International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
Coden: IJARQG(USA)

Research Article

Reasons for low use of phosphatic fertilizer and its impact on paddy yield: a field survey analysis

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Abstract

The rational of this research study was to explore the reasons for low use of Phosphatic (P) fertilizer and its impact on paddy yield in wheat-rice cropping system. During crop year 2014 three districts including Gujranwala, Sialkot and Hafizabad of Punjab, Pakistan were purposively selected due to their highest share of paddy. Cobb Douglas type production function and marginal value of product concept was employed to assess the impacts of variable inputs including phosphate fertilizer application. The data was collected and analyzed in two categories i.e. fine and coarse paddy varieties. Adjusted R^2, F-value and Returns to scale were found as 0.789, 17.55 and 0.566 for fine varieties while as 0.936, 44.87 and 0.507 for coarse paddy varieties respectively. The farmers are suggested to apply the required dose of P fertilizer to wheat at sowing time because the residual effects of P enhance the paddy yield in wheat-rice cropping system. Moreover at least half recommended dose of phosphorus was also be applied to paddy at puddling time due to its cumulative effect.

Keywords: Phosphorus; Residual; Paddy; Gujranwala.

Introduction

Rice (*Oryza sativa* L.) is the second largest staple food crop after wheat in Pakistan and also a major source of export earnings. It contributes 3.1% in value addition of agricultural commodities and 0.7% in GDP. In Pakistan it is grown on 2789 thousand hectares with average yield of 2437kg ha^{-1} giving total production 6798 thousand tonnes (Government of Pakistan, 2014).

Judicious and proper use of fertilizer can markedly enhance the yield and improve the quality of rice (Alam *et al.*, 2009). Phosphorus is the second key nutrient after nitrogen. It is crucial for vegetative and reproductive growth of plants, because it helps in photosynthesis, respiration, energy production and storage metabolism of starch, protein and fats (Yaseen *et al.*, 1999). Use of P stimulates blooming and seed formation in paddy. Proper use of P helps in enhancing yield in forms of normal kernels (Demkin and Ageev, 1990). Phosphorus plays main physiological role in the accumulation and release of energy during cellular metabolisms resulting in chalky kernels (Khalil *et al.*, 2002).

Phosphorus also stimulates roots growth and is associated with early maturity of crops. It offers increased disease resistance to plants. It prevents from lodging by providing strength to straw. According to Vance et al., (2003) application of phosphatic fertilizers is not much feasible because of its low use efficiency, highly increased prices, environmental concerns and fear of depletion of non-renewable rock phosphate mined for production of P fertilizers.

Grotz and Guerinot (2002) reported that due to the complexity of phosphorus chemistry in soil only about 20% of the total amount of P fertilizer is utilized by the first crop and the remaining 80% is fixed in soil in unavailable form. Tahir *et al.,* (1991) explained that most of the applied P becomes unavailable to growing plants due to alkaline and calcareous nature of the soils in Pakistan.

At national level total consumption of nutrients (N-P-K) of gross cropped area is 147.4 kg ha^{-1}in which N is 115.6 kg ha^{-1}, P2O5 is 30.8 kg ha-1 and K2O is 1 kg ha^{-1}(Anonymous, 1995). Reasons for low use of P in Pakistan are attributed to high prices, lack of promotional activities and tight availability during peak demand period (Anonymous, 1984).

Appropriate and balanced fertilization to wheat and rice not only causes yield enhancement but also has good impact on phosphorus uptake by these crop plants (Rehman *et al.* 2006). Nitrogen affects the vegetative as well as quality yield whereas phosphorus plays a fundamental role in metabolism and energy producing reaction and enable the crop to stand with the adverse environmental effects, thus causing boost in yield (Azink and Kajfez, 1983).

The wheat-rice rotation is one of the world s largest agricultural production system and occupies about 14 million hectares of cultivated land in India, Pakistan, Bangladesh and Nepal (Zia *et al.,* 2000). Wheat-rice rotation is very common in northern and some parts of the central Punjab. Nitrogen and phosphorus are applied to both the crops. Wheat being a winter crop responds more to P application. The high temperature and submerged conditions in rice helps to improve the availability of native P. Thus the recommended rate of P applied to wheat can meet P requirement of the submerged rice crop to some extent.

In spite of the above mentioned importance of P, its usage is very low especially in paddy. This study had been planned to determine the extent of P usage to wheat and paddy along with the reasons for low usage to paddy crop in wheat-rice cropping system.

Materials and Methods

The study area was the agro-ecological zone of Gujranwala. The data was collected by purposively selecting three districts i.e. Gujranwala, Sialkot and Hafizabad during Kharif year 2014. The selected districts were claiming the highest production of 578, 303 and 272 thousand tonnes respectively in Punjab province (Government of Punjab, 2013).

Those farmers were interviewed whom had grown paddy soon after wheat crop. To get data from the whole district was lengthy, costly and time consuming procedure; therefore, two tehsils from each district were randomly selected. Then from each tehsils four villages were randomly selected and from each village five farmers were interviewed thus making a total sample of 120. The data was collected by personal contact method.

The collected data was analyzed in two categories i.e. fine and coarse paddy varieties. The reasons for low usage of P fertilizer were recorded and analyzed by descriptive statistics. Cob-Douglas production function was used to estimate the effects of various inputs on the yield of different paddy varieties. Ahmad *et al.,* (2004), Bakhsh *et al.,* (2005), Majumder *et al*., (2009), Hassan *et al.,* (2010) and Chapke *et al.*, (2011) also used the same statistical analysis method. Seven independent variables namely, education of farmer, DAP bags/ha to wheat crop sown before rice, Area under paddy variety in hectares, No. of irrigations/ha, No. of Urea bags/ha, No. of DAP bags/ha and Zinc in kg/ha to rice crop were taken into consideration.

The specification of the model applied is given as:

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}\,X_5^{b5}\,X_6^{b6}\,X_7^{b7}e^u$$

Or in linear form as:

$$\ln Y= \text{In } a + b_1\ln X_1 + b_2\ln X_2 + b_3 \ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6 + b_7\ln X_7 + U$$

Where

Y = Yield in mounds/ha
X_1 = Education of farmer
X_2 = DAP bags/ha to wheat crop sown before rice
X_3 = Area under paddy variety in hectares
X_4 = No. of irrigations/ha to rice crop
X_5 = No. of Urea bags/ha to rice crop
X_6 = No. of DAP bags/ha to rice crop
X_7 = Zinc in kg/ha to rice crop

In order to test the efficiency, the ratio of marginal value product (MVP) to the marginal factor cost (MFC) for each input was computed and tested for its equality to 1, i.e;

MVP/MFC = 1

The marginal productivity of a particular resource represented the addition to yield level caused by an additional unit of that resource, while other inputs were held constant. When the marginal physical product (MPP) is multiplied by the product price per unit, the MVP is obtained. The most reliable, perhaps the most useful estimate of MVP is obtained by taking resources (X_i) as well as yield (Y) at their geometric means (Dhawan and Bansal, 1977). Since all the variables of the regression model were measured quantitatively, therefore MVPs were calculated by multiplying the production co-efficient of given resources with the ratio of geometric mean (GM) of yield to the GM of the given resources, i.e.;

$\ln Y = \ln a + b_i \ln X_i$
$dY/d X_i = b_i \ (Y/ X_i)$
Therefore,
$MVP (X_i) = b_i Y (GM)/ X_i(GM)$ where, Y(GM) = Geometric mean of Y
X_i (GM) = Geometric mean of ith variable input

The prevailing market price of inputs was used as the marginal factor cost (MFC) since the farmers were assumed to be operating under purely competitive markets. On the basis of the economic theory, a firm maximizes profits with respect to resource use when the ratio of the marginal return to opportunity cost is one. MFC is the price per unit of input. In calculating the ratio of MVP to MFC, the denominator will always be one and therefore, the ratio will be equal to their respective MVP.

Results and Discussion

Mostly the loamy soil type (66 percent) was found in the study area. About 75 percent soil fertility was counted as medium. In wheat crop 2013-14, the majority of farmers (92 percent) used DAP as a phosphorus source (Table II), while in case of fine and coarse paddy varieties, 88 and 85 percent of farmers applied DAP as a source of phosphorus respectively (Table I). Therefore to estimate the impact of phosphorus application in wheat-rice system and particularly for paddy, only DAP fertilizer application was considered.

Table I. percent distribution of fertilizers for Phosphorus source in paddy crop

Form of P-fertilizer in paddy	Fine varieties	Coarse varieties
DAP	88	85
SSP	12	10
NP	0	5
Total	100	100

The mean value of DAP application on per acre basis for wheat crop 2013-14, fine and coarse paddy varieties were found as 59 kg, 1.4 kg and 3 kg respectively. Only 3 percent farmers applied SOP in their soils at the time of rice transplanting, that s why the factor of K was not included in the regression model to calculate resource use efficiency (Table II).

Table II. Description about fertilizer application in wheat-rice system (percent)

Fertilizer	Variety	Yes	No	If yes then mean value (kg)
DAP used in wheat before rice		92	8	59
SSP used in wheat before rice		5	95	80
NP used in wheat before rice		3	97	70
Urea use in paddy 2014	Fine	87	13	56.25
	Coarse	92	08	67.5
DAP use in paddy 2014	Fine	10	90	1.4
	Coarse	7	93	3
SSP use in paddy 2014	Fine	2	98	6.9
	Coarse	1	99	17.5
SOP use in paddy 2014	Fine	1	99	0.93
	Coarse	0	100	0
Zinc use in paddy 2014	Fine	40	60	3.30
	Coarse	44	56	4

Most of the farmers cultivated supper basmati with highest share of 83% in fine rice varieties. Therefore, yield information of basmati-515 and PS-2 was considered in supper basmati to make the yield data of fine varieties. Similarly PK-386 was dominant variety (85% share) among coarse rice varieties, therefore supri and super fine yield information was considered in PK-386 variety data to make the yield data for coarse rice varieties (Table III). The survey results also revealed that there was no significant difference in total cost of production among all the varieties under same farm conditions.

Table III. Distribution of paddy varieties

Distribution of varieties		Percent
Fine	Supper Basmati	83
	Basmati-515	5
	PS-2	12
Coarse	PK-386	85
	Suppri	10
	Super Fine	5

The farmers response about percent yield increase by using phosphorus was recorded as mean value 15 and 11 for fine and coarse varieties respectively.

Reasons for low use of P fertilizer

Reasons for less use of phosphorus in paddy were also probed from farmers which are mentioned below:

(a) P fertilizer applied to wheat helps paddy crop:

Most of the farmers (59%) were of the view that P fertilizer applied to wheat crop helped the paddy crop. This view is supported by Grotz and Guerinot (2002) whom reported that due to the complexity of phosphorus chemistry in soil only about 20% of the P fertilizer is utilized by the first crop and remaining 80% is fixed in soil in unavailable form. Nadeem and Ibrahim (2002) also reported that utilization of P fertilizer is very low (10-30%) and its availability increases under submerged (flooded) conditions.

(b) Farmers budget constraints:

Majority of farmers (61%) indicated that due to lack of budget they could not apply P fertilizer to the paddy crop. About 42% were small farmers having below 5 acres. Due to more fragmentation of land and shifting of agricultural land to residential colonies and commercial area were main reasons for small land holding size.

(c) Less response of applied P fertilizer to paddy:

About 52% of the respondents pointed out that there was no benefit of phosphorus application to paddy. The scientific reason was that P applied to paddy increased P accumulations but did not consistently increase paddy yields because flooding increased P sorption and increased P diffusion resulting in higher P supply to paddy relative to wheat crop.

(d) High prices of P fertilizer:

Some farmers (18%) stated that due to high prices of P fertilizer they could not apply to paddy. Vance *et al.* (2000) also pointed out that highly increased prices of P fertilizer is one of the constraints in the use of P fertilizer.

(e) P fertilizer caused Zn deficiency in paddy:

Only a few farmers (2%) reported that the application of P fertilizer created Zn deficiency in paddy crop. According to Naik and Das, (2007) P after its absorption interacts in a complex manner with zinc, Mn, Fe and Cu affecting their mobility and translocation in the plant system which outcomes in chalky and opaque kernels.

Resource use efficiency

Resource use efficiency means how efficiently the farmer can use his resources in production process. It is very important because farmers resources are very limited. For calculating the resource use efficiency seven factors were considered namely education of farmer, DAP bags/ha to wheat crop sown before rice 2014, Area under paddy variety in hectare, No. of irrigations/ha, No. of urea bags/ha, No. of DAP bags/ha and zinc (kg/ha). The regression co-efficient of all the explanatory variables were estimated at 5% level of significance (Table IV). The following were the findings of research study:

Education of Farmers (X_1)

The regression co-efficient of Education of farmer was 0.2 (significant) for fine paddy growers. It indicated that considering all other factors constant, one percent increase in level of Farmer s education would increase yield by 0.2 percent. Education plays a key role in adoption of improved technology and attaining higher productivity level. The educated farmers could manage various farm operations in a better way. In case of coarse paddy growers, the said regression co-efficient was -0.047 and non-significant. The reason was that mostly the coarse growers were less educated in sampled farmers.

DAP bags/ha to wheat crop sown before rice (X_2)

As studies on residual effects of phosphorus on succeeding crops and the farmers decreasing trend of phosphorus application to paddy crop motivated to include this factor to determine the resource use efficiency of residuals phosphorus element on the paddy yield. The co-efficient was highly significant and positive (0.173) indicated that keeping all other factors constant, one percent increase in use of DAP to wheat sown before paddy crop would increase paddy yield by 0.17 percent for fine paddy varieties, while in case of coarse paddy varieties it was 0.18 which interpreted that considering all other factors constant, one percent increased use would increase the paddy yield by 0.18 percent. The coefficient was highly significant at 5 percent level of significance. Khan *et al.,* (2007) also supported this research finding that phosphorus application significantly increased the grain yield of wheat and rice. With direct application of 90 kg P2O5 $ha^{-1}$the increase in paddy yield was 54% where as in case of residual effect the increase was 47%. The cumulative application of 45 kg P2O5 ha^{-1} (half dose) proved more economical. Rehman *et al*. (2007) concluded that residual P up to 13.1 mg kg^{-1} can support two to three succeeding crops in loose textured soils. Singh *et al*., (2000) concluded from a long term study that application of 32 kg P $ha^{-1}$to wheat and 15 kg P $ha^{-1}$to rice was optimal for achieving economic and agronomic goals in wheat rice cropping system.

Area under paddy variety in hectare (X_3)

Co-efficient of area under paddy varieties was non-significant at 5 percent level of significance which indicated that the farmers having more hectare of land for paddy obtained low yield as compared to small farmers. The reason for higher yield by small farmers could be that they provide intensive care to crop. Mostly the family labor and self employed labor had been observed in agricultural operations during survey.

No. of irrigations/ha (X_4)

Irrigation is the key component for yield function of paddy. The regression coefficient of no. of irrigations per hectare was 0.029 for fine paddy varieties indicating that keeping all other factors constant one percent increase in irrigations would increase yield level by 0.029 percent. While it was -0.143 for coarse varieties expressing that 1 percent increase in no. of irrigations would decrease the yield level by 0.14 percent as in Kharif-2014. Seasonal rain and flood condition caused severe lodging of early maturing coarse varieties.

No. of Urea bags/ha (X_5)

The regression coefficient of no. of urea bags per hectare was 0.118 for fine paddy varieties indicating that keeping all other factors constant 1 percent increase in urea application would increase yield level by 0.118 percent. While it was 0.151 for coarse varieties expressing that 1 percent increase in urea application would increase the yield level by 0.151 percent.

No. of DAP bags/ha (X_6)

The coefficient of DAP used for fine paddy varieties was highly significant (0.105) at 5 percent level of significance. This indicated that one percent increases in use of DAP increased the yield by 0.105 percent. While for coarse paddy varieties it was also highly significant (0.162) represent that by increase of one percent in DAP would increase the yield by 0.162 percent. Hussain (2004) also supported that paddy yield was increased from 2 to 21 % by the residual application of P over control. The direct application of P @ 45 kg ha-1 increased the yield by 11.4 to 35 % while cumulative application of P increased the yield by 18 to 39 % over control in rice-wheat system. Nadeem *et al*., (2013) also concluded that combine application of Zn and P at the time of last puddling increased the yield of paddy. The response about yield increase by using phosphorus in paddy was also determined.

The overall mean percent yield increase in fine and coarse paddy varieties was calculated as 15 and 11 respectively.

Zinc in kg/ha (X_7)

The coefficients of zinc use for fine and coarse paddy varieties were 0.006 and -0.003 being non-significant respectively. Because the zinc deficiency was common in affected soils i.e. saline and sodic soils. Moreover most of the farmers use zinc sulphate when zinc deficiency symptoms appear, due to which the effect of zinc application was non significant. Mafi *et al.*, (2013) reported that 30% decrease in yield of wheat, rice, corn and the other eatable crop plants is common even in soils with mild zinc deficiency.

Value of R^2

For the fine varieties, the co-efficient of multiple determinations R^2 of 0.837 indicates that about 84 percent of the variations in yield level have been explained by the explanatory variables, which were included in the model. This was 0.957 for coarse paddy varieties which showed that about 95 percent variation in yield is being explained by the explanatory variables, which were included in the model.

F -Value

The F-values of the equation derived for growing of fine and coarse paddy varieties were 17.55 and 44.87 respectively which were highly significant at 5 percent level of significance.

Returns to scale

The summation of all the production co-efficient indicates returns to scale. For fine varieties the value for returns to scale was 0.566 which means that the production functions exhibit decrease returns to scale. On the other hand for coarse varieties it was 0.507 which also indicate that the production functions exhibit decrease returns to scale.

Table IV. Estimated values of co-efficient and related statistics of Cobb-Douglas production function model

Variables	Fine varieties			Coarse varieties		
	Co-efficient	Std. Error	t-value	Co-efficient	Std. Error	t-value
Yield in mounds/ha (Y)	3.202	0.309	10.352	3.490	0.597	5.849
Education of farmer (X_1)	0.2	0.058	3.474	-0.047*	0.032	-1.491
DAP bags/ha to wheat crop before rice (X_2)	0.173	0.037	4.625	0.180	0.044	4.072
Area/ha under paddy variety (X_3)	-0.065*	0.026	-2.471	0.014*	0.011	1.213
No. of irrigations/ha (X_4)	0.029*	0.112	0.254	-0.143*	0.075	1.899
No. of urea bags/ha (X_5)	0.118	0.053	2.230	0.151*	0.036	1.622
No. of DAP bags/ha (X_6)	0.105	0.038	2.732	0.162	0.045	3.595
Zinc in kg/ha (X_7)	0.006*	0.048	0.128	-0.003*	0.040	-0.087
R^2	0.837			0.957		
Adjusted R^2	0.789			0.936		
F-value	17.55			44.87		
Std. Error of the Estimate	0.093			0.052		
Returns to scale	0.566			0.507		

*non significant at 5 percent level

Elasticity of production

The elasticity of production refers to the percentage change in output in relation to the percentage change in input. The concept of elasticity can be applied to the production function to determine the stage in which farmers are allocating their resources.

In this study, the scale of production for all farmers were estimated by summation of the values of the co-efficients (b_i) as the co-efficient of Cobb-Douglas production functions give the direct measure of returns to scale indicate the stage of production. Elasticity for all type of variable categories was less than one which indicates that the growers allocated their resources in the rational stage of production (Stage-II) where diminishing returns to scale existed.

For estimating resource use efficiency, the MVPs for both categories i.e. fine and coarse varieties of paddy were calculated.

The values of MVPs for DAP bags/ha to wheat crop sown before rice, no. of urea bags/ha to paddy and no. of DAP bags/ha were greater than one and positive (5.798, 4.790 and 4.656 for fine varieties while 9.272, 7.778 and 16.251 for coarse paddy varieties respectively) indicating that the farmers had the opportunities to increase per acre yield by using more of these inputs. Sanil *et al.,* (2010) found the same results for fertilizer, labor and area under crop.

Besides the MVPs for all other explanatory variables included in the model were less than one. It indicates that the farmers should limit the use of these inputs. The MVP for no. of irrigations was 0.07 and 0.483 of fine and coarse varieties respectively. The major reason for lower MVP was rainy climate during kharif 2014 season (Table V).

Table V. MVPs of inputs in production function for fine and coarse paddy varieties

Variables	Fine varieties			Coarse varieties		
	Geometric mean	Co-efficient	MVP	Geometric mean	Co-efficient	MVP
Yield in mounds/ha (Y)	28.82			38.12		
Education of farmer (X_1)	8.49	0.2	0.679	7.55	-0.047	-0.237
DAP bags/ha to wheat crop before rice (X_2)	0.86	0.173	5.798	0.74	0.180	9.272
Area/ha under paddy variety (X_3)	6.74	-0.065	-0.278	8.52	0.014	0.063
No. of irrigations/ha (X_4)	11.93	0.029	0.070	11.28	0.143	0.483
No. of urea bags/ha (X_5)	0.71	0.118	4.790	0.74	0.151	7.778
No. of DAP bags/ha (X_6)	0.65	0.105	4.656	0.38	0.162	16.251
Zinc in kg/ha (X_7)	4.99	0.006	0.035	4.46	-0.003	-0.026

Conclusion

Phosphorus application response was highly variable, influenced by soil characteristics and growing environment of the crop. In loamy soil where farmers had applied recommended dose of phosphorus to wheat crop, the paddy (particularly coarse varieties) yield was significantly higher instead of using negligible quantity of P fertilizer for paddy due to the residual effects of phosphorus in soil. Therefore farmers are suggested to apply the departmental recommended dose of P fertilizers to wheat at sowing time to get maximum yield of both wheat and rice crops. However application of phosphorus to rice crop may be more beneficial if it is applied at proper time i.e. during puddling.

The Elasticity for all type of variable categories was less than one which indicated that the growers allocated their resources in the rational stage of production (Stage-II) where diminishing returns to scale existed. For estimating resource use efficiency, the values of MVPs for residual impact of phosphorus, direct application of phosphorus and nitrogen were greater than one and positive indicating the farmers had the opportunities to increase per hectare yield by increasing these inputs.

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