Research Article

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

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Abstract | Increasing concern over food security was a factor behind the estimation of resource use efficiency of crops. Present study explored the resource use efficiency and return to scale in off-season cucumber production in Punjab, Pakistan. Primary data were collected from 70 off-season cucumber growers by using simple random sampling. Cobb-Douglas was good on the basis of R^2 (0.748) and f-statistics (17.505). Production elasticity was positive for education, polythene sheet, fertilizers, chemical, irrigation and labour days. Under utilization of resources was found for polythene sheet, fertilizers, chemicals, irrigation and labour days. Over utilization of resources was observed for seed quantity and use of tractor. There exist decreasing return to scale (87.7%) but its value will surely increase after efficient use of inputs. A little adjustment is required in the use of inputs for receiving more output. A comprehensive agricultural policy is required based on support price of vegetables; subsidize the input resources, improvement in vegetable markets and provision of extension services.

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Introduction

Developing countries faced increasing demand of vegetables due to increase in population and income (Arsanti et al., 2007). In Pakistan, 19.80% of gross domestic product comes from agriculture with the involvement of 42.3% of labour force. Agriculture is also important for food security (GOP, 2016). Vegetables are inevitable for human due to provision of macro and micro food nutrients (Muhammad et al., 2015). Pakistan faced 96 million increase in population from 65 million in last 3 decades and it will be 234 million by 2025. The shortage of vegetables created food insecurity. Vegetables can increase food security and showed 6% and 22% share in GDP and food production, respectively (Sheikh et al., 2012).

Cucumber (*Cucumis sativus* L.) belongs to Cucurbitaceae family which consists of 118 genera and 825 species (Khan et al., 2015). It is called Khira in local language and a basic component of salad. It is helpful against human constipation and considered a cooling food in summer (Maurya et al., 2015). It gives vitamin C, iron, niacin, calcium, fibers, thiamine and phosphorus. Above 50% cucumber production comes from Asia. Turkey, Iran, Uzbekistan and Japan are leading cucumber producers in Asia (Khan et al., 2015).

Pakistan shows 0.83% increase in area under cucumber and gherkins from 3,499 ha to 3,528 ha in 2013.

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Its production was also rises by 0.43% in 2013 from 49,947 tonnes to 50,164 tonnes. Its yield decreases by 0.39% from 14,274.6 kg to 14,218.8 kg in 2013 (FAO, 2016). In 2012-13, Punjab had 1,795 ha under cucumber with total production of 40,439 tonnes and shows high yield than other provinces (GOP, 2014). Vegetable shortage increase prices but technology provides a way to achieve higher production. Off-season vegetable production under plastic tunnel is a better option to encounter with higher prices and increasing demand. Pakistani soil and climate is good for vegetables under tunnel covered with plastic sheet. Plastic sheet store solar energy and maintain the temperature in tunnels (Muhammad et al., 2015). Moreover, the duration of crop is extended and vegetables reached 7 to 14 days earlier in the market. It also shows 2 to 3 times increase in the yield (Iqbal et al., 2009).

Agricultural economists always provide the guidance to farmers about efficient utilization of inputs. Efficient utilization of inputs is also important for food security (Chiedozie et al., 2010). Resource use efficiency explored the efficiency of each input and indicates the overutilization or underutilization of inputs. A fine literature is available about the estimation of resource use efficiency for different agricultural crops (Abid et al., 2011; Ashfaq et al., 2012; Mohammed et al., 2014; Ibitoye et al., 2015; Umar and Abdulkadir, 2015).

Goni et al. (2013) explored the efficiency of resource use in the production of dry season vegetables including cucumber in Nigeria. Vegetable output was significantly affected by herbicide ($p<0.10$), seed ($p<0.01$), pesticide ($p<0.01$) and land ($p<0.01$). Farmers were found inefficient in the utilization of all resources because of under-utilization (seed, pesticide and land) and over-utilization (fertilizer, herbicide and labour). They mentioned an increase in vegetable output by 114.58, 322.64 and 568.72 kg ha^{-1} due to increase the accessibility of seed, pesticide and land, respectively.

Similarly, Shrestha et al. (2015) calculated the efficiency of resource use in the production of vegetables in Nepal. The value of technical efficiency (0.79) pointed out toward the possibility of increase in the production of vegetable by efficient utilization of resources (land, seeds, labour, fertilizers, compost, farm capital and pesticides) while technology remains constant. They suggested for improvement in land, labour training, and easy capital access.

But, resource use efficiency in off-season cucumber production was still not explored in Pakistan.

The study aims for the calculation of resource use efficiency and return to scale in off-season cucumber production. Return to scale is an important indicator to check the increase in output by increasing the level of inputs.

Materials and Methods

Primary data were collected by simple random sampling from off-season cucumber farmers in 2014. Mian Shadi Agriculture Farm, Mamunkanjan, district Faisalabad is pioneer in off-season vegetables. Faisalabad is the second largest city of Punjab with a big vegetable market. At present, Kamalia, Toba Tek Singh is considered as the hub of off-season vegetable cultivation in Punjab. Therefore, district Faisalabad and Toba Tek Singh were selected for this study. Poate and Daplyn (1993), cited in Mari (2009) described that a sample size of 60 was appropriate for decision making in case of large population. However, this study used a sample size of 70 respondents. Software SPSS-15 and Microsoft Excel were used for empirical estimation of objectives.

Production function and its stages

A functional relationship between output and inputs is called production function (Jhingan, 2007). Three stages of production. MPP is negative in stage III and it is not economical to produce with negative MPP (Akighir and Shabu, 2011).

Model Specification

The Cobb-Douglas production model was useful for the estimation of resource use efficiency due to econometric and statistical advantages like sign and size of coefficients, t-test, f-test and R^2 (Ashfaq et al., 2012). It was also used in many studies (Abid et al., 2011; Mohammed et al., 2014; Ibitoye et al., 2015; Umar and Abdulkadir, 2015). Socio-economic variables in Cobb-Douglas model were used by Abid et al. (2011), Ashfaq et al. (2012), Dlamini and Kongolo (2014) and Ibitoye et al. (2015).

Current study used following Cobb-Douglas model (Ashfaq et al., 2012):

$$Y = AXi^{bi} - - - - - - - - - - (1)$$

Where "i" ranges from 1 to 10

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By taking natural logarithm on both sides:

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

Where:
ln = Natural logarithm
a = constant
Y = Off-season cucumber output (Kg/acre)
b_1- b_{10} = Parameters to be estimated or production elasticity
X_1= Area under off-season cucumber (acres)
X_2= Education of off-season cucumber grower (years)
X_3= Off-season cucumber growing experience (years)
X_4= Weight of polythene sheet (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)
e = error term (By assuming normal distribution with constant variance and zero mean).

Production elasticity (E_p)

It is simply a percentage change in output due to percentage change in variable input and expressed as:

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

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

$$MPP = \left(Ep \times \frac{Y}{\bar{X}}\right) -----(5)$$

Where:
Y= off-season cucumber output
X= different input used in production
$\bar{X}$= mean value of a particular input
$\bar{Y}$ = mean value of off-season cucumber output
MPP= marginal physical product

Resource use Efficiency

It is a ratio between Marginal Value Product (MVP) for a specific input and Marginal Factor Cost (MFC) of that particular input (Abid et al., 2011; Ashfaq et al., 2012; Mohammed et al., 2014; Umar and Abdulkadir, 2015) as:

$$r = \frac{MVP}{MFC} ----------(6)$$

where:
r = Resource use efficiency ratio
MVP = Value of additional output by using an additional unit of a particular input resource and it is a product of MPP and price of output:

$$MVP = MPP_{xi} \times P_y -----(7)$$

MFC = P_X = It is price of one unit of input resource.

Decision Rules

The decision about the under utilization, over utilization and efficient utilization of a particular input resource is taken by using following rule:

When r = 1 or MVP=MFC, it indicates efficient utilization.
When r <1 or MVP<MFC, it indicate over utilization.
When r > 1 or MVP>MFC, it indicate under utilization.
Adjustment in inputs is required when the value of "r" is greater or less than 1.
The decision about return to scale is taken as:

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

Table 1 presents the socio-economic characteristics of off-season cucumber growers. Maximum farmers had ages between 15 to 40 years which indicates the presence of young farmers in this business. Maximum (34.29%) farmers were matriculation followed by primary or below (24.29%). However, some highly educated farmers were also engaged in this activity. Increase in education is beneficial for the understanding of new technology like tunnel farming. Majority of farmers fall in lowest family size category. Majority of farmers were small farmers and 71.43% farmers had less than 5 acres. Adil et al. (2004) mentioned that small farmers are main features of agriculture in Pakistan.

Table 1: *Socio-economic characteristics of off-season cucumber growers*

Variables	Frequency	%
Age (years)		
15-40	41	58.57
41-60	22	31.43
Above 60	7	10.00
Educational attainment		
Primary or below	17	24.29
Middle	6	8.57
Matriculation	24	34.29
Intermediate	9	12.86
Graduation	9	12.86
Master or above	5	7.14
Family size		
1-10	63	90.00
11-15	4	5.71
Above 15	3	4.29
Off-season cucumber area		
Less than 1 acre	2	2.86
1 to less than 5 acre	48	68.57
5 to less than 10 acre	10	14.29
10 and more acre	10	14.29

Table 2 reveals the coefficient of Cobb-Douglas model in off-season cucumber production. Model was good on the basis of coefficient of determination (R^2) which was 0.748.It indicates that the model explained 74.8% variations in output due to variations in inputs. F-statistics was also fine (17.505). These coefficients in the model were partial coefficient which shows that we kept all other variables constant when explained the impact of a particular input on output. Coefficient of education was positive which shows that increase in output (0.076%) and it is in line with (Dlamini and Kongolo, 2014; Ibitoye et al., 2015). Coefficient for polythene sheet is positive and significant which shows the increase in output (0.124%) for 1% increase in the weight of polythene sheet. A quality polythene sheet was normally heavier and also helpful in heavy wind, a problem in off-season cultivation. Fertilizer played very important role in cucumber cultivation and its coefficient was positive which indicates 0.079% increase in output due to 1% increase in fertilizer. Use of chemical spray shows a positive (0.351%) impact on output due to 1% increase in chemical applications. Off-season cucumber cultivation is a water intensive activity and shows a positive (0.445%) impact on output due to 1% increase in water applications. It was in line with (Abid et al., 2011; Ashfaq et al., 2012; Karthick et al., 2013). The coefficient of labour man days was positive which shows a 0.295% increase in output as a result of 1% increase in labour days. The value of return to scale was 0.877and shows decreasing return to scale. Decreasing return to was mostly observed in agriculture sector. It shows that increase in off-season cucumber output was 87.7% as a result of 100% increase in the use of inputs. Return to scale was 77% in Bt Cotton as found by Ashfaq et al. (2012).

Table 2: *Coefficients of Cobb-Douglas model for off-season cucumber production*

Variable	Unit	Coefficients	t-value	Prob.
Constant		5.624*	7.626	0.000
ln-Off-season cucumber area	Acre	0.028	0.913	0.365^{NS}
ln-Education	Year	0.076***	1.790	0.079
ln-Off-season cucumber experience	Year	-0.057	-1.480	0.144^{NS}
ln-Polythene sheet	Kg.	0.124**	2.183	0.033
ln-Tractor used	Hour	-0.182	-1.419	0.161^{NS}
ln-Seed quantity	Kg.	-0.281	-1.390	0.170^{NS}
ln-NPK	Kg.	0.079**	2.455	0.017
ln-Chemical sprays	No.	0.351*	4.245	0.000
ln-Irrigation	No.	0.445*	4.367	0.000
ln-Labor man days	No.	0.295*	2.710	0.009
R^2	0.748			
Adjusted-R^2	0.705			
F-ratio	17.505			
Return to scale= Sum of production elasticity	0.877			

** significant at 1%, ** significant at 5%, ***significant at 10%, NS= Not significant*

Table 3 explores the resource use efficiency in off-season cucumber production. Underutilization of polythene sheet was observed and an adjustment is required by off-season cucumber growers in the use of polythene sheet to get more output and revenue. Overutilization was observed in case of tractor use hours and seed because of negative value of resource use efficiency. It shows that farmers should reduce the tractor hours and quantity of seed for more production. Over utilization of seed was also mentioned by Mohammed et al. (2014) and Ibitoye et al. (2015). Underutilization was observed in case of fertilizers, chemical sprays, irrigation and labour days because they showed greater than 1 value of resource

Table 3: *Resource use efficiency analysis in off-season cucumber production*

Inputs	b_i	X_i	MPP	MVP	MFC=Px	r	Status
ln-X_4	0.124	163.64	93.88	1035.56	240.12	4.31	Under
ln-X_5	-0.182	8.54	-2646.98	-29196.98	1685.31	-17.32	Over
ln-X_6	-0.281	0.15	-226489.24	-2498240.99	361389.15	-6.91	Over
ln-X_7	0.079	1498.72	6.52	71.97	67.10	1.07	Under
ln-X_8	0.351	34.59	1259.20	13889.37	1116.04	12.45	Under
ln-X_9	0.445	42.27	1305.47	14399.70	625.38	23.03	Under
ln- X_{10}	0.295	402.34	91.00	1003.81	255.28	3.93	Under

$\bar{Y} = 124123.21\ Kg/acre$, $P_y = Rs.11.03/Kg$

use efficiency. Therefore, a little adjustment is required to increase the level of fertilizer, chemical application, water application and labour man days for more output. Irrigation coefficient was in line with Abid et al. (2011), Ashfaq et al. (2012) and Karthick et al. (2013). Labour coefficient was also positive as reported by Abid et al. (2011), Akighir and Shabu (2011), Ashfaq et al. (2012) and Anim et al. (2015). Positive coefficient of chemical was also reported by Abid et al. (2011), Ashfaq et al. (2012) and Akighir and Shabu (2011). Underutilization of fertilizers was also mentioned by Abid et al. (2011) and Ashfaq et al. (2012).

Conclusions

The present study calculated resource use efficiency and return to scale in off-season cucumber production in Punjab. Cobb-Douglas model was good on the basis of R^2 (74.8%) and f-statistics (17.505). The impact of education, polythene sheet, fertilizer, chemicals, irrigation and labour was positive and significant. Underutilization of resource was observed for polythene sheet, fertilizers, chemicals, irrigation and labour. Over utilization of resources was observed for seed and tractor use hours. There exists decreasing return to scale (87.7%) but it will be increasing return to scale after the elimination of overutilization of some inputs. A comprehensive agricultural policy will be helpful for the promotion of vegetables and prices stability. Government should subsidize the inputs like fertilizers, chemical. Government should ensure the availability of canal water. Improvement in extension services is a pre-requisite for the progress of agriculture sector.

Authors' Contributions

This research study was a collaborative effort of all authors. Author QA conceived the idea, designed the study, performed statistical analysis and wrote this manuscript. Authors MA provided technical guidance, supervision and checked the work. Authors MTIK supported in data collection, data entry and analysis. All authors read the manuscript.

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