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Technical Efficiency in Bhendi Production in Coimbatore District of Tamil Nadu

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ABSTRACT

The study was conducted in selected peri-urban blocks of Coimbatore district. The maximum average yield of bhendi was 14 tonnes per hectare with the coefficient of variation of 24.85 per cent. The maximum net return from bhendi cultivation reported that ₹ 27334 with the benefit-cost ratio of 1.22. The results of resource use efficiency revealed that quantity of nitrogen, number of irrigations and the human labour had a positive and significant influence on the yield of bhendi. The ratio of MVP to MFC was greater than one for all the significant variables indicating the underutilization of resources and there exists the possibility of enhancing their yield by increasing their use. The overall mean technical efficiency was 0.80, which indicated the possibility of increasing the yield of the crops by adopting better technology and cultivation practices.

Key words: Resource-use efficiency, Technical efficiency, Data envelopment analysis, Brinjal production

Tamil Nadu is the second-largest producer of vegetables in South India. The area under vegetables was 2.41 lakh hectares and the production was 6.39 million tonnes in 2017-18. The important vegetables cultivated in the state are tomato, onion, brinjal, drum stick, ladies-finger and chillies. The state achieved the highest average vegetable productivity in the country with 31 tonnes per hectare in 2014-15 and it was also close to the worlds' second-largest average productivity of 32.6 tonnes per hectare reported by United States (Anonymous 2015). However, average vegetable productivity has reduced to 26.5 tonnes per hectare in 2017-18. Further, brinjal is one of the important vegetables consumed in the state and the production (3.02 lakh tonnes) and productivity (20 tonnes/ha) were also low compared to other leading states in the country (Anonymous 2018). Brinjal is cultivated by marginal and small farmers largely under irrigated condition in the state. Since the crop uses critical production resources and not able to achieve the expected productivity, the analysis of resource-use efficiency and technical efficiency would provide a better insight into the utilization of the resources. Enhancing and sustaining productivity would help to meet out the growing urban demand in the state. With this background, the present study was carried out with the overall objective of assessing the technical efficiency of bhendi production in Coimbatore district of Tamil Nadu.

MATERIALS AND METHODS

Coimbatore district was purposively selected for the study. At the first stage, three blocks were purposively selected based on the area under horticultural crops. The blocks selected for the study were Thondamuthur, Madukkarai and Karamadai. In each block, one peri-urban cluster village was selected. From each cluster, 30 farmers were selected at random and the total sample size was 90. The farmers who cultivated bhendi were selected for the study. The sample farmers were personally interviewed and the data were obtained using a structured interview schedule.

Analytical framework

Production function: The Cobb-Douglas production function was fitted to establish the input-output relations and to calculate the efficiency of the inputs used. The dependent

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and independent variables used in the equation are given below:

The equation is specified as follows:

$$Y= \beta_0 X_1^{\beta1} X_2^{\beta2} X_3^{\beta3} X_4^{\beta4} X_5^{\beta5} X_6^{\beta6} X_7^{\beta7} X_8^{\beta8} X_9^{\beta9} e^U$$

The logarithmic expression of the equation is:

$$ln\ Y = \beta_0 + \beta_1\ ln\ X_1 + \beta_2\ ln\ X_2 + \beta_3\ ln\ X_3 + \beta_4\ ln\ X_4 + \beta_5\ ln\ X_5 + \beta_6\ ln\ X_6 + \beta_7\ ln\ X_7 + \beta_8\ ln\ X_8 + \beta_9\ ln\ X_9 + U$$

Y- Output of the bhendi (t/ha),
$\beta_0 \ldots \beta_9$ - Parameters to be estimated,
X_1 - Quantity of seed (kg/ha) or number of seedlings
X_2 - Machine labour (hrs/ha)
X_3 - Human labour (man-days/ha)
X_4 - Farm yard manure (tonnes/ha)
X_5 - Quantity of nitrogen (kg/ha)
X_6 - Quantity of phosphorous (kg/ha)
X_7 - Quantity of potassium (kg/ha)
X_8 - Plant protection chemicals (₹/ha)
X_9 - Irrigation (No. /ha)

Resource-use efficiency: Marginal productivity analysis was done to study the efficiency of various resources used for production. The efficiency of resources is determined as follows:

$$r = Marginal\ Value\ Product\ (MVP)/Marginal\ Factor\ Cost\ (MFC)$$

Where,
r = Efficiency ratio
MVP = Product of marginal physical product and unit price of output (MPP. PY)
MFC = Cost of one unit of a particular resource
If, r = 1, it implies efficient use of the particular resource
r < 1, it implies inefficient (over-utilizing resources) use of the particular resource

Technical efficiency: Technical efficiency measures the farm's ability to produce the maximum possible output from a given combination of inputs and technology. Data envelopment analysis (DEA) is having an advantage over the parametric approach. It does not impose any apriori parametric restriction and distributional assumption on efficiency. Hence, it used in the present study to examine technical efficiency.

Data envelopment analysis (DEA)

In the present study, the Data Envelopment Analysis (DEA) technique was employed to estimate the technical and allocative efficiencies of the brinjal crops raised by the peri-urban farmers. The DEA was applied by using both classic CRS (constant returns to scale) and VRS (variable returns to scale) equations with input orientation, in which one seeks input minimization to obtain a particular product level.

Constant returns to scale

Under the assumption of constant returns to scale, the linear programming equations for measuring the efficiency of farms are:

$$\text{Min}_{\theta, \lambda}\ \theta$$

Subject to (i) $- y_i + Y\lambda \geq 0$

(ii) $\theta x_i - X\lambda \geq 0$

(iii) $\lambda \geq 0$ …………………..… (1)

Where,
y_i is a vector (m × 1) of the output of the i^th farm,
x_i is a vector (k × 1) of inputs of the i^th farm,
Y is the output matrix (n × m) for n farms,
X is the input matrix (n × k) for n farms,

θ is the efficiency score, a scalar whose value will be the efficiency measure for the i^th farm. If θ =1, the farm will be efficient; otherwise, inefficient, and λ is a vector (n × 1) whose values are calculated to obtain the optimum solution.

For an inefficient farm, the λ values will be the weights used in the linear combination of other, efficient farms, which influence the projection of the inefficient farm on the calculated frontier.

The specification of constant returns is only suitable when the farms work at the optimum scale. Otherwise, the measures of technical efficiency can be mistaken for scale efficiency, which considers all the types of returns to production, i.e., increasing, constant and decreasing.

Variable returns to scale

The CRS equation was reworked by imposing a convexity constraint. The measure of technical efficiency obtained in the equation with variable returns is also named as 'pure technical efficiency', as it is free of scale effects. The following linear programming equation estimated it:

$\text{Min}_{\theta, \lambda}\ \theta$

Subject to (i) $- y_i + Y\lambda \geq 0$

(ii) $\theta x_i - X\lambda \geq 0$

(iii) $N_1\ \lambda = 1$

(iv) $\lambda \geq 0$ …………………………. (2)

Where, N_1 is a vector (n × 1) of ones.

When there are differences between the values of efficiency scores in the equations of CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, i.e. it can be increasing or decreasing (Färe and Grosskopf 1994).

The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows:

$$\theta s = \theta_{CRS} (X_K, Y_K) / \theta_{VRS} (X_K, Y_K) \ldots\ldots\ldots (3)$$

Where,
θs = Scale efficiency,
$\theta_{CRS} (X_K, Y_K)$ = Technical efficiency for the equation with constant returns, and
$\theta_{VRS} (X_K, Y_K)$ = Technical efficiency for the equation with variable returns.

It could be seen that equation (2) makes no distinction as to whether the farm is operating in the range of increasing or decreasing returns (Coelli *et al.* 1998). The only information one has is that if the value obtained by calculating the scale efficiency in Equation (3) is equal to one, the farm will be operating with constant returns to scale. However, when θ's is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming, i.e. the convexity constraint of equation (2), $N_1\lambda = 1$, is replaced by $N_1\lambda \leq 1$

for the case of non-increasing returns, or by $N_1\lambda \geq 1$, for the equation with non-decreasing returns. Therefore, in this work, the following equations were also used for measuring the nature of efficiency.

Non-increasing returns:

$\text{Min}_{\theta,\lambda}\ \theta$

Subject to (i) $-y_i + Y\lambda \geq 0$

(ii) $\theta x_i - X\lambda \geq 0$

(iii) $N_1 \lambda \leq 1$

(iv) $\lambda \geq 0$ ………………………….… (4)

Non-decreasing returns:

$\text{Min}_{\theta,\lambda}\ \theta$

Subject to (i) $-y_i + Y\lambda \geq 0$

(ii) $\theta x_i - X\lambda \geq 0$

(iii) $N_1 \lambda \geq 1$

(iv) $\lambda \geq 0$ ………………………………… (5)

It is to be stated here that all the above equations should be solved n times, i.e. the equation is solved for each farm in the sample. The quantity produced (t/ha) was used as an output (Y) in the present case and total labour days (man-days), machine power (hours), seeds/plant population (No.), farmyard manure (t), plant nutrients N (kg), P (kg), K (kg) separately, capital inputs (₹) on plant protection, other input costs and fixed input costs as inputs (X). The equations were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels (Murthy *et al.* 2009).

RESULTS AND DISCUSSION

Input use in bhendi cultivation

The input usage in Bhendi cultivation among the selected farms is presented in (Table 1). The average quantity of seed used for cultivation of bhendi varied from 2 to 2.5 kg per hectare. Similarly, machine labour usage was also varied from 3 to 3.5 hours. However, the human labour varied at a greater extent among the selected farms with 58 to 68 man-days. The nitrogen usage varied from 120 kgs/ha to 150 kgs per hectare, the phosphorus usage varied from 90–95 kgs per hectare and potassium usage varied from 80 kgs per hectare to 100 kgs per hectare. The expenditure on plant protection chemical was the highest among Thondamuthur block (₹ 9435) sample farms and lowest among Madukkarai block sample farms (₹ 8256).

Table 1 Input use for bhendi cultivation in selected farms of Coimbatore district

Particulars	Karamadai Block	Madukkarai Block	Thondamuthur Block
Seed (Kgs)	2	2.5	2
Machine labour (hours)	3.5	3	3
Human labour (man days)	58	59	68
Nitrogen (kgs)	120	140	150
Phosphorous (kgs)	95	95	90
Potassium (kgs)	100	80	95
Plant protection chemicals (₹)	8639	8256	9435

Yield of bhendi crop among the sample farms

The yield of bhendi crop among the sample farms is presented in (Table 2). The maximum average yield of bhendi crop was reported among the Thondamuthur block sample farms with a yield of 14 tonnes per hectare. However, the lowest average yield of 12.5 tonnes per hectare was reported among the Karamadai sample farms. The maximum yield variation was reported among Madukkarai block sample farms with 24.85 per cent. The average yield of the sample farms was more than the district average yield of 11.35 tonnes per hectare.

Table 2 Yield of bhendi among sample farms in Coimbatore districts (Tonnes/ha)

Block	Minimum	Maximum	Average	C.V. (%)
Thondamuthur	10	17	14	19.20
Madukkari	7	15	13	24.85
Karamadai	6	12	12.5	21.76

Costs and returns

The cost and returns of bhendi crop among the sample farms of Coimbatore district are presented in (Table 3). The cost of cultivation of bhendi was 1.26 lakhs per hectare among Thondamuthur block farms and the minimum was 1.14 lakhs per hectare among Karamadai block farms. However, the net return was the highest in Thondamuthur farms with ₹ 27334 per hectare and lowest among Karamadai farms with ₹ 22630 per hectare. The benefit-cost ratio was also highest in Thondamuthur block with 1.22 and minimum in Karamadai with 1.20. However, Maurya and Pal (2012) reported that the benefit-cost ratio of bhendi farmers was higher than the results of the study with 1.59.

Table 3 Costs and returns of bhendi crop among the sample farms in Coimbatore districts (₹/ha)

Block	Total cost of cultivation	Gross returns	Net returns	B:C ratio
Thondamuthur	126666	154000	27334	1.22
Madukkari	117949	143000	25051	1.21
Karamadai	114870	137500	22630	1.20

Table 4 Production Function Estimates of Bhendi

Particulars	Co-efficient	t-value
Constant	-5.3094	-2.00
Seed rate (X_1)	-0.1951^{NS}	-0.88
Machine labour (X_2)	-0.1810^{NS}	-0.98
Human labour (X_3)	0.5684***	1.84
Nitrogen (X_4)	1.0882*	4.02
Phosphorous (X_5)	-0.0737^{NS}	-0.53
Potassium (X_6)	-0.2287^{NS}	-1.15
Plant protection chemicals (X_7)	-0.1903^{NS}	-1.07
Irrigation (X_8)	1.8716**	3.13
Adjusted R^2	0.5751	

*1% level of significance, **5% level of significance
***10% level of significance, N: Non-Significant

Resource-use efficiency in bhendi: The results of the production function analysis for bhendi are presented in (Table 4). The table shows that the value of adjusted R^2 is 0.575 which indicates that about 58 per cent of the variation in the yield of bhendi is explained by the variables included in the equation. The coefficients of the quantity of nitrogen, the number of irrigations and human labour are positive and significant at 1%, 5% &10% respectively. This indicates that these variables positively contributed to the bhendi yield.

Marginal productivity analysis

The efficiency in the use of the various resources are estimated using marginal productivity analysis and are presented in (Table 5). The results of the table show that MVP is greater than MFC for human labour, nitrogen and number of irrigations. This indicates that these resources are underutilized and there is scope for increasing the output per hectare by increasing the use of these resources.

Table 5 Resource use efficiency in bhendi

Variables (units/ha)	Geometric mean	Regression co-efficient	MVP	MFC	Ratio of MVP to MFC
Human labour (days)	62	0.5684	1018.1	600	1.70
Nitrogen (kg)	157	1.0882	767.6	66	11.63
Irrigation (No.)	13	1.8716	15995	250	63.98

Technical efficiency in bhendi production

Bhendi was cultivated in 30 out of 90 sample farms. The analysis was carried out for these 30 farms and the results are presented in (Table 6).

Table 6 Efficiency measures and descriptive statistics for bhendi producing farms (n=30)

Descriptive statistics	CRSTE	VRSTE	SE
No. of efficient farms	10	30	10
(≥ 0.90)	(33.33)	(100.00)	(33.33)
Mean	0.80	0.99	0.81
Standard Deviation	0.16	0.03	0.15
Minimum	0.47	0.90	0.50
Maximum	1.00	1.00	1.00

Figures in parentheses indicate percentages to total number of farms
CRSTE- Technical Efficiency under Constant Returns to Scale
VRSTE- Technical Efficiency under Variable Returns to Scale
SE- Scale Efficiency

Overall technical efficiency: The above table shows that 33.33 per cent of the bhendi producing farms were operating with the overall technical efficiency of more than 0.90 under the assumption of Constant Returns to Scale (CRS) and the remaining farms were technically inefficient. The overall technical efficiency of the farms ranged from 0.47 to 1.00 with the mean technical efficiency of 0.80. The remaining farms (66.67%) which did not operate at the maximum efficiency level could increase the efficiency by 20 per cent.

Pure technical efficiency: The pure technical efficiency, calculated by using variable returns to scale equation ranged from 0.90 to 1.00 with a mean efficiency score of 0.99. It could be observed that the farms with pure technical efficiency score more than 0.90 (33.33%) increased to 100% and the mean technical efficiency increased to 0.99 from 0.80 when the assumptions of constant returns to scale was relaxed and assumed to have variable returns to scale.

Scale efficiency: The farms operating with scale efficiency of more than 0.90 accounted for about 33.33 per cent of the total farms and the remaining farms were operating in a less than optimum scale size. The scale efficiency among the farms ranged between 0.50 &1.00 with mean scale efficiency score of 0.81. The above result indicates that the remaining farms which were operating in less than optimal scale size (scale inefficiency) have the scope of increasing their scale efficiency by 19% to increase their net farm income.

Scale of operations: The distribution of bhendi farms in the various regions of the production frontier revealed that nearly 83.33 per cent of the farms were found in the region of increasing returns to scale or the sub-optimal region. Around 16.67 per cent of the farms were found to operate with constant returns to scale. It could be observed that the farms operated only with constant returns to scale and increasing returns to scale.

The average yield of bhendi sample farmers in Coimbatore district was the ranged from 6 tonnes/ha to 17 tonnes/ha with the coefficient of variation of 24.85%. The maximum net return in bhendi cultivation was ₹ 27334 with the benefit-cost ratio of 1.22. Resource use efficiency analysis revealed that the human labour, nitrogenous fertilizer and number of irrigations were significantly influenced the yield of bhendi crop. The MVP to MFC ratio also revealed that the increased use of these input increases the profitability of the crop. The technical efficiency analysis revealed that nearly 33.33% of the bhendi producing farms were operating with the overall technical efficiency. Hence, there is an opportunity to increase the bhendi production by adopting new technology and efficient use of resources.

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