Journal of Agricultural Development and Policy, 2021
Volume 31, No. 2, 175-181

Resource Use Efficiency of Tomato Production in Punjab

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Abstract

The study was conducted to analyze the productivity and resource use efficiency of tomato production in Punjab state. The production function analysis estimated that 41 percent of the variation in the yield of tomato crop among sampled farmers was explained by the specified inputs. The coefficients of labour, fertilizers, insecticides were observed positive and significantly influenced the yield of tomato production. Similarly fertilizers, insecticides and labour were found to be less than one indicating over utilization of these resources by the farmers, therefore, reduction in the use of these resources would have optimize returns. The findings of the study further revealed that the coefficient of dummy district was found negative indicating average yield of Amritsar district was found significantly lower than Patiala district by 0.113 percent. The large yield differential between Patiala and Amritsar tomato growers could be due to differences in their cultivation methods (bamboo staking vs open field culture), soil type, varietal difference, location specification in terms of access to services, and input management approaches. Tomato farmers were technically and economically inefficient in utilizing inputs. As per the recommendation, farmers' access to these resources must be improved by effective and efficient extension services, simple access to formal credit facilities, and encouragement to create cooperative organizations to acquire their input supplies at a lower cost that will be able to expand the scope of production and boost in output levels.

Keywords: Resource use efficiency, Tomato, Punjab, Productivity, China, India

JEL Classification: D24, P32, O13, I30

Introduction

Vegetables play an influential role in Indian agriculture by supplying food, nutritional and budgetary security to the community with maximum returns per unit area to the producers. After China, India is the world's second largest vegetable producer, accounting for 16.95 per cent of global vegetables production (FAO 2020). Potato (26.75%), onion (13.94%), tomato (10.72%), brinjal (6.66%), cabbage (4.80%), cauliflower (4.61%), okra (3.32%), and pea (2.97%) accounting for 74 per cent of total production in the country (GoI, 2020). Tomato (Lycopersicon esculentum) is a popular, nutrient-dense food that is also known as the poor man's orange because of its high vitamin C content. With 21.95 million tonnes (12.13 per cent of global production) and a productivity of 26.07 tonnes/hectare, India is the world's second-largest tomato producer, accounting for 15.52 percent of the world's total area under tomato (FAO, 2020).

Increasing the efficiency in production assumes greater significance in attaining potential output at the farm level. Farmers' reluctance to properly exploit current technologies has also been blamed for low agricultural output, resulting in inefficiencies in the production system (Murthy *et al*, 2009). Productivity may be raised by enhancing one or more of its determinants, namely technology, quantity, type, and efficiency of resources utilized. Investing in new technologies is pointless unless the present technology is fully utilized (Kalirajan and Shand, 1994). Given the existing resource base and available technology, agricultural productivity may be grown and sustained

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through making effective use of resources. Improvement in the efficiency of resources at the disposal of farmers is of great concern. An efficient farmer distributes resources in the most effective way to maximize his revenue while lowering his production costs. Numerous studies, on the other hand, reveal that farmers frequently spend their resources inefficiently. The net returns per unit of input utilized vary greatly from farm to farm due to differences in resources (both qualitative and quantitative) and management efficiency. It is vital to study the current level of resource-use efficiency in order to identify the elements that contribute to this level of efficiency and to enhance productivity. Tomatoes have a lot of potential and are in high demand, but because to rising input costs and low yields, output is dropping in many locations. A combination of initiatives aiming to enhance available farm resources and efficiency in the use of existing resources is required to boost agricultural output (Farlane, 1953; Afolami, 1982; Aigner *et al*, 1977; Ibitoye *et al*, 2015). Other factors include farmers fear of taking risks and a lack of information about how to combine these resources in the most effective and optimal way. In this context the present study has been taken to analyze the productivity and resource use efficiency of tomato production in selected districts of Punjab state.

Data Sources and Methodology

The primary data were collected for the year 2019-20 by using multistage stratified random sampling technique. In the first stage, two top ranking districts namely Amritsar and Patiala on the basis of probability proportional to area under tomato crop in the Punjab state were purposively selected. In the second stage, two blocks from each district i.e. Jandiala and Raiyya from Amritsar district and from Patiala district, Sanaur and Patiala were selected where the density of tomato growers was higher. In third stage, the villages/ cluster of villages with highest concentration of tomato growers from each block were selected in consultation with the officials of Horticulture/Agriculture Department. In next stage, a complete list of tomato growing farmers was prepared from the selected villages/cluster of villages with the help of *Sarpanch* of the village or societies in the villages and from each cluster of villages 50 tomato growers were selected randomly, 100 each from both the districts (Table 1). The farm size categories were selected on the basis of operational holdings i.e. small (less than 5 acres), medium (5-15 acres) and large (15 and above). The selection of farms was done on the basis of probability proportion to the number of farmers in each category. Consequently, 27 small, 58 medium and 15 large farmers were selected from Patiala district and 13 small, 23 medium and 64 large farmers were selected from Amritsar district. Overall 40 small, 81 medium and 79 large farmers were selected randomly resulting in the total sample of 200 farmers.

Production function analysis

Efficiency can be defined in terms of producing a maximum amount of output, given a set of inputs; or producing a given level of output using a minimum level of inputs; or a mixture of both. Efficient farms either use less input than others to produce a given quantity of output or for a given set of inputs they generate a greater output. For obtaining resource use efficiency at the farm level different production function forms were tried.

Table 1. Selected districts, blocks, villages and number of respondents, Punjab, 2019-20

Districts	Blocks	Selected villages	No. of villages in the cluster	Sample size
Amritsar	i) Jandiala	Teerthpur, Mallkpur, Wadhala johl, Chappa ram singh, Nawan pind, Fatehpur rajputan	6	50
	ii) Raiyya	Dhyanpur, Usma, Bhlaipur purba, Mehtampur, Sudhar rajputa, Sherbagha, Bheni ramdayal, Wadhala kala, Nangli kala, Nangli khurd, Jodhe	11	50
Patiala	i) Patiala	Lalucchi and Nwi Lalucchi	2	50
	ii) Sanaur	Sanaur and Asarpur	2	50
Grand Total			21	200

To identify the factors affecting the productivity of tomato, both linear and log linear production functions were fitted and numerous equations were tried by taking different explanatory variables. Best fit function was determined on the basis of the level of significance of the explanatory variables. The value of coefficient of multiple determination R^2 and the signs of the explanatory variables included in the model. The Cobb-Douglas Production Function of the following form was considered the most appropriate for the present investigation. These procedures were done using SPSS 16.0.

The general form of Cobb-Douglas equation used was.

$$Y = \beta_0 \times \prod_{i=1}^{n} X_i^{\beta_i} \times e^u$$

$$\text{Log Y} = \text{Log A} + \sum_{i=1}^{n} b_i \log x_i + u$$

$$\text{Log Y} = \text{Log A} + b_1 \log x_1 + b_2 \log x_2 + \ldots\ldots\ldots\ldots + b_{14} \log x_{14} + u$$

Where, Y represents the gross returns per acre in quintals of tomato crop under study, X_i the selected explanatory variables (per acre). A, the technical efficiency parameter and bi the coefficient of elasticity of production of the respective variable X_i at the mean level of input used and output obtained. The e is an error term.

The variables defined in the model are as follows:

Y= Yield of tomato in quintals per acre
X_1= Area under tomato crop (acres)
X_2= Expenditure on seed per acre (Rs.)
X_3= Expenditure on fertilizers per acre (Rs.)
X_4= Expenditure on fungicides per acre (Rs.)
X_5= Expenditure on insecticides per acre (Rs.)
X_6= Expenditure on weedicides per acre (Rs.)
X_7= Expenditure on human labour (Rs.)
X_8= Expenditure on machine use (Rs.)
X_9= Irrigations per acre (No.)
X_{10}= Expenditure on other micro nutrients per acre (Rs.)
X_{11}= Dummy district (D_1=1 for Amritsar and 0= Patiala)
X_{12}= Dummy farm size category (D_2=1for large and 0 for otherwise)
X_{13}= Dummy farm size category (D_3=1 for medium and 0 for otherwise)

Statistical significance of the estimates

To test the statistical significance of these estimates, t-value of the estimates was worked out at (n-k) degrees of freedom. The t-value of the regression coefficients (b_i) were worked out as under:

$$t_{(n-k)} = \frac{b_i}{S.E.(b_i)}$$

Where

S.E. is the standard error of the variable X_i

Coefficient of multiple determination (R^2)

The coefficient of multiple determination was worked out to estimate the proportion of variation in total output/gross returns per acre explained by the different explanatory variables, taken together in analysis. Statistical significance of R^2, which examine the goodness of fit of the function, was tested by working out F-ratio as follows:

$$F = \frac{R^2/K}{(1 - R^2)/n - k}$$

Where

R^2 is the value of the coefficient of multiple determination

n is the number of observations

K is the number of parameters included in the study

Resource Productivity

Estimation of MVP and MFC

The resource-use efficiency was examined on the basis of marginal value productivity (MVP), which indicated the increase in the returns from the use of an additional unit of a given input, while keeping the level of other inputs constant. The marginal value productivity (MVP) of the i^{th} input was calculated as following:

$$MVP = bi\left(\frac{\overline{Y}}{\overline{X}}\right)Py$$

Where,

b_i = regression coefficient of i^{th} input

$\overline{Y}_i$ = geometric mean level of tomato productivity per acre

$\overline{X}_i$ = geometric mean level of the i[th] input used

Py = price of tomato

(i) Marginal value product (MVP)

MVP_{xi} = Price per unit of output

(ii) Marginal factor cost (MFC)

MFC= Price per unit of input

Resource-use efficiency was studied by comparing the MVPs of each resource with corresponding factor cost.

Resource use efficiency

After estimating the MVP, the resource use efficiency of different resources was evaluated with the help of MVP to factor price (P_x) ratio as under:

MVP/MFC = 1 Optimum use of resource

MVP/MFC < 1 Excess utilization of resource

MVP/MFC > 1 Underutilization of resource

Results and Discussion

Production function analysis of tomato crop

Production function analysis was carried out to ascertain the functional relationship of various inputs used in production with the output. The basic functional relationship recognized by functional analysis relates to decision making. The marginal productivities or the elasticities obtained from the functional analysis can be further used to obtain the marginal rate of return, otherwise called as allocative efficiency. This allocative efficiency can be applicable to optimize the allocation of resources for profit maximisation. In this section elasticity of crop productivity with respect to different inputs was examined by fitting Cobb-Douglas type production function all the farms pooled together and the results are discussed below:

The results of estimated Cobb-Douglas production function in the production of tomato crop are presented in table 2. The results revealed that the value of coefficient of multiple determination (R^2) was estimated to be 0.41 per cent. Thus 41 per cent variation in the yield of tomato crop was explained by the explanatory variables included in the model and the rest 59 per cent were remained unexplained. This was due to the reason that yield from tomato cultivation not only depends on the inputs used but also on some other factors such as time of sowing, variety chosen, weather which are not included in the model.

The results indicated that the coefficients of human labour, fertilizers, insecticides, other micro and macro nutrients and dummy variable for district were observed positive and significant but the coefficient of area under tomato (-0.071) was found negative and significant at one per cent level of significance indicated that with one per cent increase in area under tomato, the yield would have been decrease by 0.071 per cent. The negative and significant coefficient of area under tomato may be due to diseconomies of scale i.e. managerial efficiency may have been reduced with the increase in area under tomato leading to reduction in yield. The per acre yield from tomato with respect to the fertilizers was found positive and significant at ten per cent level. The value of coefficient (0.087) indicated that if the use of fertilizers was increased by one per cent, the yield from tomato would have been increased by 0.08 per cent respectively. The coefficients of insecticides application in relation to tomato yield were found to be positively significant at ten per cent level. The value of the coefficient (0.003) indicated that with one per cent increase in the use of insecticides, the increase in the yield from tomato would have been 0.003 per cent. The elasticity coefficient of human labour use (0.120) in relation to yield from tomato was found positive and significant at ten per cent indicated that one per cent increase in the use of human labour, the yield from tomato would have been increase by 0.12 per cent. The elasticity (0.007) with respect to the use of other micro and macro nutrients like iron, sulphur, gypsum and plant growth hormones in tomato cultivation was found positive and significant at five per cent level implied that with an increase in the use of other micro and macro nutrients, the yield from tomato would have been increase by 0.007 per cent. From the results, it was also found out that the coefficient of dummy district for Amritsar was found negative and significant at 10 per cent level of significance indicating average yield of Amritsar district was found lower than Patiala district by 0.113 per cent. The large yield differential between Patiala and Amritsar tomato growers can be due to differences in their cultivation methods (bamboo staking vs open field culture), soil type, varietal difference, location specification in terms of access to services, and input management approaches (Ali *et al,* 2017; Paudel and Adhikari, 2018; Kumar *et al,* 2016). The coefficient from the inputs like seeds, fungicides, weedicides,

machine use, number of irrigations was found positive but non-significant indicated that with one per cent increase in these inputs would have no effect on the yield of tomato cultivation. No significant effect of farm size categories and yield was observed indicating these as scale neutral.

Resource use efficiency

Allocative efficiency is a measure of the firm's success in choosing an optimal set of inputs. It is an indication of gains that can be obtained by varying the input ratio based in a certain assumption about future price structure of the input and factor markets. The allocative efficiency was analysed using the ratio of marginal value productivity (MVP) and marginal factor cost (MFC). The efficiency of resources used by the farmers was examined by comparing the estimated marginal value products (MVPs) of various inputs with their respective factor costs. The same is presented in table 3. The MVP to MFC ratio with respect to

Table 2. Estimated parameters of production function (Cobb-Douglas) for tomato production in Punjab, 2019-20.

Variables	Parameter estimate
Intercept	2.625**
	(1.028)
Area under tomato (Acres)	-0.071***
	(0.023)
Seed (Rs./acre)	0.042
	(0.061)
Fertilizers (Rs./acre)	0.087*
	(0.052)
Fungicides (Rs./acre)	0.006
	(0.004)
Insecticides (Rs./acre)	0.003*
	(0.010)
Weedicides (Rs./acre)	0.008
	(0.011)
Human labour use (Rs./acre)	0.120*
	(0.069)
Machine use (Rs./acre)	0.025
	(0.040)
Irrigation (No./acre)	0.112
	(0.083)
Other micro and macro nutrients (Rs./acre)	0.007**
	(0.003)
Dummy (D_1=1 for Amritsar and 0= Patiala)	-0.113*
	(0.066)
Dummy (D_2=1for large and 0 for otherwise)	0.023
	(0.055)
Dummy (D_3=1 for medium and 0 for otherwise)	-0.051
	(0.046)
R^2	0.414
F-value	10.11***
No. of observations	200

*Note: ***, **, * denotes significance level at 1 per cent, 5 per cent, 10 per cent level respectively*
Figures in the parentheses indicate the standard error.

Table 3. Marginal value product (MVP) and Marginal factor cost (MFC) of the variable inputs for tomato, Punjab, 2019-20.

Inputs	MVP	MFC	MVP/MFC	Ratio	Efficiency
Fertilizers	0.003	1	0.003	r < 1	Over utilization
Insecticides	0.0001	1	0.0001	r < 1	Over utilization
Human labour	0.0009	1	0.0009	r < 1	Over utilization
Other micro and macro nutrients	0.0016	1	0.0016	r < 1	Over utilization

specific input equals one indicates the efficient use of respective input. A ratio of more than 1 indicates the under utilization of that particular resource and scope of increase in its application till the ratio reached one and if the ratio is less than one indicating over utilization of that resource and reduction in its application will optimize yield. The ratio of MVP to MFC for fertilizers (0.003), insecticides (0.0001), human labour use (0.0009) and other micro and macro nutrients use (0.0016) were found to be less than one indicating over utilization of these resources by the farmers, therefore, reduction in the use of these resources would have optimize returns. The results for fertilizer application, insecticides and other micro and macro nutrients use indicated that an increase of one rupee in fertilizer application, insecticides and other micro and macro nutrients use would reduce a return of Re 0.003, Re 0.0001 and Re 0.0009. This showed that the fertilizer application, insecticides application and other micro and macro nutrients application should enhance tomato cultivation to curtail their excessive use to reap benefits. The results for human labour use indicated that the farmer would gain Re. 0.0009 if they applied an additional unit of labour worth Rs. 1. The farmers will suggest curtailing the excessive use of human labour in tomato cultivation.

Conclusion and Policy Implications

The study indicated that the coefficients of human labour, fertilizers, insecticides, other micro and macro nutrients and dummy variable for district were observed positive and significant but the coefficient of area under tomato (- 0.071) was found negative and significant at one per cent level of significance indicated that with one percent increase in area under tomato, the yield would have been decreased by 0.071 per cent. The coefficient of dummy district for Amritsar was found indicating average yield of Amritsar district was found significantly lower than Patiala district by 0.113 per cent. The significant difference in the mean yield of the tomato growers of Patiala and Amritsar could be attributed to difference in their methods of cultivation (bamboo staking vs open field cultivation), soil type, varietal difference, location specification in terms of access to services and input management methods. No significant effect of farm size categories and yield was observed indicating these as scale neutral. The ratios of MVP to MFC for fertilizers (0.003), insecticides (0.0001), human labour use (0.0009) and other micro and macro nutrients use (0.0016) were found to be less than one indicating over utilization of these resources by the farmers, therefore, reduction in the use of these resources would have optimize returns. The findings of the study implies that for the optimum level of production to be achieved, the resources must be used efficiently. In this study, tomato farmers were technically and economically inefficient in utilizing inputs. As per the recommendation, farmers' access to these resources must be improved by effective and efficient extension services, simple access to formal credit facilities, and encouragement to create cooperative organizations to acquire their input supplies at a lower cost that will be able to expand the scope of production and boost in output levels.

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Received: July 12, 2021 Accepted: October 3, 2021