Economic efficiency of improved red gram variety (BRG-2) in Karnataka: a DEA analysis

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ABSTRACT

Red gram (*Cajanus cajan*) is an important pulse crop in India. Red gram is also known as Tur, Arhar and Pigeonpea. Red gram is a staple food and rich in protein. It contains about 22 per cent of protein, which is almost three times of cereals. It is resistant to drought and suitable for dry land farming and predominately grown as an intercrop with other crops. The present paper attempts to show the economic efficiency of the new variety of red gram crop BRG 2 developed and released by University of Agricultural Sciences, Bangalore (UAS B), Karnataka compare to the check variety TTB 7. The data needed for the study collected from the farmers in southern region of Karnataka state. The cost concepts and Data envelopment analysis are used to measure the economic viability and economic efficiency of improved variety of red gram crop. The results showed that the net return (with red gram as pure crop) was the higher (₹ 5, 629 per acre) for BRG2 red gram farms than (₹ 3,936 per acre) for check variety farms, with a difference of ₹ 1,692, by 30 per cent. DEA analysis shows that farmers of BRG 2 have greater economic efficiency, allocative efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilisers, human labour, bullock labour, machine labour and plant protection chemicals. The BRG 2 red gram variety is economically performing well in field conditions and offering higher returns to farmers compared to the check varieties. Hence the Department of Agriculture, GOK can popularise and encourage the widespread adoption of red gram BRG variety for improving the nutritive capacity of farmers and consumers.

Keywords: economic efficiency, technical efficiency, red gram, improved variety, DEA, cost-return

Access this article online	
Publisher	Website: http://www.ndpublisher.in
	DOI: 10.5958/0976-4666.2016.00012.7

Red gram (*Cajanus cajan*) is an important pulse crop in India. Red gram is also known as Tur, Arhar and Pigeonpea. It is largely cultivated and consumed in developing countries and this crop is widely grown in India. India ranks first in the production and consumption of red gram in the world. Red gram accounts for about 20 per cent of the total production of pulses in the country. Red gram is a staple food and

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rich in protein. It contains about 22 per cent of protein, which is almost three times of cereals. Red gram is consumed in the form of split pulse as dal, which is an essential supplement of cereal diet. It also plays a crucial role in sustaining soil fertility by improving physical properties of soil and fixing atmospheric nitrogen. It is resistant to drought and suitable for dry land farming and predominately grown as an intercrop with other crops.

Red gram is grown throughout the tropical and subtropical countries of the world especially in South Asia, Eastern and Southern Africa, Latin America, Caribbean countries and Australia. In India, Red gram is one of the most widely grown pulse crops. It was cultivated over an area of 4.36 million hectares with a production of 2.86 million tonnes and productivity of 655 kgs. per hectare in 2010-11. Maharashtra is the largest producer of red gram accounting for nearly 34.11 per cent of the total production followed by Karnataka (18.49%), Uttar Pradesh (10.80%), Gujarat (9.54%), Andhra Pradesh (9.26%) and Madhya Pradesh (5.75%). These six major states together contribute about 88 percent of the total production and about 90 percent of the total area in the country in 2010-2011. Among the major red gram growing states, Maharashtra state occupied largest area under the crop and accounts 29.82 percent of the total area in the country followed by Karnataka (20.40%), Andhra Pradesh (14.63%), Madhya Pradesh (11.16%), Uttar Pradesh (7.88%) and Gujarat (6.34%). The productivity of red gram is highest in Delhi (1750 kg/ha) followed by Kerala (1489 kg/ha), West Bengal (1422 kg/ha) and Bihar (1403 kg/ha). Red gram in Karnataka is largely grown in Northern parts of Karnataka which accounts nearly 90 percent of total red gram area in the state. During 2010-11 the red gram was grown over 8.91 lakh hectares with a production of 5.29 lakh tonnes and a productivity of 625 kg/ha.

Red gram is popularly taken as an intercrop in rainfed areas in southern Karnataka, while cultivating as a pure crop in northern Karnataka. University of Agricultural Sciences, Bangalore (UAS B) has released BRG 2 (Bangalore Red Gram Variety 2) suitable for southern agro climatic zones in Karnataka in 2006 after a prolonged research effort of 11 years. The variety is spreading fast due to quick adoption and is in process of showing rapid increase in area as it is in high demand by farmers. Due to its quick popularity in southern districts, for this study on analysis of economic efficiency of new technology, BRG 2 variety of red gram was purposively selected. The specific objectives of the study are (1) to analyse comparative economics of improved variety and check variety in red gram and (2) to analyse the economic efficiency of improved variety v/s check variety in red gram crop

Database and Methodology

For this study the sample of farmers included those cultivating red gram as pure crops and red gram as intercrop in rainfed areas of Karnataka. For this, 35 farmers cultivating BRG 2 variety of red gram (Pigeon pea) as pure crop as under rainfed conditions in Eastern dry agro climatic zone (in Magadi and Doddaballapura) have been chosen purposively. For comparison, 35 farmers cultivating the local check variety TTB-7 variety of red gram have been chosen in the same areas as counterfactual. In addition, 35 farmers cultivating red gram variety BRG-2 as intercrop under rainfed conditions are chosen in central dry agro climatic zone (Chitradurga district - Hiriyur and Hosadurga taluks). Another 35 farmers cultivating red gram variety TTB 7 are chosen purposively in Chitradurga district as counterfactual. In all, 140 farmers have been chosen for this study. The data needed for the study was collected from the farmers by personal interview method using pre-tested schedule prepared during 2011-12.

To estimate cost of cultivation of red gram intercrop row ratios considered according to that the proportion of cost incurred for red gram cultivation estimated. In the study area farmers followed 8: 1 ratio for maize+ red gram. Therefore, here we considered $1/9^{th}$ of cost of cultivation maize+ red gram to estimate cost of cultivation of red gram separately excluding the seed cost of intercrop and labour cost incurred for harvesting and threshing of red gram intercrop. In the case of groundnut+ red gram, the ratio was 10:1. Hence, $1/11^{th}$ of cost of cultivation of ground nut +red gram considered for estimation.

Data envelopment analysis (DEA) is the non-parametric mathematical programming approach for frontier

estimation (Coelli, 1996). This approach was first used by Farrell (1957) as a piecewise linear convex hull approach to frontier estimation and later by Boles (1966) and Afriat (1972). The term data enveloped analysis coined by Charnes *et al.* (1978) after publication of their paper. DEA method has the disadvantage that it does not explicitly accommodate the effects of data noise (Murthy *et al.* 2009).

The DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level (Murthy *et al.* 2009). In this study, to estimate the technical efficiency, allocative efficiency and economic efficiency input oriented and cost minimization DEA were used.

The linear programming model for measuring the efficiency of farms under constant returns to scale is (Coelli, 1996):

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

Subjected to,

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0$$

Where,

θ is a scalar, the efficiency score whose value will be the efficiency measure for the i^{th} farm. If θ =1 the farm will be efficient; otherwise, it will be inefficient,

y_i is a vector (m x 1) of output of the ith farm,

x_i is a vector (k x 1) of inputs of the ith farm

Y is a output matrix (n x m) for n farms

X is a input matrix (n x k) for n farms

λ is a vector (n x 1) of constants whose values are estimated to obtain the optimum solution.

The constant returns to scale are only appropriate when the farms are operating at an optimal scale (Murthy *et al*. 2009).

Banker *et al*. (1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) conditions because of imperfect competition, finance constraint, etc. all farms not to be operating at optimum scale (Coelli, 1996; Johansson, 2005; Baris and Nilgun, 2007). Hence, when not all farms are operating at the optimal scale, we use VRS to avoid scale efficiency effects in calculation of technical efficiency.

The CRS linear programming problem can be easily modified by imposing a convexity constraint (N1'λ = 1) to account for VRS. The following linear programming model estimated is:

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

Subjected to,

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0,$$

Where,

N_1 is a vector (n x1) of ones.

The VRS approach forms a frontier of intersecting planes which envelope the data points more tightly than the CRS frontier. Therefore, it provides efficiency scores which are higher than or equal to those obtained using the CRS specification (Coelli, 1996; Manjunatha *et al.* 2009).

If we have price information and our objective is to cost minimisation, then we can measure both technical and allocative efficiencies. The cost minimization DEA formulated as follows

$$Min_{\lambda,xi}{}^{*}\ W_i' X_i^{*},$$

Subjected to,

$$-y_i + Y\lambda \geq 0,$$

$$X_i^{*} - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

Where, W_i is the vector of input prices for the i^{th} farm and X_i^{*} is the cost minimizing vector of input quantities

for the i^{th} farm, given the input prices W_i and output levels y_i. The total cost efficiency or economic efficiency (EE) of the i^{th} farm is calculated as:

$$EE = W_i' X_i^* / W_i' X_i$$

That is, the ratio of minimum cost to observed cost, for the i^{th} farm. The allocative efficiency is calculated residually by

$$AE = CE/TE$$

The DEAP version 2.1 software developed by Tim Coelli (1996), Centre for Efficiency and Productivity Analysis, University of Queensland, Australia, was used in this study to compute the efficiency levels of ragi and red gram farms separately by taking input oriented method.

The main product and by product per acre considered as outputs in the present study and seeds (kgs), farm yard manure (tons), human labour (Man days), bullock labour (pair days), machine labour (hours), chemical fertilisers (kgs), plant protection chemicals (in red gram) were taken as inputs. The prices of inputs used for cost minimization problem to estimate the economic efficiency.

Results and Discussion

The details of the cost of cultivation, as well as the gross and the net returns from an acre of red gram cultivation on BRG 2 and Check variety farms during the crop year 2011-12 are given in Table 1.

Farmers of BRG 2 variety used 21.10 man days of human labour, 1.51 pair days of bullock labour, 5.20 kg of seeds and 2.22 tonnes of farm yard manure. Whereas check variety(TTB 7) farmers used 19.53 man days of human labour, 1.25 pair days of bullock labour, 4.86 kgs of seeds and 2.14 tonnes of farm yard manure. Check variety Red gram farmers incurred higher cost of ₹ 501 towards plant protection chemicals compared with BRG 2 farmers (₹ 429.78). The machine labour (2.04 hours) used was nearly same by both categories of farmers. BRG 2 and check variety farmers incurred a total cost of ₹ 12,883.84 and 12,146.10 respectively. Human labour cost accounted maximum share in total cost of cultivation in both categories of farms (34.57% and 33.86%) respectively. The variable cost was higher in the case BRG 2 farms (₹ 9,274.50) than ₹ 8, 637.58 incurred by check variety farmers. The fixed cost was uniform in BRG 2 farms and check variety farmers. The share in total cost was 29% in check variety farms and 28.01 % in BRG 2 farms.

The BRG 2 farmers obtained higher yield in both main product (5.02 quintals/acre) and by-product (3.65 quintals of stubbles) compared to check variety farmers who obtained 4.50 quintals of red gram as main product and 3.24 quintals of stubbles as by-product. The gross return was ₹ 18, 513 and ₹ 16, 082 in BRG 2 farms and check variety farms respectively with a difference of ₹ 2430.36 per acre. The net return was the highest being 5,629 in the case of BRG2 red gram variety as against ₹ 3936 in the case of check variety farms with a difference of ₹ 1,692.

Table 1: Economics of BRG 2 variety of red gram as main crop and check variety of red gram cultivation (₹/acre)

Sl. No.	Particulars	Unit	BRG 2 Variety		TTB 7 (Check variety)	
			Quantity	Value (₹)	Quantity	Value (₹)
A			Variable costs			
1.	Human labour	Man days	21.10	4453.97 (34.57)	19.53	4112.81(33.86)
2.	Bullock labour	Pair days	1.51	760.95 (5.91)	1.25	626.19 (5.16)
3.	Machine labour	Hours	2.04	526.67 (4.09)	2.04	521.90 (4.30)
4.	Seed	Kgs.	5.20	408.52 (3.17)	4.86	378.76 (3.12)
5.	FYM	Tons	2.22	884.10 (6.86)	2.14	701.43 (5.77)
6.	Chemical Fertilisers	Kgs.	83.55	1168.68 (9.07)	84.07	1165.25 (9.59)
7.	Plant protection chemicals	₹	-	429.78 (3.34)	-	501.00 (4.12)

8.	Miscellaneous	₹	-	328.19 (2.55)	-	338.14 (2.78)
	Sub total			8960.87 (69.55)	-	8345.49 (68.71)
9.	Interest on working capital at 7%		-	313.63 (2.43)	-	292.09 (2.40)
	Total variable cost (A)			9274.50 (71.99)	-	8637.58 (71.11)
B.			**Fixed costs**			
10.	Land Revenue and Taxes	₹	-	15.00 (0.12)	-	15.00 (0.12)
11.	Depreciation	₹	-	143.77 (1.12)	-	94.81 (0.78)
12.	Rental value	₹	-	3295.14 (25.58)	-	3247.62 (26.74)
13.	Interest on fixed capital at 9%	₹	-	155.43 (1.21)	-	151.08 (1.24)
	Total fixed cost (B)			3609.34 (28.01)	-	3508.52 (28.89)
	Total cost of cultivation (A+B)			12883.84 (100.00)	-	12146.10 (100.00)
C.			**Returns**			
1.	Main product	Qtls	5.02	17140.81	4.50	14941.90
2.	By-product	Qtls	3.65	1372.05	3.24	1140.60
	Gross return	₹	-	18512.86	-	16082.50
D	Net return	₹	-	5629.02	-	3936.40

Table 2: Economics of BRG 2 variety of red gram intercropping with maize (ratio 8:1)

₹/acre

Sl. No.	Particulars	Unit	BRG 2 Variety		TTB 7 Check variety	
			Phy. Units	Value	Phy. Units	Value
A						
1.	Human labour	Man days	2.68	425.46 (32.11)	2.93	440.68 (32.39)
2.	Bullock labour	Pair days	0.10	50.18 (3.79)	0.12	62.39 (4.59)
3.	Machine labour	Hours	0.19	94.50 (7.13)	0.20	101.11 (7.43)
4.	Seed	Kgs	2.20	166.05 (12.53)	2.43	194 (14.30)
5.	FYM	Tons	0.15	80.09 (6.04)	0.17	72.31 (5.31)
6.	Fertiliser	Kgs.	8.69	112.96 (8.53)	8.38	105.68 (7.77)
7.	Pesticides	₹	-	13.28 (1.00)	-	17.47 (1.28)
8.	Miscellaneous	₹	-	22.55 (1.70)	-	11.97 (0.88)
9.	Interest on working capital at 7%	₹	-	33.78 (2.55)	-	35.22 (2.59)
10.	Total variable cost	₹	-	844.16 (75.39)	-	1041.41(76.54)
11.	Land revenue and taxes	₹	-	1.50 (0.11)	-	1.50 (0.11)
12.	Depreciation	₹	-	14.38 (1.09)	-	9.48 (0.70)
13.	Rental value	₹	-	296.13 (22.35)	-	294.44 (21.64)

14.	Interest on fixed capital at 9%		-	14.04 (1.06)	-	13.74 (1.01)
	Total fixed cost			326.04 (24.61)	-	319.17 (23.46)
	Total cost			1324.89 (100.00)	-	1360.58 (100.00)
		Returns				
1.	Main product of inter crop	Qtls	1.26	3832.16	0.97	2833.67
2.	By product of intercrop	Qtls	0.78	271.61	0.65	225.07
3.	Gross income	₹	-	4103.77		3058.73
	Net income	₹	-	2778.88		1698.15

Note: Figures in brackets indicates percentages to the total

The costs incurred and return realised by the farmers by adopting red gram as intercrop with maize and groundnut during the year 2010-11 are presented in the Tables 2 and 3. Farmers who cultivated BRG 2 variety of red gram as intercrop with maize incurred human labour cost of ₹ 425 accounting 32% of total cost of cultivation as against ₹ 440 (32.39%) incurred by check variety farmers. the quantity of red gram seed used was 2.20 kgs in the case of BRG 2 farms and 2.43 kgs in check variety farms. the cost of plant protection chemicals, bullock labour, machine labour, farm yard manure and seeds of red gram were higher in check variety farms compared with BRG 2 farms. The cost incurred on chemical fertilisers was ₹ 112 (8.5%) in BRG2 farms and ₹ 105 (7.77%) in check variety farms. Miscellaneous cost and interest on working capital were found nearly same in both categories of farms.

The total variable cost was high in check variety farms contributing 76% (₹ 1041) to the total cost of cultivation whereas it was ₹ 998 (75%) in BRG 2 farms. The return realised by the BRG2 red gram farmers was observed to be higher compared with that of check variety farmers. The BRG2 red gram farmers obtained 1.26 quintals of red gram yield as against 0.97 quintals obtained by check variety farmers. The gross return and net return on BRG2 red gram farms were ₹ 4,103 and ₹ 2778 per acre, respectively as against ₹ 3,058 and ₹ 1,698 per acre, on the check variety farms.

In order to analyse efficiency levels of individual farms as decided by the physical inputs (quantities) and their prices, DEA model (input oriented) were used at different production scales under assumption of constant returns to scale and variable returns to scale. The results on efficiency measures with constant and variable returns for red gram farms are in Table 4.18. The farms that operated at 90 or higher were considered 'efficient farms'.

It is evident from the Table 4 that in the case of BRG 2 farms, all most all farms (97%) under the assumption of constant returns to scale, performed with technical efficiency level equal to score0.9 and above i.e. 34 of 35 farms and under the assumption variable returns to scale all farms performed technical efficiency level equal to 90and above. The average technical efficiency score was 0.98 and 0.99 under the assumptions of constant returns to scale and variable returns to scale respectively. Whereas in the case of check variety farmers, about 77.14 % performed with technical efficiency level higher than equal to 90 % under the assumption of constant returns to scale. The average technical efficiency score was 0.95 and 0.98 under the assumptions of constant returns to scale and variable returns to scale respectively. It was evident that BRG 2 farmers have greater technical efficiency than check variety farmers under the both CRS and VRS.

With regard to allocative efficiency and economic efficiency is concerned about 22.86 % of both BRG2 red gram farmers and check variety farmers attained efficiency level 90 and above under VRS assumption. Thus, their performances with the allocative and economic efficiency level of 90 and above under the assumption of VRS. The average allocative efficiency and economic efficiency score was 0.74 and 0.72 for BRG 2 farmers under the assumption of CRS respectively, whereas, it was 0.73 and 0.70 for check variety farms under the assumption of CRS respectively.

Table 3: Economics of BRG 2 variety of red gram intercropping with groundnut (ratio 10:1)

₹/acre

Sl. No.	Particulars	Unit	BRG 2 Variety		TTB 7 Check variety	
			Phy. Units	value	Phy. Units	Value
A						
1.	Human labour	Man days	2.22	351.39 (30.83)	2.31	366.73 (32.51)
2.	Bullock labour	Pair days	0.10	51.83 (4.55)	0.12	58.28 (5.17)
3.	Machine labour	Hours	0.08	41.94 (3.68)	0.10	47.51 (4.21)
4.	Seed	Kgs	1.91	152.63 (13.39)	2.31	185.43 (16.44)
5.	FYM	Tons	0.17	82.71 (7.26)	0.14	61.46 (5.45)
6.	Fertiliser	Kgs.	4.78	78.43 (6.88)	4.23	53.92 (4.78)
7.	Pesticides	₹	0.00	22.20 (1.95)	-	19.46 (1.72)
8.	Miscellaneous	₹	-	21.32 (1.87)	-	17.84 (1.58)
9.	Interest on working capital at 7 %	₹	-	28.09 (2.46)	-	28.37 (2.52)
10.	Total variable cost	₹	-	830.55 (72.86)		839.00 (74.38)
11.	Land revenue and taxes	₹	-	1.35 (0.12)		1.35 (0.12)
12.	Depreciation	₹	-	12.94 (1.14)		8.53 (0.76)
13.	Rental value	₹	-	281.74 (24.72)		266.70 (23.64)
14.	Interest on fixed capital at 9%		-	13.32 (1.17)		12.45 (1.10)
	Total fixed cost			309.35 (27.14)		289.03 (25.62)
	Total cost			1139.90 (100.00)		1128.03 (100.00)
			Returns			
1.	Main product of inter crop	Qtls	1.34	4056.21	0.94	2754.12
2.	By product of intercrop	Qtls	0.80	274.63	0.80	274.94
3.	Gross income	₹	-	4330.84	-	3029.06
	Net income	₹	-	3190.94	-	1901.03

Note: Figures in brackets indicates percentages to the total

Table 4: Distribution of Red gram famers according to technical efficiency, allocative efficiency and economic efficiency scores

Sl. No.	levels of efficiency (%)	BRG 2 farmers					
		Constant returns to scale			Variable returns to scale		
		Technical efficiency	Allocative efficiency	Economic efficiency	Technical efficiency	Allocative efficiency	Economic efficiency
1.	90 and above	34 (97.14)	4 (11.43)	4 (11.43)	35 (100.00)	8 (22.86)	8 (22.86)
2.	80 to 89.99	1 (2.86)	10 (28.57)	8 (22.86)	0 (0.00)	8 (22.86)	7 (20.00)
3.	70 to 79.99	0 (0.00)	8 (22.86)	7 (20.00)	0(0.00)	7 (20.00)	8 (22.86)
4.	60 to 60.99	0 (0.00)	8 (22.86)	9 (25.71)	0 (0.00)	9 (25.71)	7 (20.00)

5.	50 to 50.99	0 (0.00)	2 (5.71)	4 (11.43)	0 (0.00)	1 (2.86)	3 (8.57)
6.	<50	0 (0.00)	3 (8.57)	3 (8.57)	0 (0.00)	2 (5.71)	2 (5.71)
7.	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.98	0.74	0.72	0.99	0.77	0.76
				Check variety farmers			
1.	90 and above	27 (77.14)	6 (17.14)	6 (17.14)	35 (100.00)	8 (22.86)	8 (22.86)
2.	80 to 89.9	5 (14.29)	6 (17.14)	4 (11.43)	0 (0.00)	6 (17.14)	5 (14.29)
3.	70 to 79.9	3 (8.57)	9 (25.71)	8 (22.86)	0 (0.00)	8 (22.86)	6 (17.14)
4.	60 to 70.9	0 (0.00)	4 (11.43)	4 (11.43)	0 (0.00)	5 (14.29)	7 (20.00)
5.	50 to 50.9	0 (0.00)	8 (22.86)	9 (25.71)	0 (0.00)	7 (20.00)	7 (20.00)
6.	<50	0 (0.00)	2 (5.71)	4 (11.43)	0 (0.00)	1 (2.86)	2 (5.71)
7.	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.95	0.73	0.70	0.98	0.75	0.74

Note: Figures in brackets are percentages to the total

Economic efficiency score for BRG 2 farmers was 0.77 and 0.76 under the assumption of VRS respectively, whereas as in the case of check variety farms it was 0.5 and 0.74 under the assumption of VRS respectively. It was evident from the analysis that farmers of BRG 2 have greater economic efficiency, allocative efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilisers, human labour, bullock labour, machine labour and plant protection chemicals.

Conclusion

The BRG 2 red gram variety economically performing well in field conditions and offering higher returns to farmers compared to the check varieties. The BRG2 red gram as pure crop offered 30 percent higher net return over the control TTB 7. The BRG 2 red gram as intercrop with maize offered 64 per cent higher net return over check variety and BRG 2 red gram as intercrop with groundnut offered 40 percent higher net return over the check variety TTB 7. Under both CRS and VRS assumptions the farmers of BRG 2 have greater technical efficiency, allocative efficiency and economic efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilisers, human labour, bullock labour, machine labour and plant protection chemicals. Hence the Department of Agriculture, GOK can popularise and encourage the widespread adoption of red gram BRG 2 variety for improving the nutritive capacity of farmers and consumers.

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