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Resource productivity and resource use efficiency of soybean varieties MAUS-612 vis-à-vis KDS-753 in Hingoli district of Maharashtra

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Abstract

This study explores the “Comparative economics of production of soybean varieties MAUS-612 vis-à-vis KDS-753 in Hingoli district of Maharashtra state. Multistage sampling design will be adopted in selection of district, two tehsils, eight villages and variety wise soybean grower MAUS-612 and KDS-753. The sampling technique was only be purposive. In all 96-variety wise soybean growers will be selected to collect the data for the year 2023-24. Soybean growers were stratified into two groups like MAUS-612 (48) and KDS-753(48). The result revealed that marginal value product (MVP) to price ratio with respect to area, hired human labour, family human labour, machine, seed, manure, bullock pair and potassium was greater than unity while MVP to price ratio of Nitrogen, Phosphorus, and plant protection was negative. The results inferred that there was greater chance to increase seed, Potassium, manure and hired human labour utilization.

Keywords: Cobb-Douglas, production function, resource use efficiency, resource productivity, marginal value product.

Introduction

Soybean (*Glycine max.* L) is a leguminous crop and belongs to family Leguminosae. It is originated in China. It is an important crop grown in India for dual purpose that is oil seed and legume crop. Contributing significantly to income security and nutritive diets of many households. It is high-protein food (42% protein, 21% oil) which is used for manufacturing vegetable oil and several other industrial products, it contains a good amount of minerals, salt and vitamin A and C. Soybean is widely used in the antibiotic industry for making penicillin and other drugs. Consumption of soy products is reported to be beneficial to prevents kidney disease, heart disease, diabetics, obesity, blood cholesterol and cancer, it a good supplement for cereals that can be used to improve the diet of millions of people. The soy protein market was valued at USD 8.75 billion in 2022, projected to reach USD 12.5 billion by 2027 at a CAGR of 7.3%.

Soybean is known as the “Golden bean”, and “miracle crop”, because of its several uses. Soybean has been knows by various names in India popularly known as the “Queen of Pulses”, wonder crop, farmers friends, and agriculture’s Cinderella. It was introduced in India 1970-71 mainly for rich protein and edible oil contain. Soybean was introduced in Maharashtra during the year 1984-85. It was become popular because it is short duration crop (90-110 day) with higher productivity as compared to other pulse crops. The average area under soybean in the world was 121.53 million ha, yield was 2.76 t ha⁻¹ and production 334.89 million.

In 2024, the area under soybean cultivation in Maharashtra was 24.87 lakh hectares, with a production of 33.05 lakh metric tons. The productivity was 1329 kilograms per hectare. In Marathwada region soybean was cultivated on 24.87 lakh ha with production of 33.05 lakh tons and productivity of 1329 Kg per hectare in kharif season. Area of soybean cultivation in Maharashtra was 49.09 (ha), in Marathwada maximum cultivation is in Latur district that is 4.89 (Lakh/ha), production is 5.39 (Lakh Mt/ha) and productivity is 1102 (kg/ha). In 2023-2024, Maharashtra produced 45.74 lakh tonnes of soybeans, according to the Government of India. Soybean is an important food legume that's high in protein and edible oil. It also improves soil health and fertility. (Department of Farmers ‘Welfare’ third advance estimation)

Hingoli. is one of the largest soybean-producing districts in the Maharashtra. Hingoli District located in the Marathwada region of Maharashtra. It has five blocks Higoli,. In Hingoli district, 2024 Soybean crop area under cultivation was 35.4 thousand hectares, with a production of 33.0 thousand tonnes and a productivity of 946 kg/ha. Major crops in kharif season are soybean, cotton, tur, and gram in the district.

Objective

To study resource productivity and resource use efficiency in soybean crop

Methodology

The multi stage sampling design was adopted for selection of district, tehsil, villages as well as soybean producer of MAUS-612 and KDS-753. In first stage, Hongli district was purposively selected on the basis of area under soybean production. In the Second stage Basmat tehsil and Kalmnuri tehsil was selected on the basis of higher area under both soybean production varieties MAUS-612 and KDS-753. In third stage eight villages were selected from four from Basmat tehsil and four villages from Kalmnuri tehsil having highest area under soybean cultivars. In the fourth stage, from each village, the separate list was prepared for MAUS-612 and KDS-753 varieties of soybean grower. From each of the village six farmers of MAUS-612 and six from for KDS-753 were randomly selected. Thus from one village, twelve farmer were selected. Thus making of 96 farmer (48 each from both varieties).

Analysis of data

The object that is to resource productivity and resource use efficiency in soybean production was estimated by fitting Cobb-Douglas to the per farm input output data.

Materials and Methods

Resource use efficiency

The production function approach was used to examine the productivity of resources used in soybean cultivation. For this purpose, the Cobb-Douglas production function was employed. The single most advantage of this production function has been that the input coefficients constituted the respective elasticity. The Cobb-Douglas type of Production Function was used and is usually defined as follows

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} \dots X_n^{b_n} e^u \dots\dots\dots(1)$$

Where,

Y = Output of soybean crop including main produce and by products (qts./ha).

a = Intercept.

X₁, X₂, X₃,-----X_n

Different variables used or independent variables.

e^u = Error term.

bⁿ = regression coefficient of the respective resource variables.

The function given in equation (1) can be expressed as,

$$\log Y = \log_a + b_1 \log X_1 + b_2 \log X_2 + \dots\dots\dots b_n \log X_n + u \log e \dots\dots\dots(2)$$

For fitting the production function in soybean crop, eleven input variables were considered as important factors by considering the problem of multicollinearity in estimating production function. Multicollinearity refers to situation where because of storing interrelationship among the independent variables, it becomes difficult to disentangle their separate effects on the dependent variables. Some of the independent variables are not important just because the standard errors are high. It might be due to the presence of multicollinearity.

The main consequences of multicollinearity are (a) the sampling variances of the estimate coefficients increase as the degree of collinearity increase between the explanatory variables, (b) estimated coefficients may become very sensitive to small changes in some of the estimates of the coefficients. This result in non-significance of regression coefficients. Sometimes it happens that more of the regression coefficients are significant but the value of R² is very high.

The equation fitted was of the following formula.

$$\hat{Y} = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} X_9^{b_9} X_{10}^{b_{10}}$$

Where,

Y = Yield of the crop in quintal per hectare

a = Intercept of production function

b_i = Partial regression coefficients of the respective resource variable

(i = 1, 2, 3,.., 11)

X₁ = Area of the crop in hectare

X₂ = Hired human labour in man day per farm

X₃ = Family human labour in man day per farm

X₄ = Bullock labour in pair day per farm

X₅ = Machine labour in hours per farm

X₆ = Seed in kg per farm

X₇ = Manures in quintal per farm

X₈ = Nitrogen in kg per farm

X₉ = Phosphorus in kg per farm

X₁₀ = Potassium in quintal per farm

X₁₁ = Plant protection in litre per farm

e^u = Error term

Elasticity of production (EP)

The elasticities of the respective variables are equal to the regression coefficient of the resource in Cobb-Douglas production function. The elasticity of production can be calculated as follows.

$$EP = \left\{ b_a X^{b-1} \right\} \frac{x}{y} = \frac{b_a X b}{X} \cdot \frac{X}{Y} = \frac{b_y X}{X \cdot Y} = b$$

Testing of regression coefficient

Partial regression coefficients are tested for significance by applying 't' test at n-k-1 degree of freedom as under:

$$t_{(n-k-1)} = \frac{b_i}{SE(b_i)}$$

Where,

b_i = Partial regression coefficient of particular variable

SE = Standard error of b_i

n = No. of observations

k = Dependent variables

Marginal product (MP)

Cobb-Douglas production function allows either constant, increase or decrease marginal productivity. In other words, resource productivity refers to marginal product with respect to added unit of input. The marginal product equation is as:

$$MP = \frac{dy}{dx} = b_i X^{b_i-1} = \frac{b_i \bar{X}^{b_i}}{\bar{X}} = b_i \bar{Y}$$

Where,

b_i = Elasticity of production

$\bar{X}$ = Geometric mean of output and

$\bar{Y}$ = Geometric mean of respective input

Marginal value product (MVP)

It refers to the product of MP and P_y , where MP is marginal productivity and P_y is the price of soybean per quintal. The MVP with respect to input factor is worked out by the following formula

$$MVP = b_i \bar{X}^{b_i-1} P_y$$

Where,

b_i = Regression coefficient of particular independent variable

$\bar{X}$ = Geometric mean of particular independent variable

$\bar{Y}$ = Geometric mean of dependent variable

P_y = Price of dependent variable

Optimum resource use efficiency

Optimum resource use efficiency was calculated by following formula

$$\text{Optimum resource use} = \frac{b_i \bar{Y} P_y}{P_x}$$

Where,

b_i = Partial regression coefficient of particular independent variable

$\bar{Y}$ = Geometric mean of dependent variable

P_y = Price of dependent variable

P_x = Price of independent variable

Returns to Scale

It refers to summation of b_i values.

$$\text{Returns to scale} = \sum b_i$$

If $\sum b_i = 1$, constant return to scale

If $\sum b_i < 1$, decreasing return to scale

If $\sum b_i > 1$, increasing return to scale

Its significance is tested by 'F' test as

$$F = \frac{(\sum b_i - 1)(n - k)}{[\sum \text{var}(b_i)](k - 1)}$$

Results and Discussion

Analysis and interpretation

Resource productivity and resource use efficiency in soybean crop

Cobb-Douglas production function was used and on the basis of goodness of fit (R^2) proper function was selected. The independent variables used in the production function, correlation matrix for soybean crop was developed. On the basis of non-significant correlation coefficients, some of the variables were dropped. Similarly in order to solve problem of which had less than the value of multiple determinations was taken in to consideration and one of the variables was dropped. Thus, remaining independent variables were used in specific production. Mostly Cobb-Douglas production function was used whereas, the regression coefficient are the elasticities of production and easy to determine the returns to scale in production.

Estimation of Cobb-Douglas production function in MAUS-612 soybean production

Regression coefficients with relation to various explanatory variables, geometric mean of input, marginal products, marginal value of product, price of input, MPV to price ratio and optimum resource use were calculated and presented in (table 1). Coefficient of multiple determinations model Fit & Returns to Scale $R^2 = 0.96$: The model explains 96% of the variation in soybean production, indicating an excellent fit. Returns to Scale ($\sum b_i$) = 1.09: Indicates increasing returns to scale, suggesting that a proportional increase in all inputs results in a more-than-proportional increase in output. F-value = 82.48: The model is statistically significant overall. Significant Inputs (based on t-values and coefficients), Seed ($b_i = 1.24$, $t = 3.97$): Strong positive impact on yield. MVP-to-price ratio = 20.92, suggesting underutilization; scope to increase seed usage. Area under soybean ($b_i = 0.81$, $t = 8.55$): Highly significant and positively impacts yield. MVP-to-price ratio = 4.85, also underutilized. Bullock labour ($b_i = 0.11$, $t = 2.61$): Positive and significant. MVP-to-price ratio = 14.22. Machine labour ($b_i = 0.07$, $t = 1.93$): Slightly significant and underutilized (MVP-to-price ratio = 1.18). Plant protection ($b_i = -1.12$, $t = -3.52$): Significant negative effect, MVP-to-price ratio is negative, indicating severe overutilization and potential crop damage.

Inputs with negative or in significant effects Nitrogen ($b_i = -1.50$, $t = -1.90$): Large negative coefficient, MVP-to-price = -258.23, suggesting serious overuse causing yield decline. Human labour ($b_i = -0.04$, $t = -0.44$): In significant and slightly negative effect. Phosphorous ($b_i = 1.43$, $t = 1.56$): High coefficient but not statistically significant at the 5% level. Potash and FYM Low, statistically in significant impact on yield.

Seed and area under cultivation are most productive the highest elasticity ($b_i = 1.24$) for seed indicates it has the strongest influence on soybean yield. MVP-to-price ratio of seed (20.92) far exceeds 1, indicating that increasing seed application would significantly enhance productivity and profit. Labour inputs need rationalization human labour has a negative and insignificant impact, possibly due to inefficiency or over-employment. Bullock and machine labour are underutilized. Machine labour, while marginally significant, still shows a potential for increased mechanization. Imbalanced fertilizer use Nitrogen shows a strong negative effect on yield, likely due to overuse or improper application timing. Phosphorous, though

positively associated, is statistically insignificant, possibly due to soil conditions or crop uptake inefficiencies. Potash and FYM have minor roles in yield variation. Overuse of plant protection chemicals the negative coefficient (-1.12) and extremely low MVP-to-price ratio (-314.65) suggest excessive or inappropriate use of pesticides/herbicides is damaging yields. Economic Implications Inputs like seed, bullock labour, and machine labour show high economic efficiency, suggesting that farmers should invest more in these. Conversely, plant protection and nitrogen inputs are economically inefficient, requiring better education, soil testing, and IPM (Integrated Pest Management) practices

Conclusion

Seed, Phosphorous, bullock labour, and potash are underutilized and significantly improved soybean productivity. Nitrogen and plant protection chemical have negative coefficient and MVP-price ratios, suggesting overuse that harms products and profitability. Increasing returns to scale indicate potential for higher productivity if inputs are proportionally increased. Resources like human labours and nitrogen are used inefficiently or in excess, resulting in low or negative returns.

Estimation of Cobb- Douglas production function KDS-753

Regression coefficient with relation to various explanatory variables, geometric mean of input, marginal products, marginal value product, price of input, MVP to price ratio and optimum resource use were calculated and presented in (Table 2) Coefficient multiple determination. The R^2 value is 0.91, indicating that 91% of the variation in soybean output is explained by the selected independent variables. This demonstrates a high degree of explanatory power of the Cobb-Douglas production function. The R^2 value is 0.91, indicating that 91% of the variation in soybean output is explained by the selected independent variables. This demonstrates a high degree of explanatory power of the Cobb-Douglas production function. Returns to Scale The sum of the regression coefficients (Σb_i) is 1.06, indicating increasing returns to scale. This means that a 1% increase in all inputs together results in more than a 1% increase in output.

Significance of Inputs (based on t-values) Statistically

Significant Inputs ($t > 1.96$ or $t < -1.96$). Area under soybean (ha/farm) Regression Coefficient: 0.33. t-value: 3.18 Significant and has a strong positive impact on production. Manures (qtl/farm) Coefficient: 0.10 t-value: 2.53 Significant and positively contributes to output. Marginally or in significant inputs Human labour, machine labour, seed, nitrogen, plant protection: t-values between 0.43 to 1.93. These are not statistically significant individually, but may still contribute economically. Bullock labour, phosphorous, potash: t-values < 1 and even negative in the case of bullock labour and phosphorous, indicating insignificance or negative relationship with output.

Marginal Value Product (MVP) and Price Ratios. Efficient Use ($MVP > Price$) Area under soybean: $MVP/Price = 2.62$ (Underutilized), can be expanded. Seed: $MVP/Price = 2.16$ (Underutilized). Manures: $MVP/Price = 8.49$ (Highly underutilized). Nitrogen: $MVP/Price = 89.34$ (Extremely underutilized). Potash: $MVP/Price = 2.69$ (Underutilized). Plant Protection: $MVP/Price = 96.94$ (Highly profitable and underutilized). Inefficient Use ($MVP < Price$) Human labour: $MVP/Price = 0.69$ (Overutilized). Machine labour: $MVP/Price = 0.11$ (Overutilized). Bullock labour: $MVP/Price = -2.71 \rightarrow$ Highly overutilized and negatively impacting output. Phosphorous: $MVP/Price = -14.81 \rightarrow$ Highly overutilized and negatively correlated with production

The table suggests that manures, nitrogen, and plant protection chemicals are far below their optimal use levels (e.g., Optimum for nitrogen is 3198.66 vs actual of 35.81). Inputs like bullock labour and phosphorous are being used inefficiently and should be reduced drastically or replaced. Human and machine labour should be used cautiously, possibly optimized via mechanization or better scheduling. The production of KDS-753 soybean is significantly influenced by land area, manures, and to a lesser extent, plant protection and nitrogen. These inputs show high marginal value products and are currently underutilized. Conversely, bullock labour and phosphorous show negative effects on production and should be minimized. There is scope for improving efficiency by reallocating resources toward inputs with higher MVP-to-price ratios, thereby enhancing productivity and profitability for soybean growers

Table 1: Estimation of Cobb- Douglas production function for MAUS-612 soybean growers

Sr. No	Independent variables	Regression Coefficient (bi)	Standard Error	t-value	Geometric Mean of Input (xi)	Marginal product (q)	Marginal value product (Rs)	Price of Input (Rs)	MVP to price ratio	Optimum Resource Use
1	Area under soybean (ha/farm)	0.81	0.09	8.55	1.17	21.66	97069.45	20000.0	4.85	5.69
2	Human labour (man day/ farm)	-0.04	0.08	-0.44	33.65	-0.03	-155.80	800.00	-0.19	-6.55
3	Bullock labour (pair day/farm)	0.11	0.04	2.61	1.73	-1.90	8532.94	600.00	14.22	24.59
4	Machine labour (hours/ farm)	0.07	0.04	1.93	8.63	0.26	1182.59	1000.00	1.18	10.21
5	Seed (kg/farm)	1.24	0.31	3.97	69.40	0.56	2510.67	120.00	20.92	11452.07
6	Manures (FYM) (qtl/ farm)	0.03	0.04	0.85	1.26	0.74	3315.99	1000.00	3.32	4.17
7	Nitrogen (kg/ farm)	-1.50	0.79	-1.90	54.42	-0.86	-3873.49	15.00	-258.23	-14052.22
8	Phosphorous (kg/ farm)	1.43	0.91	1.56	74.53	0.60	2692.84	40.00	67.32	5017.57
9	Potash (kg/ farm)	0.06	0.16	0.40	53.96	0.04	167.30	30.00	5.58	300.92
10	Plant protection (kg/lit)	-1.12	0.32	-3.52	1.11	-31.59	-141594.46	450.00	-314.65	-350.23

Intercept (log a) -1.01 Geometric mean (Y) of soybean production 31.34ql/ha

F value 82.48 Price of soybean (Rs/ qtl) 4481.87

R^2 0.96 Returns to Scale (Σb_i) 1.09

Table 2: Estimation of cobb- Douglas production function for KDS-753 soybean growers

Sr. No	Independent variable	Regression Coefficient (bi)	Standard Error	t-value	Geometric Mean of Input (xi)	Marginal product (q)	Marginal value product (Rs)	Price of value product (Rs)	MPV to price ratio	Optimum Resource Use
1.	Area under soybean (ha/farm)	0.33	0.11	3.18	0.96	11.90	52343.69	20000.00	2.62	2.52
2.	Human labour (man day/farm)	0.12	0.07	1.82	33.09	0.12	548.53	800.00	0.69	222.69
3.	Bullock labour (pair day / farm)	-0.02	0.05	-0.42	2.02	-0.37	-1625.39	600.00	-2.71	-5.47
4.	Machine labour (hours/farm)	0.01	0.05	0.10	7.34	0.03	114.13	1000.00	0.11	0.84
5.	Seed (kg/farm)	0.11	0.10	1.16	60.78	0.06	277.02	128.00	2.16	131.55
6.	Manures (qtl/ farm)	0.10	0.04	2.53	1.73	1.93	8485.12	1000.00	8.49	14.65
7.	Nitrogen (kg/farm)	0.32	0.75	0.43	35.81	0.30	1340.03	15.00	89.34	3198.66
8.	Phosphorous (kg/ farm)	-0.22	0.64	-0.34	54.82	-0.13	-592.49	40.00	-14.81	-812.07
9.	Potash (kg/farm)	0.02	0.88	0.02	30.67	0.02	80.72	30.00	2.69	82.54
10	Plant Protection (kg/ml)	0.29	0.18	1.60	1.01	9.92	43624.40	450.00	96.94	98.36

Intercept (log a) 0.99 Geometric mean (Y) of soybean production 34.19 qtl/ha

F Value 39.65 Price of soybean (Rs/qtl) 4398.65

R² 0.91 Returns to Scale (Σbi) 1.06

Conclusion

The production of KDS-753 soybean is significantly infused by land area, manures, and to a lesser extent, plant protection and nitrogen. These inputs show high marginal value products and are currently underutilized. Conversely, bullock labours and phosphorous show negative effects on production and should be minimized. There is scope for improve efficiency by reallocation resource toward input with higher MVP-to-price ratios, thereby enhancing productivity and profitability for soybean growers.

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