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Efficiency of Pomegranate Growers: A Data Envelopment Analysis

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ABSTRACT

The present study aims at examining the level of efficiency of Pomegranate growers in Solapur district of Maharashtra which happens to be the leading district in terms of production and area under cultivation of this crop. The variation in the level of efficiency is estimated by using Data Envelopment Analysis (DEA) technique. There is a wide variation in the level of efficiency among the sample farmers for both of orchard age group-II (3rd year to 5th year) and group-III (6th year to 12th year) with mean technical efficiency scores estimated as 69.89 per cent and 85.03 per cent respectively. Thus, there is an opportunity of augmenting production with the available resources in both groups. Pomegranate growers in both groups have been clustered by using K-means cluster analysis in four categories on the basis of their technical efficiency scores as efficient, semi efficient, moderately efficient and poor. An attempt has been made to estimate the excessive amount of inputs used by the Pomegranate growers over the targeted level in the study area. The cost on their excessive inputs can be minimized without affecting output level of particular farms.

Highlights

- In this study for examining the level of efficiency of Pomegranate growers Data Envelopment Analysis (DEA) technique was used.

Keywords: DEA, efficiency, Pomegranate, Solapur etc.

Pomegranate which has greater relative advantage in Maharashtra compare to other regions of the country has a definite commercial status in recent times particularly during the past two-three decades due to increasing urban affluence with changing life style. The state Maharashtra represents one of the leading Pomegranate growing states in India in terms of its area under cultivation recorded as 147910 hectares. This shares 63.22 per cent of total area under this crop in India. Again this state shares 62.90 percent of countries total pomegranate production. (Statistics Division, Department of Agriculture, Coopn & Farmers Welfare 2017-18). Data Envelopment Analysis (DEA) is a mathematical programming approach for estimating the relative Technical Efficiency of production activities. Data Envelopment Analysis was introduced by Farrell (1957) and later on extended by Charnes *et al.* (1978), to incorporate multiple inputs and multiple outputs simultaneously for estimating technical efficiency relative to a production frontier.

Data Envelopment Analysis (DEA) is used to analyze the technical efficiency, i.e. the degree to which a grower uses the minimum feasible amount of resources to produce a given level of output (Coelli *et al*. 2005). Data Envelopment Analysis (DEA) calculates the relative efficiency scores of various Decision-Making Units (DMUs) in a particular farm sample. DEA technique is a non-parametric measure showing performance or

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technical efficiency of an existing technology relative to an ideal "best practice" or frontier technology (Coelli *et al*. 1998). The frontier or best practice technology is a reference technology or production frontier that depicts the most technically efficient combination of inputs and outputs. The frontier technology is formed as a non-parametric, piece wise linear combination of observed -best practice" activities. Data points are enveloped with linear segment and technical efficiency score are calculated relative to the frontier technology.

An assessment of performance of technical efficiency of an existing technology relative to an ideal 'Best Practice' or frontier technology will be helpful to the pomegranate growers for scaling down the scare factors in order to minimize the cost of cultivation of that crop without affecting level of output. Considering the importance of Pomegranate crop in farm economy, the specific objective of study was to analyse the efficiency of selected Pomegranate growers using the input factors.

METHODOLOGY

Simple Random Sampling Without Replacement (SRSWOR) method has been used for selection of sample farmers in this study. Five blocks namely Sangole, Pandharpur, Malshiras, Mangalvedha and Mohol have been selected from Pomegranate cultivating eleven blocks contained in Solapur district. One hundred fifty (150) cultivators representing ultimate sample unit have been chosen from total number of Pomegranate cultivators contains in selected five blocks by SRSWOR. The collected data have been rearranged, processed and analyzed to fulfill the stated objective of the study by employing Data Envelopment Analysis (DEA) technique.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a mathematical programming to construct a production frontier comprising a set of linear segments. The frontier relates to best performance at a point in time. The points separating the segments are forming the best practice Decision Making Unit (DMUs) within a sample. The frontier "envelopes" the entities with the best of output/input ratios. The distance of an inefficient DMU from the frontier is the measure of its inefficiency. For each organization inside the frontier that is found by DEA to be inefficient, the technique identifies at least one DMU on the production frontier. That is a "peer" or role model to the inefficient organization. The technique assigns a wait to each peer reflecting the relevance of that peer to the inefficient DMU.

Briefly, DEA uses mathematical programming to construct a production frontier comprising a set of linear segments. The Frontier relates to the best performance at a point of time and technical efficiency of a DMU (Decision Making Unit) is measured in terms of distance from the frontier. Mathematically the problem DEA is expressed as,

$$\text{Max } \phi,\lambda\ \phi,$$

Subject to,

$$-\phi\, y_i + Y\lambda \geq 0,$$
$$x_i - X\lambda \geq 0,$$
$$N_1'\lambda = 1$$
$$\lambda \geq 0$$

In the above mathematical model, φ can take any value between one and infinity. The proportional increase in output that could be achieved by the i^{th} Pomegranate producing farm or decision making unit (DMU) with input quantities held constant is indicated by (φ-1). Y is ($1 \times N$) the output matrix, λ is ($N \times 1$) vector of intensity variables, X is ($K \times N$) the input matrix, y_i is the output of i^{th} farm, x_i is the input of i^{th} farm, N_1' is a vector of ($N\times1$) and convexity restriction. The ratio of 1/φ defines a technical efficiency score between zero and one (Coelli *et al.* 1998). One output and eight inputs were used in the model. The output is the per hectare yield of pomegranate production in Solapur district. Inputs included are number of plants per hectare, total human labour (days) per hectare, bullock labour (days) per hectare, machine labour (days) per hectare, irrigation (hours) per hectare, manures (tonnes) per hectare, total fertilizers (kg) per hectare and plant protection chemicals (lit) per hectare. A plant protection chemical represents the total amount of insecticides, fungicides, and herbicides etc., used in pomegranate production.

Using k-means cluster analysis Pomegranate growers are classified into four homogenous groups, viz.; efficient, semi efficient, moderate and poor in terms of technical efficiency scores.

RESULTS AND DISCUSSION

Efficiency of selected pomegranate cultivators:

Solapur district in Maharashtra state is dominated by pomegranate crop for a long time. Pomegranate growers of the study area follow more or less same techniques for production but differ widely in terms of output per unit of area. The causes of such variation are owing to differences in the level of efficiency. An attempt has been made to measure the extent of such variation using Data Envelopment Analysis i.e. DEA techniques, which is farm specific influencing production variation. Another objective of using DEA method is to find out the scope for minimizing valuable resources in the disposal of pomegranate growers. The efficiency scores of decision making units i.e. DMUs estimated by DEA for orchard age group II (3rd year to 5th year) and III (6th year to 12th year) are shown in Table 1.

The technical efficiency relates to the degree to which a grower uses the minimum feasible amount of resources to produce a given level of output (Coelli *et al*. 2005). When considering the maximum and minimum values in Table 1, it can be seen that there is a wide variation in the level of efficiency among the sample pomegranate growers for both groups. The mean score level has been estimated as 69.98 per cent for group II and 85.03 per cent for group III. Thus, there is an opportunity of augmenting at least 30 per cent of production in II and 15 per cent for group III with the available farm resources. In other words there is a scope for lifting the inefficient producers belongs to both groups to the level of best practice by increasing the production to the extent of 30 per cent and 15per cent respectively. Similar results were found by Suresh, (2015), Suresh and Chandrakanth (2016) and Kavand and Sargazi (2016).

Additionally, summary statistics for variables used in the efficiency analysis of age group II (3rd year to 5th year) and III (6th year to 12th year) are presented in Table 2.

Table 1: Efficiency scores of DMUs by DEA method for group II and III

Sl. No.	Technical Efficiency		Sl. No.	Technical Efficiency		Sl. No.	Technical Efficiency	
	II	III		II	III		II	III
1	0.536	1.000	26	0.466	1.000	51	0.621	1.000
2	0.588	1.000	27	0.413	1.000	52	0.358	0.783
3	0.458	1.000	28	0.732	0.893	53	0.689	0.724
4	0.496	1.000	29	1.000	0.794	54	0.732	1.000
5	0.322	1.000	30	0.784	0.828	55	0.554	0.885
6	0.317	0.611	31	0.572	0.852	56	1.000	0.799
7	0.496	0.863	32	0.790	0.877	57	0.909	0.937
8	0.497	0.860	33	0.696	0.894	58	0.874	0.742
9	0.553	0.852	34	0.699	0.880	59	0.753	0.789
10	0.636	1.000	35	1.000	0.922	60	0.797	0.733
11	1.000	0.852	36	0.625	1.000	61	1.000	0.706
12	0.651	1.000	37	0.640	0.652	62	0.959	0.558
13	0.651	1.000	38	0.805	1.000	63	1.000	0.444
14	0.720	0.672	39	1.000	0.844	64	0.968	0.672
15	0.552	0.679	40	0.875	1.000	65	0.928	0.672
16	0.695	0.709	41	0.946	0.780	66	1.000	0.733
17	0.525	0.847	42	0.990	1.000	67	1.000	0.587
18	0.513	0.786	43	0.782	0.979	68	0.630	0.634
19	0.456	0.864	44	0.629	0.858	69	0.794	0.519
20	0.386	0.709	45	0.797	0.877	70	1.000	1.000
21	0.564	0.980	46	0.457	0.850	71	0.787	1.000
22	0.524	1.000	47	0.773	0.937	72	0.633	0.963
23	0.380	0.757	48	0.559	0.839	73	0.564	0.984
24	0.477	1.000	49	0.503	0.610	74	0.903	0.940
25	0.553	1.000	50	0.880	0.763	75	1.000	1.000

Mean - Group II: 0.699 and Group III: 0.850.

Table 2: Summary statistics for variables used in the efficiency analysis of group II (3rd year to 5th year) and III (6th year to 12th year)

Variables	Mean	Min.	Max.	Std. deviation
Orchard age group II				
Pomegranate Yield (tonnes /ha)	8.00	4.13	13.92	2.22
Planting Material (No of Plants/ Ha)	738.07	662.21	799.00	23.19
Total Human Labour (Days)	277.25	86.00	982.00	143.10
Bullock Labour (Days)	20.40	9.89	43.29	6.66
Machine labour (Days)	7.05	3.06	13.46	2.35
Irrigation (hrs)	111.40	57.00	333.15	46.87
Mannures (tonnes)	11.01	8.10	14.70	1.60
Total Fertilizres (Kg)	1341.12	1083.47	1758.75	129.47
Plant Protection chemicals (Lit)	645.17	127.50	1626.71	205.50
Orchard age group III				
Pomegranate Yield (tonnes /ha)	9.31	5.31	13.31	1.65
Planting Material (No of Plants/ Ha)	700.64	677.54	712.20	5.26
Total Human Labour (Days)	169.89	72.00	288.00	45.79
Bullock Labour (Days)	15.45	4.98	30.53	5.36
Machine labour (Days)	5.69	2.91	10.39	1.94
Irrigation (hrs)	175.15	52.46	582.75	107.18
Mannures (tonnes)	11.91	9.65	15.30	1.07
Total Fertilizres (Kg)	1444.94	1070.00	1991.25	164.83
Plant Protection chemicals (Lit)	897.56	439.31	2426.83	319.92

Table 3: Distribution of sample DMUs according to level of technical efficiency for group II and III

Particulars	Cluster I (Poor)		Cluster II (Moderate)		Cluster III (Semi efficient)		Cluster IV (Efficient)	
Age group	II	III	II	III	II	III	II	III
Technical Efficiency	0.408	0.526	0.571	0.692	0.754	0.843	0.963	0.988
No. DMUs	11	04	26	17	17	24	21	30
Number of farms under different size groups								
Small	00	00	00	00	08	11	16	22
Medium	01	00	09	08	09	13	05	08
Large	10	04	17	09	00	00	00	00

Note: *Number of farms in group II and group III are 75 each.*

When considering the maximum and minimum level of inputs used in the efficiency analysis, it is observed that there is a wide variation in the level of application of inputs in the sample farms. Distribution of pomegranate growers into four distinct groups according to level of technical efficiency for both groups of sample pomegranate farmers Adhikari *et al.* (2012), Bhatt and Bhatt (2014), Ray *et al*. (2016) and Singh and Kaur (2014) and it has been presented in Table 3.

Table 3 shows that, out of 75 farmers in group II, 21 farmers which accounts for 28 per cent belong to efficient cluster. Similarly 30 farmers in group III show their efficiency which is accounted for 40 per cent of the sample pomegranate growers belongs to the efficient cluster. It is also seen that maximum number of DMUs of group II comes under moderately efficient category with mean efficiency 0.57. On the other hand maximum number of DMUs of group III comes under efficient category with mean efficiency 0.98. It is also estimated that 50.66 per cent of sample units from group II belongs to semi efficient and efficient category and 72 per cent from orchard age group III. It is also estimated that 14.66 per cent and 5.33 per cent of group II and group III in poor category farms can be improved by augmenting output with 60 per cent and 58 per cent respectively. Similarly 34.66 and 22.66 per cent moderate category farmers can increase output by 43 and 31 per cent of group II and III respectively, with the existing level of resources.

Group-wise average inputs used and possibilities

Table 4: Group-wise average inputs used and possibilities of minimization for orchard age group II (3rd year to 5th year)

Cluster Groups	Planting Material		Human Labour		Bullock Labour		Machine labour		Irrigation		Mannures		Fertilizres		Plant Protection	
	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target
Poor	734.54	681.08	289.82	212.52	22.10	18.07	7.88	6.54	108.88	107.01	11.54	9.96	1339.78	1208.02	690.06	595.71
Moderate	734.15	695.67	299.04	257.49	20.19	16.49	6.72	5.81	128.50	128.15	11.60	10.20	1384.32	1263.54	635.28	571.90
Semi efficient	752.46	714.70	213.67	187.56	22.76	19.78	7.50	7.06	97.40	97.25	10.52	9.32	1335.94	1243.99	613.46	568.43
Efficient	737.45	710.76	327.73	302.60	17.23	15.73	6.06	5.74	106.34	106.34	10.40	9.85	1291.41	1236.00	609.24	573.68

Table 5: Group-wise average inputs used and possibilities of minimization for orchard age group III (6th year to 12th year)

Cluster Groups	Planting Material		Human Labour		Bullock Labour		Machine labour		Irrigation		Mannures		Fertilizres		Plant Protection	
	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target	Used	Target
Poor	701.41	651.73	215.75	178.41	16.32	14.80	5.94	5.16	179.93	166.14	11.98	10.93	1440.61	1295.99	882.33	713.93
Moderate	697.30	690.17	184.76	162.47	16.70	15.43	6.24	5.61	167.74	143.63	12.26	11.52	1461.26	1378.96	1038.82	981.54
Semi efficient	702.81	700.35	159.71	142.12	13.32	12.19	4.44	3.97	151.14	139.79	12.05	11.43	1453.33	1416.02	951.87	894.84
Efficient	697.45	697.45	152.93	151.97	15.17	15.15	5.68	5.63	160.14	159.21	11.45	11.35	1416.78	1409.90	886.88	876.61

of critical input without loss of current level of production reduction for group II and III has been shown in Table 4 and 5. A wide variation between used and targeted amount of inputs has been found in all cluster groups for the orchard age group II. The similar variation has also seen in case of group III.

An attempt has been made to analyze the slack variables which indicate the excessive amount of inputs used by the pomegranate growers over the targeted level in the study area (Ozalp and Yilmaz 2015). Mean of actual amount of inputs used and their slacks of the group II and III are presented in Table 6.

Table 6: Distribution of input slacks and number of farms using excess inputs for group II and III

Inputs	Numbers of farms	Mean slack	Mean input use	Excess input use (%)
Orchard age group II				
Planting Material (No of Plants/ Ha)	43	37.68	738.07	5.10
Total Human Labour (Man Days)	40	42.92	277.33	15.47
Bullock Labour (Days)	48	3.09	20.40	15.14
Machine labour (Days)	33	0.83	7.05	11.77
Irrigation (hrs)	3	0.78	111.40	0.70
Mannures (tonnes)	51	1.07	11.01	9.71
Total Fertilizres (Kg)	42	147.21	1341.12	10.97
Plant Protection chemicals (Lit)	29	65.12	645.17	10.09
Orchard age group III				
Planting Material (No of Plants/ Ha)	31	20.11	700.64	2.87
Total Human Labour (Man Days)	34	14.17	169.89	8.34
Bullock Labour (Days)	21	0.81	15.45	5.24
Machine labour (Days)	32	0.45	5.69	7.90
Irrigation (hrs)	28	0.95	175.15	0.54
Manures (tonnes)	45	0.65	11.91	5.45
Total Fertilizres (Kg)	42	77.48	1444.94	5.36
Plant Protection chemicals (Lit)	16	72.68	897.56	8.09

The excessive inputs used in total human labour and bullock labour are found to be maximum in group II (3rd year to 5th year) as revealed by the Table 5.25. In other words it can be said that farm can minimize human labour and bullock labour use by 15.47 per cent and 15.14 per cent respectively. Thus, there are ample scope of minimizing 42.92 man days per hectare and 3.09 bullock pair days without curtailing existing output. This will lead to saving labour as well as reducing input costs. It is also estimated that 53.33 per cent man days and 64 per cent for bullock labour days of DMUs have potential for scaling down in group II. In the same way the particular farm can minimize their machine labour use by 11.77 per cent. As well, in case of manures and fertilizers there is scope for decreasing their quantum by the amount of mean slack i.e., on an average of individual pomegranate grower possess the potential for cutting down manure amount by 1.07 tonnes per hectare and 147.21 kg fertilizers per hectare. Automatically costs on these inputs can be decreased without affecting output level of particular farms. Optimum use of irrigation is witnessed in study area because majority of pomegranate growers are using drip irrigation system for irrigating the orchard. Similarly the excess use of human labour followed by plant protection chemicals and machine labour is found to be high in the farms belong to group III. Therefore, the particular farms may curtail their 8.34 per cent human labour, 8.09 per cent plant protection chemicals and 7.90 per cent machine labour while maintaining the same level of output. Thus, there is a good opportunity of curtailing 14.17 man days per hectare and 72.68 lit plant protection chemicals which leads to diminishing input costs. A farm can reduce its expenditure on key inputs like manures and fertilizers by 5.45 per cent and 4.36 per cent amount for particular slack variable. In the same way the particular farm can minimize their bullock labour use by 5.24 per cent and number of plants per hectare by 2.87 per cent. Hence costs on these excessively used inputs can be decreased without affecting output level of particular farms.

CONCLUSION

The study conclude that there is a wide variation in the level of efficiency among the sample farmers for both of orchard age group-II (3rd year to 5th year) and group-III (6th year to 12th year). So, there is ample scope for saving critical inputs. Overall technical efficiency suggests that the average farm can reduce its amount of input usage without reducing its output. This can be achieved by improving farm technologies and managing improper input use. In group II and III 28 per cent and 40 per cent farmers belong to efficient cluster respectively. Similarly, it is also seen that maximum number of Decision Making Unit's (DMUs) of group-II comes under moderately efficient. In group-III, the maximum number of DMUs comes under efficient. The estimated mean efficiency in poor category farms reveals that 14.66 per cent of group-II and 5.33 per cent of group-III farms belong to poor category can be improved by augmenting output by 60 per cent and 58 per cent respectively. A farm can reduce its spending on a particular input to the tune of the amount of that slack variable, without dropping its production level.

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