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AN ECONOMETRIC ANALYSIS OF BED-FURROW IRRIGATION FOR CULTIVATED WHEAT IN IRRIGATED AREAS OF PUNJAB, PAKISTAN

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Pakistan is primarily an agricultural country and its agricultural production depends on adequate availability of irrigation water supplies. Wheat is an important staple food and its share in value added is 12.5 percent and 2.6 percent in agriculture and Pakistan's GDP, respectively. With the increasing food demand and growing population at increasing rate of 2 percent, the agricultural economy of Pakistan is under stress with many problems. Shortage of irrigation water is one of the most import issue which contributes in low crop productivity. However, bed planting of wheat is one of the modern technique that saves significant amount of irrigation water and also increases the wheat yield. Therefore, bed planting of wheat was compared with conventional irrigation method in economic terms. Cross-sectional data was collected from farmers through a comprehensive questionnaire from the districts Faisalabad and Toba Tek Singh for the cropping season 2013-14. The information was gathered from 60 farmers who adopted this technology and 60 non-adopters of bed planting. The study also determined the factors which were considered to be responsible for the adoption of bed planting of wheat. Results revealed that adopters typically have a more favorable resource base as compared to non-adopters. More access to education and other indicators increases the chances to adopt new technologies by the farming community. The economic analysis results showed the total revenue and gross margins from one acre of wheat was significantly high for adopters compared to non-adopts of bed planting. It was due to more wheat yield (< 185.6 kgs) in case of wheat under bed planting. That earned revenue of Rs. 64,425 compared to Rs. 58,274 for non-adopters. Gross margin for adopters and non-adopters was calculated to be Rs. 38,185 and 29,405, respectively. Similarly, net returns were Rs. 25,178 and Rs. 17,012 for adopter and non-adopters of bed planting technology, respectively. The BCR were also high in case of bed planting in both districts and found highest BCR (2.40) in district. Hence effective policy should be made in order to suffice these farming communities for bed planting of wheat to save large amount of irrigation water.
Keywords: Bed planting, wheat crop, cross sectional data, adopters and non-adopters, logit model and economic analysis

INTRODUCTION

Pakistan depends largely on agricultural production mainly comes from irrigated land because it lies in the arid to semi-arid region. Agriculture still remains the second largest sector after services sector and contributing 19.82 percent to annual Gross Domestic Product (GDP) of Pakistan's economy (GOP, 2016). Pakistan has been granted with abundant water resources by the nature. However, due to competing demands of water for domestic and industrial uses, only a part of irrigation water is available for crop production. The supply of irrigation water is further limited due to other factors as topographical, geological, melting of glaciers and limiting storage capacity of water. Further, the significant amount of irrigation water is lost in the system due to conveyance losses and traditional water application methods being employed at farm (Asghar *et al.,* 2001). The major sources of irrigation water are river supplies i.e. canal commanded irrigated area is about 16.00 Mha in addition to small share of 4 Mha of rainfed areas. Now the situation has been changed, the irrigation water is becoming scarce as the water availability in Pakistan has approached about 1000 m^3/capita, categorizing the country as a water deficit country (Hussain *et al*., 2011). Moreover, projections show that with the current pace of increasing population, water availability will reach 915 m^3/ capita in 2020 (Bakhsh *et al*., 2015).

Pakistan is facing a great challenge of food insecurity for its population of 195.4 million (GOP, 2016). Wheat is one of the leading cereal crop of rabbi season and the main staple food of the Pakistani people. Wheat contribution in value added is 9.9 percent and 2 percent in Pakistan's GDP, respectively. Total area under wheat was 9260 thousand hectares during 2015-16 compared to 9180 thousand hectares in the last year. Among different cropping systems of Pakistan, only Cotton-Wheat and Rice-Wheat systems together account for 60 percent of the total wheat area whereas one third of the wheat area is covered by rain-fed (1.5 t/ha). Among different factors responsible to the low wheat yield, shortage of irrigation water is the most important limiting factor. The water availability in rabi season is estimated 32.9 Million Acre Feet (MAF), which is 9 percent less than the average normal water availability

(GOP, 2016). With the imbalance between increasing demand of wheat and decreasing water resources, it is necessary to make efficient use of available water by adopting modern irrigation techniques. There are a number of irrigation technologies, which have the potential to apply irrigation water efficiently. But each method works at the best under specific farming conditions. In Punjab, Pakistan, under irrigated canal command areas, the cultivated land is mostly flat and fields are leveled where farmers grow mostly row crops and apply irrigation water in the form of flooding. Huge water losses are being experienced during different phases of its conveyance from the main source to the farmer fields through unlined courses.

In spite of constrained availability of water resources in Pakistan, farmers are still employing conventional irrigation practices which may result in huge water losses. Under these circumstances there is need to apply irrigation water efficiently not only to save the irrigation water but also to increase water productivity, reported to be as low as 0.1 kg/m^3 water productivity as compared to India (1 kg/m^3) and other countries (GOP, 2011).

Moreover, the uniform and required application of water will increase the overall water use efficiency. The research is now putting great emphasis and efforts to manage the precious water through different modern water saving techniques with less wastage. To improve water productivity, it is necessary either to increase the crop yields or minimize the water losses or manage both the parameters. As in Punjab, majority of the farmers hold land less than 5 acres, so beside the desire of efficient application of water, they are not in the financial position to use expensive irrigation systems such as sprinklers and drip irrigation systems.

Bed planting is one of the better irrigation techniques which is used for efficient use of water and inputs and is practiced for all crops all over the world with several advantages. The bed planting technique applies the equal distribution of water in smooth and straight furrows to plants on the beds. It gives efficient nutrient management, increase irrigation efficiency and reduce the crops lodging on beds (Hobbs and Gupta, 2003). Researchers describe that increase in crop yield is because of the above-mentioned advantage of bed planting of crops. It also reduces tube well pumping costs and time of irrigation thus enables tube wells to irrigate larger areas more efficiently. By using this technology in wheat and maize, up to 30 percent on-farm irrigation efficiency can be increased by minimizing water loss (Hassan *et al*., 2005).

This research study has strongly emphasized that there are both equity and efficiency rationales for bringing agriculture within the tax net. It argues that Pakistan's agriculture sector consumed 95 percent of surface water annually.

However, the use of ground water has increased in recent years, farmers tend to use subsidized water and electricity tariffs have induced adoption and expansion of electric pumps to tap groundwater at an alarming rate. Approximately 60 percent of farm-gate-delivered water in Punjab comes from tube wells. This water saving depends on size of bed-furrow system and other topographic characteristics. However, number of beds should be made according to plant population in per unit area and water channels to meet crop water requirement and also row to row distance of plants. This effort aims at minimizing required time to irrigate the fields as well as apply water uniformly when requires time is decreased. All the modern technologies are assumed to achieve the required goals (increased yield or saving inputs use or both) and the extent of achievements of these targets are effective under specific soil, climate and management conditions (Bakhsh *et al*., 1994). The present study was designed to comprehend the factors affecting the adoption of bed planting as well as economics comparison of adopter with non-adopters of bed planting technology for wheat crop in the irrigated areas of Punjab. The study also suggested policy recommendations for enhancing the adoption of bed planting of wheat for precious resource conservation of water in Punjab, Pakistan.

MATERIALS AND METHODS

This study describes an economic analysis of bed furrow irrigation system in comparison with conventional flat sowing (flood irrigation system) in Punjab, Pakistan. Although the adopters of bed planting of wheat were limited due to less adoption of this new technology. However, the present study was conducted in the project area entitled “Watershed Rehabilitation and Improvements in Pakistan: Demonstrating and Disseminating the Best Practices and Technology to Help Rural Farmers”. It is an outcome of International Center for Agricultural Research in Dry Areas (ICARDA) and executed by Water Management Research Center (WMRC), University of Agriculture, Faisalabad, Pakistan. Mechanized wheat bed planting is being promoted by the WMRC in the project area. The project was operational in four districts of Punjab namely Faisalabad, Toba Tek Singh, Nankana Sahib and Chiniot since 2012 and still is operational.

From above described areas, the data of wheat crop were collected from two districts (mixed cropping zone) namely Faisalabad and Toba Tek Singh, during the rabbi season 2013-14. A list of adopters of bed planting of wheat in the above said districts was taken from the WMRC. All of the adopters i.e. 60 were interviewed by using a well-structured questionnaire. The other 60 farmers (non-adopters) were purposively selected as the next door neighbor of the adopters so that uniformity in topography, soil type, soil fertility and distance from main road and market can be assured. Serial numbers were assigned to the questionnaires and data were entered into data analyzing software

Statistical Package for Social Sciences (SPSS)-17, Microsoft Excel-13 and Stata-12.

In the direction of descriptive statistics of collected data, the study found out different basic factors as percentages and frequencies for the farmers who used bed planting technology and their counterparts. To check the differences in various characteristics of adopters and non-adopters of bed planting technology for wheat crop, the two sample means were also compared.

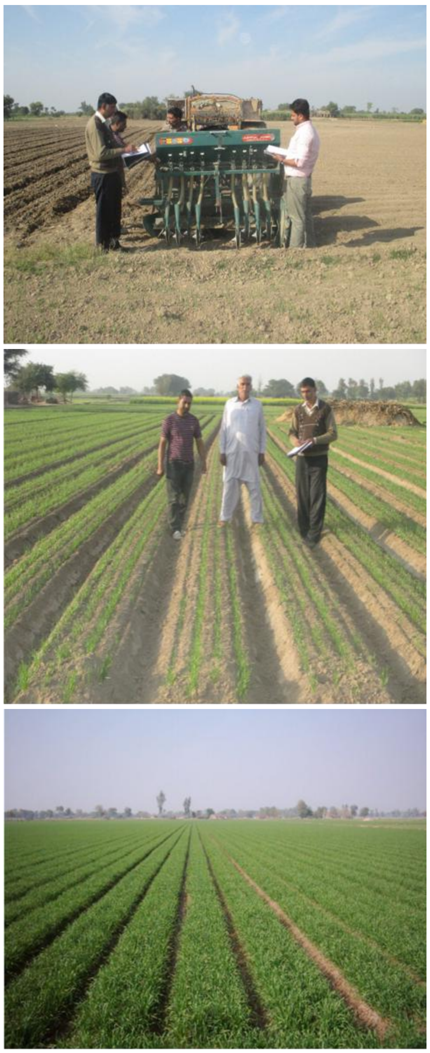

Figure 1. Field survey, 2013-14 in irrigated areas of Punjab

To identify the determinants of adoption for wheat bed planting, logit model (a standard limited-dependent variable approach) was employed, as it was best representative of the data on the basis of Akaike Information Criteria (AIC) and Schwartz Information Criteria (SIC) values. For this dichotomous type of variable, Maximum Likelihood Estimation (MLE) approach is the most suitable approach rather than classical linear regression methods (Greene, 2010). The MLE approach has many properties namely sufficiency, consistency, efficiency and parameterization invariance. However, no such thing is available in the least square estimation (Myung, 2003). Therefore, maximum likelihood approach was adopted (Herath and Takeya, 2003).

In this model, the dependent variable is dummy variable having value 1 for the farmers who adopted bed planting technology and 0 otherwise. The independent variables taken in the logit model were age (years), education (years), tenancy status (dummy), land holding (acres), family size (Nos.), ownership of tractor (dummy) and contact with extension agent (dummy).

The probability that a given farmer will adopt bed planting technology can be expressed as a function of X as follow

$$P(Y = 1) = P(X\beta_{BPT} + \varepsilon_{BPT} > X\beta_{NBPT} + \varepsilon_{NBPT}) = P[X(\beta_{BPT} - \beta_{NBPT}) > (\varepsilon_{BPT} - \varepsilon_{NBPT})] = P(X\beta > \varepsilon) = F(X\beta) \quad (1)$$

Here P is a probability function, $\varepsilon = \varepsilon_{BPT} - \varepsilon_{NBPT}$ is a random disturbance term, $\beta = (\beta_{BPT} - \beta_{NBPT})$, a vector of unknown parameters to be estimated and it is interpreted as the net influence of vector of independent variables on adoption of Bed Planting Technology (BPT), NBPT stands for non-adoption of bed planting technology and *F (Xβ)* is the cumulative distribution for *s* evaluated at *Xβ*. The maximum likelihood approach has been used to estimate the Logit model. The empirical Logit model used to estimate the impact of various factors on adoption of water conservation bed planting technology is given as under:

The relative odds of BPT versus NBPT by the wheat growers are given by:

For more detail about Logit model [Greene (2000); Wooldridge (2000)].

$$\frac{P(BPT/Z)}{P(NBPT/Z)} = \frac{[\exp(Z\beta + \varepsilon)]\,[1 + \exp(Z\beta + \varepsilon)]}{[1 + \exp(Z\beta + \varepsilon)]} = [\exp(Z\beta + \varepsilon)] \quad (2)$$

By taking logarithm on both sides,

$$\ln\left[\frac{P(BPT/Z)}{P(NBPT/Z)}\right] = Z\beta + \varepsilon \quad (3)$$

The logistic regression of adoption of bed planting technology is thus specified as a function of various socioeconomic variables as:

$$y_t = \beta_0 + \beta_1 Age + \beta_2 Educ + \beta_3 FSize + \beta_4 LHold + \beta_5 Trac + \beta_6 QLand + \beta_7 AExt + \beta_8 TStatus + \varepsilon_t \quad (4)$$

The equation 4 represents the log of odds of adoption of BPT for the *i*th farm, Age is the age of respondents in years, Educ shows years of schooling of respondents, FSize is the family size of the respondents in numbers, LHold is the land holding in acres whether own or rented, Tract is the dummy variable for having/not having the tractor, QLand is quality of land which is accessed based on farmer's perceptions about their land, AExt is the contact with extension agents and TStatus is a dummy variable of having/not having own land.

For economic analysis, the procedure adopted by Chaudhry *et al*. (1992) in estimating and subsequently apportioning the cost and returns of various items was used in the present study.

Gross margin was estimated for the purpose of making comparisons. The formula used to calculate the gross margins is as under:

$$\text{Gross Margin (GM)} = \text{Total Revenue (TR)} - \text{Total Variable Cost (TVC)} \quad (5)$$

Net Return was computed by total revenue less total cost. The formula of the net return is as under:

$$\text{Net Return (NR)} = \text{Total Revenue (TR)} - \text{Total Cost (TC)} \quad (6)$$

To estimate the impact of various factors of production (inputs) on yield of wheat, the following Cobb-Douglas production function in logarithmic form was used (Hassan *et al.,* 2005).

$$\text{Ln } Y = \beta_0 + \beta_1 \text{Ln } X_1 + \beta_2 \text{Ln } X_2 + \beta_3 \text{Ln } X_3 + \beta_4 \text{Ln } X_4 + \beta_5 \text{Ln } X_5 + \beta_6 \text{Ln } X_6 + \beta_7 \text{Ln } X_7 + \beta_8 \text{Ln } X_8 + \beta_9 \text{Ln } X_9 + \beta_{10} \text{Ln} X_{10} + \beta_{11} \text{Ln} X_{11} + \mu_i \quad (7)$$

Where Y= wheat yield in kgs per acre

X_1 = number of rotavator operations; X_2 = number of ploughing; X_3 = seed quantity in Kgs; X_4 = number of DAP bags; X_5 = number of urea bags; X_6 = number of irrigations; X_7 = per irrigation times in hours; X_8 = weedicide cost in Rs.; X_9 = manual labor in working hours; X_{10} = dummy variable 1 for adopters and 0 otherwise; X_{11} = total land holding in acres

μ_i = error term

RESULTS AND DISCUSSION

Socioeconomic and demographic characteristics of adopters and non-adopters of bed planting technology: The Tables 1 and 2 shows the average values of socioeconomic and demographic characteristics of adopters and non-adopters of bed planting technology. The data based on mean values of continuous variables indicated that adopters were young (31 years) compared to non-adopters of bed planting technology (44 years). The results showed that adopters had higher education level compared to non-adopters i.e. 10 and 6 years of schooling, respectively. Education is an important factor as it broadens farmers' intelligence and enables them to perform the farming activities accurately and efficiently. Moreover, better educated farmers tend to be more innovative and can use the resources efficiently (Fakoya *et al*., 2007). Summary statistics also explains that adopters possessed large land holding (30 acres) compared to their counterparts (13 acres). The average family size did not show any significant difference between two categories of farmers. However, non-adopters of bed planting technology had slightly more number of family members.

Table 1. Summary characteristics of adopters and non-adopters (continuous variables).

Variable	Units	Adopters (N=60)		Non-adopters (N=60)	
		Mean	SD	Mean	SD
Age	Years	30.63	10.72	44.10	12.30
Education	Years	9.90	2.69	5.68	4.58
Family size	Number	8.50	2.95	9.60	2.70
Land holding	Acres	29.28	20.39	12.83	6.73

SD is standard deviation.

The Table 2 explains the distribution of frequencies and percentages of categorical variables for adopters and non-adopters of bed planting technology having discrete values. The tractor ownership was included as dummy variable i.e., 1 for the owner and 0 for the rented. The results showed that 65 percent of adopters of bed planting had their own tractors while only 20 percent of the non-adopters were owner of their tractors. Most of the non-adopters had to rent in tractors for wheat cultivation. None of the farmer had high soil quality so that this variable contains value 1 for medium soil and 0 for low soil quality. This did not show significant difference due to the fact that adopters and non-adopters were interviewed in the same villages. Adopters of bed planting technology had more contact with extension agents compared to non-adopters. Tenancy status refers to the total land acreages that a farm household owned or acquired on rent basis. Analysis showed that most of the adopters had their own land (72%) while only 10 percent of the non-adopters were the owners of their land.

Table 2. Summary characteristics of adopters and non-adopters (categorical variables).

Variable	Item (Dummy)	Adopters (N=60)		Non-adopters (N=60)	
		N	%	N	%
Tractor	Own=1	39	65	12	20
	Rented=0	21	35	48	80
Soil quality	Medium=1	30	50	28	47
	Low=0	30	50	32	53
Access to extension services	Yes=1	35	58	29	48
	No=0	25	42	31	52
Tenancy status	Own=1	43	72	6	10
	Own-cum-tenant=0	17	28	54	90

N is number of respondents

Source: Own computation from survey results, 2014.

Determinants of adopters of bed furrow irrigation in wheat production: The results of logit model explained in equation 4 represents that coefficient of age was negative and significant at 10 percent level of significance, indicating that young farmers were more likely to adopt this technology as compared to old aged farmers. The education coefficient was positive and highly significant indicating that higher literacy level plays a significant and positive role in the adoption of raised bed technology. The access to extension services was included as dummy variable. The coefficient of this variable was positive but non-significant. This non-significance may be due to week linkages and poor access of the extension agents to the updated technologies. The parameter of household size had negative coefficient and statistically non-significant that implies no effect in adoption of raised bed technology.

The tenancy status was included as dummy variable i.e. one for the owner and zero for the tenant. The tenancy status coefficient was positive and highly significant. It explains that farmers having their own land take early initiatives to adopt new technology and are more risk bearers compared to the farmers not having their own land. The coefficient of land holding was positive and highly significant at 5 percent level of significance. The tractor ownership also represented a positive and significant association with the adoption of bed planting technology in wheat crop. As land holding and mechanization is considered a healthy indicator of household wealth, so it can be safely concluded that the farmers having a large resource base can more likely to adopt any new technology. Soil quality was included as dummy variable in the model i.e. one for medium soil quality and zero otherwise. This variable showed a positive but non-significant result. It may be due to the fact that all of the adopters and non-adopters were interviewed from the same villages/localities so they have more or less the same soil quality, indicated an insignificant response. These results are in line with that of Taj *et al*. (2013). The value of R^2 was estimated to be 0.69 which explains that 69 percent probability to adopt this technology was due to the factors included in the model.

Table 3. Logit model for the determination of factors affecting the adoption of bed planting technology (marginal effects).

Variables	Dy/dx	Std. Error	Change in Probability
Age	-0.019	0.011	0.081*
Education	0.061	0.026	0.020**
Access to extension service	0.024	0.188	0.899^{NS}
Family size	-0.059	0.039	0.129^{NS}
Soil quality	0.056	0.196	0.774^{NS}
Land holding	0.044	0.015	0.003**
Tenancy status	0.56	0.132	0.001***
Tractor ownership	0.327	0.172	0.057**
LR χ^2 (8)	116.44***		
Pseudo R^2	0. 69		
Log likelihood	-24.96		

Note: ***, **, and * are statistically significant at 1%, 5%, and 10%, respectively.

Source: Own computation from survey result, 2014.

***Economic comparison of wheat production under bed planting and conventional sowing*:** Table 4 and 5 indicates the economic analysis of adopters and non-adopters of bed planting technology of per acre wheat production for cropping season 2013-14. Table 4 explains the average yield and inputs applied to one acre of wheat in unitary terms. As for as the land preparation and cultural operations are concerned, number of ploughing and planking for adopters was slightly less than non-adopter of bed planting technology. While the number of rotavator operations are more in case of adopters. This operation is considered more important for land levelling before the cultivation of wheat through bed planter. There was a large variation in seed sown on beds through bed planter and in flat sowing. The average seed rate used to be 38 and 49 Kg per acre for bed planting and conventional sowing, respectively.

The average number of bags of DAP and urea were used to be 1.12 and 1.59 by adopters and 1.52 and 1.62 by non-adopters, respectively. NPK applied by farmers known to be 0.4 and 0.5 bags for adopters and non-adopters. There was little difference in the number of irrigations applied to wheat crop between adopters and non-adopters. It was observed that adopters of bed planting technology were using more number of irrigations but per irrigation average time was less. The hours worked by permanent hired and family labor for wheat crop were 27 and 32 for adopters and non-adopters, respectively. The average wheat yield per acre on bed furrow irrigated and conventional irrigated farms were 1760 and 1600 kgs respectively, showing a direct positive relationship of bed planning on wheat yield. Table 4 shows that the wheat sown under bed furrow irrigation saves inputs and increases per acre yield.

Table 4. Input use in wheat production under bed planting and conventional sowing.

(Per acre basis)

Item	Unit	Adopters	Non-adopters
Land Preparation			
Rotavator	Nos.	0.51	0.43
Ploughing	Nos.	3.37	4.57
Planking	Nos.	1.63	1.69
Seed application			
Seed Rate	Kgs.	37.69	49.40
Fertilizers			
DAP	Bags	1.12	1.52
Urea	Bags	1.59	1.62
Other (NPK)	Nos.	0.40	0.52
Irrigation			
Canal	Nos.	2.86	2.03
Tube well	Nos.	1.83	0.94
Per Irrigation Time	Hrs./ Irrig.	0.85	1.15
Other item			
Manual Labor	Hrs	27.21	32.11

Product			
Yield	Kgs	1778.40	39.82

Source: Own computation from survey result, 2014.

Table 5 segregated the Total Cost (TC) into Total Variable Cost (TVC) and Total Fixed Cost (TFC). Total fixed cost included the fixed water charges (Abiana) and land rent. The total cost, total revenue and gross margins were calculated for both categories of farmers. In the study area, total cost of production for one acre of wheat includes land preparation, seed, fertilization, plant protection (weedicide), manual labor charges, irrigation cost, harvesting and threshing. Total variable cost also includes opportunity cost (markup @ 4% i.e. close to real interest rate prevailing in Pakistan) incurred on inputs from land preparation to fertilizer application and manual labor.

Table 5. Total cost, gross margin and net returns in wheat production under bed planting and conventional sowing for cropping year 2013-14.

(per acre basis)

Item	Unit	Adopters	Non-adopters
Land Preparation			
Rotavator	Rs.	861.43	692.30
Ploughing	Rs.	2240.56	2842.67
Planking	Rs.	499.04	514.14
Seed Application			
Seed Cost	Rs.	1870.00	1769.01
Plant Protection			
Weedicide	Rs.	886.57	815.83
Fertilizers			
DAP	Rs.	4161.48	5629.36
Urea	Rs.	2921.76	2982.75
Other (NPK)	Rs.	1032.50	1764.29
Irrigation (Tube well)	Rs.	668.26	726.97
Other Costs			
Markup *(@ 4 % i from land prep. to fert. appl. and manual labor)*	Rs.	313.86	355.71
Manual Labor Charges	Rs.	2198.44	2615.83
Harvesting	Rs.	3728.57	3657.50
Threshing	Rs.	4305.71	4455.00
Total Variable Cost	Rs.	26239.75	28869.36
Abiana	Rs.	50.00	50.00
Land Rent	Rs.	12957.14	12342.86
Total fixed cost	Rs.	13007.14	12392.86
Total Cost	Rs.	39246.89	41262.22
Total Revenue	Rs.	64424.75	58274.54
Gross Margin	Rs.	38185.00	29405.18
Net Return	Rs.	25177.86	17012.32

Source: Own computation from survey result, 2014.

Total cost of production for one acre of wheat was less for the adopters compared to non-adopters i.e. Rs. 39247 and 41262, respectively. It was explained in Table 4 above that the large number of inputs were saved in bed planting cultivation which reduced per acre total costs of production. The average seed rate was less for bed planting with cost of Rs. 1870 compared to Rs. 1769 for non-adopters. This slight increase in cost was due to the reason that adopters of bed planting were mostly using the certified seed rather conventional seed. Conversely, more number of irrigations was applied to wheat crop in case of bed furrow irrigation method but it incurred less cost of tube well irrigation due to less time required to irrigate the wheat under bed planting.

Table 5 further shows the total revenue and gross margins from one acre of wheat was significantly high for adopters compared to non-adopts of bed planting. It was due to more wheat yield (<185.6 kgs) in case of wheat under bed planting. That earned revenue of Rs. 64,425 compared to Rs. 58,274 for non-adopters. Gross margin for adopters and non-adopters was calculated to be Rs. 38,185 and 29,405, respectively. Similarly, net returns were Rs. 25,178 and Rs. 17,012 for adopter and non-adopters of bed planting technology, respectively. The whole picture depicted the absolute advantage of bed planting technology over traditional sowing of wheat.

***Regression Analysis for Wheat in the Study Area*:** The impact of physical inputs and some other variables on wheat yield has been presented in Table 6. The signs of coefficients were found to be as per expectation. The land holding was highly significant which explains that large land holding enable the farmer to produce more agricultural output by increasing the per acre yield. The coefficient of the quantity of seed sown and irrigation time were significant at less than 5 percent level; coefficients of ploughing and urea explained significance at less than 10 percent while other variables as rotavator, DAP, number of irrigation, weedicide and manual labor were found to be non- significant.

The magnitude of coefficient of seed quantity was -0.404 indicated that 1 percent increase in seed application reduced the wheat yield by 0.40 percent. As in the model both adopters and non-adopters were taken together and for traditional sowing the recommended seed rate are higher compared to bed planting. The results already showed a higher per acre yield for adopter than the non-adopters. So this result clearly strengthens the earlier findings as more seed used for traditional sowing, less per acre yield was observed. Similarly, irrigation time variable showed that on the average one percent increase in irrigation time decreased the wheat yield by 0.09 percent. The regression results of irrigation time also complimented the previous results as more time is required to irrigate one acre of wheat crop in

Table 6. Summary statistics of analysis of wheat yield (Cobb-Douglas production function).

Item	Units	Coefficient	Standard Error	t-stat	Level of Significance
Intercept		6.471	1.179	5.487	0.000***
Rotavator (X_1)	Nos.	-0.009	0.021	-0.448	0.655^{NS}
Ploughing (X_2)	Nos.	0.006	0.013	0.498	0.0620*
Seed Quantity (X_3)	Kgs.	-0.404	0.093	-4.333	0.001***
DAP (X_4)	Bags	-0.015	0.017	-0.870	0.386^{NS}
Urea (X_5)	Bags	0.035	0.020	1.803	0.074*
Irrigation Number (X_6)	Nos.	-0.029	0.051	-0.568	0.571^{NS}
Irrigation Time (X_7)	Hrs.	-0.087	0.021	-4.151	0.002***
Weedicides(X_8)	Rs.	0.019	0.040	0.479	0.633^{NS}
Manual Labor (X_9)	Hrs.	-0.166	0.181	-0.920	0.360^{NS}
Adoption (X_{10})	Dummy	0.093	0.030	3.152	0.002**
Land Holding (X_{11})	Acres	0.046	0.013	3.589	0.001***
R^2	0.678				
Adjusted R^2	0.645				

Note: ***, **, * and NS are statistically significant at 1%, 5%, 10% and non-significant, respectively.
Source: Own computation from survey result, 2014.

case of traditional sowing. The per acre yield was found to be less for non–adopters represented in Table 4, supported the negative relationship between irrigation time and wheat yield.

The coefficient for the urea variable was significant with a positive magnitude of 0.035. This indicated that on an average one percent increase in the urea (bags) increased the wheat yield by 0.035 percent. It has also been observed during field surveys that most of the farmers under dose of urea fertilizer to wheat due to which they could not obtain the desired yield. More the urea fertilizer farmers applied, more the per acre wheat yield they got. Ploughing was another important variable in the study area as the wheat crop mostly being grown after sugar cane, rice, maize or cotton. Land preparation becomes a hard task to sow wheat after harvesting these crops. So the coefficient of ploughing showed a positive and significant relationship with wheat yield. Wheat sowing was mostly delayed due to late harvesting of kharif crops as little time was available for the land preparation and the farmer apply less cultivation to land. The results showed that wheat yield can be increased by 0.01 percent by increasing 1 percent ploughing.

The dummy of adopters and non-adopters of bed planting was also regressed on wheat yield. The dummy variable for adoption was included in the model having value 1 for adoption of bed planting and 0 otherwise. The coefficient of this variable showed a positive sign with high significance level. The results explained that farmers who adopted bed planting for wheat enjoyed about 10 percent higher wheat yield than the non-adopters.

The value of the R^2 was 0.68, indicated that 68 percent variation in wheat yield is explained by the factors included in the model i.e. equation 7. The Cob-Douglas regression equation was developed as under:

$$\text{Ln } Y = 6.471 - 0.009\, X_1 + .006\, X_2 - 0.404\, X_3 - 0.015\, X_4 + 0.035\, X_5 - 0.029 X_6 - 0.087\, X_7 + 0.019\, X_8 - 0.166\, X_9 + 0.093\, X_{10} + 0.046\, X_{11}$$

***Conclusions*:** The results of economic analysis showed that per acre wheat production under beds were generating higher outcomes as compared with conventional sowing because of more wheat yield and less total cost. Further, the production function indicated that magnitude of irrigation time and quantity of seed were significant and negative in sign indicating wheat yield can be increased by applying less quantity of seed and saving irrigation time. Moreover, increase in the urea quantity and more number of ploughings also contributed in increasing the wheat yield. The results of production function as well as economic comparison showed that all this can only be possible when wheat is cultivated under the bed planting technology. The results of the logistic model indicated that young and educated farmers are more likely to adopt bed planting technology as compared to old aged farmers. The coefficients of land holding, tenancy status and tractor ownership are positive and significant. Therefore, it can be concluded that more access to education along with young and resource base household increases the chances of adoption of the raised bed technology.

The need of the time is to allocate more resources and efforts to divert media towards creation of awareness among the farming community about conservation of natural resources. Steps should be taken by the Department of Agricultural Extension and Agricultural Universities in setting up radio channels on agriculture to disseminate new technologies and production practices. It is also recommended that Agricultural Services Providers (ASPs) and progressive farmers should be provided bed planter on subsidized rate in order to suffice the large farming communities for the adoption of bed planting to save large amount of irrigation water. There is need to train and educate Agricultural Services Providers (ASPs) regarding the use of bed planters so that dissemination and adoption of this technology can be ensured on sustainable basis.

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