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YIELD GAP DETERMINANTS FOR WHEAT PRODUCTION IN MAJOR IRRIGATED CROPPING ZONES OF PUNJAB, PAKISTAN

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ABSTRACT:- Yield gap is useful measurement for crop productivity and the extent to which crop productivity falls below some potential level. The study was carried out to analyze the yield gap and determinants of wheat production in the Punjab province of Pakistan. It is based on cross sectional data from 210 farmers for the crop year 2009-10. Results suggest that farm level wheat yields are less than the potential yield level by 33.0%, 43.0% and 50.6% in the mixed-cropping, cotton-wheat and rice-wheat zones of the province, respectively. Ordinary least square regression analysis of wheat production by assuming Cobb-Douglas specification reveals that the number of irrigations, usage of farm yard manure and fertilizers contribute positively and significantly to wheat crop production. Coefficients of dummy variables for cropping zones indicate that farmers in the mixed cropping zone are obtaining better yield of the wheat crop as compared to their counterparts in other selected cropping zones. These results suggested that farmers can increase wheat productivity by increasing the use of factor inputs; however, poverty may be a constraint on realizing these gains. Thus, wheat production can be increased in the country by helping resource poor farmers through suitable support mechanisms.

Key Words: Wheat; Crop Productivity; Determinants; Yield Gaps; Punjab; Pakistan.

INTRODUCTION

The crop sector is the second largest contributor to agricultural value added in Pakistan after the livestock sector. In the crop year 2012-13, crop subsector contributed 37.6% to agricultural value added. Four major crops (wheat, rice, cotton and sugarcane) contributed 29% to the value added in overall agriculture and 6% to GDP (GoP, 2013). Wheat is the main grain crop and provides a major share of food requirements in the country. It is considered a main pillar of food security, as it provides about half of the calories (48%) consumed in the daily diet of the people (GoP, 2008). The share of wheat in national GDP is 2.2% and the crop contributes 10.1% to value added agriculture. In brief, the crop has a dominant status in the formulation of agriculture sector policies in the country (GoP, 2013).

Since independence in 1947, population of the country has increased manifold; while increase in cultivated area is just 40%. Thus, pressure on cultivated land is mounting with the passage of time (Ahmad and Farooq, 2010). However,

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average yields of major crops obtained by farmers are 30-60% below than their demonstrated potential at research stations (GoP, 2010). Potential yield is defined as the level of yield of any crop obtained by sowing best varieties, adopting most appropriate agronomic practices and no manageable biotic or abiotic stresses (Fischer et al., 2009). In this perspective, yield gaps for cotton, rice, sugarcane and maize crops are 71%, 58%, 48% and 41%, respectively (Hussain, 2014). Though, research stations operate under highly controlled circumstances, in general with no binding on use of input resources. However, such big gaps between yield levels at farmers' fields and research stations indicate that productivities of major crops can be improved enormously. Similarly, the wheat yield per hectare is low in Pakistan (2787 kg) as compared to other wheat producing countries e.g. United Kingdom 8281 kg, Germany 8087 kg, France 7101 kg, China 4762 kg (FAO, 2011). Although, Pakistan's wheat yield has increased over time by about 198.6% from 909 kg ha^{-1} in 1947-48, with annual growth rate in wheat yield improvement of 1.7% (GoP, 2007). However, improved semi-dwarf wheat cultivars available in the country have much higher genetic yield potential of 5928 - 7904 kg ha^{-1} (PARC, 2013). In short, yield gap in wheat is about 60%, indicating tremendous opportunity to increase its productivity.

Due to importance of the wheat crop for Pakistan's food security, a decline in its production in any crop year raises concerns at the government level (GoP, 2013). Moreover, as majority of the farmers are resource poor; either they are incognizant of proper production technology or cannot afford to follow improved production practices (Hussain et al., 2012). Therefore, analysis of determinants of wheat productivity is very important. This study has been carried out in Punjab province of Pakistan. It is the largest wheat-producing province and accounts for 76% of the wheat area in the country and contributing 77% to the wheat production. In the province, about 39% of the total cropped area is allocated to this crop every year (GoP, 2012). The province is well bestowed with resources for wheat growth and production e.g. productive land, better varieties and hard working farming community. In spite of all this, farmers are unable to achieve the optimum yield level of the crop (Tahir and Javeed, 2010).

Iqbal et al. (2001) studied the determinants of higher wheat productivity in irrigated areas of Pakistan. The study was based on primary data and the sample included wheat growers of major as well as small irrigated cropping zones of the country. They found that number of ploughings for land preparation, seed use, number of irrigations and application of fertilizer nutrients contribute significantly to wheat crop production in the country. Since then, few researchers (Abbas et al., 2007; Mahmood et al. , 2006; Ahmad et al., 2002) have conducted studies on wheat crop production in the country, but these are different in scope and coverage. While, few researchers have analyzed technical efficiency of wheat famers (Hussain et al., 2012; Fatima, 2010; Abbas, 2005; Hassan, 2004; Ahmad et al., 2002). Another reason to conduct this study is a decline in input resource use capacity of the farmers due to general increase in input prices. In Pakistan, domestic wheat prices are kept below international trade level to benefit net buyers of this staple, who accounts for 80% of country's population (Dorosh and Salam, 2007). Thus, to control food prices in the country, it is suggested that food production may be encouraged by increasing wheat support prices (Azeem et al., 2012). Government increased procurement prices for the wheat produce in 2008-09 and then again in 2011-12. However, increase in wheat prices from 2007-08 to 2011-12 was just 67.4%. On the other hand, during the same period increase in nominal prices of high speed diesel, electricity tariff for agricultural tube-wells, prices of urea and DAP are recorded as 151.3%, 440.3%, 195.9% and 109.6%, respectively (GoP, 2008; 2012; 2013). Thus, farmers have further lost the ground in wheat crop production due to these price changes. This study has been carried out to determine yield gaps of wheat crop across main irrigated cropping zones of Punjab province viz., cotton-wheat, mixed-cropping and rice-wheat. Determinants of wheat production in the province have also been analyzed. Moreover, input usage levels for wheat crop by poverty status of the farmers have also been determined.

MATERIALS AND METHOD

The data for the study have been collected by using a multistage random sampling technique. Cropping zones are the first stage units, which are selected to determine yield gaps of the wheat crop by cropping systems. Punjab province is divided into five cropping zones namely, cotton-wheat zone, mixed-cropping zone, rice-wheat zone, low-intensity zone and rainfed zone. This study has been carried out in three major irrigated cropping zones of the province. Low-intensity zone and rainfed cropping zone are excluded due to subsistence nature of crop farming in these zones. Low-intensity and rainfed cropping zones contribute about 15.6% and 4.2% in total wheat production of the province, respectively. Second stage units were districts within each cropping zone. One of the top four districts by wheat area from each cropping zone was selected. Tehsils and farmers were third and fourth stage units, respectively. These were selected randomly (Table 1). Farm-level cross-sectional data were collected for the cropping year 2009-10, for wheat crop in particular and other *rabi* as well as *kharif* crops in general. Details about livestock, non-farm and rental incomes, as well as information about remittances of the farming household were also inquired. A comprehensive pre-tested questionnaire was used as the data collection tool. Wheat farmers were personally interviewed at their farms during July to December, 2010.

Data from filled questionnaires were then carefully entered in a data sheet. The data were analyzed using SPSS-20 package both for descriptive statistics as well as poverty analysis. Multiple regression analysis of wheat production has been carried out through statistical package E-Views 5. In Pakistan, official poverty estimates as well as methodology, including poverty line are quite controversial. Thus, to analyze the data, internationally used poverty line of US$ 1.25 per capita per day was used, which is equivalent to Rs.3086 per capita per month at the exchange rate (1US$ = Rs.82.3: average of the daily exchange rates for the financial year 2009-10; SBP, 2013). The head-count poverty ratio developed by Foster et al. (1984) was estimated to determine the poverty status of the farm families. The head-count ratio is the proportion of population for which income 'y' is less than poverty line 'z'. Suppose 'q' people are poor by this definition in a population of size 'n' then head-count index is as given by equation (1).

$$H = q/n.........(1)$$

Multiple regression analysis, assuming Cobb-Douglas functional form of the production function has been applied to find out determinants of higher wheat productivity in the Punjab province (equation 2). Trans-log functional form of the production function was also tested; however, was not found suitable due to problem of serious multi-collinearity among the independent variables.

$$\ln(YIELD) = \beta_0 + \beta_1 \ln PLOH + \beta_2 \ln SEED + \beta_3 \ln IRRI + \beta_4 \ln FYM + \beta_5 \ln FERT + \beta_6 DCT + \beta_7 DRI + \mu..(2)$$

where,

YIELD = Yield of wheat on the i^{th} farm (kg ha^{-1})

PLOH = Ploughings for land preparation (No.)

SEED = Seed rate (kg ha^{-1})

IRRI = Irrigations (No.)

FYM = Farm yard manure (t ha^{-1})

FERT = Qantity of fertilizer ($N+P_2O_5+K_2O$) nutrients (kg ha^{-1})

DCT = Dummy variable for cotton-wheat cropping zone (value is '1' if the farmer is from cotton-wheat cropping zone otherwise 0).

DRI = Dummy variable for rice-wheat cropping zone (value is '1' if the farmer is from rice-wheat zone otherwise 0)

β_is, I = 1, 2, 3,......7 are unknown parameters for the production function to be estimated.

μ = Error term which may result due to errors in the production of

Table 1. Selected districts, tehsils, union councils and villages

Zones	Cotton-wheat	Rice-wheat	Mixed-cropping
Districts	Bahawalnagar	Sheikhupura	Okara
Tehsils	Chistian	Ferozewala	Okara
Villages	Chak Number, 20, 24, 28, 30, 35-Fateh, 36-Fateh, 44-Fateh, 45-Fateh and 109-Fateh	Ali Pur, Kalar, Kot Noor, Kot Pind, Machiali, Messan, Kukhanpur, Shamkay and Wagray	Chak Number 1/4-L, 2/4-L, 3/4-L, 25/4-L, 24/2-L, 24/G-D, 32/G-D (Bangla Gogerat), 38/G-D (Young Pur) 25/2-R, 26/2-R, 27/2-R, 51/3-R, Awan Mouza, Mouza Musinke, Mouza Musta Puruka, Razi Shankir Das, and Thatta Ghulam ka

Table 2. Area allocation to wheat crop, yield and use of main input variables for crop production by poverty status of the farmers

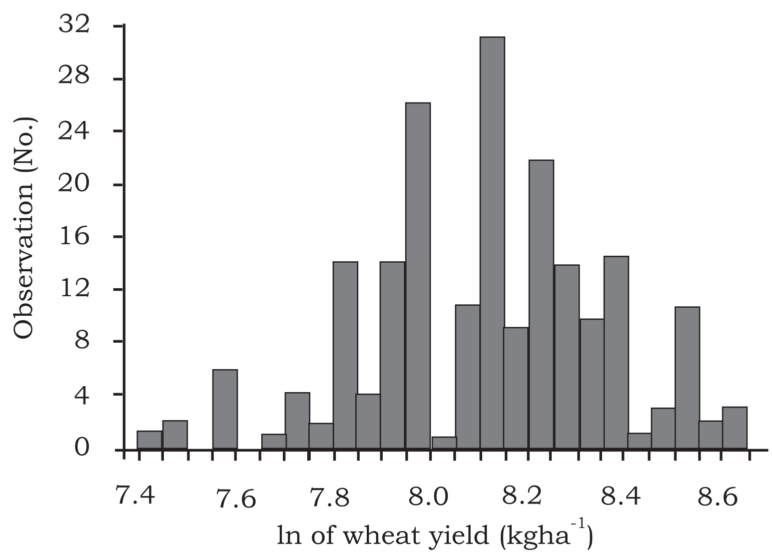
Parameter	Cropping zones											
	Cotton-wheat			Rice-wheat			Mixed-cropping			All zones		
	Poor	Non-poor	All farmers	Poor	Non-poor	All farmers	Poor	Non-poor	All farmers	Poor	Non-poor	All farmers
Wheat area (ha)	4.0	7.7	5.5	5.2	9.8	7.0	2.2	5.2	3.7	3.9	7.4	5.4
	(4.7)	(7.5)	(6.2)	(6.1)	(10.2)	(8.2)	(2.7)	(10.6)	(7.8)	(4.9)	(9.7)	(7.6)
Yield (kg ha^{-1})	3239	3647	3379	2821	3144	2927	3866	4139	3971	3293	3670	3426
	(630)	(651)	(662)	(668)	(1021)	(808)	(731)	(761)	(749)	(796)	(907)	(854)
Ploughings (No.)	3.8	4.4	3.9	7.1	7.2	7.1	7.4	8.1	7.7	6.1	6.5	6.2
	(0.8)	(0.8)	(0.8)	(2.2)	(1.2)	(1.9)	(1.8)	(1.5)	(1.7)	(2.4)	(2.1)	(2.3)
Seed (kg ha^{-1})	131.2	128.5	130.1	117.6	118.2	117.9	118.9	116.4	117.7	122.8	120.7	121.9
	(10.6)	(13.3)	(11.7)	(7.7)	(10.2)	(8.7)	(13.1)	(13.2)	(13.1)	(12.2)	(13.3)	(12.7)
Irrigations (No.)	3.9	4.0	3.9	2.5	2.8	2.6	4.0	4.1	4.1	3.4	3.6	3.5
	(0.9)	(1.0)	(1.0)	(0.6)	(0.6)	(0.6)	(1.0)	(1.1)	(1.0)	(1.1)	(1.1)	(1.1)
FYM (t ha^{-1})	2.4	3.3	2.8	1.4	2.6	1.9	0.6	2.1	1.3	1.5	2.6	2.0
	(3.1)	(3.8)	(3.4)	(2.8)	(7.6)	(5.2)	(1.3)	(4.7)	(3.5)	(2.7)	(5.5)	(4.2)
Fertilizer nutrients (kg ha^{-1})	189.5	207.1	196.5	169.8	203.3	183.2	193.0	181.5	187.3	183.6	196.1	189.0
	(39.3)	(45.7)	(42.6)	(45.3)	(187.0)	(123.2)	(103.3)	(62.5)	(84.9)	(66.6)	(112.8)	(89.6)

Figures are means and standard deviations are in parenthesis wheat, weather conditions, economic adversities or plain luck, or the aggregate effect of input variables not included in the production function.

RESULTS AND DISCUSSION

Head count ratio based on poverty line of US $ 1.25 per capita per day revealed that 57% of the sampled farm families were poor in the study area. The incidence of poverty was high in the rice-wheat and cotton-wheat zones (60% of the sampled farm families were poor in each zone) as compared to the mixed-cropping zone (50% of the sampled farm families were poor). The mean area under wheat crop was higher at the farms of non-poor farmers than the poor ones in all the cropping zones. Irrespective of the cropping zones, mean area allocation to wheat crop was 3.9ha and 7.4ha on the farms of poor and non-poor farmers, respectively (Table 2). The mean number of ploughings for land preparation for the crop given by the poor and non-poor farmers were 6.1 and 6.5, respectively.

Seed use by the poor and non-poor farmers was almost equal across cropping zones, as well as on overall basis. Similarly, the mean number of irrigations given to the crop was also similar across poverty status categories. Both poor and non-poor farmers irrigated the crop two to three times in the rice-wheat zone; and about four times in the cotton-wheat and the mixed cropping zone each. Non-poor farmers were using higher levels of farm yard manure for the wheat production in all the cropping zones. On overall basis, mean uses of farm yard manure were 1.5 and 2.6 t ha^{-1} by the poor and non-poor farmers, respectively. Similarly, application of fertilizer nutrients was higher by the non-poor farmers than their counterparts both in the cotton-wheat and rice-wheat zones; while mean levels of fertilizer nutrients applied per hec-



Series: SER01	
Sample: 1- 210	
Observations: 207	
Mean:	8.119945
Median:	8.148446
Maximum:	8.618449
Minimum:	7.426311
Std. Dev.:	0.243059
Skewness:	-0.345082
Kurtosis:	2.927557
Jarque-Bera:	4.153578
Probability:	0.125332

Figure 1. Histogram of natural log of wheat yield (kg ha^{-1})

tare were slightly higher among poor farmers than non-poor farmers in the mixed cropping zone. Mean wheat yield at the sampled farms was 3426 kg ha^{-1}. The yield gap between the poor and non-poor farmers was about 11.5 %.

Crop experts of Punjab research system claim that potential yield of wheat is 5928.0 kg ha^{-1} (Anonymous, 2013). Keeping this in view, yield gaps for wheat crop in the rice-wheat,

Table 3. White Heteroskedasticity Test

F-statistic	1.607	Probability	0.136
Obs R-squared	18.716	Probability	0.137

Test Equation
Dependent Variable RESID^2
Method: Least Squares
Sample: 207

Variable	Coefficient	Standard Error	F-Statistics	Probability
C	0.020	5.666	0.003	0.997
LnCULT	0.010	0.081	0.127	0.899
LnCULT^2	0.000	0.023	0.013	0.990
LnSEED	0.025	2.365	0.010	0.992
LnSEED^2	-0.008	0.247	0.031	0.975
LnIRRI	0.062	0.065	0.954	0.341
LnIRRI^2	-0.026	0.030	0.885	0.377
LnFYM	-0.031	0.012	2.615	0.010
LnFYM^2	0.013	0.005	2.468	0.014
LnFERT	0.018	0.017	1.041	0.299
LnFERT^2	-0.003	0.003	1.012	0.313
DCT	0.019	0.016	1.198	0.233
DRI	0.027	0.013	2.055	0.041

R-squared	0.090	Mean dependent var	0.041
Adjusted R-squared	0.034	S.D. dependent var	0.060
S.E. of regression	0.058	Akaike info criterion	2.780
Sum squared resid	0.663	Schwarz criterion	2.570
Log likelihood	300.682	F-statistic	1.607
Durbin-Watson stat	1.991	Prob (F-statistic)	0.136

cotton-wheat and mixed cropping zones are about 51%, 43% and 33%, respectively. As already stated, multiple regression analysis was carried out to find out determinants of the wheat crop production in the province. Dependent variable was checked for normality and three outlying values for the natural logarithm of wheat yield (kg ha^{-1}) were removed to make the distribution normal (Figure 1). The value of the Jarque-Bera test statistics indicates that the variable was normally distributed. Ordinary least square regression model assuming Cobb-Douglas form of the production function used for the study was also tested for heteroskedasticity. White test for heteroskedasticity with no cross terms was used (Table 3). The F-statistic value is non-significant, indicating absence of heteroskedasticity in the data.

Durbin-Watson statistics indicates absence of multicollinearity in the explanatory variables of the model (Table 4). Results revealed that number of irrigation applications (lnIRRI), quantity of farm yard manure applied to the crop (lnFYM) and amount of fertilizer nutrients applied to the crop (lnFERT) are positive and significant

Table 4. Results of Multiple Regression Analysis

Dependent Variable: In Yield (wheat yield in kg ha^{-1})
Method: Least Squares
Sample: 207

Variable	Coefficient	Standard Error	t-Statistics	Probability
Constant*	8.660	0.753	11.497	0.000
$lnCULT^{ns}$	0.046	0.060	0.769	0.443
$lnSEED^{ns}$	-0.178	0.154	-1.153	0.250
lnIRRI**	0.111	0.058	1.909	0.058
lnFYM*	0.054	0.018	2.945	0.004
lnFERT**	0.040	0.017	2.358	0.019
DCT**	-0.139	0.056	-2.483	0.014
DRI*	-0.265	0.043	-6.121	0.000

R-squared	0.324	Mean dependent var	8.119
Adjusted R-squared	0.300	S.D. dependent var	0.246
S.E. of regression	0.206	Akaike info criterion	-0.282
Sum squared resid	8.464	Schwarz criterion	-0.153
Log likelihood	37.154	F-statistic	13.602
Durbin-Watson stat	1.796	Prob (F-statistic)	0.000

and** = Significant at 1% and 5% levels, respectively; ns = Non-significant

contributors to the wheat yield in the province. Thus, an improvement in irrigation management practices would result in better wheat crop production. Irrigation is the most critical factor to increase wheat productivity in the study area. The variable of number of irrigations has the largest and highly significant coefficient. Findings about positive and significant contribution of irrigations to wheat production are in line with Fatima (2010) and Iqbal et al. (2001). The results about positive contribution of number of irrigation to the yield of wheat crop are also quite similar to Koc et al. (2011), Kahi and Yabe (2011) and Suresh and Reddy (2006), who reported significant positive contributions of number of irrigation to crop production in various parts of the world.

The estimated coefficients of farm yard manure application shows that 1% improvement in farm yard manure use, increases wheat production by 0.05%. Shah et al. (1994) also reported farm yard manure application contribute significantly to wheat production in Khyber Pakhtunkhwa (KPK) province of Pakistan. Similarly, the estimated coefficient of fertilizer nutrients application indicates that 1% increase in use of fertilizer nutrients adds 0.04% in wheat production. These findings are in line with Kaur et al. (2010) and Ghaderzadeh and Rahimi (2008), who examined technical efficiency of wheat farmers in Indian Punjab and Kurdistan province of Iran, respectively. Battese and Broca (1997) also reported a significant contribution of fertilizers use to wheat production in the mixed-cropping zone of the Punjab (Faisalabad district), Pakistan. Similarly, Ahmad et al. (2002), Shah et al. (1994) and Battese et al. (1993) reported positive contributions of fertilizer use to wheat production in different areas of Pakistan. The results about productivity responsiveness to increase in use of farm yard manure and fertilizers, and application of irrigations are also in line with that of Wiebe and Tegene (2000). They reported that crop productivity is more responsive to increase in these inputs in countries with poor and degrading land resources.

There is an evidence of degradation of both land and water resources in the country (Ali and Byerlee, 2002). Coefficients of dummy variables for cropping zones have expected negative signs. Thus, farmers in the mixed cropping zones are better off in terms of obtaining wheat yield than their counterparts in the cotton-wheat and rice-wheat cropping zones. Other variables considered in the production function viz., number of cultivations for land preparation and seed use, have expected signs but are statistically non-significant.

Thus, it can be extracted that the yield gaps between potential and obtained yield levels of the crop, as well as between, poor and non-poor farmers can be minimized by devising some suitable support mechanisms to help resource poor small farmers. Issuing agricultural cash cards to the poor farm households, like income support cards as already been issued to the poor families in the country under income support programmes, targeted subsidies on use of tubewells for irrigation, and chemical fertilizers etc. are few realizable support mechanisms to increase the crop production in the province.

CONCLUSION AND RECOMMENDATIONS

Farmers obtain about one-half to two-third of the potential yield of wheat crop in major irrigated cropping zones of the Punjab province. Poor farmers obtain less yield of the crop than non-poor farmers. For wheat crop, poor farmers do not prepare land properly, use less farm yard manure and apply low doses of chemical fertilizers than their rich counterparts. Statistical analysis of wheat productivity reveals that number of irrigation applications contribute significantly to wheat yield in the province. Similarly, applications of farm yard manure and fertilizer nutrients contribute significantly to the crop production. Furthermore, farmers in the mixed cropping zone obtain better wheat yield than their counterparts in the cotton-wheat and rice-wheat cropping zones. It is imperative that these factors of production should be taken care off to raise wheat crop productivity in the province. More-over, the yield gap between poor and non-poor farmers can be minimized by devising some suitable support mechanisms to help resource poor small farmers.

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