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Production efficiency in gram cultivation in Nagpur district: A stochastic frontier production approach

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Abstract
The present study entitled, "production efficiency in gram cultivation in Nagpur district: A stochastic frontier production approach"". The study was undertaken to examine the cost and returns gram cultivation. For the present study 120 gram farmers were selected from Katol and Kalameshwar tehsils of Nagpur district. The primary data was collected from the gram farmers by survey method and pretested schedule. To estimate the cost and returns of gram standard cost concepts i.e. cost A_1, cost A_2, cost B_1, cost B_2, cost C_1, cost C_2 and cost C_3 were used was used and to identify the constraints faced by gram farmers and garret ranking method was used. It is revealed from the study that Cost 'C_3' of gram farmer was Rs 78783.00. Average gross returns of gram was Rs 103774.61. The Benefit-cost ratio at cost 'C_3' of gram of 1.32. It shows that the gram crop appeared to be good for monitory benefits and profitable crop. The mean technical efficiency was 89.55. It is observed that the minimum technical efficiency was 43.79 and the maximum technical efficiency was 99.47. The mean economic efficiency was 56.74. The minimum economic efficiency was 2.32 percent and maximum economic efficiency was 79.90 percent. The mean allocative efficiency of the sample farms was 63.72 percent. The minimum allocative efficiency was 5.30 percent and maximum allocative efficiency was 103.19 percent. Higher income levels and better education contribute to improved efficiency. Total family size and age have no meaningful impact on technical efficiency. However, major constraints faced by gram farmers were realisation of less prices at market price while selling, crop damaged by long spell of fog etc.

Keywords: Standard cost concepts, benefit-cost ratio, profitable, technical efficiency, economic efficiency, allocative efficiency, constraints

Introduction
Gram commonly known as chickpea (*Cicer arietinum*) is an important pulse crop belong to family *leguminosae* and native to South West Asia. In India, gram ranks 5th among food grain crops, it is the most important pulse crop. It is used for human consumption as well as feeding to animals. Gram is a highly nutritious pulse crop with low digestible carbohydrates (40-60 percent), protein (15-22 percent), essential fats (4 - 8 percent), and a range of minerals and vitamins. Gram is a good source of important vitamins such as riboflavin, niacin, thiamin, folate and the vitamin A precursor of β-carotene. In gram saponin content is high and its inclusion in human diet lowers the plasma cholesterol and reduce the risk of heart disease. Gram also helps in fixing atmospheric nitrogen and contributes to build up organic matter.
India is the largest producer of gram in the world. In India gram occupies an area of 95.87 lakh ha for the year 2023-24. According to Ministry of agriculture and Farmer's welfare, Government of India, for 2023-24 production of gram in India is 110.39 lakh tonnes for the year 2023-24.
In Maharashtra state area under gram was 26.87 lakh hectares, with production 28.35 lakh tonnes and productivity is 1055 kg/ha during the year 2023-24. (Ministry of agriculture and Farmer's welfare, Government of India). In Nagpur district area under gram is 90673.69 hectares with production 119630.33 tonne and productivity 1320 Kg/ha during the year 2023-24 (O/o Superintendent of Agriculture, Nagpur).

Objectives

1. To work out the cost and returns of Gram cultivation.
2. To estimate the technical, economic and allocative efficiency in Gram Production
3. To analyze the factors affecting technical efficiency in Gram production.
4. To analyze the constraints faced by farmers in Gram production.

Materials and methods

The present study was undertaken in Nagpur district of Vidarbha region. For the present study multistage random sampling method was used. Out of fourteen tehsils of Nagpur district two tehsils namely Katol, Kalameswar tehsil were selected randomly. From each tehsil 3 villages were selected. From each selected village 20 farmers were selected. Thus total 120 farmers were selected. The primary data was obtained from selected farmers by survey method and pretested schedule for the year 2023-24 and information was collected on input utilization, cost and returns of the farmers, efficiency estimation and the constraints faced by farmers and other relevant information is also collected. The standard cost concept i.e. cost A_1, cost A_2, cost B_1, cost B_2, cost C_1, cost C_2 and cost C_3 were used in present analysis. To estimate the technical, economic and allocative efficiency, stochastic frontier production function was used.

The analytical part of the research was mainly confined to:

Estimation of per hectare cost A_1, cost A_2, cost B_1, cost B_2, cost C_1, cost C_2 and cost C_3

Per hectare net returns at cost A_1, cost A_2, cost B_1, cost B_2, cost C_1, cost C_2 and cost C_3

$$\text{Benefit-cost ratio} = \frac{\text{Gross Income}}{\text{Respective cost}}$$

Estimation of the technical efficiency in gram was evaluated by using Stochastic Frontier Production Function.

Specification of the model

$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i)$

Where,

Y_i = Output of gram (Quintals ha^{-1})

X_1 = Human labour (hrs ha^{-1})

X_2 = Bullock hours (hrs ha^{-1})

X_3 = Machine hours (hrs ha^{-1})

X_4= Quantity of seeds (kg ha^{-1})

X_5 = Quantity of fertilizers (kg ha^{-1})

X_6 = Quantity of pesticides (kg ha^{-1})

V_i = Random variable

U_i = Farm specific technical efficiency related variable

β_0 = Intercept/Constant

Stochastic frontier profit function was used to estimate economic efficiency of gram

Specification of the model

$\text{Ln } \Pi_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i)$

Where,

Π_I = Normalized profit at cost-A of the i^{th} farmer

X_1 = Human labour wage rate per hr normalized by output price of i^{th} farm

X_2 = Bullock labour wage rate per hr normalized by output price of i^{th} farm

X_3 = Machine wage rate per hour normalized by output price of i^{th} farm

X_4 = Price of seed per kg normalized by the output price of i^{th} farm

X_5 = Price of fertilizer per kg normalized by the output price of i^{th} farm

X_6 = Price of pesticides normalized by the output price of i^{th} farm

V_i = Random variable

U_i = Farm-specific economic efficiency related variable

β_0 = Intercept

Factor price is obtained by dividing the price of input with the output price.

The allocative efficiency can be calculated using following formula.

$AE_i = EEi/Te_i$

Regression technique was adopted for determining the significant factors responsible for inefficiency.

$Y^* = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + e$

Where,

Y^* = Technical efficiency

Z_1 = Land holding

Z_2 = Cultivated area under gram

Z_3 = Total family size

Z_4 = Income

Z_5 = Age

Z_6 = Educational qualification

β = constant / intercept

e = error term

For identification of constraints faced by the gram farmers,garret ranking method was used.

Percent position = $100 (R_{ij} - 0.50) / N_j$

Where,

R_{ij} = Rank given to the i^{th} constraints by the j^{th} farmer

N_j = Number of constraints ranked by j^{th} farmer.

Results and Discussion

Per hectare cost of cultivation of gram

The per hectare cost of cultivation of gram grown by the selected farmers is presented in Table 1. It is revealed that per hectare cost of cultivation of gram for beneficiary farmers was Rs. 78783.00. The major item was working capital i.e. 57.37 percent followed by Rental Value of Land 21.81 percent, hired machine charges 13.50 percent, hired human labour 10.60 percent and family human labour 7.51 percent, seed 6.71 percent share to cost C_3, respectively. The percent share of Cost A_2 and Cost B_2 were 59.74 percent and 83.39 percent respectively in total cost. The per hectare yield was 15.73 quintal and gross return obtained was Rs.103774.61. The per quintal cost of production was Rs. 4942.88.

Table 2 revealed that, per hectare average gross returns for gram was worked out to Rs. 103774.61. The net returns per hectare obtained at various costs were Rs. 56706.98 at cost 'A_2', Rs. 38076.15 at cost 'B_2' 24991.61 at cost 'C_3'. This means gram crop appeared to be good for monitory benefits and profitable crop. The benefit-cost ratio at cost 'C_3' was recorded 1.32.

The benefit-cost ratio which is an indicator of economic efficiency in crop production for the crop and other discussion indicated that Gram registered a good benefit-cost ratio *ratio* 1:1.32 means this is profitable crop.

Table 1: The per hectare cost of cultivation of gram

Sr. No.	Particulars	Unit		Input/ ha.	Rate/ Unit of input	Total Cost per ha.	Percent to Cost 'C3'
1	2	3			4	5	6
1	Hired Human Labour	Male	Days	12.61	355.00	4476.55	5.68
		Female	Days	18.45	210.00	3874.50	4.91
		Total	Days	31.06		8351.05	10.60
2	Bullock Labour		Days	3.47	642.25	2228.61	2.82
3	Machine charges	Hired	Hrs	13.30	800.00	10640.00	13.50
4	Seed		Kgs	67.41	78.50	5291.69	6.71
5	Manure		Qtls.	10.73	150.00	1609.19	2.04
6	Fertilizer	N kg/h	Kg.	27.50	38.75	1065.63	1.35
		P kg/h	Kg.	40.20	47.67	1916.33	2.43
		K kg/h	Kg.	5.10	30.67	109.75	0.13
		Total	Kg.		90.87	3091.71	3.92
7	Irrigation charges	(Rs.)				2957.00	3.75
8	Incidental charges	(Rs.)				453.18	0.57
9	Plant Protection	(Rs.)				1376.29	1.74
10	Repairing charges	(Rs.)				850.76	1.07
11	Working Capital (1 to 10)	(Rs.)				45200.53	57.37
12	Interest on working Cap @ 6% per annum	(Rs.)				904.01	1.14
13	Depreciation charges	(Rs.)				851.45	1.08
14	Land Revenue, cess and other taxes	(Rs.)				111.24	0.014
15	COST "A1" (11 to 14)	(Rs.)				47067.23	59.74
16	Rent paid for Leased in land					0.00	0.00
17	COST "A2" (15 + 16)					47067.63	59.74
18	Int. on Fixed Capital. @ 10%					1446.30	1.83
19	COST "B1" (17 + 18)					48513.93	61.57
20	Rental Value of Land	(Rs.)				17184.53	21.81
21	COST "B2" (19 + 20)					65698.46	83.39
22	Family Human Labour	Male	Days	10.55	355.55	3751.05	4.76
		Female	Days	10.34	210.00	2171.4	2.75
		Total	Days	20.89		5922.45	7.51
23	Cost " C1 " (19 + 22)	(Rs.)				54436.38	69.09
24	Cost " C2 " (21 + 22)	(Rs.)				71620.91	90.91
25	Supervision charges@10% Cost C2*					7162.09	
26	Cost " C3 " (24 + 25)					78783.00	100.00
27	Yield per hectare	(qt)		15.73	6531.67	102743.16	
28	Value of by-produce/ha.	(qt)		4.21	245	1031.45	
29	Value of total produce	Rs.				103774.61	
30	Per quintal cost of Production	(Rs.)				4942.88	

Table 2: Per hectare cost and returns of gram farmers

Sr. No	Particulars	Value(gram)
1.	Main Produce (quintal/ha)	15.73
2.	Value of Main Produce	102743.16
3.	Gross Returns	103774.61
4.	**Cost of Cultivation at**	
	Cost 'A1'	47067.23
	Cost 'A2'	47067.23
	Cost 'B1'	48513.93
	Cost B2	65698.46
	Cost C1	54436.38
	Cost C2	71620.91
	Cost C3	78783.00
5.	**Net Returns at**	
	Cost 'A1'	56706.98
	Cost 'A2'	56706.98
	Cost B1	55260.68
	Cost B2	38076.15
	Cost C1	49338.23
	Cost C2	32153.70
	Cost C3	24991.61
6.	**Benefit-cost ratio**	
	Cost 'A1'	2.20
	Cost 'A2'	2.20
	Cost B1	2.13
	Cost B2	1.57
	Cost C1	1.90
	Cost C2	1.44
	Cost C3	1.32

Technical, economic and allocative efficiency of gram:

Maximum likelihood estimates (MLE) of stochastic frontier production function along with mean technical efficiency are presented in Table 3

The result of the stochastic frontier production function have shown that the estimated value of coefficient of machine labour (0.23481), seed (0.16899) was positively significant at 10% level of significance estimates for gram are shown in Table 3. The coefficient of Fertilizer (0.85613), Pesticides (0.62712) are positive and statistically significant at 1% level of significance. Positive and significant value of estimated coefficients indicated that farmers could increase per hectare yield by applying more units of inputs.

Table 3: Coefficient of stochastic frontier production function of gram

Variables	Coefficient	Standard Error
Constant	-0.634**	(0.202)
Human labour	0.034	(0.037)
Bullock labour	-0.107***	(0.009)
Machine labour	0.234*	(0.096)
Seed	0.168*	(0.081)
Fertilizer	0.856***	(0.074)
Pesticide	0.627***	(0.138)
Sigma Square	0.019	(0.002)
Gamma	0.964	(0.016)
log likelihood	133.283	
Mean TE	89.56	

Table 4: Technical efficiency of sample farmers of gram (N=120)

TE (%)	No. of Farmers	Percentage to total	Average	Percentage to increase production to achieve maximum efficiency
<10	0.00	0.00	0.00	0.00
10.01-20	0.00	0.00	0.00	0.00
20.01-30	0.00	0.00	0.00	0.00
30.01-40	0.00	0.00	0.00	0.00
40.01-50	3.00	2.50	43.79	55.67
50.01-60	1.00	0.83	57.31	42.08
60.01-70	0.00	0.00	0.00	99.70
70.01-80	11.00	9.17	76.04	23.26
80.01-90	16.00	13.33	85.77	13.47
>90	89.00	74.17	95.80	3.39
Mean TE (%)	89.5569			
Max TE (%)	99.47			
Min TE (%)	43.79			

Table 4 revealed that, The mean level of technical efficiency has been estimated 89.55 percent for farmers as a whole, tend to realize around 90 percent of their technical abilities. Hence, on an average, approximately 10 percent technical potentials were not realized. it was observed that a majority of the farmers (74.17 percent) were operating close to the frontier with the technical efficiency of more than 90 percent.

The maximum likelihood estimates of the Stochastic Profit Frontier production are represented in Table 5.

The coefficient of prices of pesticides (0.48401) showed a significant positive effect on the profits at 1% level of significance. The coefficient of prices of seed (-0.15830) was negatively significant at 10% level of significance

Table 5: Coefficient of Stochastic Frontier Profit Function of gram

Variable	Coefficient	Standard Error
Constants	7.219***	(0.575)
Human labour price	-0.148***	(0.030)
Bullock labour price	0.046	(0.027)
Machine labour price	-0.004	(0.070)
Seed price	-0.158*	(0.064)
Fertilizer price	-0.005	(0.012)
Pesticide price	0.484***	(0.020)
Sigma Square	0.369	
Gamma	0.926	
log likelihood	-96.877	
Mean EE	56.75	

(Note: ***, ** and * indicates significance at 1%, 5% and 10% levels, respectively)

The frequency distribution of sample farms by the level of economic efficiency in rising the gram crop is shown in Table 6.

Table 6 revealed that, The mean level of economic efficiency has been estimated as 56.75 percent which means, in principle that the sample farmers can potentially reduce their overall cost of gram production and still achieve existing level of output. These results indicate the potential to further improve the economic efficiency of the gram.

Table 6: Economic efficiency of sample farmers of gram (N=120)

EE (%)	No. of Farmers	Percentage to total	Average	Percentage to increase production to achieve maximum efficiency
<10	3.00	2.50	3.30	95.87
10.01-20	0.00	0.00	0.00	0.00
20.01-30	5.00	4.17	24.12	75.86
30.01-40	7.00	5.83	34.38	65.58
40.01-50	21.00	17.50	45.43	54.53
50.01-60	26.00	21.67	54.98	44.96
60.01-70	29.00	24.17	65.83	34.10
70.01-80	29.00	24.17	74.48	25.44
80.01-90	0.00	0.00	0.00	0.00
>90	0.00	0.00	0.00	0.00
Mean EE (%)	56.75			
Max EE (%)	79.90			
Min EE (%)	2.32			

An examination of the Table 6 indicates that majority 24.17 percent of the farmers in sample operated at economic efficiency levels of 60-70 and 70-80 percent followed by 21.67 percent of the farmers with economic efficiency of 50-60 percent. Only 17.50 percent of the farmers achieved higher efficiency levels of greater than 40-50 percent.

Allocative efficiency of sample farmers of gram is presented in the Table 7. The mean allocative efficiency of the sample farms was 63.72 percent which means, the potential to further improve the allocative efficiency by 36.28 percent. In the area the allocative efficiency ranges from 5.30 to 103.19 percent with a mean efficiency of 63.72 percent. The minimum allocative efficiency was 5.30 percent and maximum allocative efficiency was 103.19 percent.

Table 7: Allocative efficiency of sample farmers of gram

AE (%)	No. of Farmers	Percentage to total	Average	Percentage to increase production to achieve maximum efficiency
<10	4.00	3.33	5.58	94.60
10.01-20	0.00	0.00	0.00	0.00
20.01-30	6.00	5.00	25.24	75.54
30.01-40	7.00	5.83	36.43	64.69
40.01-50	16.00	13.33	46.97	54.48
50.01-60	20.00	16.67	55.59	46.12
60.01-70	23.00	19.17	64.51	37.48
70.01-80	30.00	25.00	75.41	26.92
80.01-90	9.00	7.50	83.36	19.22
>90	5.00	4.17	97.58	5.44
Mean AE (%)	63.72526			
Max AE (%)	103.19			
Min AE (%)	5.30			

Factor affecting technical efficiency of gram production

The factor affecting technical efficiency was worked out by using linear regression analysis for gram are presented in Table 8. The results have shown that the income of farmer, land holding were the significant factors affecting technical efficiency, their coefficients being 0.03579, -7.18866, respectively. This implies that farmers with higher income and high land holding indicates more efficient in producing gram

Table 8: Factors affecting technical efficiency in gram production

Variables	Coefficient	Standard error
Constant	0.81611	0.05394
Land holding	0.03520***	0.00759
Cultivated area under gram	0.03755*	0.03140
Total Family size	-0.00173	0.00448
Income	0.07080**	4.28E -08
Age	-0.00026	0.00054
Education qualification	0.01036**	0.00537
R^2	0.82370	

(Note: ***, ** and * indicates 1 percent, 5 percent and 10 percent levels of significance, respectively)

Constraints faced by gram farmers

The significant issues faced by the gram farmers is presented in Table 9, all of the chosen gram farmers were questioned about the challenges they face in growing of gram. The farmers are analysed with the aid of the ranking technique, and the overall results are shown in the following Table. The farmers face a variety of issues like realisation of less prices at market price while selling, crop damaged by wild animals, disease and pests infestation, crop damaged by long spell of fog, farms not protected by fencing, non availability of labour in time of harvesting such etc

Table 9: Constraints faced by gram farmers

Sr. No.	Constraints	Mean Score	Rank
1	Non availability of labour in time of harvesting	55.00	IV
2	Crop damaged by Wild animals	20.00	VII
3	Crop damaged by long spell of fog	70.00	II
4	Farms not protected by fencing	48.00	VI
5	Unavailability of crop variety at sowing time	37.00	V
6	Realisation of less prices at market price while selling	82.00	I
7	Disease and pests infestation	63.00	III

Based on the Garrett's score, among the various gram production constraints, realisation of less prices at market price while selling (82.00) was the major production constraint followed by, crop damaged by long spell of fog (70.00), disease and pests infestation(63.00), non-availability of labour in time of harvesting (55.00), unavailability of crop variety at sowing time (37.00), farms not protected by fencing, crop damaged by wild animals(20.00).

Conclusion

1. Per hectare Total cost of cultivation of gram was Rs.78783.00. The percent share of Cost A_2 and Cost B_2 were 59.74 percent and 83.39 percent respectively in total cost. The per hectare yield was 15.73 quintal and gross return obtained was Rs.103774.61. The per quintal cost of production was Rs. 4942.88.
2. The net returns per hectare obtained at various costs were Rs 56706.98 at cost 'A_2', Rs. 38076.15 at cost 'B_2' 24991.61 at cost 'C_3'. The benefit-cost ratio which is an indicator of economic efficiency in crop production for the crop and other discussion indicated that Gram registered a good benefit-cost ratio 1:1.32 means this is profitable crop.
3. The mean technical efficiency of gram farmers in Nagpur district was 89.55. It is observed that the minimum technical efficiency was 43.79 and the maximum technical efficiency was 99.47.
4. The mean economic efficiency of gram farmers in Nagpur district was 56.74. The minimum economic efficiency was 2.32 percent and maximum economic efficiency was 79.90 percent.
5. The mean allocative efficiency of the gram farmers in Nagpur district was 63.72 percent. The minimum allocative efficiency was 5.30 percent and maximum allocative efficiency was 103.19 percent.
6. Higher income levels and better education contribute to improved efficiency. Total family size and age have no meaningful impact on technical efficiency.
7. Based on the Garrett's score, among the various gram production constraints, realisation of less prices at market price while selling was the major production.

Policy Implication

1. Efficient allocation of loan and subsidy to the farmers should be there as farmers are not able to utilise cost efficiently despite using input effectively.
2. Financial assistance should be given under low interest rate, from which farmers can invest in better technology and inputs.
3. Policies should focus on reducing production cost, enhancing market access, ensuring stable pricing.
4. Continued investments in infrastructure, sustainability, financial support can help to bridge the gap between technical and economic efficiency, leading to better profitability and sustainability for farmers.

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