Research Article

Does Cotton Crop affect the Wheat Crop Efficiency and Productivity? Case Study of Rahim Yar Khan District, Pakistan

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Abstract | The study was aspired to investigate the factor of production that were influencing the technical efficiency of wheat crop in Pakistan. A formal survey of 430 wheat crop farmers was conducted in the district of Rahim Yar Khan in year 2014. In order to estimate the impact of farm inputs on wheat crop production, Stochastic Frontier Analysis (SFA) was used. The major objectives of this survey were to identify factors of variation and effect of planting of wheat after BT and Non-BT-cotton varieties on wheat production. In this study, the average technical efficiency of wheat farms on collective level was around 0.76. The mean technical efficiency of wheat after Non-BT and BT-cotton was 0.78 and 0.74, respectively. The result of the study revealed that those farmers cultivated the wheat crop after Non-BT cotton were technically more efficient compared to those who cultivated wheat after BT-cotton. The major factors that were found to be compliant for improved wheat production in study area were operational holding under wheat crop, which was cultivated after Non-BT or BT cotton, date of sowing, number of irrigations, tractors and tubewell's ownership, tenancy status, farmer's education and experience. The result of the study reported that farmers of wheat crop have the potential to produce the maximum level of wheat production provided that the farmers should improve their management skills. It is prerequisite in farm sector that farmers should use their managerial ability, knowledge, and technical skills in order to obtain the higher production and farm returns.

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Introduction

Agriculture sector in Pakistan plays persuasive and vast share in GDP of Pakistan. However, this sector is undergoes the problem of yield variation, low production and unpredictability due to inept consumption of scarce farm resources. The yields of wheat crop in Pakistan are comparatively lower than other agriculturally advanced countries. The future gains in wheat production depends on the improvement of supplementary agricultural based resources which are illustrated by Ahmad et al. (2002) and Fatima et al. (2015). According to economic survey of Pakistan, compared to last year (2016-17) wheat crop production (25.674 million tons), in year 2017-18 wheat crop production was decline around 4.4 percent. The contribution of wheat crop in farm sector of Pakistan is about 9.1 percent and 1.7 percent of GDP of Pakistan. In year 2017-18, wheat crop was sown around 8,734 thousand hectares indicating about 2.6 percent diminution related to previous year's area of 8,972 thousand hectares. Crops in general and wheat in particular plays a persuasive role in order to stimulate economic progression of

industrial sector of Pakistan due to the existence of backward and forward linkages in both sectors. The domestic consumption of wheat crop in Pakistan is around 9 percent. In rural sector of Pakistan, wheat is one of the major consumption items. In case of urban sector, after housing, wheat is the subsequent consumption item in Pakistan, GoP (2005).

According to Ahmad (2003) farm sector generally plays a leading role in suppression of poverty in less developed countries. But the problems of low farm productivity and rapid growth in population result in shortages of food supplies and industrial crops. The shortages of farm produces eventually increase the food and fiber prices and mostly push the growing ration of the population further down to the line of poverty. In Pakistan, a number of time, the demand of wheat crop was greater than supply resultantly the supply of wheat crop was not being able to fulfilling the nation's demand. Hence, import of wheat crop in order fill the supply and demand gap is the last resort (Ahmad et al., 2002). First time in year 2000, Pakistan entered to the world market to export wheat crop into the markets of Iraq. The amount of export varies around the years. Apart of exporting, Pakistan also constantly importing the wheat crop. In year 2012, Pakistan import around 200 million tons of wheat crop. (PARC, 2013). Pakistan spends huge foreign exchange for wheat import to meet food requirement of growing population (Akhter et al. 2006).

According to Ahmad (2019) the yield gap in Pakistan is around 79% to 45% between progressive and small scale farmers. Whereas wheat yield gap is turn out to be relatively more widen, when it is equated with global scale. Approximately average wheat yield of progressive and small scale farmers per hectare is around 4.6 and 2.6 tons per hectare in Pakistan. According to Aslam (2016) the average wheat yield in Pakistan is about 2.26 tons/ha and best practice wheat farms yield is around 4.50 tons/ha. Prikhodko and Zrilye (2015) reported that wheat yield in Pakistan is still low compared to the countries who share the matching agro-climatic settings. Given agro-ecological condition, Pakistan might be realized around 6 tons' wheat yield per hectare.

According to a report of Pakistan Agricultural Research Council (PARC) by 2030 the requirement of wheat crop would be greater than before, which is around 34.25 million tons. Currently, Pakistan has 60% wheat yield gap, which is need to be overcome with the aid of well-organized farm management practices on existing farm land. It is desirable to put maximum efforts towards expanding the average yield of wheat crop. In order to fulfill the future wheat crop requirements and evade the chances of wheat crop import in Pakistan, it is need of the hour to avoid the late wheat crop plantation, as it is one of the important determinants that affect the quality and quantity of wheat grain. In wheat-cotton growing areas, where both crops are planted subsequently by and large result in late sowing of wheat crop. Randhawa (1979), Hobbs (1997) and Ahmad et al. (2002) argued that wheat yield declined by 30-40 kg/ha for each day delay after 15 November. On the other hand, inefficient application of fertilizer and pesticide sprays, application of water on time and availability and accessibility of latest agro-based technology to farmers. Efficient and productive part of extension services system in Pakistan is also vital to accomplish the future objectives of improved wheat yield per hectare. Numerous studies such as Croppenstedt (2005), Kamruzzaman and Islam (2008), Javed et al. (2009) conducted the efficiency analysis of wheat crop in order to ascertain the dynamics that impact contrariwise on wheat crop production. The one of the key objectives of the current study is to investigate the implications of emerging BT cotton system on wheat cropping systems. Second, to identify factors influencing wheat productivity.

Materials and Methods

A formal survey of wheat crop was conducted in district Rahim Yar Khan in year 2014 cotton-wheat cropping season. The data were collected from those farmers who were cultivating wheat crop after Non-BT and BT cotton. The survey of this study was conducted to find out the factors of variation and special problems of planting of wheat after Non-BT and BT-cotton that limiting the wheat productivity. In study area, cultivating wheat crop after cotton is a foremost crop rotation mode. This study is a primary research and had utilized the interview based questionnaire method to gather the data from the farmers. In building up the questionnaire the main focus was confined to wheat and cotton crop. The population of this research encompasses the area of district *Rahim Yar Khan*, Punjab Pakistan. Where 430 farmers were selected who were adopted the cotton-wheat cropping system. Hence, data were collected

from those fields where wheat crop was planted after BT and Non-BT Cotton.

To evaluate the technical efficiency of wheat growers in study area, technical efficiency analysis has been used. Efficiency is a comprehensive term containing different kinds of it for instance allocative efficiency, technical efficiency and economic efficiency. Allocative efficiency refers to measuring of modification of inputs with regards to output, throwing light on prices. Economic efficiency includes technical as well as allocative efficiency. A firm is said to be efficient after adding up of technical and allocative efficiency. After the work of Farrell (1957), measuring inefficiency goes along frontier functions. The difference between level shown on the frontier and actual values of variables under study is known as inefficiency. Meeusen and Broeck (1977) and Aigner et al. (1977) contemporaneously introduced stochastic frontier model. They defined production frontier as a mix of inputs to attain maximum level of production, meaning that a firm can be on the frontier only if production reaches maximum level with the given set of inputs. A firm on the frontier is known to be technically efficient. Those firms which fail to come on the frontier are inefficient. It is inconvenient to calculate production function in case when firm is producing more than on output, frontier approaches are the best possible option as used by in farm sector. These models can be accredited to Gathon and Perelman (1992) and Filippini and Maggi (1993).

Stochastic production frontier model, analyze the technical efficiency of wheat crop production of current study in two steps. The first step involves calculating frontier framework through maximum likelihood and the second one assembles efficiency or inefficiency from the calculated model. Individual estimates provide the basis of comparison among firms or in absolute terms. Cross-sectional data of wheat crop after the plantation of BT and Non-BT cotton is based on model of inefficiency in stochastic production frontiers, is formed on the model of Battese and Coelli. The model is stochastic because of inefficiency, shocks or measurement faults.

$$Y_i = f(X_i\beta)\exp(V_i - U_i) \quad (1)$$

Where;
$Y_i = f(X_i\beta)$ is the stochastic frontier wheat production function. The term V_i is independent and has equally distributed random errors having mean zero and unknown variance. U_i are unobserved random errors linked with technical inefficiency. In order to measure the effect of technical inefficiency and random errors distinctly, the stochastic production models stochastic part facilities the researchers to do it separately. The stochastic production model comprises of production inefficiency effect and random errors. These two are pointing out to two different kinds of random errors which are not linked with output and input quantities. Inefficiency variables are a set of explanatory variables calculated with stochastic frontier. The U_i term is the inefficiency effects equated as:

$$U_i = \delta_\circ + \delta_i Z_j + \omega_i \quad (2)$$

Whereas;
U_i is a vector showing potential and actual determinants whereas, ω_i transmits normal distribution having mean value as zero. The term δ_i is a vector that captures the unobservable unknown variables Methods for determining technical efficiency used by various parametric pool of studies, is facing disagreements. Identical distribution assumption used in the first stage is contradictory to the regression technical inefficiency model.

The Equation 3 represents the disagreement was resolved by Battese and Coelli through simultaneously estimating stochastic frontiers and inefficiency model. Ratio of maximum output to calculated output reports s the level of technical efficiency of each farm and the value of it varies between zero to one. The Y_i term represents the observed wheat output whereas Y_i^* term shows the maximum wheat output compared to actual output (Y_i) that would be possible at given level of available farm inputs.

$$E = \exp(-U_i) = \frac{Y_i}{Y_i^*} \quad (3)$$

The wheat crop production model is based on Cobb-Douglas production function. For minimizing restraining properties on production process, translog production function was comparatively tested with Cobb-Douglas functional form. The result of translog production model highly influenced by the problem of multicollinearity. Hence, Cobb-Douglas production functional form is used for the estimation of wheat production.

The empirical model of wheat production frontier is written as:

$$\ln Y_i = \ln \beta_0 + \sum_{j=1}^{9} \beta_j \ln X_j + V_i - U_i \quad (4)$$

The empirical analysis of wheat crop is based on per acre. In Equation 4, Y_i represents wheat output per acre of selected farms in study area. One of the major variables that included in this study is the impact of BT and Non-BT cotton on wheat crop (X_1) used as a dummy variable, where the value of dummy variable =1 shows that wheat crop planted after BT cotton and value of dummy variable = 0 represents the wheat crop planted after Non-BT cotton. The impact of wheat crop plantation after BT and Non-BT cotton variable isone of the most distinguish factors. It makes the present study different from all other studies that estimated the technical efficiency of wheat crop in Pakistan and around the globe. The other variables that are included: area under wheat crop (X_2), wheat crop sowing week (X_3), days allocated for land preparation before wheat seed sowing (X_4), Cost of weedicide spray is used as a proxy variable for weedicide spray (X_5), total number of irrigation for wheat crop (X_6), Ratio Nitrogen (N) and Phosphors (P) fertilizer for wheat crop (X_7), seed rate (Kg) (X_8) and number of ploughing and planking for wheat crop (X_9).

The technical inefficiency model for wheat crop is also estimated in order to understand the impact of socio-economic background and farm management of farmers on technical efficiency of wheat crop. This analysis is accommodating in isolating the foundations of farmer's inefficiency and impact of production inputs (fertilizer, pesticide, seed, labor etc.) on wheat production. The wheat crop technical inefficiency model is given in Equation 5 as:

$$U_i = \delta_0 + \sum_{i=j}^{7} \delta_i Z_j \quad (5)$$

Where;
U_i symbolizes the technical inefficiency of each selected wheat farm in existing study. The symbol Z_i signifies the factors (i.e. socio-economic and farm management variables) that might have an impact on wheat crop technical efficiency. Where Z_1 represent wheat farmers years of education, Z_2 represent Farmer's age , Z_3 denotes farming experience in years, Z_4 contains the dummy variable, where value =1 and value =0 shows the crop sale in village or crop sale in market, respectively. The variable Z_5 is also constructed as a dummy variable, where value =1 represents if farm tubewell is on rent, otherwise zero. The variable of Z_6 represents tractor ownership status, where the value =1 shows that tractor is on rent, otherwise zero (owned by farmer). In wheat inefficiency model, Z_7 and Z_8 variables are used as dummy variables which represents the tenancy status of wheat farmers. The variable of farm ownership (farmer owned the wheat farm) is used as base category in both variables of tenancy status (tenant and owner-cum-tenant). The value =1 in Z_7 shows that wheat farmers is tenant, otherwise zero. In Z_8 variable, the value =1 shows that farmers is owner-cum-tenant, otherwise zero.

Results and Discussion

The Table 1 reports the estimates of Maximum Likelihood Estimation (MLE) of wheat crop stochastic production model. Where wheat frontier production model contains 9 and wheat inefficiency model holds 8 parameters, respectively. The Table 1 is also comprehend the parameters such as Vi and U_i, which are associated with variance parameters of wheat production stochastic model. The gamma value in Table 1 reports all the variations in farm technical efficiency that are institute in wheat production process.

To examine the effect of planting of wheat crop after BT and non-BT cotton o nwheat crop technical efficiency dummy variable is introduced in the wheat production frontier model that defined as '1' if wheat crop planted after BT-cotton, otherwise Non-BT cotton. The parameter estimates of wheat planted after BT or non BT cotton in Table 1 carries negative sign and has a significant impact on wheat production. This result indicates that production of wheat crop tends to decline as wheat crop planted after BT-cotton. The major cause behind this result is that BT-cotton is generally planted over an extended period of time, hence resulted in late plantation of wheat crop. This late plantation adversely affect the productivity of other farm inputs that are used in wheat production process. Such as: less time available for land preparation, lesser time for sowing bed preparation, and other activities related to land preparation. On the other hand, farmers have lesser number of irrigation, lesser time for fertilizer and pesticide application. Hence, long duration of BT-cotton

Table 1: *OLS and maximum likelihood estimation of the cobb-douglas stochastic production frontier.*

			OLS	Frontier function	
Variables	**Parameters**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Stochastic Production Frontier					
Constant	β_0	-1.4765	-0.3220	-1.0951	-0.3098
DNonBt/Bt	β_1	-0.1244	-1.9094	-0.1506	-2.6639***
Ln(Warea)	β_2	0.0416	4.9993	0.0347	5.1459***
Sowing	β_3	-0.6744	-2.1101	-0.4871	-1.9170**
Ln(land pre days)	β_4	1.2500	4.4132	1.1473	5.6013***
Ln(weedcost)	β_5	0.1197	5.7473	0.0852	4.8883***
Ln(irri)	β_6	0.2643	5.4066	0.1317	2.9588***
NP ratio	β_7	0.1988	2.8493	0.1885	3.1819***
Ln(seed)	β_8	-0.0511	-0.5013	-0.0280	-0.2593
Ln(Plough)	β_9	0.1862	5.3629	0.1446	5.1249***
Variance Parameters					
Sigma squared	Σ			0.1637	3.8060
Gamma	Γ			0.9226	37.651
Log Likelihood function		-37.201		26.614	
Inefficiency Model					
Variables		Parameter	Coefficient	t-ratio	
Constant		δ_0	-1.7876	-1.6956*	
Educ		δ_1	-0.3339	-2.2261**	
Exp		δ_2	-0.1404	-1.8300*	
Age		δ_3	0.3253	1.8220*	
Crop sale		δ_4	0.2881	2.9434***	
Tubewell		δ_5	0.3606	2.6048***	
Tractor		δ_6	0.2019	2.1051**	
Tenant		δ_7	-0.6724	-2.4409**	
Owner-Tenant		δ_8	-0.3687	-1.5166	

****: 1% significance, **: 5% significance, *: 10% significance.*

standing is one of the major reasons that effect negatively to the production of wheat crop in study area.

The coefficient of area under wheat crop reported in Table 1 shows positive impact on wheat production. This result indicates that an increase in the area under wheat crop would significantly increase the production of wheat crop in selected study area. This finding is also highlighted the fact that in Pakistan increasing the area under crops is still the key solution to increase the farm production. In recent times increasing the farm production by increasing the land area under production is not a justifiable solution. It is desirable that to look into the most efficient and progressive methods of production in order to increase the wheat productivity in Pakistan. Earlier study of Basnayake and Gunaratnen (2002) found the alike result in Scottish farms that are engaged in production of cereal crops. Hassan (2005) also found the parallel impact of farm size on wheat producing farmers in Pakistan.

To see the impact of sowing timing on wheat production, this study used a variable which is defined as the sowing week of wheat crop. The parameter of estimate of sowing week is negative and significant. The result of the study reported that each week consecutive delay in plantation/sowing of wheat seed after the month of November has adverse impact on quality and mass of wheat grain. According to Blue et al. (1990) delayed planting of wheat influence the growth and performance of wheat plant, and eventually resulted in reduced wheat production. In study area, after the adoption BT cotton variety of cotton crop, farmers are incessantly facing the problem of late

planting of wheat after cotton crop harvesting. This late planting eventually imbalances the physiological development of wheat crop. Hence, most of the farmers are failed in sustaining the high-quality and production of wheat due to late sowing of wheat crop. According to Khan and Salim (1986) and Ansari et al. (1989) timely planting of wheat crop resulted in higher yield and improved quality of wheat grain.

Table 2: *Elasticity of production and return to scale.*

Variables	Parameters	Elasticity
DNonBt/Bt	β_1	-0.2862
Ln(Warea)	β_2	0.0347
Sowing	β_3	-0.4871
Ln(land preparation days)	β_4	1.1473
Ln(weedcost)	β_5	0.0852
Ln(irri)	β_6	0.1317
NP ratio	β_7	0.1885
Ln(seed)	β_8	-0.0280
Ln(Plough)	β_9	0.1446
Return to Scale		0.9307

In order to attain the greater crop production, farmers' consideration about land preparation activities is a fundamental step towards the realization of improved land productivity and alternatively higher farm production. The coefficient of land preparation days for wheat crop has positive sign and statistically significant. Hence, timely and well managed land preparation of wheat field, significantly aid in increasing wheat production.

The coefficient of weedicide cost variable reported in Table 1 demonstrates it's positive and strong influence on wheat production. Weedicide cost variable is used as a proxy variable of weedicide sprays. This result is according to our expectations, rapid growth of weeds in study area is one of the problems that stimulus the growth of wheat crop. As a remedy, famers of the study area are applying greater number of weedicide sprays. Due to this reason, farmers are prepared to endure higher cost for the suppression of weeds from their farms. Prior study of Hassan and Ahmad (2005) also found positive and significant association between weedicide cost and wheat yield. Therefore, improved and on time farm management practices in order to restrain the weeds growth has the added positive impact on wheat production.

Proper and well-timed accessibility of water has the dynamic impact on wheat production as well as on other production, particularly on fertilizer and seed. The coefficient of number of irrigation in Table 1 has significant and promising impact on wheat production. The magnitude of the parameter estimate reports the increasing trend in wheat production as number of irrigation increases. Bashir et al. (2004) also stated that basic reason of low wheat yield is the shortage of water at critical stages of wheat crop. Earlier studies of Hassan (2004), Ahmad et al. (1998) and Ahmad (2002) also found the positive impact of irrigation on wheat prodution.

The coefficient of NP ratio in Table 1 reports its positive and significant impact on wheat production. The required and balanced quantity of fertilizer would have increase the wheat production in study area. According to Salam (1981) intensive use of fertilizer on wheat crop is one of the major sources of higher wheat yield. According to Battese et al. (1996), Ahmad et al. (2002) Hassan and Ahmad (2005), Ghaderxadeh and Rahimi (2008), Sekhon et al. (2010) and Fatima et al. (2015) also found that the appropriate use of NP fertilizer would positively influence the wheat production and efficiency.

The coefficient of seed rate (Kg.) in Table 1 reports negative but insignificant impact on wheat production. This result pointed out the excessive application of wheat seed per acre in study area. By and large in Pakistan, the recommended use of wheat seed rate is around 45 to 50 per acre. The undue application of wheat seed is only results in higher cost of production, without having any supplementary addition on wheat production. Earlier studies of Sekhon et al. (2010) and Hassan (2005) also found the negative and insignificant relationship in between seed rate and wheat production. However, Battese and Hassan (1999) found negative and significant influence of seed rate on wheat production. Rafique et al. (2010) stated that disproportionate application of seed input simply augment the cost of production. Instead of applying the additional quantities of seed, it is needed that farmers adopt new and high yielding varieties of wheat seed which in turn upsurge the wheat yield per acre. According to Forster et al. (2017) effects of delayed wheat planting on wheat yield would not be preserved by increased seed rate. Pfeiffer et al. (2000) pointed out that proper farm management and agronomic practices might be effective to overcome the impact of late planting of wheat crop.

Table 3: *Frequency distribution of technical efficiency of wheat farmers.*

Over all			Non BT wheat			BT wheat		
Efficiency level	Frequency	%	Efficiency level	Frequency	%	Efficiency level	Frequency	%
<0.20	0	0.00	<0.20	0	0.0	<0.20	0	0.0
0.21 -0.30	1	0.23	0.21 -0.30	0	0.0	0.21 -0.30	1	0.5
0.31-0.40	10	2.33	0.31-0.40	4	1.9	0.31-0.40	6	2.8
0.41-0.50	21	4.88	0.41-0.50	7	3.3	0.41-0.50	14	6.5
0.51-0.60	36	8.37	0.51-0.60	15	7.0	0.51-0.60	21	9.8
0.61-0.70	69	16.05	0.61-0.70	33	15.3	0.61-0.70	36	16.7
0.71-0.80	74	17.21	0.71-0.80	33	15.3	0.71-0.80	41	19.1
0.81-0.90	138	32.09	0.81-0.90	71	33.0	0.81-0.90	67	31.2
>0.90	81	18.84	>0.90	52	24.2	>0.90	29	13.5
Total	430	100	Total	215	100	Total	215	100
Mean	0.76		Mean	0.78		Mean	0.74	

The coefficient of number of ploughing in Table 1 demonstrates significant and positive impact on wheat production. This result illustrates that systematically arranged seed bed with the help of well managed land ploughing boost the efficiency of land and soil quality, and assertively impact the wheat production process. This result is in line with former studies of Battese et al. (1996) and Hassan and Ahmad (2005).

In order to examine the factors (i.e. socio-economic and farm management) that impact on the technical efficiency of wheat production, this study estimated the wheat crop technical inefficiency model which is reported in Table 1.

In earlier studies such as Ahmad et al. (2002) and Fatima et al. (2017) stated that aged farmers are uncertain to make the risking taking decision regarding adoption of new farm related technologies. In current study, the coefficient of farmer's age also imitate that as farmers age is increased, it affect the production process negatively. It is due to the fact that most of aged famers are risk averse and required more time to decide in indeterminate conditions(such as: Pest attack, water shortages), where quick actions are needed. This delay decision making regarding farm management might have strong impact of farm efficiency.

Inefficiency model of wheat crop

Furthermore, an inefficiency model of is also estimated in order to evaluate the impact of socio-economic and farm-specific factors on wheat crop technical efficiency. the results of inefficiency model are reported in Table 1. The coefficient of farmer's experience shows that experienced wheat farmers are capable to control the indeterminate farming and marketing conditions in an improved manner. In this study the relationship between experienced farmers and technical inefficiency have the inverse and significant relationship. Abedullah et al. (2006) Stated that experienced farmers are handy in in order to sustain the maximum level of farm technical efficiency.

The coefficient of education variable has the significant and negative relationship with technical inefficiency. This result reports that an educated farmer is able to realize the higher farm efficiency by evading the factors that contributes negatively towards wheat farm inefficiency. This result is consistent with our expectations and also in line with earlier studies such as Ali and Flinn (1989), Rauf (1991), Coelli, (1995), Ahmad et al. (2002), Fatima and Khan (2015), Fatima et al. (2017).This result implies that education is an essential factor for farmers in order to keep up with new farming techniques, implementation of new farming systems and rapid adoption of changed environment conditions.

The parameter estimates of the sale of crop used as dummy variable. The parameter estimates of the sale of crop have the positive association with technical inefficiency of wheat production in study area. The positive association between crop sale in village and wheat farm technical efficiency clearly reveals that farmers have to sale the wheat crop in competitive markets instead of village market. By doing this, farmers will be able to acquire the best possible prices of their farm produces. Fatima and Khan

(2015) stated that right prices in agriculture sector is highly required to reassure the farmers towards the attainment of rapid growth in farm sector.

The coefficients for the tube well and tractor ownership variables reported in Table 1 is used as dummy variables where value = 1 shows that tube well and tractor on rent, otherwise farmer owned the tractor and tube well. Both variables show the positive relationship with wheat farm technical inefficiency. Having the tube well and tractor on rent generally restricted the farmers towards its partial accessibility. Therefore, farmers are incapable to execute the due farming operation on time. On the other hand, those farmers who owned the tractors and tube wells always have a preference to use these inputs on their farm fields first, and then offered those possessions for rent to gain the added earnings. Due to these reasons ownership of tube well and tractor have the significant and positive impact on technical inefficiency of wheat production.

The parameter estimates of tenancy status in Table 1 reported that in study area, those farmers having the status of tenants are more efficient compared to farm owners. This result implies that the farm efficiency would significantly increase if farmer is tenant. Tenant farmers typically have the burden to recompense the rent of rented land. And also need to earn the enough profit to accomplish their household prerequisites and able to generate enough credit for next cropping season. Hence, it appears that in order to realize those objectives, tenant farmers operated the available farm resources more efficiently compared to the farm owners and contributes positively towards the attainment of concentrated farm technical efficiency in wheat production system.

The returns to scale of wheat production function in this study is estimated with the help of Cobb-Douglas (C-D) production function. It is homogenous production function and its elasticity of substitution is equal to one. Hence, by summing the coefficients of parameters estimates of wheat stochastic (C-D) production function reported in Table 1 gives the returns to scale around 0.93. The returns to scale of wheat production function demonstrates that farmers are experiencing the decreasing returns to scale in the study area. In future, same level of wheat output might be attained by reducing the 0.7 percent of farm inputs.

Table 3 reported the frequency distribution of estimated technical efficiency for wheat growers after BT and Non-BT cotton. The predicated technical efficiency of wheat farms in study area is ranges from 0.27 to 0.97. The estimated technical efficiency result shows the paramount variation among the wheat producing farms. This result is also highlighted the fact there is a great potential to increase the per acre wheat production by overcoming the existing factor of technical inefficiency. The mean technical efficiency of selected wheat farms of study area is turned out to be 76 percent at aggregate level. Hence, wheat growing farmers can farther escalate the 24 percent of wheat production by utilizing the existing level of farm resources.

This study also separately observed the technical efficiency analysis of wheat crop after Non-BT and BT cotton group of farmers. The result shows that the mean technical efficiency of wheat crop planted after BT and Non- BT cotton is around 74 and 78 percent, respectively. The estimated technical efficiency analysis specified that those farmers cultivate wheat crop after Non BT-cotton are about 4 percent more technically efficient than those farmers who cultivates wheat after BT-cotton. The stochastic frontier estimates of technical inefficiency reported the 24 percent technical inefficiency at the aggregate level. Around 22 and 26 percent of technical inefficiency is found when wheat planted after Non-BT and BT-cotton farms, respectively. In other words, wheat-cultivating farmers can increase the production of wheat by 22-26 percent just by way of realizing efficiency, without necessarily increasing the quantity of inputs.

Conclusions and Recommendations

One of the most important fundamental conclusions of this study is that under cotton-wheat cropping system, wheat crop affected more adversely when planted after BT-cotton compared to Non-BT cotton. This conclusion owes its origin to basic conclusions. The results of study indicate that wheat productivity has a negative relationship while wheat is cultivated after BT cotton. This result shows that wheat production per acre tends to declines significantly when wheat is cultivated after BT-cotton. The reason for this negative relationship could be the late planting of wheat, less time for land preparation. The result of study shows that wheat productivity has a positive relationship with farm size, increased farm size under wheat crop

significantly affects wheat production. The study also identifies the increase in land preparation days positively and extensively effects wheat productivity. The study concludes that late sowing of wheat is a major problem, due to delayed harvesting of cotton crop, especially in case of wheat after BT cotton which has the characteristic late maturing, adversely affected the vegetative procedure of wheat crop. As late planting of wheat crop leaves very short time for farmer for land preparation of wheat crop. Hence, it is necessary to establish such programs research programs that should include evolution of short term duration of crop and HYVs of cotton and wheat. Which will in turn create additional opportunities for Pakistan farm community towards the attainment self-sufficiency in food and fiber production and expansion of farm returns. On the other hand, to ensure desirable farm production, improvement in farm infrastructure, socio-economic conditions and farm management is an essential perquisite to realize the objectives of self-sufficiency and sustainability in farm sector of Pakistan.

Novelty Statement

This study investigatde the impact of BT and Non-BT cotton crop cultivation on the technical efficiency and productivity of wheat crop in Pakistan. Moreover, how late planting of wheat crop especially after BT-Cotton harvesting affect the technical efficiency of wheat crop.

Author's Contribution

In this article, the main idea, introduction, methodology, empirical analysis, investigation and result and discussion was done by Dr. Hina Fatima. Overview, technical input and supervision on every step of this research is provided by Dr. Abdul Jabbar and Dr. Khurram Nawaz Saddozai.

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