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Resource use efficiency of bitter gourd (*Momordica charantia* L.) in Sultanpur district of Uttar Pradesh, India

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Abstract

This study aimed to assess the profitability and resource use efficiency of bitter gourd production during the agricultural year 2021-22 in Sultanpur district of Uttar Pradesh. A multistage stratified purposive cum random sampling technique was employed to select the district, block, villages, and respondents. A pre-tested questionnaire collected primary data and information from 100 bitter gourd-producing farmers. These farmers were classified into 66 marginal, 23 small, and 11 medium categories, selected from five villages in the Dubeypur block of Sultanpur district. Cobb-Douglas production function was employed to estimate resource use efficiency and analyse the functional relationship between inputs and output. The t-test was used to examine the significance of factor elasticities, while the F-test was applied to test the significance of the R^2. The findings of the study revealed that the return to scale in bitter gourd production was increasing, indicating the potential for further investment in variable inputs to optimize income. Moreover, the Marginal Value Product was greater than one in most cases, indicating favourable prospects for investment. Aggregate measures calculated for financial efficiency indicated that marginal farms yielded higher profitability than small and medium farms. This demonstrates the comparative advantage of marginal farms regarding farm business income. The study highlights the importance of resource allocation and investment decisions for enhancing profitability in bitter gourd production.

Key words: Bitter Gourd, Cobb-Douglas, farm business income, production, profitability, resource use efficiency

Introduction

Indian agriculture and related sectors are the backbone of the India's economy, providing livelihood security and contributing significantly to the national GDP. Despite accounting for a diminishing share of GDP due to rapid industrialisation, urbanisation, globalisation, and shifting consumer patterns, the sector remains a key employer and the backbone of India's rural economy (Singh *et al.* 2022; Kumar *et al.* 2023). According to recent official estimates, agriculture and allied activities would account for around 17.8% of India's GDP in 2023-24, employing nearly half of the country's total workforce. This sustained contribution demonstrates its enduring socioeconomic significance, especially as the country shifts to a service- and industry-driven economy (Gautam *et al.* 2023). To ensure agricultural sustainability, it is critical to change production systems, improve infrastructure, increase financial access, and reorient agricultural policies towards productivity, resource efficiency, and climate resilience.

Demand for high-value horticulture commodities, particularly fruits and vegetables, has increased dramatically as a result of economic expansion, urbanisation, and shifting dietary habits (Arsanti *et al.* 2007; Agarwal *et al.*, 2016). India, the world's second-largest producer of fruits and vegetables, is sometimes referred to as the "Fruits and Vegetable Basket" (Chari and Madhav Raghavan, 2012; Sudarshan *et al.,* 2013; Nabi and Bagalkoti, 2017;Narmadha and Karunakaran, 2022). Horticulture has emerged as a crucial driver of agricultural diversification, with an increasing contribution to Gross Value Added (GVA) and national GDP (Fedorov and Kuznetsova, 2020; Schenau *et al.,* 2022; Agrawal *et al.,* 2016). Horticulture now accounts for around 30.4% of agricultural GDP and 33% of GVA, demonstrating its critical role in improving food security, job creation, and export revenues (Mishra *et al.* 2023). Over the last decade, India's horticultural output has grown at a rate of 4.8% per year, with cultivated land increasing by 2.6% (Kumar and Singh 2020). This rapid expansion highlights the sector's ability to boost agricultural profitability and contribute to sustainable rural living (Nishad *et al.* 2023).

Members of the Cucurbitaceae family are particularly well-known in horticulture for its nutritional, economic, and medicinal properties. Bitter gourd (*Momordica charantia* L.), one of the most significant cucurbit crops, is grown extensively throughout tropical and subtropical Asia, Africa, and the Caribbean (Anilkumar *et al.,* 2015; Butt *et al.,* 2018; Shamima Khatun *et al.*, 2024). Aside from its culinary use, bitter gourd has significant therapeutic properties and is used in traditional medical systems such as Ayurveda and traditional Chinese medicine (Nair and Groot, 2021). Bitter gourd is high in vitamins A, C, and E, as well as minerals including potassium and iron (Jan *et al.*, 2020). It is also known for its hypoglycemic, anti-inflammatory, antioxidant, and antibacterial properties (Banerjee, *et al.*, 2019. Because of these characteristics, contemporary research has shifted towards investigating its functional dietary and nutraceutical potential

(Behera *et al.*, 2012 Chen and Huang, 2019 Shamima Khatun *et al.*, 2024).

In the face of rising input costs, deteriorating soil fertility, and environmental concerns, increasing resource use efficiency (RUE) has become critical to sustainable crop production. RUE measures how efficiently agricultural inputs such as land, water, fertilisers, and labour are used to generate maximum output while minimising waste and environmental degradation (Horton *et al.*, 2016). Efficient resource management not only increases production and profitability, but it also ensures ecological balance and the long-term viability of the farming system. As resource constraints tighten and climate variability increases, an emphasis on RUE research is critical for guiding technology adoption, input optimisation, and policy design for resilient agricultural growth (Horton *et al.*, 2016). As a result, studying the resource use efficiency of bitter gourd production provides critical insights into input utilisation patterns, cost structures, and productivity factors, all of which contribute to enhancing horticulture systems' sustainability and economic viability.

The Marginal Value Productivity (MVP) of an input is the additional monetary value generated by the last unit of that item used; it is an important indication for input management and cost-efficiency. In bitter gourd cultivation, inputs such as labour and fertilisers have been shown to have high MVP, highlighting their importance in increasing yield and economic returns (Mishra *et al.* 2023). These production economics metrics are critical for directing sustainable and lucrative bitter gourd cultivation, ultimately enhancing resource utilisation efficiency and farm-level decision-making.

Taking this into account, a study was conducted to evaluate the resource use efficiency of bitter gourd production in the study area, with the goal of identifying crucial input-output correlations and potential areas for increased profitability and sustainability

Material and methods

This research involved the collection of primary data through a multistage purposive cum random sampling technique from bitter gourd farmers during the agricultural year 2021-22. The study was specifically conducted in Sultanpur district, chosen based on the intensity of bitter gourd cultivation in the region. To ensure a representative sample, one block named Dubeypur was purposively selected as considerable bitter gourd cultivation is prevalent in that area. A comprehensive list of all the villages within the block was prepared, along with the corresponding area dedicated to bitter gourd cultivation. From this list, five villages were randomly selected. Subsequently, a proportionate allocation was employed to randomly select 100 respondents from the selected villages. These respondents comprised 66 marginal farmers, 23 small farmers, and 11 medium farmers. The necessary data for the study were collected through a survey method. In order to achieve the objectives of the study, primarily descriptive statistics such as averages and percentages were utilized to analyse the collected data. These statistical measures were employed to gain insights and draw meaningful conclusions from the research findings.

Functional analysis

Cobb-Douglas production function: The Cobb-Douglas production model was useful for the estimation of resource use efficiency due to econometric and statistical advantages like sign and size of coefficients, t-test, f-test and R^2 (Mishra *et al.,* 2023). It was also used in many studies (Abid *et al.,* 2011; Mohammed *et al.,* 2014; Ibitoye *et al.,* 2015). Socio-economic variables in Cobb-Douglas model were used by Abid *et al.* (2011), Ashfaq *et al.* (2012), Dlamini and Kongolo (2014) and Ibitoye *et al.* (2015).

The mathematical form of Cobb Douglas production function is:

$$Y = a\, x_1^{b1} x_2^{b2} x_3^{b3} x_4^{b4} x_5^{b5} x_6^{b6} \ldots\ldots\, x_n^{bn} e^{\mu}$$

Where,

Y = Per hectare output (Rs./ha)

x_i = i^{th} independent variable (Rs./ha)

x_1 = Human labour (Rs./ha)

x_2 = Machinery charges (Rs./ha)

x_3 = Seed (Rs./ha)

x_4 = Manure and fertilizers (Rs./ha)

x_5 = Irrigation (Rs./ha)

x_6 = Plant protection

a = Constant

b_i (i = 1, 2, 3, 4, 5, 6) = Production elasticity with respect to X_i

e = Error term or disturbance term

μ = Random variables

The values of the constant (a) and coefficient (bi) in respect of independent variables in the function have been estimated by using the method of least squares (Bakhsh, 2007; Kshirsagar *et al.,* 2016).

Log form of Cobb Douglas production function is:

$$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 \log x_4 + b_5 \log x_5 + b_6 \log x_6 \ldots\ldots\ldots\ldots\, b_n \log x_n + \mu \log e$$

This form was used for estimating the parameters of the function based on sample data.

Marginal value productivity (MVP): The marginal value product of input was estimated by taking partial derivatives of returns with respect to the input concerned, at the geometric mean level of inputs (Maurya *et al.,* 2018; Maurya *et al.,* 2021). The marginal value product of inputs was estimated by the following

$$MVP(X_j) = \frac{b_j \bar{Y}}{\bar{X_j}}$$

Where, V*P* = Marginal Value Product

b_j = Production elasticity with respect to X_j

= Geometric mean of the dependent variable (Y)

= Geometric mean value of X_j independent variable

MVP_j = marginal value production j^{th} input

j = 1, 2, 3, 4, 5 variables included in the study.

Significance tests of the sample regression coefficients: After estimating the elasticity coefficient, reliability of these estimates was worked out. The most commonly used “t” test was applied to ascertain whether the sample production elasticity coefficient, b_j is significantly different from zero or not at some specified probability level (Mishra, 2022).

$$'t'\ calculated = \frac{b_j}{S.E. of\ b_j}$$

Where,

b_j = Production Elasticity of X_j

S. E. = Standard Error

If calculated ‘t’ value is greater than the table value of ‘t’ at specified probability level and 'n-k-1' degree of freedom, b_j is said to be significantly different from zero 'K' is number of independent factors and 'n' is sampled size (Maurya *et al.,* 2018; Choudhri and Singh, 2019; Kant and Singh, 2020).

$$F = \frac{Regression\ Mean\ Square}{Error\ Mean\ Square} = \frac{RSS/K}{\sum e^2/n-k-1}$$

Where,

RSS = Regression Sum of Square

e^2 = Error Sum of Square

Return to scale: The returns to scale can be easily estimated from this type of production function.

Thus,

Returns to Scale = $a_1 + a_2 + \ldots. + a_n$

$$= \sum_i a_i = 1, 2, \ldots\ldots, n$$

The summation of the powers of all the input variables provided directly with a ready estimate of the returns to scale as also the degree of homogeneity of the production function. The returns to scale are decreasing, constant or increasing, depending on whether a, is less than, equal to or greater than one (Rede *et al.,* 2013).

Result and discussion

The production function analysis was carried out to determine the efficiency of prime included resources viz. human labour, machinery charge, seed, manure and fertilizer, irrigation and plant protection as explanatory variables used in the production of bitter gourd. The Cobb-Douglas production function as best fit was explored and respective results are summarized in this section.

Elasticity of production: The table and figure in this study depict the calculated values of production elasticity, standard error, coefficient of multiple determination (R^2) and returns to scale of bitter gourd production across various farm sizes (as shown in Table 1).

Coefficient of multiple determinations: Table 1 presents the coefficient of multiple determinations (R^2) for different farm size groups: marginal, small, and medium. The R^2 values for these groups are 0.8591, 0.8840, and 0.9017, respectively. These values indicate that the combination of explanatory variables, including human labour, machinery charges, seed, manure and fertilizer, irrigation, and plant protection, collectively contributed to 85.91%, 88.40%, and 90.17% of the variations observed in the respective farm size groups.

Significance of factor of production: The analysis of Table 1 reveals significant observations for different farm sizes. For marginal farms, the elasticity of production in relation to human labour and plant protection was found to be statistically significant at the 5 percent and 1 percent levels of significance, respectively. This suggests that these input factors significantly contributed to the overall output. Similarly, for small farms, both the elasticities of production with respect to human labour and manure/fertilizer were statistically significant at the 5 percent level of significance, indicating their substantial impact on output. In the case of medium farms, the elasticity of production associated with human labour and irrigation showed significance at the 1 percent level, while machinery charges were significant at the 5 percent level. However, other factors of production included in the study were found to be statistically non-significant. Therefore, it can be inferred that there is limited potential for further application of these inputs in the production of bitter gourd.

Returns to scale: Returns to scale pertained to marginal, small and medium farms were analysed *i.e.*, 0.9043, 0.8667 and 0.8305, respectively, which was found to be less than unity. Less than unity value of returns to scale indicates that the nature of the functional analysis is of diminishing return to scale. It is therefore, inferred that increasing all factors by one per cent simultaneously results increase of the returns by less than 1 per cent on each farm situation.

Table 1. Production elasticity of bitter gourd crop on different size groups of farms

Size group of farms	Production Elasticity						Return to Scale	R^2
	Human labour (X_1)	Machinery charges (X_2)	Seed (X_3)	Manure/ fertilizer (X_4)	Irrigation (X_5)	Plant protection (X_6)		
Marginal	0.4150*	0.0778	0.1323	0.0682	0.0951	0.1158**	0.9043	0.859
	(0.1095)	(0.1124)	(0.1069)	(0.1283)	(0.0942)	(0.0727)		
Small	0.3772**	0.0317	0.0615	0.1995**	0.0766	0.1202	0.8667	0.884
	(0.1719)	(0.1438)	(0.1990)	(0.1481)	(0.1267)	(0.1500)		
Medium	0.1758*	0.2572**	0.1051	0.1248	0.1362*	0.0315	0.8305	0.902
	(0.2272)	(0.1968)	(0.2349)	(0.2059)	(0.2077)	(0.1244)		

*Significant at 1% level of probability, **Significant at 5% level of probability. Where, X_1, X_2, X_3, X_4, X_5 and X_6 stand for human labour, machinery charges, seed, manure and fertilizer, irrigation and plant protection (₹), respectively.

Marginal value productivity (MVP) of bitter gourd: It is evident from Table 2 that marginal value productivities were positive and more than unity in all cases on marginal and medium farms, which indicates scope for increasing the expenditure on this input variable. But in the case of small farms only X^2 variable, *i.e.*, machinery charges, were found to be less than unity which indicated excess investment on this variable; hence, there was the need to decrease it to increase the profitability of small farms.

In marginal farms, the MVP of human labour was 4.38, machinery charges were 1.16, seed was 2.23, manure and fertilizer were 1.21, irrigation was 2.72 and plant protection was 4.15 this shows that for the production of one additional quintal of bitter gourd the additional cost incurred for different is equal to the respected MVP. In small farms the MVP of human labour was 4.08, machinery charges were 0.59, seed was 1.02, manure and fertilizer were 3.61, irrigation was 1.99 and plant protection was 4.14 this shows that for production of one additional quintal of bitter gourd the additional cost incurred for different is equal to the respected MVP. In medium farms the MVP of human labour was 1.81, machinery charges were 4.65, seed was 1.70, manure and fertilizer were 2.21, irrigation was 3.69 and plant protection was 1.05. This shows that for the production of one additional quintal of bitter gourd, the additional cost incurred for different is equal to the respected MVP.

Table 2. Marginal Value Productivity (MVP) of included factors in the production process of bitter gourd cultivation

Size group of farms	Marginal value productivity of input/factors					
	X_1	X_2	X_3	X_4	X_5	X_6
Marginal	4.38	1.46	2.23	1.21	2.72	4.15
Small	4.08	0.59	1.02	3.61	1.99	4.14
Medium	1.81	4.65	1.70	2.21	3.69	1.05

Overall, this study provides valuable insights into the production dynamics and resource use efficiency across different farm sizes in the cultivation of bitter gourd. The findings highlight the statistical significance of various inputs such as human labour, machinery charges, seed, total, manure and fertilizers, irrigation, and plant protection. Notably, marginal and medium farms exhibited decreasing returns to scale in bitter gourd production, while small farms showed a nuanced scenario with only machinery charges displaying excess investment. The high R^2 values of 85.91%, 88.40%, and 90.17% for marginal, small, and medium farms, respectively, underscore the substantial explanatory power of the independent variables, indicating a commendable resource use efficiency. The positive and greater-than-unity MVP on marginal and medium farms suggest opportunities for further investment, whereas the need for cost reduction is evident in the case of machinery charges on small farms. These findings collectively contribute to a comprehensive understanding of agricultural production dynamics, offering practical implications for optimizing resource allocation and enhancing the profitability of diverse farm sizes.

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