Plant Archives Vol. 26, Supplement 2, 2026 pp. 1321-1326 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.158

RESOURCE USE EFFICIENCY AND DETERMINANTS OF CUCUMBER PRODUCTIVITY: A VILLAGE-LEVEL REGRESSION ANALYSIS IN COOCH BEHAR DISTRICT OF WEST BENGAL, INDIA

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(Date of Receiving : 07-03-2026; Date of Revision : 19-04-2026; Date of Acceptance : 14-05-2026)

ABSTRACT

In West Bengal, the cucumber (*Cucumis sativus* L.) is among the most important vegetable crops for small and marginal farmers, with a short duration. Using purposively selected three villages (Moyamari, Kalpani, and Matikata) of Cooch Behar district, this study focused on factors affecting yield and resource use efficiency in the cucumber. Primary data on four crop schedule groups of cucumber growers was collected from a total of 60 randomly selected cucumber farmers (20 per village) during the 2022-2023 cropping season. A Cobb-Douglas production function was estimated using ten input variables measured in monetary unit (Rs. bigha^{-1}) in log-linear form both at the aggregate level and village level. Marginal value productivity (MVP) and marginal factor cost comparison helped assess the resource utilization efficiency. It was found that the organic manure, Plant protection chemicals + plant growth regulators (PPC+PGR), and hired labour were the most consistent positive and significant predictors of production in all villages; MVP > 1 indicates that resources were not fully utilized. While the seed input adversely affected the production in Matikata, the irrigation had a considerable adverse effect in Moyamari. The range of R^2 value was 0.559 to 0.955, suggests moderate to high explanatory power of the estimated models. Based on the results from this study, village-specific solutions that would emphasize nutrient balance, good seed quality, proper irrigation, and optimal application of PPC+PGR may enhance cucumber production. The suggested policy interventions include provision of subsidies, formation of farming communities, and strengthening extension services.
***Keywords* :** Cucumber, Resource use efficiency, Cobb-Douglas production function, Marginal value productivity, Returns to scale, Cooch Behar, West Bengal.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetables grown worldwide for its high nutritional value, short duration, and significant economic returns to small and marginal farmers. It is consumed as a salad, cooked vegetable, and pickle, and serves as a rich source of vitamins (K, C), minerals, and antioxidants with cooling and hydrating properties. In India, cucumber plays a vital role in diversifying cropping systems, enhancing farm income, and improving nutritional security, particularly among resource-poor households in eastern and northern states. India ranks among the leading global producers of cucumber (Food and Agriculture Organization of the United Nations, 2024). The country has witnessed consistent growth in area and production of horticultural crops, driven by rising domestic demand, export potential, and government initiatives. West Bengal has emerged as a frontrunner in cucumber production. As per the final estimates for 2024-25, the state cultivated cucumber on 24.81 thousand hectares, producing around 349.95 thousand metric tonnes (West Bengal Department of Food Processing Industries & Horticulture, 2025). The state also maintains a strong position in overall vegetable production in India, with notable performance in crops like brinjal, cabbage, cauliflower, and cucumber (Ministry of Food Processing Industries, 2025). Cooch

Behar district, located in the northern part of West Bengal, is an important agricultural region characterized by smallholder farming, fertile alluvial soils, and a humid subtropical climate conducive to vegetable cultivation, including cucumber. Cucumber cultivation is particularly popular among small and marginal farmers in Cooch Behar because of its short growing cycle (60-90 days), relatively low input requirement in the initial stages, and good market demand both locally and in nearby markets. Horticultural crops, including cucumber, contribute substantially to household agricultural income in the district. Studies have shown that cucumber, along with other cucurbits like bitter gourd, pointed gourd, and watermelon, generates significant gross returns per hectare for farmers in Cooch Behar (e.g., garlic, bitter gourd, watermelon, and cucumber are among the top income-generating horticultural crops). Despite its economic importance and favourable agro-climatic conditions, cucumber productivity in Cooch Behar and similar regions of West Bengal often falls short of its full potential. Common constraints include imbalanced use of chemical fertilizers and organic manure, inefficient irrigation practices, poor quality seeds, labour scarcity during peak periods, incidence of pests and diseases, and limited adoption of modern technologies such as mulching, staking, and integrated nutrient management. Climate variability, including erratic rainfall, occasional floods in low-lying areas, and rising temperatures, further exacerbates these challenges. Small and marginal farmers, who constitute the majority of cucumber growers, frequently operate with suboptimal resource allocation, leading to lower technical and economic efficiency. Understanding the determinants of productivity and resource use efficiency is therefore critical for designing targeted interventions that can enhance yields, profitability, and sustainability. This study employs the Cobb-Douglas production function to analyze the influence of key inputs -such as tractor use, mulching, manure, fertilizer, seed, plant protection chemicals + plant growth regulators, staking, irrigation, and family/hired labour-on cucumber yield across selected villages in Cooch Behar district. By estimating elasticities, marginal value productivity, and returns to scale at the village level, the research identifies over- or under-utilized resources and provides village-specific policy insights. The findings aim to contribute to evidence-based strategies for improving cucumber productivity and supporting the livelihoods of smallholder farmers in West Bengal and similar agro-ecological regions.

Materials and Methods

The present study was conducted in three villages of Cooch Behar district, West Bengal: Moyamari (Village 1), Kalpani (Village 2), and Matikata (Village 3). These villages were purposively selected based on the prominence of cucumber cultivation among small and marginal farmers.

Different types of Crop practice

On the basis of different sowing time, 4 types of crop schedule has been chosen by farmer through variation of sowing time in different land situation.

Name of the village	Early season crop (Crop 1)	First middle season Crop (Crop 2)	Second middle season crop (Crop 3)	Late season crop (Crop 4)
Moamari	High land	Medium land	Low land	Not practiced
Kalpani	High land	Not practiced	Not practiced	Low land
Matikata	Not practiced	High land	Medium land	Low land

Seasonal time scheduling of cucumber crops and their respective management phases

Actual time scheduling of cucumber crop over the season follows as:

Crop cultivation phases	Duration	Seasonal crop options adopted by the practicing farmers			
		Early season crop (Crop 1)	First middle Season Crop (Crop2)	Second middle season crop (Crop3)	Late season crop (Crop 4)
Land preparation phase	2 weeks	Mid-September to End September	First October to Mid-October	Mid- October to End October	First November to Mid-November
Vegetative growth phase	6 weeks	First October to Mid-November	Mid October to End November	First November to Mid-December	Mid- November to End December
Harvesting phase	8 weeks	Mid November to Mid-January	First December to End January	Mid-December to Mid-February	First January to End February

Sampling and Data Collection

A total of 60 cucumber-growing farmers (20 from each village) were selected using simple random sampling. Primary data were collected through face-to-face interviews with structured schedules during the 2022-23 cropping seasons. Information was gathered on various inputs used (tractor/power tiller use, mulching material, manure, fertilizer, seed, Plant protection chemicals + plant growth regulators (PPC+PGR), staking, irrigation, family labour, and hired labour) and the corresponding cucumber yield (output). All variables were converted into per-hectare basis for uniformity.

Reference period

The collected data were related to September 2022 to February 2023 season.

Analytical Framework

Production function analysis

The Cobb-Douglas production function in log-linear form was used to estimate the relationship between inputs and output:

The fitted function is as:

$$Y = a\, X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8} X_9^{b9} X_{10}^{b10}$$

Where,

Y = Gross return (in Rs/bigha), a = Intercept
X_1 = Tractor (Rs / Bigha)
X_2 = Mulching material (Rs / Bigha)
X_3= Manure (Rs / Bigha)
X_4 = Fertiliser (Rs / Bigha)
X_5= Seed (Rs / Bigha)
X_6= Plant protection chemicals + plant growth regulators (PPC+PGR) (Rs / Bigha)
X_7 = Staking (Rs / Bigha)
X_8 = Irrigation (Rs / Bigha)
X_9 = Family (Rs / Bigha)
X_{10} = Hired (Rs / Bigha)

Data analysis was carried out separately for individual crops, villages, and pooled data using statistical software. Significance of coefficients was tested at 1%, 5%, and 10% levels.

Resource use efficiency

Resource use efficiency was estimated following the methodology outlined in Ugwumba (2010), where the efficiency ratio of MVP/MFC was computed to assess resource use efficiency. However, in this instance, since both the output and inputs were considered in terms of their values, the resource use efficiency can be directly determined by multiplying the regression coefficient with the GM ratios of output and input.

Where,

$$RUE = \beta_i \frac{\bar{y}(GM)}{\bar{x}_i(GM)}$$

$\bar{y}$ = Geometric mean of output
β_i = Regression coefficient of i^{th} input (i=1, 2, 3)
$\bar{x}_i$ = Geometric mean of i^{th} input.

Results and Discussion

The estimated regression coefficients, standard errors, t-values, p-values, and MVP for different inputs across villages and crops are presented in Tables 1 to 4

Table 1: Estimated Regression coefficients of various factors for cultivation of cucumber as Crop

Factors	Farmers for Moyamari (Village 1)					Farmers for Kalpani (Village 2)				
	Regression coefficients	Std. error	t value	P value	MVP or RAU	Regression coefficients	Std. error	t value	P value	MVP or RAU
Intercept	10.486	1.446	7.252	0		6.724	4.878	1.379	0.262	
Tractor X_1	0.096*	0.04	2.436	0.051	5.07	-0.041	0.091	-0.459	0.678	-2.844
Mulching material X_2	0	0.057	-0.006	0.995	-0.036					
Manure X_3	-0.022	0.037	-0.606	0.567	-0.523	0.160**	0.039	4.079	0.027	2.688
Fertiliser X_4	0.044	0.045	0.982	0.364	1.633	0.206	0.136	1.52	0.226	5.839
Seed X_5	0.028	0.1	0.278	0.791	1.302	0.115	0.116	0.992	0.395	7.165
PPC+PGR X_6	0.025	0.059	0.432	0.681	0.666	0.228	0.189	1.208	0.314	3.824
Staking X_7	-0.015	0.068	-0.227	0.828	-1.999	0.546*	0.22	2.477	0.089	42.412
Irrigation X_8	-0.177**	0.051	-3.478	0.013	-45.404	-0.06	0.095	-0.634	0.571	-13.261
Family X_9	0.021	0.036	0.583	0.581	0.185	-0.429	0.213	-2.015	0.137	-2.55
Hired X_{10}	0.125**	0.047	2.644	0.038	2.425	-0.01	0.075	-0.137	0.9	-0.208
R^2	0.877					0.934				
Adjusted R^2	0.672					0.734				
Sum of b_i	0.125					0.713				

Level of significance: * at 10 %, ** at 5% and *** at 1%

The Table-1 showed that in Moyamari village, the use of tractors and labor was identified as the primary factors positively affecting crop productivity ($p<0.10$), whereas irrigation had a negative impact on productivity (p=0.013), implying overuse or mismanagement. The model accounted for 87.7% of the variance in the output. In Kalpani village, organic fertilizer and staking were the main positive determinants of productivity (p<0.10), implying greater sensitivity to these factors. The regression model had good predictive capability (R^2=0.934). In general, the findings illustrate input efficiencies specific to each location, where farmers from Kalpani appear to be more sensitive to input usage (sum of β_i = 0.713) than those from Moyamari (0.125).

Table 2: Estimated Regression coefficients of various factors for cultivation of cucumber as Crop 2

Factors	Farmers for Moyamari (Village 1)					Farmers for Matikata (Village 3)				
	Regression coefficients	Std. error	t value	P value	MVP	Regression coefficients	Std. error	t value	P value	MVP
Intercept	4.358*	2.236	1.949	0.092		2.151	2.991	0.719	0.504	
Tractor X_1	0.124*	0.054	2.281	0.057	4.849	0.159	0.187	0.85	0.434	7.973
Mulching material X_2	-0.061	0.082	-0.741	0.483	-5.023					
Manure X_3	0.205***	0.043	4.764	0.002	3.917	0.338**	0.128	2.647	0.046	4.862
Fertiliser X_4	0.19**	0.058	3.267	0.014	5.142	0.167	0.133	1.257	0.264	2.453
Seed X_5	-0.034	0.121	-0.279	0.788	-2.025	-0.44**	0.162	-2.717	0.042	-15.798
PPC+PGR X_6	0.067	0.163	0.41	0.694	1.088	0.334	0.209	1.598	0.171	4.163
Staking X_7	0.204	0.258	0.789	0.456	15.285	-0.091	0.236	-0.384	0.717	-5.917
Irrigation X_8	0.009	0.075	0.122	0.907	2.001	0.339	0.288	1.177	0.292	53.453
Family X_9	-0.025	0.057	-0.435	0.677	-0.187	0.186*	0.087	2.139	0.085	1.737
Hired X_{10}	0.195*	0.089	2.194	0.064	3.066	0.103	0.137	0.752	0.486	1.174
R^2	0.895					0.903				
Adjusted R^2	0.745					0.729				
F value	0.875					1.094				
Sum b_i										

Level of significance: * at 10 %, ** at 5% and *** at 1%

The Table-2 showed that in Moyamari, the input effects of manure, fertilizer, tractor use, and hire labor had a great impact on improving agricultural productivity (p<0.10). In Matikata village, however, manure and labor by family members had a positive effect on productivity but seed had a negative influence on productivity (p=0.042). On the whole, both villages had relatively high explanatory ability of their models (R^2>0.89). However, the total returns to scale (sum of β_i) for Matikata was greater than for Moyamari village (1.094 > 0.875).

Table 3 : Estimated Regression coefficients of various factors for cultivation of cucumber as Crop 3

Factors	Farmers for Moyamari (Village 1)					Farmers for Matikata (Village 3)				
	Regression coefficients	Std. error	t value	P value	MVP or RAU	Regression coefficients	Std. error	t value	P value	MVP or RAU
Intercept	8.127*	3.553	2.287	0.084		9.037***	2.95	3.063	0.01	
Tractor X_1	-0.052	0.166	-0.316	0.768	-1.592	0.075	0.231	0.326	0.75	4.757
Mulching material X_2	0.354	0.214	1.657	0.173	19.174					
Manure X_3	0.144*	0.066*	2.183	0.094	1.869	0.183*	0.084	2.163	0.051	3.658
Fertiliser X_4	0.063	0.094	0.668	0.541	1.304	0.193*	0.099	1.947	0.075	4.502
Seed X_5	0.264	0.194	1.361	0.245	7.492	-0.238	0.208	-1.145	0.275	-9.267
PPC+PGR X_6	0.039	0.149	0.263	0.805	0.484	0.092	0.195	0.473	0.645	1.6
Staking X_7	-0.398**	0.119	-3.338	0.029	-27.245	-0.024	0.146	-0.164	0.872	-2.461
Irrigation X_8	-0.087	0.096	-0.911	0.414	-12.357	0.005	0.136	0.038	0.97	0.945
Family X_9	-0.058	0.063	-0.921	0.409	-0.293	-0.007	0.071	-0.104	0.919	-0.07
Hired X_{10}	0.086	0.059	1.47	0.216	1.134	0.024	0.086	0.275	0.788	0.327
R^2	0.955					0.559				
Adjusted R^2	0.843					0.228				
F value	8.526			0.027		1.687			0.196	
Sum of b_i	0.354					0.303				

Level of significance: * at 10 %, ** at 5% and *** at 1%

The Table-3 showed that Village 1 (Moyamari) had a very significant production function ($R^2 = 0.955$, $F = 8.526$). Staking labour (X_7) had a significant negative effect ($\beta = -0.398$, $p < 0.05$), and manure (X_3) had a positive significant effect ($\beta = 0.144$, $p < 0.10$), which means that the returns to scale were getting smaller ($\Sigma b_i = 0.354$). Village 3 (Matikata) had a weaker model fit ($R^2 = 0.596$, $F = 1.687$, $p = 0.196$). The only inputs that were slightly significant were manure (X3) and fertilizer (X4), with MVP values of 3.658 and 4.502, respectively. This suggests that these resources were not being used to their full potential. The sum of regression coefficients ($\Sigma b_i < 1$) across both villages indicates declining returns to scale, which means that if all inputs are increased by the same amount, the cucumber output will not increase by the same amount.

Table 4 : Estimated Regression coefficients of various factors for cultivation of cucumber as Crop 4

Factors	Farmers for Kalpani (Village 2)					Farmers for Matikata (Village 3)					Total Farmers of study area				
	Regression coefficients	Std. error	t value	P value	MPV	Regression coefficients	Std. error	t value	P value	MPV	Regression coefficients	Std. error	t value	P value	MPV
Intercept	12.687***	1.969	6.445	0.008		2.527	2.964	0.853	0.427		6.471	1.393	4.644	0	
Tractor X_1	0.009	0.034	0.254	0.816	0.33	0.133	0.145	0.921	0.393	4.671	0.035	0.043	0.812	0.427	1.276
Mulching material X_2															
Manure X_3	0.166*	0.07	2.38	0.098	1.226	0.215*	0.096	2.229	0.067	2.309	0.091**	0.036	2.528	0.02	0.826
Fertiliser X_4	-0.147	0.094	-1.557	0.217	-1.833	0.216	0.123	1.763	0.128	2.956	0.037	0.061	0.603	0.554	0.486
Seed X_5	-0.058	0.079	-0.741	0.512	-1.41	-0.192	0.225	-0.85	0.428	-4.389	0.02	0.078	0.255	0.801	0.468
PPC+PGR X_6	0.298*	0.114	2.601	0.08	2.244	0.289**	0.116	2.488	0.047	2.691	0.245***	0.075	3.271	0.004	2.075
Staking X_7	-0.252	0.146	-1.731	0.182	-13.171	0.006	0.187	0.03	0.977	0.311	0.09	0.109	0.828	0.418	4.681
Irrigation X_8	0.083	0.063	1.324	0.277	8.066	-0.01	0.12	-0.084	0.936	-0.806	0.043	0.058	0.743	0.467	3.76
Family X_9	-0.361*	0.132	-2.736	0.072	-0.981	0.092	0.125	0.736	0.49	0.426	-0.095	0.058	-1.628	0.12	-0.346
Hired X_{10}	0.071*	0.025	2.79	0.068	0.654	0.216*	0.092	2.353	0.057	1.578	0.093**	0.036	2.605	0.017	0.754
R^2	0.946					0.816					0.639				
Adjusted R^2	0.784					0.54					0.468				
F value	5.85			0.087		2.959			0.1		3.736			0.007	
Sum b_i	-0.192					0.965					0.559				

Level of significance: * at 10 %, ** at 5% and *** at 1%

The Table-4 revealed that the production function analysis for Village 2 (Kalpani) yielded a strong model fit ($R^2 = 0.946$, $F = 5.85$), wherein PPC+PGR (X_6) and hired labour (X_{10}) exerted significant positive effects ($p < 0.10$), while family labour (X_9) showed a significant negative influence, with a sum of coefficients ($\Sigma b_i = -0.192$) indicating negative returns to scale. Village 3 (Matikata) demonstrated a moderately significant model ($R^2 = 0.816$, $F = 2.959$, $p = 0.10$), with manure (X_3), PPC+PGR (X_6), and hired labour (X_{10}) emerging as significant positive determinants of cucumber output, and a near-unity Σb_i (0.965) suggesting approximately constant returns to scale. For the pooled sample of all farmers across the study area, the model was highly significant ($F = 3.736$, $p = 0.007$, $R^2 = 0.639$), with manure (X_3), PPC+PGR (X_6), and hired labour (X_{10}) identified as the most consistently significant inputs ($p < 0.05$), and a Σb_i of 0.559 confirming decreasing returns to scale in cucumber production across the study villages.

Analysis of Resource Use Efficiency

For most input variables, MVP was greater than 1, which shows that using organic fertilizers, PPC+PGR, and labor can help improve the profit level of the farmers. Seed and irrigation should be considered urgently for Matikata and Moyamari, respectively, since the value of MVP is generally negative for both of them. The findings of this study are in line with previous studies from eastern India (Kavya & Nahar, 2018; Qamar *et al*., 2017).

Conclusion

The study revealed that organic manure, labour hired, PPC+PGR, and chemical fertilizers proved to be the most influential positive determinants of cucumber production in Moyamari, Kalpani, and Matikata villages. These variables had MVPs of more than one, which indicated insufficient utilization of these resources. Water input had a large negative influence on cucumber production, particularly in Moyamari (Village 1). It was possible that either excessive water use or poor management of the resource was responsible for this result. A negative and significant seed input influence was observed in Matikata (Village 3), which implied possible low-quality and inadequate seeds for cucumber production. On the other hand, Σb_i results indicated that most village-crop combinations experienced decreasing returns to scale, except Matikata under Crop 2 ($\Sigma b_i = 1.094$), where there were increasing returns to scale. In essence, these results implied that resource utilization efficiencies differed across villages, which called for village-specific and input-oriented policies to enhance cucumber productivity in Cooch Behar district. To enhance the productivity of cucumbers in the study villages, emphasis had to be placed on increased use of organic fertilizer, effective utilization of labor, and availability of PPC+PGR through input subsidy schemes, formation of farmer cooperatives, and extension efforts led by KVKs. Additionally, corrective actions for overutilization of irrigation, lack of adequate control of seed quality, and variation of economies of scale within the region could only be addressed through customized village-level input-based consulting.

Acknowledgement

We express our sincere gratitude to each of our respective universities for providing the resources and assistance required to conduct this study. We also like to express our sincere gratitude to the local leaders and extension agents in the research region for their helpful support throughout the field survey. Lastly, we would want to express our gratitude to our friends and family for their unwavering patience, moral support, and encouragement during the research process. The authors did not receive any outside support for this study; it was entirely self-funded. The study's design, data collection, analysis, interpretation, and paper preparation were all independent of the sponsoring organization.

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