J. Appl. Environ. Biol. Sci., 7(1)11-18, 2017

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Resource Use Efficiency and Return to Scale Analysis in Off-Season Tomato Production in Punjab, Pakistan

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Received: August 30, 2016
Accepted: November 2, 2016

ABSTRACT

Agriculture sector contribute 20.88% in gross domestic product of Pakistan and engaged 43.5% of labor force. Progress in agriculture sector is necessary for the development of all other sectors. Efficient utilization of resources in agriculture is very important for food security and elimination of poverty. Vegetables have a key role in agriculture and their production increases in different countries. The purpose of current study is to check the resource use efficiency and return to scale in off-season tomato production in Punjab province of Pakistan. Simple random sampling was used for primary data collection from 70 off-season tomato growing farmers. Cobb-Douglas function was used to check the production elasticity of different inputs. Overall goodness of model was revealed from coefficient of determination (R^2) (0.693) and f-statistics (11.888). Elasticity of production showed positive sign in case of age, education, experience, polythene sheet, tractor use, irrigation, labour-man days and contact with extension agents. Under utilization of resource was found for polythene sheet, tractor hours and irrigation. Over utilization of input resources was observed for NPK, seed quantity, chemical sprays and labour-man days. There exist decreasing return to scale but its value would increases after efficient use of all inputs. Results showed the possibility of increasing output by adjusting the use of inputs. It is helpful for policy makers to develop a horticulture based agricultural policy. Government should introduced support prices for vegetables, subsidize the tunnel material and input resources, ensure canal water supply, improve vegetable markets and extension services.
KEYWORDS: Cobb-Douglas, food security, MPP, production elasticity, tunnel farming, vegetables

1. INTRODUCTION

Developing countries faced new challenges and targets due to globalization and free trade. Rise in population and income increased the vegetables demand in developing countries [1]. Government tried to increase quality and quantity of crops by new technologies. The contribution of agriculture sector in gross domestic product of Pakistan was 20.88% and it also engaged 43.5% of labor force. Progress in agriculture sector is necessary for the development of all other sectors. To ensure food security, increase in the yield and production of crops are inevitable [2].

Vegetables have a key role in agriculture and their production increases in different countries. These are important not only for domestic market but also for export markets. Vegetable use is necessary for health because these are cheap source of micronutrients. These provide protein, vitamins, iron, minerals, lipids, fiber, calcium, carbohydrates and resistance against stomach and colon cancers. It increases employment opportunities and foreign exchange earnings in the country [3-5]. Per capita availability of vegetables was less than recommended level in various developing countries [3]. In Pakistan, there exists 27.4 kg per capita shortage in vegetable consumption while the recommended level was 73 kg per capita on annual basis [6].

The population of Pakistan increases from 65 to 161 million in past three decades and it will be 234 million by 2025. The vegetable shortage is increasing and creating food insecurity. Production of vegetables can eliminate this problem because horticultural crops had 6% share in GDP and 22% share in food production. Although vegetable crops are termed as minor crops but these are necessary due to rise in yield potential, low production cost and healthy nutritional composition [7].

Tomato (Lycopersi Conesculentum Mill) is second most popular and widely grown vegetable after potato with 124.75 million tones of production. Tomato is a necessary part of diet for a many people in the World. It is useful in raw form as well as in cooked form for various dishes like soup, sauces and juice, purees, jelly, ketchups, pickles and paste. Tomato is a main source of vitamin A, B and C with 20% share in daily

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usage, and it also provide other nutritional elements like potassium, calcium, fiber and iron. Presence of Lycopene made it useful against cancer [5, 8-10].

Pakistan had 63200 ha area and 599700 tons production under tomato in 2013-14. Punjab had 7800 ha area and 100100 tons production under tomato in 2013-14. Area was increased by 1.71% due to rise in prices but rain and flood decreased their production by 0.65% [11]. Monthly per capita tomato consumption was 0.39 kg and 0.42 kg for rural and urban people, respectively [12]. Vegetable prices were higher at end and start of season in Pakistan but these prices could be reduced by using new techniques like plastic tunnels. Farmers cultivated off-season vegetables under plastic tunnels by controlling temperature and moisture [13].

The soil and climate of Pakistan is favorable for a large number of vegetables. Tunnel farming is useful due to rising population and presence of small landholders. It required high investment but it was found economical to produce summer season vegetables in winter by using plastic sheet. Plastic sheet save solar energy and maintain the temperature in tunnels with sunlight absorption [4, 14]. The duration of off-season vegetable is longer and their area was increased in Pakistan. These vegetables reached in the market 7 to 14 days earlier than normal season vegetable. The yield is also increased by 2 to 3 times under tunnel [15].

Difference in input combination was responsible for difference in yield among farmers and it shows that the input use was not efficient by the farmers [16]. Agricultural economists have interest to guide farmers about the efficient use of input for the development of agriculture. A good farmer can use the existing resources wisely and get maximum output with minimum cost. Therefore, efficient utilization of scarce resources is required to ensure food security [17]. Calculation of resource use efficiency provides a way to check the efficiency of input individually for the determination of overutilization and underutilization of inputs.

There exist a large number of previous studies about resource use efficiency analysis of agricultural crops [5, 10, 18-24]. Literature about resource use efficiency in tomato cultivation was less [5, 10, 25]. But no research study was found about resource use efficiency in off-season tomato production in Pakistan and other countries.

Umar and Abdulkadir [5] described the productivity and efficiency of resource use in tomato cultivation in Nigeria. Significant impact on tomato yield was observed in case of land, labour and seed. Underutilization was observed for land and seed while overutilization was observed in case of labour. They recommended for increase in the use of modern technologies, extension services and availability of credit.

Ibitoye et al. [10] explored the efficiency of resource use in tomato cultivation in Nigeria. Education, experience, contact with extension agents and size of farm had a significant impact on production. Inputs like labour, pesticide, education, seed and farm size showed a significant and positive impact on output. Overutilization was recorded in case of seed, pesticide and fertilizer while underutilization was found in case of labour and farm size.

Dlamini and Kongolo [22] explored the efficiency of input resources in different organic vegetables like cabbage, beetroot, carrot, spinach, pepper and tomato. They found a significant impact of land, organic manure, labour, soil preparation, seeds, children, age, education and farm legal entity on the production of organic vegetables. Results showed increasing return to scale in the production of organic vegetables.

Kuwornu et al. [25] investigated about the productivity of tomato and their resource use efficiency in Ghana. They found total cost of GH¢704.59 per hectare in the production of tomato. The impact on production was significant in case of labour, land and experience. Inefficient use of labour and land was recorded in tomato production. Underutilization was recorded in case of fertilizer.

Due to increasing concern on food security, the current study was designed to check the resource use efficiency of different inputs in off-season tomato production. Return to scale demonstrated the increase in output by increasing the level of input resources. In Pakistan, a large number of farmers are still uneducated and unaware about the efficient use of inputs. By using the information about resource use efficiency, off-season tomato growers can increase their production.

MATERIALS AND METHODS

Data Collection and Study Area:

The current study was based on primary data collected in 2014 by using comprehensive and pre-tested questionnaire from off-season tomato growers in district Toba Tek Singh and Faisalabad of Punjab province. Off-season tomato growing farmers were personally interviewed with the help of simple random sampling. Mian Shadi Agriculture Farm located in Mamunkanjan, district Faisalabad is considered as pioneer in off-season vegetable growing in Punjab. Faisalabad is the second largest city of Punjab province with a big vegetable market. At present, Kamalia, district Toba Tek Singh is considered as a hub of off-season vegetable growing in Punjab province. Therefore, district Faisalabad and Toba Tek Singh were selected for this study. The population size of off-season tomato growers was high in district Toba Tek Singh as compared to district Faisalabad. Poate and Daplyn [26], cited in Mari [27] had a view that a sample size of 60 respondents was least requirement for better decision making if population size was large. Thus, total 70 off-season tomato farmers were interviewed

in the study area. These farmers were distributed in three categories as small farmers with less than 12.5 acres cultivation area, medium farmers with less than 25 acres and more than 12.5 acres cultivation area and large farmers with more than 25 acres cultivation area [28]. Different software like SPSS-15, Microsoft Excel, Stata were used for empirical analysis of research objectives.

Concept of production function and its stages:

Production function is a functional association of output and inputs [29]. There are three stages in the production function. In stage I, the total physical product (TPP) is increases with increasing rate; the marginal physical product (MPP) first increases than decreases after reaching its maximum point; average physical product (APP) first increases and achieve their peak and lies below MPP. Stage I ends and stage II starts where MPP = APP. In stage II, the TPP increases with decreasing rate and both APP and MPP are decreases. But MPP decreases quickly as compared to APP. This stage ends when MPP equals to zero and TPP achieve their maximum. Later, stage III starts and TPP start to decrease, MPP is negative and APP decreases but remains positive. Stage II is considered as rational production stage while stage I and III are irrational production stages. The point of profit maximization also lies in stage II [19].

Econometric Model and Data Analysis:

Cobb-Douglas production function was used to check the change in off-season tomato output due to various inputs. Ashfaq et al. [20] explained that Cobb-Douglas production function was appropriate for resource use efficiency analysis on the basis of econometric, statistical and economic criteria like sign and size of coefficients, standard error, t-test, f-test and R^2 as compared to other functional forms. Moreover, Cobb-Douglas production model was also used by a large number of researchers [5, 17, 19, 23-25, 30] to check resource use efficiency of different agricultural crops. Demographic variables in Cobb-Douglas model were also used by researchers [10, 18, 20-22, 31].

Current study used following Cobb-Douglas production function in accordance with [20]:

$$\boldsymbol{Y = AXi^{bi}} \quad ----------(\mathbf{1})$$

Where "i" ranges from 1 to 11

By taking natural logarithm on both sides, the Cobb-Douglas production function becomes:

$$\boldsymbol{lnY = lna + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + b_4 lnX_4 + b_5 lnX_5 + b_6 lnX_6 + b_7 lnX_7 + b_8 lnX_8 + b_9 lnX_9 + b_{10} lnX_{10} + b_{11} lnX_{11} + lne} \quad -----(\mathbf{2})$$

Where,

ln = Natural logarithm

a = constant

Y = Off-season tomato output (Kg/acre)

b_1- b_{11} = Parameters to be estimated

X_1= Age of off-season tomato grower (years)

X_2= Education of off-season tomato grower (years)

X_3= Off-season tomato growing experience (years)

X_4= Weight of polythene sheet used (Kg/acre)

X_5= Tractor used in farming operations (Hours/acre)

X_6= Total seed quantity (Kg/acre)

X_7= Total NPK used as fertilizer (Kg/acre)

X_8= Chemical sprays (No./acre)

X_9= Total irrigations (No./acre)

X_{10}= Total labour man-days for all activities (No./acre)

X_{11}= Contact with extension agents (No.)

e = error term (By assuming normal distribution with constant variance and zero mean value).

Another advantage of using Cobb-Douglas production function is that its coefficients (b_i) directly represents the production elasticity for different inputs. These coefficients were also used to check the return to scale in off-season tomato production.

Production elasticity (E_P): Production elasticity (E_P) tells about the percentage change in the quantity of output due to percentage change in the quantity of variable input. Coefficients of production elasticity for different input can be calculated by using formula:

$$Ep = \left(\frac{dy}{dx}\right)\left(\frac{\bar{X}}{\bar{Y}}\right) \quad -------(3)$$

$$Ep = (MPP)\left(\frac{\bar{X}}{\bar{Y}}\right) \quad ------(4)$$

$$Ep = \left(\frac{MPP}{APP}\right) - - - - - - - - - (5)$$

$$MPP = \left(Ep \times \frac{\bar{Y}}{\bar{X}}\right) - - - - - (6)$$

Where Y is off-season tomato output
X's are the different input used in off-season tomato production
$\bar{X}$ is the mean value of a particular input used in off-season tomato production
$\bar{Y}$ is the mean value of off-season tomato output
MPP is the marginal physical product
APP is the average physical product

Resource use Efficiency: Resource use efficiency was represent by "r" and it is the ratio between Marginal Value Product (MVP) for a specific input with Marginal Factor Cost (MFC) of that particular input [5, 10, 18-20, 23-25, 30].
Mathematically,

$$r = \frac{MVP}{MFC} - - - - - - - - - - - - - - (7)$$

Where:
r = Resource use efficiency ratio in off-season tomato production
MVP = It is value of additional off-season tomato output by using an additional unit of input or it is simply a product of MPP and price of off-season tomato:

$$MVP = MPP_{xi} \times P_y - - - - - - (8)$$

$$MVP = E_p \times \frac{\bar{Y}}{\bar{X}} \times P_y - - - - - - (9)$$

$$MVP = b_i \times \frac{\bar{Y}}{\bar{X}} \times P_y - - - - - - (10)$$

MFC = P_X = it is the cost or price of one unit of a specific input resource.

Decision Rules: The decision about the under utilization, over utilization and efficient utilization of a particular input resource is taken on the basis of following rule:
When r = 1 or MVP=MFC, it indicate that the particular input resource is utilize efficiently.
When r <1 or MVP<MFC, it indicate the over utilization of particular input resource.
When r > 1 or MVP>MFC, it indicate the under utilization of particular input resource.
Therefore, when the value of resource use efficiency "r" is greater than 1 or less than 1, than adjustments in input quantity and production cost are made for efficient utilization.
The decision about return to scale is taken on the basis of given rules:
If $\sum Ep = 1$ than it shows constant return to scale
If $\sum Ep < 1$ than it shows decreasing return to scale
If $\sum Ep > 1$ than it shows increasing return to scale

RESULTS AND DISCUSSION

A summary about socio-economic characteristics of off-season tomato growers is pictured in table 1. Maximum off-season tomato growers lie between 15 to 40 years category of age. It shows that this business is more popular in young ones. The educational level of many off-season tomato growers was intermediate which shows that comparatively educated farmers were involved in this business. Tunnel farming is a new technology and education is helpful for understanding a new technology. Muhammad et al. [32] mentioned that there was a positive association between education and efficiency of training programme in tunnel farming. Highly educated workers adopted a new technology earlier as compared to those with less education [33]. An educated farmer can read and understand the introductory material or pamphlets easily. Majority of off-season tomato growers fall in lowest category of family size. 61.43% farmers have only 1 acre under off-season tomato cultivation while only 21.43% farmers use more than 1 acre for off-season tomato. Adil et al. [34] already pointed out that small farmers are main features of agriculture in Pakistan.

Table 1: Socio-economic characteristics of off-season tomato growers

Variables	Frequency	Percentage (%)
Age (years)		
15-40	33	47.14
41-60	31	44.29
Above 60	6	8.57
Educational attainment		
Primary or below	13	18.57
Middle	7	10.00
Matriculation	9	12.86
Intermediate	20	28.57
Graduation	16	22.88
Master or above	5	7.14
Family size		
1-10	64	91.43
11-15	4	5.71
Above 15	2	2.86
Off-season tomato area		
Less than 1 acre	12	17.14
1 acre	43	61.43
More than 1 acre	15	21.43

The results of Cobb-Douglas function in off-season tomato production were pictured in table 2. The value of coefficient of determination (R^2) was 0.693 and it was fine in case of cross sectional data. It shows that the proposed model explained 69.3% variations in output as a result of variations in inputs. Model was also significant according to f-statistics (11.888). The coefficients in Cobb-Douglas production function are partial coefficients. It means that all other variables kept constant to explain the effect of an individual input variable on output. Coefficient of age was positive and significant at 0.1%. It shows that the output of off-season tomato increased by 0.188% due to 1% increase in age and it was in line with previous studies [22] and [31]. Coefficient of education was positive and significant at 0.3% level of significance and has a support from previous studies [10] and [22]. It explored that for every 1% increase in education, the output of off-season tomato increases by 0.073%. Education is an important factor especially to understand a new technology. A farmer also learns from previous experience and the impact of experience was positive and significant in off-season tomato production. For 1% increase in the experience, the value of output increases by 0.149%. The positive impact of experience was in line with the findings of previous studies [10] and [21]. Polythene sheet is a pre-requisite for tunnel farming and its coefficient was also positive and significant at 1.5%. The increase in output was 0.132% for 1% increase in the weight of polythene sheet. Farmers used polythene sheet of different qualities. A good quality polythene sheet has more weight. A good quality polythene sheet is helpful during heavy wind, a major problem in off-season vegetable cultivation. Tractor was used in off-season tomato production to perform various operations like ploughing, planking, with rotavator and for ridge making. Tractor used hours had a positive impact on output but their level of significance was high i.e. 23.1%. Its impact was also positive in a previous study [30]. Quantity of seed had significant and negative impact on output at 4.9% level of significance. It means that off-season tomato output was reduced by 0.051% when seed quantity was increased by 1%. It was due to the increase in competition for nutrients or input when the quantity of seed was increased. It is also supported by the results of previous studies [9] and [23]. Fertilizer is also very important in vegetables. The coefficient of NPK was negative and highly insignificant. It is interpreted as the off-season tomato output reduced by 0.033% for 1% increase in the quantity of NPK. Use of fertilizer mostly depends on composition of soil and condition of crop. A large number of farmers had no attachment with a soil scientist and they use fertilizers without any guidance. Use of fertilizer is beneficial but third stage of production always waiting for the excessive use of input. The fertilizer result was in line with [24]. Use of chemical spray showed negative and insignificant impact on output. It shows a 0.112% decrease in output when number of sprays increases by 1% and it was in line with some previous findings [9] and [21]. Normally vegetables are very sensitive to disease attack and farmers told that disease attack was a major problem in off-season tomato. They told that the quality of tomato was deteriorated due to disease attack. Therefore, farmers perform more chemical sprays which place a negative impact on output. Tomato production also requires more water. The coefficient of irrigation found positive and significant at 10.1% level of significance. The increase in output was 0.073% for 1% increase in number of irrigations. The regression for irrigation was also positive in some studies [18], [20] and [30]. The coefficient of labour was positive but highly insignificant. Positive coefficient of labour was also observed in previous studies by [5, 7, 17-18, 20-21, 23, 31]. The coefficient of contact with extension agent was positive and significant at 5% significance level. It shows that for 1% increase in the contact with extension agent the level of output increase by 0.168%. An extension agent has technical knowledge which is beneficial for the output. This result has a support from previous findings [9-10]. Return to scale was estimated by

summing all production elasticity (Ep) in off-season tomato production. The value of return to scale was 0.725% which implies the presence of decreasing return to scale. Decreasing return to was mostly observed in agriculture sector. It means that increase in off-season tomato output was less than 1% when all input were increased by 1%. It is low because the impact of NPK, chemical sprays and seed quantity was negative. It will be increased after adjusting the use of seed, NPK and chemical spray.

Table 2: Estimation of Cobb-Douglas production function for off-season tomato production

Variable	Unit	Coefficients	t-statistics	Sig. level
Constant		7.918	12.75	0.000
ln-Age	Years	0.188	3.34	0.001
ln-Education	Years	0.073	3.12	0.003
ln-Off-season tomato experience	Years	0.149	4.48	0.000
ln-Polythene sheet	Kg.	0.132	2.52	0.015
ln-Tractor used	Hours	0.135	1.21	0.231^{NS}
ln-Seed quantity	Kg.	-0.051	-2.01	0.049
ln-NPK	Kg.	-0.033	-0.58	0.563^{NS}
ln-Chemical sprays	No.	-0.112	-1.90	0.063
ln-Irrigation	No.	0.073	1.66	0.101
ln-Labor man days	No.	0.003	0.04	0.968^{NS}
ln-Contact with extension agent	No.	0.168	2.91	0.005
R^2			0.693	
Adjusted-R^2			0.634	
F-ratio			11.888	
Return to scale= Sum of production elasticity			0.725	

Table 3 shows the ratio of resource use efficiency for different inputs in off-season tomato production. Greater than 1 value of resource use efficiency (r) showed the under utilization of resources while less than 1 value showed the over utilization of inputs in off-season tomato cultivation. A negative value of resource use efficiency also pointed out toward over utilization of resources and it is possible in third stage of production function. The ratio of MVP to MFC for polythene sheet was greater than 1 and positive which shows the under utilization of polythene sheet. A little adjustment is required by off-season tomato growers in the use of polythene sheet in order to get more output. The value of resource use efficiency for tractor use hours was 13.09 which was positive and greater than 1. It implies that off-season tomato growers have the ability to increase the output by increasing the tractor hours. Its value was also positive and greater than 1 in previous study [30]. The MVP to MFC ratio for seed quantity was -1.45 which was negative. A negative value of resource use efficiency implies that the quantity of seed place a negative impact on output. It shows the overutilization in case of seed and adjustment in seed quantity is required. Over utilization of seed was also explored in previous studies [10 23]. The resource use efficiency was -0.64 in case of NPK which is less than 1. It also shows the over utilization of fertilizer NPK in off-season tomato production. Over utilization of fertilizer was also explored in previous studies [10, 31]. The resource use efficiency for fertilizer was also negative in some studies [35, 36]. It shows that farmer used more than recommended level of fertilizer which placed a negative impact on production. The resource use efficiency for number of chemical sprays was -6.14 which is negative. It also implies the over utilization of chemical sprays in off-season tomato production and has a support from previous studies [10, 21, 31]. It shows the fact that farmers excessively use chemical sprays to avoid insect pest attack without knowing the optimum use of chemicals sprays according to type of attack. Off-season tomato growers can increase the level of output by adjusting the use of chemical sprays. Tomato requires more water and the ratio of MPV to MFC was positive in case of number of irrigations applied. Its value was 6.77 which shows the under utilization of irrigation water. Off-season tomato production can increase by increasing the number of irrigation applied because it is underutilized. This finding has a support from literature [18, 30]. Coefficient of labour was highly insignificant but its resource us efficiency was 0.05 which is less than 1. It shows the labour use is over utilized and adjustment is required in number of labour-man days in order to increase the level of output. It is also in line with previous results [5, 10, 21, 24].

Table 3: Resource use efficiency analysis of off-season tomato production

$\bar{Y} = 28714.84\ Kg/acre$, $P_y = Rs.46.96/Kg$

Inputs	b_i	$\bar{X}_i$	MPP	MVP	MFC=Px	r	Utilization
ln-X_4	0.132	165.16	22.93	1076.80	242.89	4.43	Under
ln-X_5	0.135	8.31	465.59	21865.54	1669.78	13.09	Under
ln-X_6	-0.051	0.10	-14215.84	-667612.26	461569.65	-1.45	Over
ln-X_7	-0.033	632.69	-1.48	-69.65	109.16	-0.64	Over
ln-X_8	-0.112	24.99	-128.74	-6045.74	985.13	-6.14	Over
ln-X_9	0.073	28.12	74.15	3482.19	514.71	6.77	Under
ln- X_{10}	0.003	380.29	0.25	11.72	251.87	0.05	Over

CONCLUSION AND RECOMMENDATIONS

The current study aims for the estimation of resource use efficiency in off-season tomato production in Punjab. The study also explored the return to scale in this business. Coefficient of determination (R^2) and f-statistics were 69.3% and 11.888, respectively which indicates the overall goodness of Cobb-Douglas model. The impact of age, education, experience, polythene sheet, number of irrigation and contact with extension agents was positive and significant. The effect of seed quantity and chemical sprays was negative and significant. Under utilization of inputs was revealed for polythene sheet, tractor hours and irrigations. Over utilization of inputs was revealed for NPK, seed quantity, chemical sprays and labour-man days. There exists decreasing return to scale which is widely observed in agricultural production. There is a need of comprehensive horticultural based agricultural policy that provide support price of vegetables; subsidize tunnel material and input resources, make sure the availability of canal water, improve vegetable markets and extension services. Government should take necessary steps for the growth of this sector.

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