.59 |
| | No | 100 | 100 | 0 | |
| OFWM. | Yes | 0 | 0 | 0 | - |
| | No | 100 | 100 | 0 | |
| Agric. Research Station | Yes | 2 | 0 | 2 | -2.02*** |
| | No | 98 | 100 | -2 | |
| Soil Fertility Laboratory | Yes | 0 | 0 | 0 | 0.08 |
| | No | 100 | 100 | 0 | |
| NGOs | Yes | 0 | 0 | 0 | -1.42 |
| | No | 100 | 100 | 0 | |
| Other | Yes | 0 | 0 | 0 | 1.10 |
| | No | 100 | 100 | 0 | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Seed source in wheat production**

Importance of high quality seed as a basic input in agricultural production is still not only intact rather increased with the modernization of technology. Good seed characteristics determine the yield and quality of the produce.

During the present study we tried to dig out basically the source of seed and its utilization by the sampled farmers. Analysis of the seed sources are presented in table below showed 64 percent beneficiaries, 74 percent non-beneficiaries used home seed for the wheat crop. Very small number of farmers purchased seed from seed companies, Research/Extension departments and NGOs. Only 4.4 percent beneficiary and 3.2 percent non-beneficiary farmers purchased seed from Research/Extension departments. Observation of t-values revealed that non-beneficiary respondents get statistically significant amount of seed from seed companies at 5 percent level of significance. Contrary to that beneficiary respondents source statistically significant quantity of seed from AIP project at 1 percent level of significance.

**Table 3.6: Seed source in wheat production**

| | **Beneficiary** Kg $^{\alpha}$ | **Non-Beneficiary** Kg $^{\alpha}$ | **Difference** Kg | **t-values** |
|---|---|---|---|---|
| Home Seed | 191.5 (64.2) | 243.5 (74.4) | -52.0 | 0.14 |
| Fellow Farmers | 139.3 (19.6) | 138.6 (50.8) | 0.7 | 0.00 |
| Seed Companies | 12.53 (6.9) | 64.71 (16.0) | -52.1 | -2.47** |
| Village/Tehsil/ District/Market | 125 (2.9) | 400 (3.2) | -275.0 | 0.23 |

| | | | | |
|---|---|---|---|---|
| Research/Extension Department | 266.1 (4.4) | 100 (3.2) | 166.1 | 0.40 |
| NGOs | 25 (0.5) | 0 | 25.0 | 0.62 |
| AIP Project | 33.8 (100) | 0 | 33.8 | 12.13*** |
| Others | 173.5 (16.7) | 0 | 173.5 | 0.10 |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

α Figures in parenthesis are percentages

**Average yield of AIP and other varieties in the study area**

On average varieties given by wheat component showed higher productivity as compared to farmer field varieties. Beneficiaries also cultivated other varieties as well and the table below is giving clear picture that other varieties were somehow showed less productivity as compared to AIP varieties. Beneficiaries were getting 35.32 mounds per acre from given varieties and 33.5 mounds per acre from their own varieties. However, comparison in the table revealed that non-beneficiaries had comparatively less (1.82 mound per acre) yield. The difference in yield of AIP and other varieties is statistically significant at 5 percent level of significance.

**Table 3.7: Average yield of AIP and other varieties in the study area**

| | AIP Variety | Other Varieties | Difference | t-value |
|---|---|---|---|---|
| Beneficiary | 35.32 | 33.50 | 1.82 | 2.04** |
| Non Beneficiary | | 33.71 | | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Sample farmers' perceptions regarding improved wheat varieties**

Out of total 204 beneficiaries, 151 were of the view that given varieties were suited to the area, while 53 were not agreed with the statement. About 86 percent reported the IRD approach of accessing was very suitable for the area farmers. Moreover, 82 percent believed that the approach of reaching farmers is also very useful in the future. Majority of 93.6 percent beneficiaries were satisfied with the AIP seed packaging, while 6.4 percent were not satisfied. A large number of 72 percent farmers reported that seed was available well before sowing. The entire variables discussed in table 28 are significant at 1 percent level of significance.

**Table 3.8: Sample farmers' perceptions regarding improved wheat varieties**

| | | Numbers α | t-values |
|---|---|---|---|
| Suitability of AIP varieties to the area | Yes | 151(74) | -14.39*** |
| | No | 53(26) | |
| Suitability of IRD approach of accessing | Yes | 176(86.3) | -34.91*** |
| | No | 28(13.7) | |

| | | | |
|---|---|---|---|
| Usefulness of similar approach of reaching farmers | Yes | 158(82.3) | -29.79*** |
| | No | 34(17.7) | |
| Satisfied from AIP seed Packaging | Yes | 191(93.6) | -53.78*** |
| | No | 13(6.4) | |
| Was the AIP seed available well before sowing | Yes | 149(72) | -20.44*** |
| | No | 54(28) | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

α Figures in parenthesis are percentages

**Importance of characteristics in wheat variety selection**

Generally, wheat varieties are selected keeping in view the productivity and quality of produce. However, other factors such as seed source, disease, temperature and drought tolerance are also given due consideration. To collect all the good feature in one variety is really a hard task and difficult to achieve. Therefore, growing a combination of good qualities varieties reduce the risk of crop failure. Survey findings reveals that farmers were more concerned with the yield of the variety, followed by its end use (chapatti making), good taste, home seed, less disease attack and other characteristics respectively.

**Table 3.9: Importance of characteristics in wheat variety selection (percentage)**

| Characteristic | Beneficiary | Non Beneficiary | Overall | Difference | t- values |
|---|---|---|---|---|---|
| High Yield | 35.20 | 35.18 | 35.19 | 0.02 | 0.47286 |
| Home Seed | 15.13 | 13.23 | 13.86 | 1.91 | 0.19505 |
| Good Taste | 15.60 | 16.53 | 16.22 | -0.93 | 0.09796 |
| Less Disease Attack | 11.74 | 8.82 | 9.79 | 2.93 | 0.04785 |
| Chapatti Making | 12.77 | 19.81 | 20.46 | -7.04 | 0.00694 |
| Other Characteristics | 9.90 | 7.07 | 11.01 | 2.84 | 0.27697 |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Major issues/ problems in wheat crop production**

**Rust resistant varieties**

Different regions have different incidence of disease. Therefore location specific solutions are required. Humid areas have greater risk of foliar infection and our Great Plains have wheat streak mosaic virus (WSMV). Resistant and tolerant varieties are available for Great Plains that limit the spread of diseases. Data proclaimed that 60 percent farmers stated their varieties were rust resistant, further breakdown of into categories estimated that 57 percent beneficiaries and 69 percent non beneficiaries claimed their sown varieties were resilient against rust. This opinion of having rust resistant varieties was statistically significantly high as compare to those who think that their varieties were not rust resistant. Moreover, farmers complained about rust in their field which approximate yield loss of 11 percent for beneficiary and 17 percent for the non-beneficiary farmers. Yield loss of non-beneficiary farmers was statistically significantly more than the beneficiary farmers at 1 percent level of significance.

**Table 3.10: Rust resistant varieties**

| | | Beneficiary α | Non-α Beneficiary | Overall α | Difference α | t values |
|---|---|---|---|---|---|---|
| Are the varieties sown rust resistant? | Don't Know | 1(0.5) | 5(7.0) | 6(2.2) | -0.07 | 2.58*** |
| | Yes | 117(57.4) | 49(69.0) | 166(60.4) | -0.12 | |
| | No | 86(42.2) | 17(23.9) | 103(37.5) | 0.19 | |
| Which rust problem is common in your fields? | Stem rust | 2(7.1) | 0 | 2(6.7) | 0.07 | 3.58*** |
| | Yellow rust | 12(42.9) | 2(100) | 14(46.7) | -0.57 | |
| | Leaf Rust | 14(50) | 0 | 14(46.7) | 0.50 | |
| | Strip rust | 0(0) | 0 | 0(0) | 0 | |
| Approximate yield loss due to Rust | | 11.71 | 17 | 11.13 | 3.21 | 3.57*** |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

α Figures in parenthesis are percentages

**Loose smut problem**

Table below describes that more than 89 percent of the farmers stated there was not a loose smut problem in their fields, only 11 percent reported loose smut problem in their field. In addition to that 12 percent beneficiaries reported loose smut problem while 87 percent beneficiaries reported that there was no loose smut in their wheat fields. The results are statistically significant at 1 percent level of significance.

**Table 3.11: Loose smut problem**

| | | Beneficiary α | Non-α Beneficiary | Overall α | Difference percent | t-values |
|---|---|---|---|---|---|---|
| Is there loose smut problem in the area? | Yes | 26(12.70) | 4(5.6) | 30(10.9) | 7.1 | -3.49*** |
| | No | 178(87.30) | 67(94.4) | 245(89.1) | -7.1 | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

α Figures in parenthesis are percentages

**Yield performance and area of different wheat varieties**

About 20 wheat varieties were reported in the study area, Punjab 11 was distributed to most of the beneficiaries, and some non-beneficiaries also cultivated Punjab 11 by purchasing seed or from other sources. On average Punjab 11 performed well and farmers were satisfied with its production. Millat, Galaxy, Ujala and Faisalabad 2008 showed higher production with per acre yield of 43.1, 42.4, 41.6 and 40.7 mounds per acre. Further analysis discovered that Punjab 11 has the maximum yield obtained by the beneficiaries of AIP project as compared to other varieties given under this project. Lasani, Pak 81, TD 1, and zincol varieties gave less than 35 mounds per acre.

**Table 3.12: Yield performance and area of different wheat varieties**

| | Beneficiary | | Non Beneficiary | | Overall | |
|---|---|---|---|---|---|---|
| | **Area** | **Yield** | **Area** | **Yield** | **Area** | **Yield** |
| Millat | 1.88 | 38.1 | 3.75 | 48 | 2.82 | 43.1 |
| Galaxy | 0.97 | 43.2 | 5.25 | 42 | 3.82 | 42.4 |
| Ujala | 1.14 | 42.7 | 4.25 | 40.5 | 2.7 | 41.6 |
| Faisalabad 08 | 4.88 | 41.2 | 3.775 | 40.5 | 4.14 | 40.7 |
| Punjab 11 | 1.99 | 38 | 7.5 | 40 | 4.75 | 39 |
| Sehar | 9.19 | 34.6 | 1.7 | 41.25 | 4.19 | 39 |
| Pak 13 | 0.9 | 39.8 | 6 | 38 | 3.45 | 38.9 |
| AARI | 0.5 | 37.7 | 18.5 | 39 | 9.17 | 38.6 |
| Dharabi | 0.6 | 34.6 | 6 | 42 | 3.3 | 38.3 |
| NARC 13 | 0.5 | 37.5 | | | 0.5 | 37.5 |
| AAS | 1.9 | 40.3 | 4.99 | 35.85 | 3.45 | 37.3 |
| Inqilab | 0.5 | 36 | | | 0.5 | 36 |
| Ehsan | 0.5 | 35.5 | | | 0.5 | 35.5 |
| Chakwal 50 | 1.99 | 36.4 | 7.61 | 34.15 | 4.41 | 34.9 |
| Abdul Sattar | 0.6 | 34 | 1 | 35 | 0.8 | 34.5 |
| Mixed | 0.5 | 34.4 | | | 0.5 | 34.4 |
| TD 1 | 0.5 | 40 | 2.6 | 28.6 | 1.55 | 34.3 |
| Lasani | 0.5 | 38 | 2 | 29 | 1.25 | 33.5 |
| Pak 81 | 0.5 | 35 | 1 | 32 | 0.75 | 33.5 |
| Zincol | 1.33 | 32.3 | | | 1.33 | 32.3 |

**Institutional support available for the sample respondents**

Institutional support for the farmers regarding different cultivation practices, financial assistance, and other input support is very valuable for the farmers if disseminated with good procedure. Table below represents the information about the sampled farmers' perception regarding institutional support. Out of 204 beneficiaries only 35 (17percent) farmers reported support of Agricultural Extension Department, while 169 were not convinced. On the whole only 3, 15, 36, 32, 38 and 21 farmers stated that they are having any support from ZTBL, OFWM, research organizations, fertilizer, Pesticide Companies and soil fertility laboratory respectively. Very less percentage of farmers confirmed support of ZTBL and soil fertility laboratory. The results that state lack of institutional support are statistically significant for OFWM and soil fertility laboratory at 1 percent while for research organization was 10 percent level of significance.

**Table 3.13: Institutional support available for the sample respondents**

| | | Beneficiary | Non-Beneficiary | Overall | Difference | t-value |
|---|---|---|---|---|---|---|
| Agricultural Extension Department | Yes | 35 | 13 | 48 | 22 | 0.97 |
| | No | 169 | 58 | 227 | 111 | |
| ZTBL | Yes | 2 | 1 | 3 | 1 | 0.89 |
| | No | 202 | 70 | 272 | 132 | |
| OFWM | Yes | 14 | 1 | 15 | 13 | -2.82*** |
| | No | 190 | 70 | 260 | 120 | |
| Research Organizations | Yes | 31 | 5 | 36 | 26 | -1.91* |
| | No | 173 | 66 | 239 | 107 | |
| Soil Fertility Laboratory | Yes | 20 | 1 | 21 | 19.5 | -3.06*** |
| | No | 184 | 70 | 254 | 149 | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Credit facility**

Table below presents overall picture of farmers' availed credit and source of credit in the study area. Out of 275 farmers only 47 (17 percent) farmers availed the credit facility meaning here that farmer who have not availed credit facility were statistically significant at 1 percent level of significance. Further analysis showed those 43 beneficiaries and 4, non beneficiaries respectively availed credit facility. NRSP was the main source of credit in the study area, followed by fellow farmers.

**Table 3.14: Credit facility**

| | | Beneficiary | Non-Beneficiary | Overall | Difference | t-value |
|---|---|---|---|---|---|---|
| Availed credit facility | Yes | 43 | 4 | 47 | 41 | -3.12*** |
| | No | 161 | 67 | 228 | 104 | |
| Source of credit if availed | Arthi | 3 | 0 | 3 | 3 | |
| | NRSP | 27 | 2 | 30 | 25 | |
| | ZTBL | 0 | 1 | 1 | -1 | |
| | Fellow Farmer | 9 | 1 | 10 | 8 | |
| | Bank | 2 | 1 | 3 | 1 | |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Estimated gross family income and expenditures**

Rural household has diversified their portfolio to meet growing economic needs by establishing links outside farming. Therefore Pakistani policy makers need to take common view about rural economy among is that it is confined exclusively to agricultural sector. However, there is a growing evidence that rural sector is much more than just farming. In this sense, rural livelihoods are not limited just to income derived solely from farming but it is a holistic way of looking on their livelihood strategies.

Table below describes that in majority of the households male participation was prevailing more than females; females just gave assistance to their males especially in crops and livestock farming, not involved in revenue generation. Estimated gross income calculated for the beneficiaries were 463191 PKR per year, while non beneficiaries were generating more income as compared to the beneficiaries' i.e. 497097.5 PKR per year. The negative t value of -6.35 shows a significant difference between beneficiary and non beneficiary farmers at 1 percent level of significance.

When asked about per month expenditures and savings from the respondents, on average beneficiaries were involved in more saving as compared to non-beneficiaries, that were statistically significant at 1 percent level of significance, although their per month income was comparatively less.

**Table 3.15: Estimated gross family income and expenditures (PKR)**

| | Beneficiary | Non-Beneficiary | Overall | Difference | t-value |
|---|---|---|---|---|---|
| Crop income by male members per year | 145450 | 185744 | 172313 | -402940 | -2.04** |
| Non-farm income by female member per year | 35714 | 0 | 35714 | 35714 | 1.95* |

| | | | | | |
|---|---|---|---|---|---|
| Non-farm total income per year | 141593 | 83853 | 103100 | 57740 | 4.05*** |
| Total income by all members per year | 463191 | 497097.5 | 485796 | -33906 | -6.35*** |
| Saving per Month | 4163 | 3755 | 3891 | 408 | 5.30*** |
| Expenditures per Month | 32650 | 37339.5 | 35776 | -4689 | -1.50 |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

As evident from the table above crop and livestock income by the family members per year is greater for non-beneficiary as compare to the beneficiary respondents. Non-farm total income per year was statistically significantly greater for the beneficiary farmers at 1 percent significance level.

**Empirical analysis**

PSM is used to estimate the role of determinant and risk factors in the adoption of improved wheat varieties. PSM analysis was performed for three wheat varieties vastly cultivated in the study area. Three wheat varieties Punjab-11, Ujala and Galaxy were selected based on the fact that these varieties were latest at the time of start of this study and were being recommended by wheat program experts at NARC, PARC Islamabad, Punjab agriculture department, government of Punjab, wheat research institute, Faisalabad and International Maize and Wheat Improvement Center (CIMMYT), Pakistan.

**PSM analysis for wheat variety 1 (PUNJAB-11)**

As a first step in PSM, probit regression is run. The results of the multivariate probit regression are presented in Table 3.16, estimating the determinants of farmers' adoption of improved wheat varieties. The variable such as land holding, land rent, soil quality, access to the farm through metal road, irrigation cost and highest education have positive relation with the adoption of Punjab-11 improved wheat variety. These variables have statistically significant effect at 1 percent level of significance. The land holding of the farmer presented a positive and highly significant relationship consolidating the believe that the large farmers most likely to adopt for following reasons: (a) they were rich and have ability to spend in improved technology and (b) they wanted to maximize profit by producing marketable surplus using latest technology. Other variables such as availability of metal road and agricultural extension services illustrate infrastructure and institutional support in adoption process.

In contrary to above, feature of land fragmentation in the area has negative effect that is significant at 1percent significance level. Almost two third of household have fragmented land and majority grow on plain land (Ali, Beshir and Rahut, 2020).

**Probit regression**

| | | | |
|---|---|---|---|
| Number of observation | = 275 | LR chi2 (22) | = 105.50 |
| | | Prob > chi2 | = 0.000 |
| Log likelihood = -104.317 | | Pseudo R2 | = 0.335 |

**Table 3.16: Probit regression model for wheat variety (Punjab-11) adoption**

| Status of Respondent | Coefficient | Standard. Error | t-value |
|---|---|---|---|
| Education | .010 | .026 | 0.41 |
| Experience | 002 | .009 | 0.30 |
| Land Holding | .029 | .012 | 2.35*** |
| Wheat area sown | -.015 | .009 | 1.64 |
| Land Rent | .00006 | .00001 | 4.09*** |
| Soil Quality | .461 | .223 | 2.07** |
| Land Fragmented | -.723 | .296 | -2.44*** |
| Slop | -.402 | .303 | -1.33 |
| Use of laser Leveler | -.504 | .334 | 1.51 |
| Agricultural Extension | .068 | .361 | 0.19 |
| Metal road | .674 | .260 | 2.59*** |
| Availed credit facility | .205 | .262 | 0.78 |
| Variety rust Resistant | .322 | .223 | 1.44 |
| Irrigation Cost | .0009 | .0002 | 4.39*** |
| ZT_Drill | .066 | .583 | 0.11 |
| Seed Rate | .004 | .005 | 0.75 |
| Seed drill | -.608 | .428 | 1.42 |
| Highest education | .069 | .029 | 2.37*** |
| Female Farm worker | -.223 | .218 | -1.02 |
| Male Farm worker | -.284 | .188 | 1.51 |
| Family members | .069 | .041 | 1.66 |
| Location at distributary | -.213 | .282 | 0.76 |
| Constant | 1.808 | .793 | 2.28 |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Propensity Score test (PS test) for wheat variety Punjab-11**

The results mentioned in above table were further refined by applying PS test to remove the bias. Regression result and bias percentage are shown in Table 3.17. It is evident that the variable of education and experience previously non-significant were changed after removing the 27.0 and -31.8 percent bias to the fact that these were influencing the adoption significantly that is statistically significant at 1 percent level of significance. So it is inferred that better education levels have positive effect on technology adoption (Ali, Beshir and Rahut, 2020). Similarly slop has encumbrance on adoption significantly at 1 percent level of significance. Agriculture extension services and location of the farm on the canal distributary influence the adoption positively significant at 10 percent level of significance. Number of family members has positive while number of female workers at farm has negative effect on the adoption of improved wheat varieties.

**Table 3.17: Probit regression model with Propensity Score test (PS test) for wheat variety Punjab-11 Adoption**

| Status of Respondent | Mean | | Bias percentage | t-value |
|---|---|---|---|---|
| | Treated | Control | | |
| Education | 6.918 | 5.829 | 27.0 | 2.06 *** |
| Experience | 20.563 | 24.207 | -31.8 | -2.67 *** |
| Slop | 0.4 | 0.525 | -25.8 | -2.08** |
| Agricultural Extension | .059 | 0 | 20.7 | 1.80* |
| Female Farm worker | .437 | .555 | -23.3 | -1.93* |
| Family members | 8.703 | 9.377 | -23.5 | 1.93* |
| Location at distributary | .362 | .259 | 21.4 | 1.85* |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

| Ps R2 | LR chi2 | p>chi2 | Mean Bias | Med Bias | B | R | %Var |
|---|---|---|---|---|---|---|---|
| 0.126 | 46.33 | 0.001 | 17.3 | 17.2 | 87.1* | 1.08 | 42 |

* If B>25%, R outside [0.5; 2]

**PSM analysis for wheat variety 2 (Galaxy)**

As previously done for variety1 PSM, probit regression is run for second variety Galaxy. The results of the multivariate probit regression are presented in Table 3.18, estimating the determinants of farmers' adoption of improved wheat varieties. The variable such as land holding, land rent, soil quality, access to the farm through metal road, irrigation cost and highest education have positive relation with the adoption of Galaxy improved wheat variety. These variables have statistically significant effect at 1 percent level of significance. The land holding of the farmer presented a positive and highly significant relationship. These results also support the argument that infrastructure and institutional support accelerate adoption process.

Conversely the feature of land fragmentation in the area has negative effect that is significant at 1percent significance level. Almost two third of household have fragmented land and majority grow on plain land (Ali, Beshir and Rahut, 2020).

**Probit Regression:**

Number of observation = 275 LR chi2 (22) = 105.50

Prob > chi2 = 0.000

Log likelihood = -104.317 Pseudo R2 = 0.335

**Table 3.18: Probit regression model for wheat variety 2 (Galaxy) adoption**

| Status of Respondent | Coefficient | Standard. Error | t-value |
|---|---|---|---|
| Education | .010 | .026 | 0.41 |
| Experience | 002 | .009 | 0.30 |
| Land Holding | .029 | .012 | 2.35** |
| Wheat area sown | -.015 | .009 | 1.64 |
| Land Rent | .00006 | .00001 | 4.09*** |
| Soil Quality | .461 | .223 | 2.07** |
| Land Fragmented | -.723 | .296 | -2.44*** |
| Slop | -.402 | .303 | -1.33 |
| Use of laser Leveler | .504 | .334 | 1.51 |
| Agricultural Extension | .068 | .361 | 0.19 |
| Metal road | .674 | .260 | 2.59*** |
| Availed credit facility | .205 | .262 | 0.78 |
| Variety rust Resistant | .322 | .223 | 1.44 |
| Irrigation Cost | .0009 | .0002 | 4.39*** |
| ZT_Drill | .066 | .583 | 0.11 |
| Seed Rate | .004 | .005 | 0.75 |
| Seed drill | .608 | .428 | 1.42* |
| Highest education | .069 | .029 | 2.37** |
| Female Farm worker | -.223 | .218 | -1.02 |
| Male Farm worker | .284 | .188 | 1.51 |
| Family members | .069 | .041 | 1.66 |
| Location at distributary | .213 | .282 | 0.76 |
| constant | 1.808 | .793 | 2.28*** |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

**Propensity Score test (PS test) for wheat variety 2 Galaxy**

The results mentioned in above table were further refined by applying PS test to remove the bias. Regression result and bias percentage are shown in Table 3.19. It is evident that the variable of education and experience previously non-significant were changed after removing the 27.0 and -31.8 percent bias to the fact that these were influencing the adoption significantly that is statistically significant at 10 percent and 1 percent level of significance respectively. So it is inferred that better education levels have positive effect on technology adoption (Ali, Beshir and Rahut, 2020). Similarly slop has encumbrance on adoption significantly at 1 percent level of significance majority of the farmers have good quality soil and plain land (Ali and Erenstein, 2017).

**Table 3.19: Probit regression model with Propensity Score test (PS test) for wheat variety 2 (Galaxy) Adoption**

| Status of Respondent | Mean | | Bias | t-value |
|---|---|---|---|---|
| | Treated | Control | percentage | |
| Education | 6.918 | 5.829 | 27.0 \| | 2.06** |
| Experience | 20.563 | 24.207 | -31.8 | -2.67 *** |

| | | | | |
|---|---|---|---|---|
| Slop | 0.4 | 0.525 | -25.8 | -2.08** |
| Agricultural Extension | .059 | 0 | 20.7 | 1.80* |
| Disease resistant | .422 | .222 | 40.8 | 3.59 *** |
| Female farm worker | .437 | .555 | -23.3 | -1.93 |
| Family members | 8.703 | 9.377 | -23.5 | 1.93* |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

| Ps R2 | LR chi2 | p>chi2 | Mean Bias | Med Bias | B | R | %Var |
|---|---|---|---|---|---|---|---|
| 0.126 | 46.33 | 0.001 | 17.3 | 17.2 | 87.1* | 1.08 | 42 |

* If B>25%, R outside [0.5; 2]

Disease resistance is highly significant at 1 percent level after removing 40.8 percent bias means that farmers adopt only those wheat varieties that are disease resistant. Agriculture extension services and location of the farm on the canal distributary influence the adoption positively significant at 10 percent level of significance. Number of family members has positive while number of female workers at farm has negative effect on the adoption of improved wheat varieties

**PSM analysis for wheat variety 3 (Ujala)**

In continuation of the previous two varieties, probit regression is run for third variety Ujala. The results of the multivariate probit regression are presented in Table 3.20, estimating the determinants of farmers' adoption of improved wheat varieties. Almost same variable such as land holding, land rent, soil quality, access to the farm through metal road, irrigation cost and highest education have positive relation with the adoption of Ujala improved wheat variety. These variables have statistically significant effect at 1 percent level of significance. The land holding of the farmer maintained a positive and highly significant relationship. These results for Ujala also support the argument that infrastructure and institutional support accelerate adoption process.

**Probit regression**

Number of observations = 275 LR chi2 (22) = 105.50

Prob > chi2 = 0.000

Log likelihood = -104.317 Pseudo R2 = 0.335

**Table 3.20: Probit regression model for wheat variety 3 (Ujala) Adoption**

| Status of Respondent | Coefficient | Standard. Error | t-value |
|---|---|---|---|
| Education | .010 | .026 | 0.41 |
| Experience | 003 | .009 | 0.30 |
| Land Holding | .029 | .012 | 2.35** |
| Land Rent | .00006 | .00001 | 4.09*** |
| Soil Quality | .461 | .223 | 2.07** |

| | | | |
|---|---|---|---|
| Land Fragmented | -.723 | .296 | -2.44*** |
| Slop | -.402 | .303 | -1.33 |
| Use of laser Leveler | .504 | .334 | 1.51 |
| Agricultural Extension | .068 | .361 | 0.19 |
| Metal road | .674 | .260 | 2.59*** |
| Availed credit facility | .205 | .262 | 0.78 |
| Variety rust Resistant | .322 | .223 | 1.44 |
| Irrigation Cost | .0009 | .0002 | 4.39*** |
| ZT_Drill | .066 | .583 | 0.11 |
| Seed Rate | .004 | .005 | 0.75 |
| Seed drill | .608 | .428 | 1.42* |
| Highest education | .069 | .029 | 2.37** |
| Female Farm worker | -.223 | .218 | -1.02 |
| Male Farm worker | -.284 | .188 | -1.51 |
| Family members | .069 | .041 | 1.66 |
| Location at distributary | .213 | .282 | 0.76 |
| constant | 1.808 | .793 | 2.28*** |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

Land fragmentation in the area has negative effect that is significant at 1percent significance level. Two third of the farmers have fragmented land, and an overwhelming majority have plain land (Ali, Beshir and Rahut, 2020).

**Propensity Score test (PS test) for wheat variety 3 Ujala**

Probit regression results mentioned in above table were further refined by applying PS test to remove the bias. Regression result and bias percentage are shown in Table 3.21. As shown in table that the variable of education and experience previously non-significant were converted to statistically significant at 1 percent level of significance after removing the 27.0 and -31.8 percent bias respectively. So it is inferred that better education levels have positive effect on technology adoption (Ali, Beshir and Rahut, 2020). Slop has negative sign meaning that an inverse relation with the adoption was significant at 1 percent level of significance.

**Table 3.21: Probit regression model with Propensity Score test (PS test) for wheat variety 3 (Ujala) Adoption**

| Status of Respondent | Mean | | Bias percentage | t-value |
|---|---|---|---|---|
| | Treated | Control | | |
| Education | 6.918 | 5.829 | 27.0 | 2.06 |

| | | | | |
|---|---|---|---|---|
| Experience | 20.563 | 24.207 | -31.8 | -2.67 *** |
| Slop | 0.4 | 0.525 | -25.8 | -2.08** |
| Agricultural Extension | .0592 | 0 | 20.7 | 1.80* |
| Female Farm worker | .437 | .555 | -23.3 | -1.93* |
| Disease resistant | .422 | .222 | 40.8 | 3.59*** |
| Female farm worker | .437 | .555 | -23.3 | -1.93* |
| Family members | 8.703 | 9.377 | -23.5 | -1.93* |

Note: ***, **, * indicate significance levels at 1, 5 and 10 percent correspondingly

| Ps R2 | LR chi2 | p>chi2 | Mean Bias | Med Bias | B | R | percent Variation |
|---|---|---|---|---|---|---|---|
| 0.126 | 46.33 | 0.001 | 17.3 | 17.2 | 87.1* | 1.08 | 42 |

* If B>25%, R outside [0.5; 2]

Disease resistance is highly significant at 1 percent level after removing 40.8 percent bias means that farmers adopt only those wheat varieties that disease resistant. Agriculture extension services and location of the farm on the canal distributary influence the adoption positively significant at 10 percent level of significance. Number of family members has positive while number of female workers at farm has negative effect on the adoption of improved wheat varieties.

## POLICY RECOMMENDATIONS

The empirical results based recommendations are presented here;

### Researcher

High yielding wheat varieties having disease resistance and relatively low water requirements were readily acceptable to farmers and significantly high adoption rate. As results revealed that disease resistance and irrigation cost were the important variable in farmers adoption decision making that the t-values are statistically significant at the 1 percent level of significance. Educated and wealthy farmers are more likely to adopt the new technology; hence, there is a need to invest in human capital development either through formal education or training on recent development of new agricultural technology. Research questions that solve the issues of small farmers need to be included in future research projects.

Majority of farmers use home seed or fellow farmer seed that causes a huge loss in terms of low yield. Hence, building the competitiveness of local seed companies by offering best possible incentives for companies involved in local seed production, fast tracking the release process of new varieties, and providing technical support for hybrid seed production are among the major areas that need policy interventions.

During field survey number of farmers was also suggesting that government should organize different trainings at basic community level regarding new agricultural technologies so that it will be helpful for the farmers to increase crop production.

In order to increase rate of adoption, close coordination of research institutions and agricultural extension services is important to bring awareness among the farmers.

**Policy Makers**

As farmers had concerns about prices and quality of inputs (especially seed, fertilizers, weedicides and pesticides). Therefore policy intervention is recommended to resolve this issue.

Shortage of irrigation water is a major prevailing problem in Rain fed areas of the sample, as the crop is totally dependent on rains. Farmers of that area suggested small dams will be the good option to fulfill the requirements of water. In irrigated areas, farmers were also grumbling about the condition of irrigation channels, rate of diesel and electricity. Marketability of crops was also seen as a predominant issue among farmers, as they had very serious concerns about the prices of the produce. They were suggesting that government must define (reasonable) prices of the produce they are taking to the markets and it is responsibility of the government to ensure this price in the markets as well. Small agricultural loans on a very least interest with nominal terms and conditions rate will also make legitimate change in the productivity, livelihood and income of the small poor farmers.

Probit regression results reported above identified few interesting facts, one, awareness and knowledge about the improved wheat varieties and benefits is associated with the adoption. Second, the results highlight that the resource endowment of the farm households to invest in new technology is necessary. Thus, following is needed: (i) enhancing awareness and projecting benefits of adoption; and (ii) increasing the affordability of the farmer by reducing the cost of adoption. Alternative livelihoods and providing support to especially the poorer households can increase the resource endowment.

**Farmers**

The rate of adoption of improved varieties, and therefore the time lag from varietals release to widespread use varies across regions. In developing world it is currently high. Farmers need to regularly review their farming practice especially the varieties being cultivated and the latest improved variety released.

The remarkable success of wheat improvement hinges on the decisions of millions of farmers to adopt or replace older wheat varieties with superior cultivar material. Because adoption is a necessary step but not a sufficient condition for realizing economic impact.

## CONCLUSION

To study the determinants of the adoption of Improved Wheat Varieties (IWVs) is well served by the findings that most farmers reuse farm produce as seed to avoid cost, but this practice results in yield losses. Less than half obtain seed from formal sources that is a limiting factor other negative influences are land fragmentation, slope, poor infrastructure, lack of awareness, and institutional outreach. Determinant that positively contribute to the adoption are education, landholding size, good soil quality, access to metal roads, agricultural extension services, irrigation infrastructure, availability of credit, rust resistance, and institutional support. Most farmers valued high yield, good taste, and disease resistance for adoption. Economic analysis used Propensity Score Matching (PSM) to compare adopters and non-adopters while controlling for selection bias. Beneficiaries were generally more educated and had larger landholdings. Yield was higher for IWVs (e.g., Punjab-11, Galaxy, Ujala) than traditional varieties. IWVs yielded 1.8 mounds more per acre than traditional varieties. Policy recommendations for researchers are to develop high-yield, disease-resistant, and drought-tolerant varieties, promote awareness and farmer training on IWVs, Improve seed certification and distribution systems. Policymakers must consider investment in rural infrastructure and irrigation, Provide affordable credit and ensure minimum price enforcement, encourage public-private partnerships for seed development and dissemination. Finally farmers are required to regularly update seed varieties to newer, improved strains. engage with extension services and training programs for better practices.

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