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Impact of Balance Use of Fertilizers on Wheat Efficiency in Cotton Wheat Cropping System of Pakistan

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Abstract: **Inefficient use of fertilizers is not only an environmental hazard but have substantial economic loss in term of efficiency of crop and profit of farmers. Keeping in view this issue, this study focused to analyzing the technical efficiency of balance and imbalance users of fertilizers by utilizing stochastic production frontier approach. A set of primary data is used, collected from district Multan in Cotton-Wheat cropping zone of Punjab province. The results are indicated that average technical efficiency is higher with balance users of fertilizers. It is found that technical efficiency improved by 14 points (p<0.00) from 70 to 84 percent by proper usage of fertilizers in balance ratio (N: P).The best policy option is to determine the proper nutrients requirements of soil by soil or plant analysis and then apply fertilizers in accordance with the requirements of soil and cropto obtain high efficiency of crop and maximizing profit of farmers. There should improvement of education and extension services to better understanding and adoption practices by farmers about balance usage of fertilizers in order to obtain high yield of wheat.**

Keywords: **Balance Usage of Fertilizers, Multan, Stochastic Frontier Approach, Technical Efficiency.**

I. INTRODUCTION

One of the strategies to enhance farm productivity and efficiency is intensification of agriculture. However, the process of agricultural intensification depends on the adequate supply of plant nutrients to the crops for securing high yield, otherwise if the process of agricultural intensification is not supported by adequate nutrient addition to soils, it would result in land degradation and therefore the sustainability of agriculture sector may be threatened [1]. The overall aim is that sustainability in agricultural growth should fulfill requirements of the growing population for food security and the promotion of economic growth.

Fertilizer is a vital input for crop productivity. Balanced use of fertilizers has a crucial role in increasing crop productivity, efficiency, farm income, sustaining and restoring soil fertility that has been degraded by wrong and exploitative activities of the past. Balanced fertilization can be defined as the rational use of fertilizers and manures for the optimum supply of all essential plant nutrients which ensures efficiency of fertilizers use as well as increase the crop productivity[2].Balanced fertilization does not only mean that a certain definite proportion of nitrogen, phosphorus, potash and other nutrients to be added in correct proportion, but it also takes into account the availability of nutrients already present in the soil[3].

At present fertilizers use in the country is imbalanced. The consumption of nitrogenous (N) fertilizer has increased more rapidly than those of phosphate (P2O5) and potash (K2O) fertilizers during the last 40 years, this leading toward serious imbalance usage of N, P and K [4] and [5].Excess nutrients, especially nitrogen is not taken up by the crop is likely to be lost to the environment.

According to NFDC report [6] balanced use of fertilizers can increase the yield of wheat by 77%, sugarcane by 100%, rice by 25-100% and cotton by 400%. Therefore it is widely recognized fact that a balanced fertilization strategy is the best way to secure food needs of country by enhancing crop productivity [2].

Two most commonly used fertilizers in Pakistan are the nitrogen based urea and phosphate based DAP. Urea is the most important nitrogenous fertilizer with a fast growing consumption trend followed by DAP. On an average urea accounted for 71% while DAP constituted 17% of total fertilizer consumption during 2003 to 2008[7]. However, with increased use of fertilizers, agricultural productivity did not improve with the same pace. Further, above fig regarding urea and DAP indicates that there is inappropriate use of these fertilizers by ignoring soil and crop requirement. One of the main constraints in exploiting the full yield potential is the imbalanced use of fertilizers [8], [9] and [2].As majority of farmers do not follow the fertilizers usage according to recommendations and therefore such types of farmers harvest low yield and efficiency. Due to general inefficiency of our agricultural

production system, the national average yields of most of the agricultural crops are far below the demonstrated potentials at the progressive farms and the research stations. The inefficiency represents large productivity and economic loss. Thus Pakistan has to rely more heavily on productivity enhancement through technological change and improvement of technical efficiency for the desired rapid agricultural growth in future.

There is a great need of utilizing recommended doses of fertilizers in order to get higher efficiency of crop. The objectives of this study to find socio-economics character-istics of farmers associated with balance and imbalance usage of fertilizers, to determine the impact of balance usage of fertilizers on efficiency and productivity of wheat crop and policy measures to increase efficiency and wheat productivity.

II. Materials and Methods

Sources of Data:

A Multi-Stage random sampling technique is used for this study. The Punjab province is selected purposively because it is the largest contributor in the economy of Pakistan. Moreover, the Punjab province comprises of various cropping zones, dominant cropping zones are rice-wheat, mixed and cotton-wheat. Multan district is selected from the Cotton-Wheat zone because it is main district in the cotton-wheat zone where wheat is one of the major crops. In the next sampling stage, Multan and Shujabad tehsils are selected randomly. For the purpose of data collection 10 villages from each tehsil are selected using systematic random sampling technique from the list of villages available from the concern district census office. At the final stage of sampling design, complete list of farmers in the selected villages is obtained and from this list, 10 % farmers are selected randomly and rest of percentage of farmers are selected by using systematic random sampling technique. Data is collected through interview schedule. The well-structured and pre-tested questionnaire is used to gather information on the use of fertilizers nutrients, other inputs and yield of wheat along with socio-economic characteristics of the 154 farmers.

Analytical Methods:

For the estimation the impact of balance uses of fertilizers on wheat crop, two techniques are used, descriptive analysis and econometric analysis.

Descriptive Analysis:

Descriptive statistical analyses namely mean, percentage etc. are carried out for making a comparison of the characteristics of sampled farmers. The comparison is between farmers using balance and imbalance fertilizers nutrients (nitrogen and phosphorus) for wheat crop. Applying nitrogen and phosphorus in the range of 1.5:1 to 2:1 (N: P)is assumed as balanced use and other than this range is taken as imbalanced use of fertilizers.

Technical Efficiency Analysis:

Technical efficiency is the ability to obtain the maximum possible output from given level of resources. In this study stochastic production frontier approach is used in order to analyze the effect of balance use of fertilizers on efficiency of wheat crop. Cobb-Douglas production function is not used for this study because it ignores the problem of technical efficiency by assuming that all techniques of production were identical across farms and each farmer is technically efficient, which many a times is not true. Therefore a stochastic frontier production approach is used, it is usual regression type with a composite disturbance term consist of two error components. Models, insitially and independently is proposed by [10] and [11].One error component is represents the effect of statistical noise (e.g. weather, topography, distribution of supplies, measurement error, etc.) and other error component captures systematic influences that are unexplained by the production function and are attributed to the effect of technical inefficiency. The stochastic production frontier for the ith farmer is given as,

$$Y_i = \alpha \sum_{j=1}^{k} Xij^{\beta j} - u_i + v_i \qquad i = 1,2,\ldots..N \qquad (1)$$

The empirical form of stochastic production frontier defined in equation 2. The model can be transformed into logarithmic form,

$$\ln Y_i = \beta_0 + \sum_{j=1}^{k} (\beta_j \ln X_{ij}) + V_i - U_i \; i = 1,2,\ldots..N \qquad (2)$$

Where, $\beta_0 = \ln(\alpha)$, Y_i is the output of wheat (kg) for the i^{th} observation, X_{ij} is the vector of physical inputs for i^{th} farmer and j^{th} input. V_i is a symmetric random error assumed to account for measurement error and other factors not under the control of the farmers and u_i is an asymmetric non-negative error term assumed to account for technical inefficiency in production. The V_i is usually assumed to be independent and identically distributed normal random error with mean zero and constant variance i.e. $v_i \sim N(0, \sigma 2v)$. Term "k" represented k^{th} input used for i^{th} farmer, ln is natural logarithm and β_0 and β_j are the parameters to be estimated.

The model is designed on acre basis by employing Frontier version 4.1c developed by Coelli[12]because it is easier to directly interpret the efficiency per unit. The technical efficiency measure is obtained by the ratio of Yi to the maximum achievable level of output Y* given as,

$$TE = Y_i \; / \; Y^* i = 1,2,\ldots.N \qquad (3)$$

Where Y*is the output that lie on the frontier. Analysis of parameters for the function and inefficiency model is estimated simultaneously. In order to test for a statistically significant difference in average technical efficiencies between balance and imbalance users of fertilizers, the Mann-Whitney test is used.

III. Results and Discussion

This sub-section is divided into two parts. The first section elaborates determinants of balance use on the base

of descriptive statistics. The second sub-section describes the impact of balance use of fertilizers on efficiency of wheat crop.

Descriptive Statistics:

This sub-section describes respondents on the base of balance and imbalance use of fertilizers nutrients. Balance use is estimated by comparing the use of nitrogen and phosphorus, since these two nutrients are commonly applied to crops in the cotton-wheat zone. The ratio of 1.5:1 to 2:1 (N: P) nutrients is considered as the balanced use of fertilizers nutrients whereas the ratio below or above considered as imbalanced use.

The descriptive statistics of variables are given in Table 1. Mann-Witney test is used to determine statically significance difference in mean values of factors. The same test is used by Mal *et al.*[13]in order to test for a statistically significant difference in average technical efficiencies between Bt and non-Bt cotton farms. Table 1 depicted that, significant differences in education, membership in farming organization, having off farm income, amount of off farm income, access to production loan, amount of production loan, and visit of extension workers to farm, whereas farming experience, age of farmer, family size, having informal training, total livestock and farm size don't have significant differences among balance and imbalance users of fertilizers groups. On the other hand on an average, there is little difference in the age of balance and imbalance users of fertilizers. However, balanced users are more experienced farmers than other group of farmers.

Considering education level of two groups of farmers under analysis, it is found that balanced fertilizers users are comparatively more educated than their counterparts, thus such farmers with more farming experience and higher education are better able to understand new technologies and proper amount of fertilizers for specific crop in right amount .Family size is approximately same for both balance and imbalance users of fertilizers.

Informal training is also important factor for practice of proper use of fertilizers by farmers. Results depicted that 14 and 10 percent of balance and imbalance users of fertilizers got informal training respectively. Such type of training was provided by different pesticide companies, fertilizers companies and extension staff. Similarly, 36 percent of balance users of fertilizers have membership with some farming organizations and only 10 percent of other group of farmers has such type of membership.

Off-farm income and its monthly amount are crucial to make decision for selection and purchasing of different types of fertilizers by farmers. By considering off-farm income, it is found that balance amount of fertilizers users have more off farm income Rs.12, 550 than other group of farmers having off farm income Rs. 3,219.Regarding to production loan, more percentage of balance users of fertilizers got production loan than other farmers and its amount is Rs. 75, 681 which is greater than the rest of farmers. Number of livestock is on higher side of imbalance users.

It is found that farmers used balance amount of fertilizers have more acreage of land (28.55 acres) than imbalance users (23.6 acres). Access to extension services has an important role in adoption of new technologies. It is found that 64 percent of balance users of fertilizers got agricultural extension services and only 39 percent of imbalance users got these services from agricultural extension officials.

Table 1. Factors influencing to balance and imbalance use of fertilizers nutrients for wheat crop

Variables	Balance used	Imbalance used	Mann-Whitney test (p-value)
	Mean	Mean	
Age of the respondents (years)	38.95	40.83	0.39
Farming experience of the respondents (years)	18.55	14.82	0.34
Education[1] of the respondents	4	2.7	0.00
Family size (Number of persons)	7.95	8.94	0.39
Having informal training (yes=1, no=0)	0.14	0.10	0.60
Membership with farming organizations (yes=1, no=0)	0.36	0.10	0.001
Having off-farm income (yes=1, no=0)	0.45	0.21	0.01
Amount of off-farm income (Rs/ Month)	12550	3219	0.003
Access to production loan (yes=1, no=0)	0.26	0.23	0.00
Amount borrowed production loan (Rs)	75681	36100	0.03
Total livestock (Number of animals)	8.82	11.68	0.38
Farm size (acre)	28.55	23.6	0.39
Extension services received by farmers (yes=1, no=0)	0.64	0.39	0.033

Note. Rs. Represent Pakistani currency in Rupees. For March, 2015, 1 USD = 101.89 Pakistani Rupee

Relationship of Fertilizers Usage and Wheat Productivity:

It is considered that balance amount of fertilizers is in ratio of 1.5-2: 1 (N: P) and found that only 14.28 percentage of farmers used fertilizers in this range and rest of farmers not used in balance ratio (Fig. 1). Results also revealed that those farmers used balance ratio of fertilizers comparatively got higher yield of wheat than other farmers and around 8.5 percent of potential increase in wheat productivity is found if all farmers used fertilizers in balance ratio.

[1] *1= Illiterate; 2= Up to primary; 3=Up to middle; 4= Up to high school; 5= Above high school.*

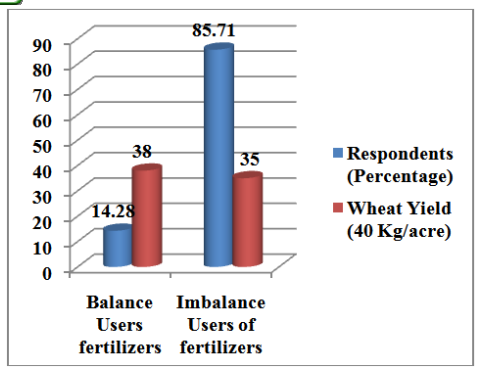

Fig.1. Percentage of farmers used balance and imbalance of fertilizers and their wheat productivity

Econometric Analysis:

In addition to variation in average yield of wheat, technical efficiency analysis might give more in-depth analysis for balance and imbalance users of fertilizers. The average technical efficiency is comparatively higher with balance users as compared to imbalance users and significance of difference of technical efficiency is found by Mann-Whitney test. The minimum level of technical efficiency is 41 and 29 percent for balance and imbalance users respectively, whereas the maximum level of technical efficiency is relatively higher in the case of balance users than other group of farmers. The differences in the technical efficiencies among balance and imbalance user of fertilizers is attributed to the significant variation in input use and output. As higher technical efficiency of balance users over imbalance users could also be attributed to the variations in the education, farm experience, membership in farming organization, amount of off farm income, excess to production loan, amount of production loan and extension services.

Table 2. Descriptive summary of technical efficiency of wheat farms

Efficiency	Balance users	Imbalance users
Average TE	0.84	0.70
Minimum TE	0.41	0.29
Maximum TE	0.99	0.94
Mann-Whitney test (p-value)	0.000	

The technical efficiency categories of farms can be explained by Table 3. Around 77.3 percent of the balance users of fertilizers fall in range of between 80 and 100 percent technical efficiency, whereas only 37.1% of imbalance users fall in this range. Similarly, 13.6% of the balance users fall in the efficiency category of 60-80%, while 36.4 percent of imbalance users fall in this category. There is no farmer of balance user of fertilizers fall in this minimum efficiency category of 20-40% but 3.1 percent of imbalance users' fall in this minimum range of efficiency. It is indicated that technical efficiency of imbalance users starts from 20 percent level of efficiency whereas balance users start from 40 percent level of efficiency.

Table 3.Categories of technical efficiency of wheat

Efficiency categories	Balance users	Imbalance users
20-30 %	0 (0)	1 (0.8)
30-40 %	0 (0)	3 (2.3)
40-50 %	2 (9.1)	11 (8.3)
50-60 %	0 (0)	20 (15.2)
60-70 %	2 (9.1)	21 (15.9)
70-80 %	1 (4.5)	27 (20.5)
80-90 %	4 (18.2)	38 (28.8)
90-100 %	8 (59.1)	11 (8.3)
Total number of wheat farmers (%)	22 (100)	132 (100)

IV. Conclusion and Suggestions

It is found that there is considerable difference of technical efficiency between balance and imbalance users for wheat crop. The average technical efficiency of balance users of fertilizers nutrients is higher than imbalance users and it is found that technical efficiency of wheat is increased by 14 points if farmers used fertilizers in proper ratio. Similarly average yield of wheat of balance users of fertilizers is also higher (38 mounds per acre)than imbalance users of fertilizers and this difference is driven by the significant variation in inputs used and realized in addition to the variation in farming experience, education, membership in farming organization, off farm income, amount of off farm income, excess to production loan, amount of production loan and access to extension services. Balance use of fertilizers is important factor that need to be take into consideration in agricultural production systems. The best policy option is to determine the nutrients status of soil and crop through soil or plant analysis and then apply fertilizers according to proper requirements of crop to obtain high efficiency and profit. It is suggested to improve the extension services and education to create awareness among farmers and adoption practices about balance use of fertilizers nutrients.

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