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Research paper



Crops and Costs: Comparing Economic Outcomes of Protected and Open Cucumber Cultivation in Haryana, India

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Abstract

The agricultural sector in Haryana is dominated by smallholder farmers practicing subsistence-level farming, which often yields low economic returns. The legacy of mono-cropping, particularly since the Green Revolution, has intensified environmental degradation through excessive use of chemical inputs and water resources. In this context, protected cultivation emerges as a potential alternative to conventional open-field methods, offering off-season production, higher yields, and resilience against climate variability. Given Haryana's proximity to the National Capital Region (NCR), the region has strong market access and high demand for fresh vegetables such as cucumbers. This study is inspired by on-ground interactions with farmers in Kurukshetra and Kaithal districts.

This study conducts a comparative economic analysis of cucumber cultivation under open-field and protected cultivation systems. Using empirical data from Haryana, we apply cost-benefit analysis, margin of safety, and regression models to evaluate economic efficiency and identify key cost-influencing inputs. The results indicate that protected cultivation yields significantly higher economic returns compared to traditional methods. However, the substantial initial investment remains a critical barrier for small-scale farmers, even when government subsidies are available.

The findings provide valuable insights for policymakers aiming to promote sustainable agriculture that balances environmental conservation with improved farm profitability. Strategic support mechanisms are recommended to enhance the adoption of protected cultivation among resource-constrained farmers, ensuring long-term agricultural sustainability in the region.

Keywords: *Protected Cultivation; Open Field Cultivation; Cucumber Economics; Cost-Benefit Analysis; Sustainable Agriculture; Agriculture Input Efficiency; Farm Profitability in Haryana; Agro-Policy Planning; Climate Resilient Agriculture.*

1. Introduction

Agriculture in India has historically been the primary source of livelihood for a significant portion of the population. With over 50% of the workforce engaged in agriculture, the sector continues to be vital to rural economies. However, the dominance of mono-cropping practices, especially the wheat-paddy rotation initiated during the Green Revolution, has led to long-term ecological and economic concerns. Haryana, one of India's leading agrarian states, exemplifies this pattern. While the Green Revolution enhanced production, it also accelerated groundwater depletion, soil salinity, and fertilizer dependency, thereby jeopardizing long-term sustainability (Jat et al., 2011; Kaur & Gehlot, 2015).

Smallholder farmers in Haryana, who constitute the majority of the farming population, face several economic constraints due to limited land, input costs, and market access. These challenges are compounded by environmental degradation, low crop diversification, and price instability. According to Kumar et al. (2020), the state's horticulture sector remains underutilized despite its high potential for economic diversification. One potential solution gaining attention is the adoption of protected cultivation, which involves growing crops under greenhouse or polyhouse structures to moderate environmental factors and improve yields.

Protected cultivation offers several agronomic and economic advantages. It supports off-season production, reduces pest infestations, improves input use efficiency, and results in better quality produce. In Haryana, where demand from nearby urban centers like Delhi is consistently high, protected farming presents a strategic opportunity (Ayog, 2024; Rajiv & Kumari, 2023). Numerous studies affirm its potential to increase farmers' income. For instance, Bhattacharjee et al. (2020) refer to protected cultivation as a non-conventional means of doubling farmer income. Similarly, Pachiyappan et al. (2022) emphasize that protected horticulture significantly improves water-use efficiency, productivity, and profitability in semi-arid regions.

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Cucumber (Cucumis sativus L.) is one of the most suitable crops for protected cultivation due to its short growth cycle, high market demand, and vulnerability to climatic fluctuations. Study by Kumar and Chauhan (2017) found that cucumber cultivation under polyhouses in Eastern Haryana resulted in significantly higher returns per unit area compared to traditional open-field methods. This is supported by research from Singh et al. (2018), who demonstrated enhanced economic viability and yield stability through fertigation and soilless cultivation techniques in controlled environments.

However, the adoption of protected cultivation is not without limitations. The initial investment required for setting up polyhouses remains prohibitively high for smallholders, despite government subsidies (Subedi & Tiwari, 2023). In Haryana, small and marginal farmers often struggle with credit access, awareness, and technical training, which hinders wider adoption (Bhatia & Bishnoi, 2017; Thakur et al., 2023). Market-related constraints, including supply chain inefficiencies and seasonal price fluctuations, also affect the profitability of high-value crops grown under protected structures (Punera, 2022).

Despite these constraints, the literature consistently highlights protected farming as a viable economic alternative to traditional methods. For example, Hebbar et al. (2024) explore the potential of off-season vegetable production and note significant gains in farmer income and climate adaptability. Mahanta et al. (2024) provide a comprehensive review affirming the broader economic and ecological benefits of protected cultivation in India. Additionally, regional studies, such as those by Bhattacharjee et al. (2020) and Al Amin et al. (2024), suggest that with adequate institutional support, protected farming can bridge the gap between subsistence agriculture and commercial viability.

Cucumber, in particular, has shown consistently high returns in various comparative analyses. Singh et al. (2018) and Kumar and Chauhan (2017) document a 30–40% increase in yield and net profit when cucumber is cultivated under polyhouses compared to open-field systems. These findings underscore the need for crop-specific economic evaluations to inform policy and guide farm-level decisions.

Recent global evidence also reinforces the economic potential of protected cultivation. González et al. (2023) reported that greenhouse vegetable farming in semi-arid regions of Mexico yielded 35–45% higher returns than open systems, mainly due to extended market windows and reduced crop losses. Similarly, Müller and Stein (2024) highlighted that protected horticulture in Mediterranean Europe improved farm profitability and water-use efficiency under climate stress conditions. A study by Hassan and El-Sheikh (2023) in Egypt demonstrated that cucumbers under controlled environments achieved a 42% increase in yield stability compared to open fields. These findings from diverse semi-arid and water-stressed regions confirm that Haryana's experience in Kaithal and Kurukshetra is not an isolated case but reflects a broader global trend toward climate-resilient and economically viable farming systems.

Nonetheless, a gap remains in the literature. While existing studies assess the agronomic and technological merits of protected cultivation, fewer works provide comprehensive economic comparisons between protected and open-field systems, especially in the context of Haryana. There is limited research integrating cost-benefit ratios, input-output efficiency, and regression-based insights to identify the economic drivers in cucumber farming under both systems.

This study seeks to fill that gap by offering a detailed empirical economic comparison of cucumber cultivation in Haryana. By utilizing cost-benefit analysis, margin of safety, and regression modeling, the research aims to evaluate the economic feasibility of both systems, identify key cost-influencing factors, and offer policy-level insights for sustainable agricultural planning. Ultimately, the study intends to support scalable, climate-resilient, and economically viable farming practices for smallholder communities in India.

2. Material and Methods

2.1. Study area

The present study was conducted in Kaithal and Kurukshetra districts of Haryana, located in the northern region of India. Kaithal shares its northern boundary with Punjab and falls within the agriculturally rich Indo-Gangetic plains. The region experiences a semi-humid climate, with most rainfall occurring during the monsoon season (June to September).

Kaithal was selected for its extensive area under protected cultivation, especially polyhouse-based vegetable farming. In contrast, Kurukshetra predominantly practices open-field farming, particularly in cucumber cultivation. The selection of these two districts enables a comparative economic evaluation under similar agro-climatic conditions but differing production technologies.

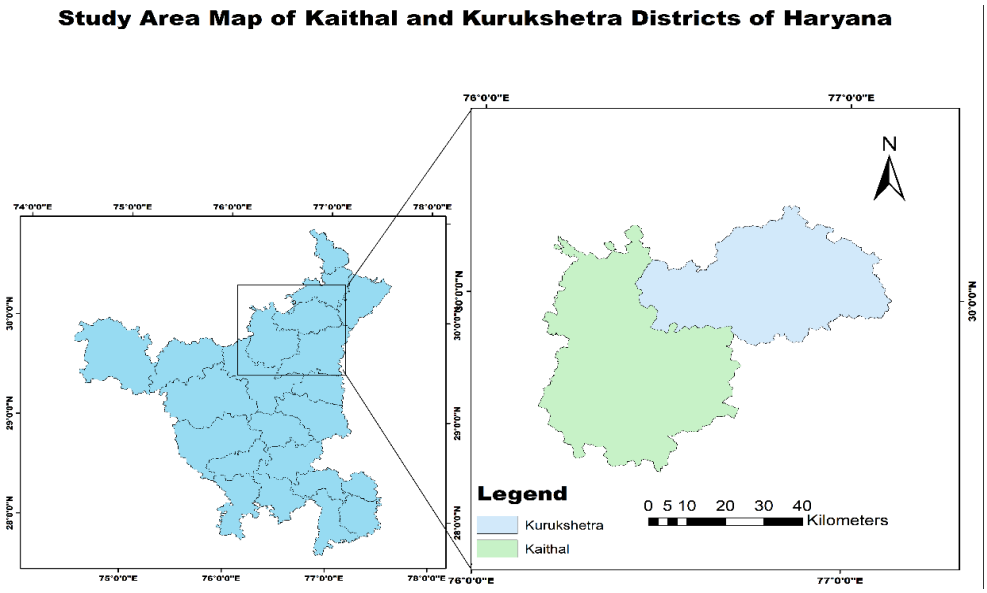


Fig. 1: Study Area Map.

Source: Survey of India.

2.2. Research design

This study adopts a comparative economic research design, focusing on the input-output dynamics, cost-benefit analysis, and factor efficiency in cucumber cultivation under protected versus open-field systems. Primary data were collected through field surveys and analysed using quantitative tools including cost accounting, regression analysis, and statistical tests.

2.3. Sampling and data collection

The sampling was conducted across two blocks — Kaithal block in Kaithal district and Pehowa block in Kurukshetra — based on their prominence in cucumber farming. Two villages from each block were selected using purposive sampling: Keorak and Nauch from Kaithal block, and Lohar Majra and Sarsa from Pehowa block. These villages host 60–70% of the total polyhouses in their respective districts, verified through data from the District Horticulture Offices and field visits.
To determine the sample size, the Taro Yamane (1973) formula was used:

$$n = \frac{N}{1+N.e^2}$$

n= sample size.
N=482 (Population of protected cucumber farmers in the two districts).
e=0.10 (significance level).

$$n = \frac{482}{1+482(0.10)^2} = 82$$

A total of 160 farmers (80 from protected and 80 from open cultivation) were surveyed. Data were collected for the year 2023–24 using pre-tested structured questionnaires covering cost components, yields, pricing, and perceptions.

2.4. Analytical framework and methods

To conduct a comprehensive economic comparison between cucumber cultivation under protected and open-field systems, the study employed multiple analytical tools. These include profitability metrics, financial safety measures, regression modeling, and statistical tests to ensure robust comparison and interpretation of the data. The equations used in the analysis are outlined below.
Equation 1: Net Income (NI)
Net income represents the farmer's actual profit after accounting for all expenses, including both fixed and variable costs. It is computed as:

$$\text{Net Income} = \text{Total Return} - \text{Total Cost}$$

This metric reflects the overall profitability of the cucumber farming system and allows direct comparison across the two cultivation methods.
Equation 2: Benefit-Cost Ratio (BCR)
The Benefit-Cost Ratio is a widely used method to evaluate the economic viability of farming systems. A ratio greater than or equal to 1.0 (BCR ≥ 1.0) indicates that the system is economically feasible:

$$\text{Benefit cost ratio} = \frac{\text{Gross Return}}{\text{Total Cost}}$$

This analysis enables the assessment of financial efficiency and return per unit cost for both protected and open-field systems.
Equation 3: Break-Even Analysis
Break-even analysis helps determine the minimum quantity of cucumber that must be sold to cover all production costs. It identifies the production threshold beyond which profits are generated:

$$\text{Break Even Quantity} = \frac{\text{Total fixed cost}}{\text{Selling price per Kg} - \text{Variable cost per Kg}}$$

This analysis is critical for risk management, especially for smallholder farmers with high upfront investments in protected farming.
Equation 4: Margin of Safety (MoS)
The Margin of Safety evaluates how far actual revenue can fall before the business reaches the break-even point. It reflects financial resilience:

$$\text{Margin of safety}(\%) = \frac{\text{Revenue breakeven point}}{\text{Total revenue at output}} \times 100$$

A higher MoS indicates greater stability in the face of market fluctuations or production shocks.
Equation 5: Multiple Regression Model
To assess how various cost components affect output, a multiple linear regression model was used. This approach helps quantify the contribution of key input categories on total output under both systems.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_i$$

Where Y_i= Total output in Cucumber vegetable cultivation, β_0= Constant, X_1= Material Cost, X_2 =Labour Cost, X_3 = Fixed Cost, X_4 = Energy Cost, X_5 = Transportation Cost and ε_i is the error term.
This model follows the methodology used by (Xu et al, 2011) in evaluating factor input effects on vegetable production economics.

Equation 6: Independent Sample t-Test
To statistically compare the mean performance of protected and open-field systems, an independent t-test was applied. The test determines if observed differences in income or productivity are statistically significant.
If the variances of the two groups being compared are different (heteroscedasticity), it is also known as t- statistic test.

$t = (x_1 – x_2) / S_p (\sqrt{1/n_1 + 1/n_2})$

where x_1 and x_2 are the sample means, n_1 and n_2 are the sample sizes, and where s_p is calculated as:

$s_p = \sqrt{(n_1-1)s_1^2 + (n_2-1)s_2^2 / (n_1+n_2-2)}$

where s_1^2 and s_2^2 are the sample variances. If p- value is less than from our chosen significance level we can reject null hypothesis.

2.5. Selection of indicators and variables

The dependent variable used in this study is Total Output, defined as the gross revenue obtained by farmers engaged in cucumber cultivation under both protected and open-field systems. The primary objective of this analysis is to identify the effect of various input cost categories on the overall output and profitability of cucumber farming.
The key independent variable is Total Cost, which was decomposed into the following components based on prior studies and field-level categorization (Xu et al., 2011). Following the approach used by (Yanyan et al, 2017), the cost of production per unit was derived by dividing the total cost per unit area by the total yield per unit area. This method provides a more accurate representation of per-unit economic efficiency across the two cultivation systems.
The quantitative data obtained from the structured questionnaires were coded and analyzed using IBM SPSS Statistics Version 26. This software facilitated the calculation of descriptive statistics, cost-benefit ratios, break-even quantities, and regression analysis. Independent sample t-tests were conducted to assess the statistical significance of differences in means between protected and open-field systems.

Table 1: Description of Variables and Descriptive Statistics (Cost per Acre)

Variable	Description	Protected (P)	Open (O)	Std. Dev (P)	Std. Dev (O)
Total Output	Total revenue from cucumber crop production	₹780,000	₹208,000	₹31,739	₹11,422
Material Cost	Seeds, fertilizers, and plant protection chemicals	₹166,990	₹33,579	₹9,882	₹4,104
Labour Cost	Includes FYM application, weeding, harvesting, irrigation, and sowing	₹163,403	₹68,956	₹7,814	₹5,594
Fixed Cost	Includes land rent, infrastructure, and machinery depreciation	₹122,865	₹18,001	₹7,339	₹1,260
Energy Cost	Irrigation costs (electricity + diesel)	₹13,418	₹1,993	₹1,950	₹278
Transportation Cost	Cost of transporting produce to the market	₹14,236	₹17,602	₹2,146	₹1,445

Source: Based on data collected from SPSS output.

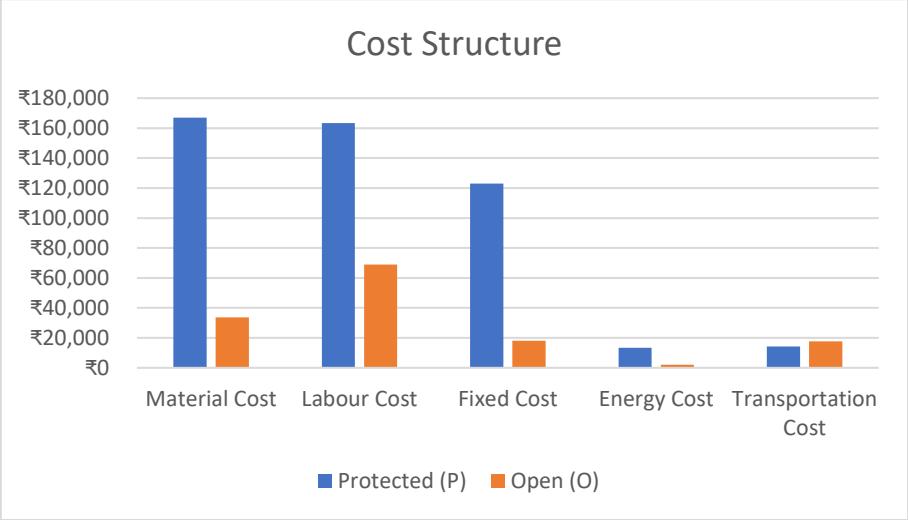


Fig. 2: Cost Structure of Cucumber Cultivation Under Open and Protected Field.

Source: Primary Survey (2023–24).

The cost distribution across major components material, labour, fixed, energy, and transportationdiffers sharply between systems. Protected cultivation has higher material and fixed costs due to technology and infrastructure, while open-field systems are more labour-intensive. These contrasts highlight the divergent economic profiles of the two systems.

3. Results and Discussion

3.1. Comparative economics of cucumber cultivation under protected and open field conditions

The comparative economic analysis of cucumber cultivation under protected and open field conditions reveals substantial differences in yield, input costs, profitability, and financial stability. The findings are based on primary data collected from selected farmers across Kaithal

and Kurukshetra districts and are summarized in Table 3. The area under cultivation in both cases is standardized to one acre (4040 m²) to facilitate direct comparison.

Table 2: Returns from Cucumber Under Open and Protected Field Conditions (Rs/acre)

Sr No	Particulars	Protected Field	Open Field
1	Total Yield (quintal)	600	230
2	Price (per kg)	₹13	₹9
3	Total Return	₹780,000	₹208,000
4	Net Return (TR - TC)	₹299,350	₹68,000
5	Benefit-Cost Ratio (BCR)	1.62	1.48
6	Break-even Quantity (kg)	17,552.14	5,142.80
7	Margin of Safety (%)	29.24%	22.22%

Source: Primary Survey (2023–24).

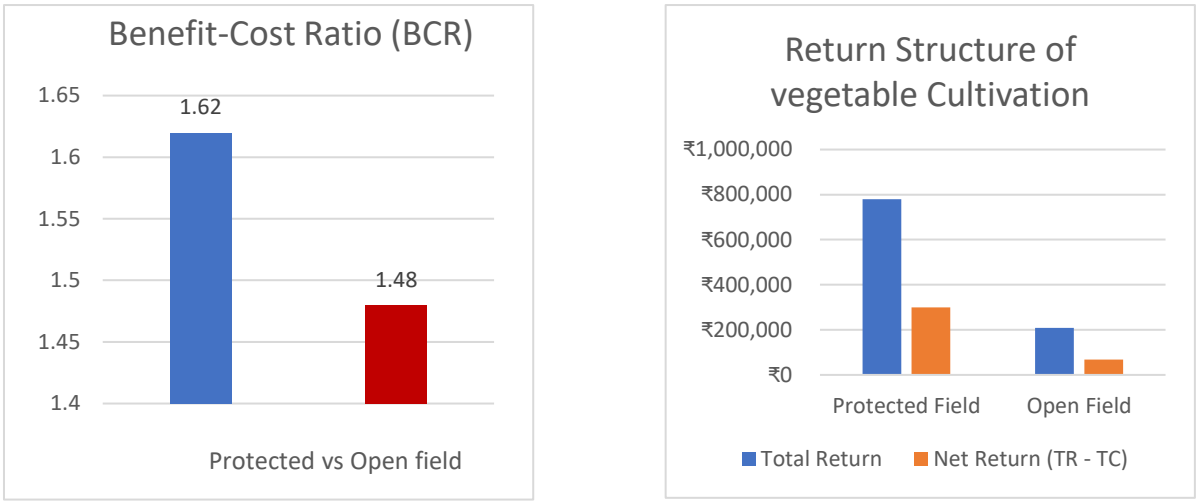


Fig. 3: Comparative Net Returns and Benefit–Cost Ratios (BCR) of Cucumber Cultivation under Protected and Open Systems.

Source: author's calculations.

This figure illustrates the difference in profitability between the two cultivation methods. Protected farming demonstrates significantly higher net returns and a superior BCR compared to open-field farming, underscoring its economic advantage despite higher input costs.
The comparative economic analysis between protected and open field cucumber cultivation reveals significant differences in productivity, cost structure, and profitability. Per-acre yield under protected conditions was 600 quintals, more than double that of the open field system at 230 quintals. With higher market prices (₹13/kg in protected vs ₹9/kg in open), the protected system generated a gross return of ₹780,000 and a net return of ₹299,350, compared to ₹208,000 and ₹68,000, respectively, in open field farming.
The Benefit-Cost Ratio (BCR) was 1.62 for protected farming, indicating a higher return per rupee of investment, compared to 1.48 in open cultivation. These findings align with the work of (Dadhich et al, 2024), who observed significantly higher returns and yield in protected cucumber farming across Rajasthan, and a favorable BCR of 2.13 in polyhouse settings. Similarly, (Padmaja et al, 2022) highlighted how controlled environments significantly boost yield and return potential through extended cropping windows and reduced losses due to biotic stress.
While fixed and input costs—particularly for seeds, fertilizers, and plant protection—are higher in protected farming, these are outweighed by the increased revenue potential. Moreover, the protected system showed a more favorable margin of safety (29.24%) compared to open field (22.22%), reflecting better financial resilience against yield and price shocks (Present Study). These insights are echoed in national-level economic studies (Meenakshi & Chattopadhyay, 2017) which advocate protected cultivation for year-round vegetable production, especially in high-demand peri-urban areas.

3.2. Correlation between total output and given costs in the cucumber cultivation

Table 3: Results of Pearson Correlation

Pearson Correlation	Protected field	Open field
Total output	1	1
Material Cost	.349**	.324**
Labour Cost	.193	.444**
Fixed cost	.080	.030
Transportation cost	.105	.119
Energy Cost	.090	.011

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson correlation analysis showed that material cost was significantly correlated with output under protected conditions ($r = 0.349$, $p = 0.002$), while other inputs like labor, energy, and transport showed weak or no association. In open field cultivation, both material cost ($r = 0.324$) and labour cost ($r = 0.444$) were significantly correlated with total output, indicating a more labor-sensitive system.
These findings are consistent with those of (Lokesh, 2024), who found that material costs had the greatest impact on cucumber yield in polyhouse setups, particularly when higher-quality inputs and fertigation were used. The open system's reliance on manual labor and input intensity has been similarly documented in cucumber and tomato systems across Himachal Pradesh and Telangana (Sharma, 2018; Manisha, 2022).

3.3. Econometric estimation of cost affecting total output in the cultivation

Table 4: Regression Model Summary

	Protected Fields	Open Fields
Model	1	1
R	.458a	.564a
R Square	.210	.318
Adjusted R Square	.156	.271
Std. Error of the Estimate	29153.881	9749.959
R Square Change	.210	.318
F Change	3.296	6.886
df1	5	5
df2	74	74
Sig. F Change	.003	.000

Note: Bases on SPSS software results.

Multiple linear regression results indicate that cost variables explained 21% of the output variance in protected systems ($R^2 = 0.210$), with an adjusted R^2 of 0.156. Although statistically significant ($p = 0.003$), the relatively low explanatory power suggests that factors beyond direct costs—like climate control, farmer expertise, or varietal choices impact productivity.

In contrast, the open field model had better predictive power, with $R^2 = 0.318$, adjusted $R^2 = 0.271$, and a significantly lower standard error, confirming a tighter relationship between cost inputs and output. This difference in model performance aligns with (Sharma, 2018), who showed that traditional open farming systems are more predictable using cost-based models, whereas polyhouse systems require multidimensional analysis to capture environmental and technological interactions.

Although the regression model for protected cultivation was statistically significant, its explanatory power was modest ($R^2 = 0.210$). This outcome indicates that factors beyond direct costs play a decisive role in determining output. Farmer expertise in managing microclimates, adoption of modern crop varieties, access to advisory services, and efficiency in climate-control technologies are likely to be critical determinants of success. Integrating these variables into future models could provide a more holistic picture of protected farming economics.

Furthermore, the present study is limited geographically to Kaithal and Kurukshetra districts and temporally to the 2023–24 season. While this design offers precision in local insights, it also restricts the generalizability of findings. Semi-arid and peri-urban regions in India, as well as comparable global contexts, may experience different patterns in costs, returns, and adoption barriers. Multi-season data and broader geographic coverage will be necessary to validate and extend these results for wider policy application.

3.4. Results of t- test (Independent sample test)

The results of the Independent Samples t-test provide a comprehensive comparison between the protected and open field production systems across various financial metrics.

Table 5:

Metric	t-value	Df	p-value
Total Output	151.628	158	< .001
Net Profit	67.824	158	< .001
Material Cost	111.507	158	< .001
Fixed Cost	125.953	158	< .001
Labour Cost	87.899	158	< .001
Energy Cost	51.862	158	< .001
Transportation Cost	-11.634	158	< .001

Note: Bases on SPSS software results.

An independent t-test comparing financial metrics between the two systems revealed statistically significant differences in total output, net return, material cost, fixed cost, labour cost, and energy cost ($p < 0.001$ for all variables). The mean output difference was ₹571,842.41 and net profit difference was ₹231,060.23 in favour of protected farming.

These results are supported by studies like (Panancheri, 2023) in Kerala and (Dadhich et al, 2024) in Rajasthan, both of whom found that polyhouse farming significantly increases income and efficiency, despite higher fixed investment costs. Furthermore, (Meenakshi & Chattopadhyay 2017), documented similar financial advantages and cost efficiencies in protected vegetable production across multiple Indian states.

Interestingly, transportation costs were found to be lower in protected cultivation, likely due to better harvest timing, reduced spoilage, and better market planning. This observation is in line with (Kumar et al, 2022), who emphasized the efficiency gains from post-harvest logistics in polyhouse-based horticulture.

4. Conclusion

The comparative economic analysis between protected and open field cucumber cultivation systems clearly reveals that protected farming offers significantly higher yields, profitability, and financial stability. In the present study, cucumber yields under protected cultivation were 600 quintals per acre, more than double the 230 quintals achieved in open fields. Coupled with a better market price (₹13/kg vs. ₹9/kg), this translated into a net return of ₹299,350 per acre, compared to ₹68,000 in open cultivation.

The Benefit-Cost Ratio (BCR) was more favourable for protected cultivation (1.62 vs. 1.48), reflecting its superior cost-effectiveness despite higher initial input costs such as seeds, fertilizers, and infrastructure investment (Present Study). These findings are consistent with those of (Dadhich et al, 2024) and (Padmaja et al, 2022), who highlighted protected farming as a profitable model, especially for high-value vegetables in peri-urban regions.

Although protected systems require a higher break-even quantity (17,552 kg), they offer a greater margin of safety (29.24%), making them more resilient to market fluctuations. This stability is particularly important in the context of increasing climate uncertainty and price volatility.

Correlation and regression analyses further showed that material costs significantly influence output in both systems, while labour costs are more impactful in open field cultivation. Despite open field models having better regression fit ($R^2 = 0.318$), the absolute financial and productivity performance of protected farming remains superior (Lokesh, 2024).

The Independent Samples t-test confirmed that protected cultivation significantly outperforms open systems in all key financial indicators, including output, net profit, material cost, and even transportation efficiency—due to better harvest planning and reduced spoilage (Panancheri, 2023; Meenakshi & Chattopadhyay, 2017).

In sum, protected cultivation is a financially viable and environmentally sustainable solution for boosting productivity and income in Indian agriculture. Its adoption, however, is currently constrained by capital requirements and knowledge gaps issues that need to be systematically addressed through policy reform and institutional support.

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