Resource Productivity in the Punjab's Agriculture

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Concerted efforts are being made at micro as well as macro levels in Pakistan to increase farm production and raise productivity in the agricultural sector. For diagnostic purposes and for formulation of general guidelines for an intelligent decision making, at micro and macro levels, it is important to identify and quantify the contribution of various factor inputs, especially of those factors whose supplies can be more easily changed in the short run.

Satisfactory quantitative estimates of resource productivity in the production of major crops in Pakistan are generally not available. Except for a few studies carried out on wheat [2], not much is known about the contribution of various factor inputs, such as farm labour, fertilizers, etc., to the final output. The main objective of this paper is to estimate and analyse the resource productivity of various factor inputs obtaining in the Punjab's agriculture. The estimates are derived from production function analysis performed on the major crops of the province, i.e. Mexi-Pak and local wheat, *Basmati* rice, IRRI rice, *Jhonna* rice, maize (corn), cotton and sugarcane. The marginal productivities of various farm inputs in the production of various crops are computed from the estimated production functions.

Under the prevailing circumstances, it is well known that farmers cannot change their inputs of land and labour in the short run. The use patterns of these inputs may be conditioned by the institutional framework and factors which are beyond the control of individual farmers. Production function studies based on cross-section data, like the present one, may not be readily useful for the

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guidance of individual farmers. Nevertheless, they are helpful to the planners and policy-makers in providing an understanding of how productively the available resources are employed under the present set-up.

The paper is divided into four sections. Section I briefly describes the size and sample procedure followed in the selection of sample. The theoretical framework of analysis, explanation of the input-output variables and limitations of data are discussed in Section II. The results of the empirical analysis are presented in Section III. Finally, the main findings of the paper are summarised and some policy recommendations made in Section IV.

I. Sample Size and Sampling Procedure

For an empirical production function analysis, a detailed set of quantitative information on farm output and factor inputs, such as crop area, labour input, irrigation, use of fertilizers, etc., is essential. To collect this information, a farm management survey in Sahiwal and Gujranwala districts of the Punjab province was organized in the fall of 1973, in which 192 farmers were interviewed. The data collected through the survey pertain to the 1972-73 cropping year.

The sampling process of the survey, which was based on a multistage sample selection procedure, is briefly described below.[1]

Selection of Districts

The 19 districts of the Punjab province were divided into three strata. The cropping pattern and the availability of irrigation water have considerable influence on the use pattern and productivity of factor inputs. Districts, whose main source of irrigation is rainfall, were excluded from the list of the districts from which the sample was drawn. Three districts, viz. Campbellpur, Jhelum and Rawalpindi, were thus dropped from the universe.

Agriculture in the canal-irrigated districts of the province is characterized by two distinct cropping patterns: wheat-rice and wheat-cotton. The canal-irrigated districts were thus stratified on the basis of the cropping pattern followed. Wheat and rice form the dominant cropping pattern in Gujranwala, Sialkot and Sheikhupura districts, whereas wheat-cotton is the main cropping pattern followed in Sahiwal, Multan, Rahim Yar Khan, Bahawalpur, Bahawalnagar, Jhang, Lyallpur, Sargodha, Dera Ghazi Khan and Muzaffargarh districts of the province. On the basis of the criteria relating to (a) relatively large percentage of crop area under wheat, rice and cotton individually, (b) availability of tubewell irrigation water not constrained by saline underground water, (c) absence of special government projects like Salinity Control and Reclamation Projects (SCARP) etc., and (d) high aggregate fertilizer consumption in the district, Sahiwal and Gujranwala districts were selected to represent wheat-cotton and wheat-rice cropping patterns respectively.

Selection of Villages

A list of all the villages in each of two selected districts was prepared. Eight 'representative' villages from each of the sample districts were selected

[1]For details of sample selection, please refer to [10, Ch. 3].

after consultation with the officials of the Department of Agriculture, Punjab Agricultural Development and Supplies Corporation and the Department of Local Government. It was ensured that none of the selected villages was less than 6 to 8 miles from the market town. This was done in order to guard against any urban influence.

Selection of Farmers

Twelve farmers from each of the selected villages were chosen in consultation with the local leaders, village headmen, and ex-members and secretaries of the union councils. The main purpose of the survey was carefully explained to the local leaders and respondents. While selecting the farmers, it was ensured that all the *pattis*[3] of the village were represented in the sample. If more than one ethnic group were living in the village, as it often happened, efforts were made to include farmers from each of the ethnic groups. It was further ensured that their farms were spread around the village. The size distribution of farms was ascertained in each village. Effort was made to select the number of small, medium and large farmers in direct proportion to their relative numbers in the sample village. Farms above 50 acres were excluded from the sample.

II. Theoretical Framework of Analysis, Explanation of Input-Output Factors and Limitations of Data

Production Function Analysis

The production function is a concept in physical and biological sciences, which has been widely used in economic analysis. "The production function refers to the relationship between the input of factor services and the output of products; product output is a function of or is 'dependent' on the input of resource services" [6, p. 30]. Mathematically, a production function may be expressed as:

$$Y = f(X_1, \ldots, X_n)$$

where Y is output (dependent variable), and

$X_1, \ldots, X_n$ are factor inputs (independent variables).

The production function, given above, describes the general form of the relationship but it does not specify the nature of functional relationship. The algebraic form of the function describing the nature of relationship will vary with soil and the type and variety of the crop under investigation. Given a functional relationship, the function describes how the average quantity of output changes when levels of various inputs are changed.

Specification of the Production Function

While formulating the economic model, the researcher faces three problems: (1) specification of the variables, (2) choice of single equation or a system

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[3]A village is often subdivided into parts called *pattis*. A *patti* is an area existing in the minds of inhabitants, but it may have very obvious physical manifestations which differentiate groups living in village [9].

of equations, and (3) selection of the algebraic form of equations. The ideally correct answers to these problems lie in the logic—economic, biological, physical —underlying the production process [7, p. 197]. For empirical research, the model has to be not only logically sound but also computationally feasible.

In order to be useful for providing guidelines in planning and policy formulation, the estimated production function must include all the important variables affecting farm production. If some of the variables relevant to the production process are omitted, the estimated function will be biased in an economic sense and would not be expected to depict truly the production process either structurally or predictively. Nevertheless, in empirical studies like this one, it becomes frequently inevitable to compromise and use second-best methods or variable because of (1) non-availability of data on certain variables, (2) immeasurability of certain inputs, and (3) limited resources at the disposal of the researchers. Griliches [5] has pointed out that specification errors arise because of approximations, omission and commission of data.

A true functional relationship underlies any given production process. Nevertheless, the economic, physical and biological logic of the production process is usually unknown to a large extent. This is particularly true of the production process involving entrepreneurial decision-making.

The ordinary least squares (OLS) method of regression analysis was used to estimate the parameters of the production function. The use of single equation models for agricultural production functions has been justified by Griliches [5], Mundlak and Hoch [8], and Zellner, Kmenta and Dreze [13] who argue that inputs in agriculture are largely predetermined because of a considerable lag in production. Moreover, since the error is largely determined by weather, it is argued that the simultaneous equation bias will be small for well-specified production functions.

Different types of production functions (Cobb-Douglas, quadratic, square root, and linear) were used in this study, depending on the appropriateness and "goodness of fit".[3] This frequently could not be determined *a priori*, but had to be evaluated after actual tried fits in the light of various economic and statistical criteria.[4]

Explanation of the Input-Output Factors

The total output of each crop is measured in physical terms (pounds) and is used as a dependent variable in the estimation of unrestricted production functions. While estimating the coefficients of per acre production function for each crop, the per acre yield of a particular crop is uesd as a dependent variable.

Independent or explanatory variables included in the production function analysis of given crops are crop acreage, manual and bullock labour used on various operations for the crop, chemical fertilizers used and farmyard manure expenses. For per acre production functions, these variables have been

[3]For an excellent discussion on the characteristics and properties of various types of production function, see [7] and [12].

[4]For a discussion on economic and statistical criteria, see [4], [7] and [11].

divided by the respective cropped acreage. Manual and bullock labour spent on various farm operations for each crop is measured in hours. The use of farmyard manure, a by-product of farm animals, was quite common in the case of cotton. To overcome problems of measurement and variations in its quality, the opportunity cost of farmyard manure (obtained by multiplying the cartloads used on a given crop by the prevailing price of similar kinds of farmyard manure in that community) is used in the analysis.

The quantity of nitrogenous fertilizer applied to a particular crop was converted into nutrient pounds and used as an independent variable in the production function analysis. For cotton crop, the use of phosphate fertilizer was represented by a dummy variable. In the case of Mexi-Pak wheat, there were quite a number of observations on the use of phosphate fertilizers (40 percent of the growers), in addition to those on the use of nitrogenous fertilizers (89 percent of the growers). Hence, it was decided to use total cash expenditure on nitrogen and phosphate fertilizers as an independent variable in the analysis.

A management index, based on the farming practices (method of crop sowing, farmer's know-how of fertilizer, and improved cultivation practices), was constructed and used as a dummy variable in the production function analysis. Farmers using improved methods of crop cultivation and showing better understanding of fertilizers etc. were rated as good and the remaining as average farmers.

Limitations of Data

The estimated functions do not include fixed capital and irrigation among their explanatory variables. The omission of these factors may have introduced some bias into the estimated coefficients of some of the variables. The production process underlying the production functions is assumed to be similar for the various farm size categories.

Nevertheless, these limitations of data or analysis are, fortunately, not likely to pose serious problems or to influence the usefulness and validity of our analysis to any great extent. Under the farming conditions prevailing in the Punjab, it is the working capital in the form of bullocks, fertilizers and farmyard manure which is more important in crop production than any fixed structures. A precise measurement of the amount of irrigation water used on a particular crop is not possible through survey methods. Data on the total number of irrigations applied to a particular crop were obtained. However, inter-farm comparison of these data did not reveal any significant variation among various farms. This observed fact was primarily due to the accessibility to tubewell irrigation of a great majority (94 percent) of the farmers. Initially, for the production function analysis, the observations were subdivided into various farm size categories but this resulted in poor fits and the number of observations in some of the farm categories became too small for subsequent statistical tests. Therefore, the observations were pooled and a single function for each crop was estimated. Moreover, it is farm management rather than farm size which is likely to result in different production functions. The inclusion of farm management, as a dummy variable, in our analysis should take care of any systematic influence on the production of different crops.

As the by-products of various crops have not been included in the analysis, the returns attributable to different factor inputs would be proportionately underestimated.

III. Results of the Empirical Analysis

The estimated coefficients for different types of "performance functions" (based on total output and total factor inputs, including crop area) and related statistics for various crops are presented in Table 1. The size of the adjusted coefficient of multiple determination, $\bar{R}^2$, shows that a major proportion of the inter-farm variation in output of these crops is explained by the factor inputs included in the performance functions. These functions, though useful in terms of their predictive value, are, nevertheless, difficult to interpret in either behavioural or structural terms. The high value of observed correlation between the land input and other farm inputs makes the interpretation of the estimated coefficients difficult, if not impossible. The collinearity between land and other factor inputs is the likely explanation of the unexpected negative coefficients obtained in some of the estimated performance functions. Nevertheless, if we wanted to predict the performance in terms of the total output of farm firms under varying input combinations, the performance functions would be the appropriate predictors.

The estimated coefficients and related statistics of the per acre production functions for different factor inputs in the production of major crop are provided in Table 2. The per acre production functions are obtained by regressing per acre yield of different crops on per acre factor inputs used per farm.

Linear and log-linear equations for the per acre production functions were selected on the basis of various economic and statistical criteria as well as for their computational feasibility. Some of these per acre production functions were not found statistically significant (insignificant F ratio and very low $\bar{R}^2$). These poor fits might have resulted from (1) the lack of significant variation in per acre yields and factor inputs, (2) factors which, though not included in our production function analysis (such as climate and soil type), may be more important in explaining differences in per acre yield of these crops, (3) the technology used on these farms, varying so widely that no relation between the observed behaviour of the different farms existed. However, the most likely explanation is that farm technology is constant and inter farm variation in yield on these farms is small. The variation in total output is effectively explained by the cropped area alone. This appears to be true for all the crops, but especially for *Basmati* rice, IRRI rice, maize (corn) and sugarcane.

Estimated Output Coefficients and Marginal Productivities

The main objective of estimating the performance and per acre production functions was to estimate the structural relationship between output of selected crops and various farm inputs. The marginal physical productivities of various factor inputs can be derived by taking the partial derivatives of the estimated per acre production functions with respect to the inputs. For linear equations it is quite straightforward and the coefficients themselves denote the marginal

Table 1

Estimated Coefficients and Related Performance Function Statistics for Selected Crops, 1972-73, *Punjab*

Crops	N	Intercept	X_1 Crop Acres	X_2 Man Hours	X_3 Bullock Hours	X_4 Expenses on Fertilizers	X_5 Pounds of Nitrogen
1	2	3	4	5	6	7	8
Mexi-Pak wheat (Cobb-Douglas)	172	+0.402	—0.208 (0.237)	+0.652* (0.471)	+0.609** (0.291)	+0.44** (0.014)	— —
Local wheat (Linear)	24	+367.40	—1694.156** (511.350)	+14.357** (2.476)	— —	— —	+6.785** (2.889)
Basmati rice (Cobb-Douglas)	133	+4.498	+0.396** (0.238)	+0.447* (0.303)	+0.113 (0.127)	— —	+0.004 (0.013)
IRRI rice (Cobb-Douglas)	33	+7.768	+1.022* (0.628)	—0.340 (0.694)	+0.377** (0.219)	— —	—0.007 (0.029)
Jhonna rice (Square root in Nitrogen)	38	—102.823	+571.519 (1581.669)	+8.556 (7.864)	— —	— —	+30.760** (11.952)
Maize (Quadratic in Nitrogen)	39	+32.489	+743.045* (530.514)	+1.305 (2.001)	— —	— —	+11.674* (7.334)
Cotton (Square root in Nitrogen)	95	+1311.88	+1033.378** (566.134)	—3.822** (1.669))	+5.900** (1.480)	— —	+10.041** (1.409)
Sugarcane (Quadratic in Nitrogen)	83	—592.477	—715.431 (2678.852)	+0.164 (3.509)	+6.524** (2.754)	— —	+13.428** (6.273)

—*Continued*

Table 1 *Continued*

Crops	x_6 $(x_5)^2$	x_7 $(x_5)^{.5}$	x_8 Expenses on FYM	x_9 Index of Management	x_{10} Phosphate use	$\bar{R}^2$	F-Ratio
	9	10	11	12	13	14	15
Mexi-Pak wheat	—	—	—	+0.142**	—	0.86	206.38
(Cobb-Douglas)	—	—	—	(0.056)	—		
Local wheat	—	—	—8.051**	—	—	0.95	112.41
(Linear)	—	—	(3.033)	—	—		
Basmati rice	—	—	—	+0.162**	—	0.93	335.26
(Cobb-Douglas)	—	—	—	(0.068)	—		
IRRI rice	—	—	—	+0.256*	—	0.84	32.69
(Cobb-Douglas)	—	—	—	(0.172)	—		
Jhonna **rice**	—	—333.195**	—4.352	—	—	0.90	67.23
(Square root in Nitrogen)	—	(193.845)	(8.927)	—	—		
Maize	—0.029*	—	—	—	—	0.73	25.31
(Quadratic in Nitrogen)	(0.022)	—	—	—	—		
Cotton	—	—110.835**	+2.468*	—	+2.90**	0.88	100.24
(Square root in Nitrogen)	—	(46.060)	(1.581)	—	(1.55)		
Sugarcane	—0.066**	—	+5.059**	—	—	0.84	73.56
(Quadratic in Nitrogen)	(0.018)	—	(2.691)	—	—		

—*Continued*

Table Indicators

\+ The types of performance functions estimated are given under the crop name in parentheses. The primary data used are output-input figures per farm. The output of the respective crops per farm measured in physical units is the dependent variable. Output of wheat and maize was measured in pounds of grain. Rice output was measured in pounds of unhusked paddy. Output of cotton refers to pounds of seed of cotton, while that of sugarcane to pounds of *gur* (raw sugar).

x_1 = Acres under respective crops

x_2 = Man hours spent on various farm operation for the respective crops

x_3 = Bullock hours spent on various farm operation for the respective crops

x_4 = Expenditure on nitrogenous and phosphate fertilizers applied on respective crops (rupees)

x_5 = Pounds of nitrogen nutrient applied for the respective crops

x_6 = $(x_5)^2$

x_7 = $(x_5)^{.5}$

x_8 = Opportunity cost of the framyard manure (FYM) used for respective crops

x_9 = Index of farm management represented by a dummy variable

x_{10} = Use of phosphate fertilizer represented by a dummy variable

N = Number of observations

( ) = Numbers in parenthese are the calculated standard errors of the respective coefficients

* = Coefficients significantly different from zero at 90 percent level of probability

** = Coefficients significantly different from zero at 95 percent level of probability

— = Indicates variable not included in the fitted regression

The non-starred coefficients are not statistically significant at the 90 percent level of probability

All of the F ratios are statistically significant

$\bar{R}^2$ = Adjusted coefficient of determination.

Table 2

Production Coefficients and Related Production Function Statistics+*(on per acre basis) for Selected Crops* 1972-73, *Punjab*

Crops	N	Intercept	Z_1 Manual Labour	Z_2 Bullock Labour	Z_3 Expenses on Fertilizers
1	2	3	4	5	6
Mexi-Pak wheat (Cobb-Douglas)	172	+1.392	+0.439 (0.471)	+0.670** (0.295)	+0.048** (0.015)
Local wheat (Linear)	24	—1032.304	+11.019** (3.288)	— —	— —
Basmati rice (Cobb-Douglas)	133	+4.150	+0.495* (0.303)	+0.118 (0.128)	—
IRRI rice (Cobb-Douglas)	33	+7.438	—0.280 (0.678)	+0.394** (0.215)	— —
Jhonna rice (Linear)	38	—893.596	+14.535** (6.956)	— —	— —
Maize (Linear)	39	+749.331	+2.037 (2.731)	— —	— —
Cotton (Linear)	95	719.027	—1.145 (1.301)	+2.272* (1.588)	— — —
Sugarcane (Linear)	83	—1296.153	+3.912 (4.072)	0.524 (2.676)	—

—Continued

Table 2—*Continued*

Group	Z_4 Pounds of Nitrogen	Z_5 Expenses on FYM	Z_6 Index of Management	Z_7 Phosphate Use	$\bar{R}^2$	F-Ratio
	7	8	9	10	11	12
Mexi-Pak wheat (Cobb-Douglas)	—	—	+0.160** (0.057)	—	0.39	28.032
Local wheat (Linear)	+11.264** (3.075)	—1.608 (2.540)	— —	— —	0.61	12.759
Basmati rice (Cobb-Douglas)	+0.012 (0.012)	— —	+0.152** (0.068)	— —	0.13	5.977
IRRI rice (Cobb-Douglas)	—0.011 (0.028)	— —	+0.272* (0.167)	— —	0.06	1.521
Jhonna rice (Linear)	+9.747** (5.765)	—4.952 (7.311)	— —	— —	0.20	4.103
Maize (Linear)	+4.358 (3.635)	+0.442 (2.175)	— —	— —	0.012	1.171
Cotton (Linear)	+3.407** (1.187)	+2.812** (1.258)	—	+0.346** (0.164)		
Sugarcane (Linear)	+1.119 (4.521)	+3.584 (2.923)	— —	— —	0.05	2.454

Continued

Table Indicators

The types of production function estimated are given in parentheses under the crop names. The primary data used are the average yield per acre and average amount of various factor inputs used for the respective crops on per acre basis. Per acre yield (physical units) was obtained by dividing total ouput of the respective crops by the acreage under particular crop and is measured in pounds.

Z_1	=	(x_2/x_1)	=	Average number of man hours spent on per acre of respective crops
Z_2	=	(x_3/x_1)	=	Average number of bullock hours spent on per acre of respective crops
Z_3	=	(x_4/x_1)	=	Average amount (rupees) spent on fertilizers for one acre of respective crop
Z_4	=	(x_5/x_1)	=	Average pounds of nitrogen (nutrient) applied per acre of crop
Z_5	=	(x_6/x_1)	=	Average expenses on farmyard manure (rupees) for an acre of respective crop
Z_6			=	Index of management, represented by a dummy variable
Z_7			=	Use of phosphate on a particular crop represented by a dummy variable
N			=	Number of observations
( )			=	Numbers in parenthesis are the calculated standard errors of the respective coefficients
*			=	Coefficient significantly different from zero at 90 percent level of probability
**			=	Coefficient significantly different from zero at 95 percent level of probability
—			=	Indicates the variables not included in the fitted regression

The non-starred coefficients are not statistically significant at the 90 percent level of probability

The F ratios for Mexi-Pak and local wheats, Basmati rice and cotton are statistically significant at 99 percent level while that for Jhonna rice is statistically significant at 95 percent level. The F ratios for maize, IRRI rice and sugarcane regressions were not found statistically significant

$\bar{R}^2$ = Adjusted coefficient of determination.

productivity of the respective factor inputs. The marginal physical products from the log-linear equations[5] are calculated by the following formula:

$$MPP_{zi} = b_i \frac{Y}{Z_i}$$

where bi = output elasticity of input i
y = output (average yield per acre in our case)
zi = i-th input

The geometric mean levels of output and inputs are employed in the above formula for marginal productivity computations.

The marginal physical productivities of different factor inputs in the production of the selected crops, derived from the per acre production functions, are given in Table 3. For the crops for which the estimated per acre production functions were not statistically significant, (IRRI rice, maize and sugarcane) the marginal productivities were not calculated. For these crops it would be reasonable to assume that the output elasticity of land equals one, which also implies that all inputs changed proportionately with the change in the cropped acreage.

Manual and Bullock Labour

Generally speaking, the estimated coefficients for the manual and bullock labour as shown in Table 1 are quite high. The share of these two factor inputs as indicated by their estimated coefficients is consistent with *a priori* expectations. For those familiar with the manual and bullock labour-oriented agriculture in the Punjab, it is not surprising to find that the contribution of labour, as manifested by the output coefficients, is quite high. However, it may be pointed out that it also incorporates the contribution of various complementary farm implements.

The low productivity of manual labour in case of cotton may be inherent in the nature of its various farming operations since some of these, such as cotton picking, are very labour-intensive.

The relatively high coefficients for manual and bullock labour might also imply comparatively less use of these resources and more use of other input factors. However, in view of the province's labour-intensive agriculture this may not be true except under the circumstances discussed later in the context of low productivity for Mexi-Pak wheat area.

Chemical Fertilizer

From the estimated coefficients of the performance functions it is clear that the output as well as per acre yield of major crops is positively associated with the use of fertilizers. The coefficient of fertilizer for IRRI rice shows a negative sign but it must be pointed out that the coefficient is statistically insignificant. In view of the small number of observations, it is difficult to make any definite statement in this regard. In the case of *Basmati* rice the yield per acre of unhusked paddy is positively associated with the use of nitrogenous fertilizers, but again the coefficient is not significantly different from zero in a statistical sense.

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[5]The coefficients of Cobb-Douglas production functions denote the output elasticities of the respective factor inputs. The output elasticities indicate the percentage change in output which would, on the average, be accompanied by one percent change in the input concerned, while all other inputs are held constant.

Table 3

Marginal Productivities for Various Factor Inputs for Selected Crops in Punjab (1972-73)

	Manual Labour		Bullock Labour		Chemical Fertilizers		FYM Expenses	
	MPP	MVP (Rs)	MPP	MVP (Rs)	MPP[1]	MVP (Rs)	MPP	MVP (Rs)
Mexi-Pak wheat	3.82*		6.45	1.68	3.91	1.02		
Local wheat	11.02	2.87			11.26	2.93	—1.61*	
Basmati rice	4.06	1.29	1.75*		2.53*			
Jhonna rice	14.54	3.05			9.75	2.05	—4.95*	
Cotton	—1.51		2.27	1.86	3.41	2.80	2.81	2.30

MPP = Marginal physical product. The marginal physical products of wheat, rice and cotton are in pounds of grain, unhusked paddy and seed-cotton respectively. The MPPS for Mexi-Pak and Basmati rice and calculated at the geometric mean levels of output and inputs.

* = MPPs are not statistically significant

— = Indicates those factor inputs not included in the estimated equation

1 = The marginal physical product for fertilizer in the context of Mexi-Pak wheat refers to cash expenses spent on nitrogenous as well as phosphate fertilizers. All other marginal physical products are for an additional pound of nitrogen nutrient.

Prices per pound of wheat grain, unhusked *Basmati* paddy, *Jhonna* paddy and seed cotton were Rs. 0.26, Rs. 0.32, Rs. 0.21 and Rs. 0.82 respectively.

Price per pound of nitrogen was Rs. 0.73.

Miscellaneous pamphlets, leaflets and market development literature issued by the ESSO fertilizer company [3] and Dawood Hercules [1] indicate that the farmers using a proper combination of nitrogenous and phosphate fertilizers have high rates of return from investment in fertilizers for all major crops including rice. Nevertheless, our analysis fails to establish a significantly positive relationship between the use of nitrogenous fertilizers and yield of rice. This may have been due either to the lack of variation in the per acre use of nitrogenous fertilizer or the over-use of nitrogenous fertilizers and inadequate use of other complementary inputs, especially phosphate fertilizers. The latter view is further confirmed by this author's earlier findings [10, 11] that show lesser appreciation among the farmers of the role of phosphate fertilizers in oop production.

From the comparatively high output elasticity of manual labour and practically zero elasticity of nitrogenous fertilizer in *Basmati* production, it may also be argued that farmers are substituting nitrogenous fertilizers for certain farm operations involving manual labour such as weeding, hoeing, etc.

During the field survey, it was observed that the farmers were quite concerned with the lodging of *Basmati* rice. It may be mentioned here that the use of nitrogenous fertilizer alone, without adequate use of phosphate fertilizers, encourages vegetative growth, and thus makes the crop vulnerable to lodging. When lodging occurs, the crop yield is adversely affected.

The total output and yield of *Jhonna* rice and local wheat were positively related to the use of fertilizer. The marginal physical product for an additional pound of nitrogen was estimated at about 9.75 pounds of unhusked paddy and 11.26 pounds of wheat grain respectively.

The total output as well as per acre yield of cotton (American) was positively associated with the fertilizer use. The marginal physical product for nitrogenous fertilizers is estimated at about 3.4 pounds of seed cotton. The use of phosphate fertilizer on cotton crop was represented by a dummy variable. Farm output as well as yield per acre of seed cotton was significantly higher on those farms using phosphate fertilizers in addition to nitrogenous fertilizers.

In the case of Mexi-Pak wheat, the input of fertilizer is measured in terms of cash expenditure on both nitrogenous and phosphate fertilizers. The output elasticity coefficient with respect to fertilizer expenditure in total production function as well as per acre production function is positive and statistically significant. The marginal physical product for an additional rupee of investment in fertilizers is estimated at about 4 pounds of wheat.

Farmyard Manure Expenses

The coefficient of farmyard manure expenses in total production function as well as per acre production function for *Jhonna* rice has a negative sign. However, the coefficients are not statistically significant. This might imply that output or yield of *Jhonna* crop is not related to or influenced by the application of farmyard manure. Probably, when both farmyard manure and nitrogenous fertilizers are applied, the crop attains greater height and becomes more vulnerable to lodging which tends to reduce crop yield. It may be pointed out here that *Jhonna* rice is generally grown on marginal lands, primarily for the reclamation of those lands. It is the reclamation of these lands through an addition of farmyard manure and additional irrigation water which is the main objective, and not the crop yields in the short run.

The output coefficients of total production function as well as per acre production function with respect to farmyard manure expenses in case of cotton crop are positive and statistically significant. This indicates that the output of cotton crop is favourably influenced by the application of farmyard manure. Similarly, the coefficient of farmyard expenses in the estimated total production function of sugarcane is positive and statistically significant, indicating a positive influence of farmyard manure on sugarcane production.

Farm Management

The coefficient of the dummy variable representing farm management was positive and statistically significant (Tables 1 & 2) for Mexi-Pak wheat, and *Basmati* and IRRI rice. This indicates that higher output as well as per acre yield of these crops is associated with "better" management.

Crop Area

As indicated in Table 1, the estimated coefficients for crop acreage under *Basmati* rice, IRRI rice, maize and cotton are positive and statistically significant. This shows that higher farm output of these crops is associated with larger acreage under these crops. Since a larger crop area under these crops is likely to be associated with large farms, it would imply that a higher farm output of these crops is associated with large farms.

The estimated coefficients for crop area under sugarcane and Mexi-Pak wheat are negative but statistically insignificant.

In the case of Mexi-Pak wheat, the comparatively high coefficients for manual and bullock labour, relatively low elasticity coefficients for the fertilizer expenses and practically zero output elasticity for wheat acreage may also indicate that variable resources of conventional inputs of farm labour and farm capital are being spread too thinly over an extensive crop area.

During the field survey, it was observed that farmers continue sowing wheat crop after the normal sowing time is over. In wheat-cotton areas, farmers continue wheat sowing after harvesting cotton, sometimes as late as January, whereas the normal wheat sowing should not go beyond November and late sowing beyond the middle of December. After cotton harvesting, there is not much time left for adequate seed-bed preparation. Farmers, after broadcasting wheat seed in the fields, plough the fields a couple of times. Under these late sowing circumstances, farmers often resort to a heavy use of nitrogenous fertilizers. This encourages rapid vegetative growth of the crop. However, it cannot make up for the late sowing of the crop. Similarly, in rice growing areas, there are not many crops which could be cultivated after rice harvesting. Nor is there much time left for adequate land preparation. This is especially true after harvesting *Basmati* rice, since this variety takes a longer time to mature than other varieties.

It can also be argued that the government policy to increase domestic foodgrain production, in order to achieve self-sufficiency, encourages farmers to cultivate wheat on the maximum possible acreage, extending its cultivation to lands otherwise left fallow for natural recuperation. This results in a low output elasticity coefficient for wheat acreage. Mexi-Pak wheat sown at the proper time with adequate use of nitrogenous and phosphate fertilizers and judicious use of irrigation water gives quite high yields. This might also have encouraged farmers to extend wheat cultivation to marginal lands and to risk the late sowing of this crop. It is thus argued that (1) by extending wheat cultivation to marginal lands, (2) by late sowing of crop without adequate land preparation, and (3) by using comparatively higher amounts of nitrogenous fertilizers, farmers may be substituting fertilizers for manual and bullock labour. This results in higher output coefficients for manual and bullock labour and relatively low output coefficients for fertilizer expenses and the crop area.

IV. Summary of Conclusions and Policy Recommendations

Different types of performance functions based on total output and total factor inputs used in the production of selected major crop were estimated. The ones giving the "best fit" were selected to describe the relationship between the farm output and factor inputs used in the production process. Production functions based on the per acre yield were also estimated to compute the resource productivity of different inputs on the average farm. Marginal productivities of various factors were derived from the per acre production functions.

The per acre production functions for IRRI rice, maize and sugarcane were not found statistically significant. From this it appears that inter-farm variation in the yield per acre of these crops is small or technology is similar on all the farms. From the wide difference in the value of $\bar{R}^2$ for the performance and per acre production functions and the statistically insignificant F ratios for the per acre production functions, it is reasonable to conclude that the variation in the total output of these crops is effectively explained by the crop area alone. This is especially true for IRRI rice, maize and sugarcane.

Generally speaking, the estimated coefficients for manual and bullock labour were positive and consistent with *a priori* expectations. Farm output of Mexi-Pak wheat and *Basmati* and IRRI rice was higher on farms having better farm management.

The productivity of chemical fertilizer as indicated by the estimated coefficients of performance and per acre production functions was quite high for local wheat and *Jhonna* rice. However, marginal productivity of fertilizer in the production of Mexi-Pak wheat, cotton and *Basmati* and IRRI rice was quite low. The main reason for the low productivity of chemical fertilizer for these crops is an undue over-reliance by farmers on the use of a single nutrient—nitrogen. Available evidence [10, 11] suggests lack of knowledge on the part of farmers about the nutrient status of their soils and requirements of different crops for different kinds of fertilizer nutrients.

The output and yield of cotton was higher on farms using phosphate fertilizers in addition to that of nitrogen. Higher output of cotton and sugarcane was also associated with the use of farmyard manure.

Policy Recommendations

There appears a considerable potential for increasing farm production through the greater use of labour, fertilizers and farmyard manure on selected crops and changing land use patterns among alternative crops. It also appears that agricultural production may be increased by adopting improved agricultural practices and improving the management of the farms. Nevertheless, it must be mentioned here that it may not be possible to change the supplies of land and labour input and improve farm management in the short run. The supplies and use pattern of these factor inputs are primarily determined and conditioned by the institutional framework beyond the control of individual farmers. But the supplies and use pattern of variable factor inputs such as fertilizers and farmyard manure may be changed more readily.

Efforts should be made to increase the use of fertilizers and emphasis should be on a proper combination of various fertilizer nutrients, depending on the soil deficiencies and particular crop requirements.

Soils vary considerably in their levels of fertility and nutrient deficiency. Pakistani soils are generally known to be deficient in nitrogen. Nevertheless, one must not lose sight of the possibilities of other deficiencies, particularly those of phosphate, potassium and other essential micro nutrients. It is recommended that soil testing laboratories should be established in each district. The nature of soil deficiencies and their remedies should be highlighted to farmers and they must be educated and encouraged to have soil samples tested and use recommended combinations of fertilizer materials.

Special extension programmes should be launched to educate the farmers in respect of the method, timing, optimal dose and ratio of fertilizer elements for different crops to increase the efficiency of fertilizer materials.

The use of farmyard manure should be encouraged and increased especially on cotton and sugarcane. During the field survey it was observed that not much attention was being paid to the proper storage of farmyard manure. A lack of proper storage results in a considerable loss of its nutrients during the rainy season. Moreover, a considerable proportion of animal dung is used as household fuel. It is unwise to waste this cheap and important substitute for chemical fertilizers in this period of increasing prices of fertilizers. It is suggested that the extension wing of the Department of Agriculture should launch a campaign to advise the farmers on the methods of proper storage and not using farmyard manure as household fuel.

It appears that too much emphasis on expansion of wheat acreage is not warranted, especially if it involves extraordinary late-sowing of the crop. It is suggested that cultivation of short duration crops such as maize (spring cultivated) should be encouraged. This would take some of the pressure off the farmers for late sowing of wheat. Agronomic research to evolve short-duration crops and wheat varieties which thrive under conditions of late sowing should be carried out.

In view of the low productivity of fertilizers in general, but in *Basmati* and IRRI rice production in particular, as suggested by our analysis, further agronomic research needs to be carried out to determine its causes and suggest appropriate remedies.

Since the geographical scope of the study was limited to the canal irrigated districts of the Punjab province, the results of the study may not be applicable to the rainfed areas.

It is proposed that similar farm management studies on a larger scale should be conducted in different agro-climatic regions of the country to determine the resource productivity of various factor inputs under different farming conditions. These studies will provide useful information regarding the structure of the country's farming sector which could be helpful in formulating region-specific strategies and programmes for increasing farm production.

References

1. Dawood Hercules Chemicals Ltd., Lahore. Miscellaneous Pamphlets and Leaflets.
2. Eckert, Jerry B. "The Impact of Dwarf Wheats on Resource Productivity in West Pakistan's Punjab." Unpublished Ph.D. Thesis, Michigan State University, 1970.
3. ESSO Pakistan Fertilizer Company Ltd., Karachi. Miscellaneous Pamphlets and Leaflets.
4. Goldberger, Arthur S. *Econometric Theory.* New York: John Wiley and Sons, Inc., 1964.
5. Griliches, Zvi. "Specification Bias in Estimates of Production Functions." *Journal of Farm Economics.* Vol. 39. February 1957.
6. Heady, Earl O. *Economics of Agricultural Production and Resource Use.* Englewood Cliffs, N.J.: Prentice Hall Inc. 1952.
7. ———— and John L. Dillon. *Agricultural Production Functions.* Ames: Iowa State University Press. 1961.
8. Mundlak, Yair and Irving Hotch. "Consequences of Alternative Specifications in Estimation of Cobb-Douglas Production Functions." *Econometrica.* Vol. 33. October 1965.
9. Raza, Mohammad Rafique. *Two Pakistani Villages: A Study in Social Stratification.* Lahore: Punjab University Sociologists Alumni Association. 1965.
10. Salam, Abdul. "Economic Analysis of Fertilizer Application in Punjab-Pakistan." Unpublished Ph.D. Dissertation, University of Hawaii, 1975.
11. ————. "Socio-Economic and Institutional Factors Influencing Fertilizer Use in the Punjab (Pakistan)." *Pakistan Development Review.* Vol. XIV, No. 4. Winter 1975.
12. Yotopoulos, Pan A. *Allocative Efficiency in Economic Development.* Athens: Center of Planning and Economic Research. 1967.
13. Zellner, Arnold, J. Kmenta and J. Dreze. "Specification and Estimation of Cobb-Douglas Production Models." *Econometrica.* Vol. 34. October 1966.