Economic Viability of Cocodust Nurseries in Vegetable Farming: A Cost-Benefit Analysis of Input Use, Production Costs, and Profitability in Bangladesh

Abstract

Seedling quality is a critical determinant of productivity, input-use efficiency, and profitability in vegetable farming, and in Bangladesh cocodust-based nursery systems have recently emerged as an alternative to traditional soil-based nurseries, although their economic performance under farm conditions has remained insufficiently quantified. This study assessed the economic viability of cocodust nursery technology using a farm-level comparative mixed-methods design. Data were collected from 80 vegetable farmers selected through stratified random sampling and grouped into cocodust user's vs traditional nursery users. A detailed cost–benefit analysis was conducted and differences between nursery systems were analysed using independent two-sample Welch's t-tests. The results show that cocodust-based nurseries incurred higher seedling costs, increasing by approximately 50–90% for most crops. However, these higher initial costs were more than offset by significant reductions in subsequent input use. Fertilizer costs declined by 18–38%, pesticide costs by up to 33%, labor costs by 16–40%, intercultural operation costs by 30–65%, irrigation costs by up to 22%, and pole and fence costs by 12–42% under cocodust-based systems. Consequently, total production costs decreased by 14–24% across crops, leading to substantial gains in net profitability. Net profit increased significantly for all vegetables, with improvements ranging from approximately 29–60% compared with traditional nursery practices. Overall, the findings indicate that cocodust nursery technology enhances input-use efficiency and reduces total production costs. This technology also significantly improve farm profitability, suggesting a financially viable and scalable option for promoting sustainable vegetable production and income growth among smallholder farmers in Bangladesh.

Keywords: Cocodust nursery; Vegetable farming; Input-use efficiency; Cost–benefit analysis; Bangladesh

1 Introduction

Vegetable farming plays a strategically important role in Bangladesh's agricultural economy by contributing to food and nutritional security, employment generation, and income diversification for smallholder farmers. Vegetables are rich sources of essential micronutrients and vitamins, and their consumption is critical for addressing malnutrition and hidden hunger. In addition, vegetable crops generally offer higher economic returns per unit area compared to cereals, making them an attractive option for resource-poor farmers (BBS 2023; FAO 2022). In response to population growth, rapid urbanization, and changing dietary preferences, demand for vegetables in Bangladesh has increased steadily over the past two decades. However, despite favorable market conditions, vegetable productivity and profitability remain below potential. One of the major constraints limiting economic productivity in vegetable farming is the use of poor-quality seedlings produced in traditional soil-based nurseries. These nurseries are often characterized by poor sanitation, uneven nutrient supply, and high exposure to soil-borne pathogens. As a result, seedlings frequently exhibit weak root systems, non-uniform growth, and high mortality rates after transplanting. Transplant shock is common, leading to yield loss, delayed crop establishment, and increased need for replanting, all of which raise production costs and reduce farm profitability (Hossain et al. 2019; Islam et al. 2020).

In addition to seedling-related problems, vegetable farmers face rising costs of key inputs such as fertilizers, pesticides, irrigation, and labor. Weak early crop establishment often compels farmers to apply higher doses of agrochemicals to compensate for poor plant vigor and pest susceptibility. Labor-intensive management practices including repeated weeding, gap filling, pest control, and staking further increase variable costs. Labor scarcity and rising rural wage rates have intensified this challenge, making labor cost one of the most critical determinants of economic performance in vegetable farming systems (Rahman et al. 2022). Consequently, many farmers experience shrinking profit margins despite high market prices for vegetables. In recent years, soilless nursery technologies have been promoted as a means to improve seedling quality and enhance production efficiency. Among these, cocodust-based nursery systems have gained increasing attention. Cocodust, a biodegradable by-product of coconut husk processing, is widely recognized for its high water-holding capacity, good aeration, low bulk density and pathogen-free nature. These properties create a favorable root-zone environment that promotes rapid and uniform seedling growth, reduces transplant shock, and enhances early crop establishment (Abad et al. 2001; Evans et al. 1996). Empirical studies conducted in different countries have shown that cocodust-based growing media improve nutrient-use efficiency, reduce water requirements, and enhance crop performance compared to soil-based systems (Abad et al. 2005; Gruda et al. 2019). More recent evidence suggests that healthier seedlings produced in soilless media can reduce the need for chemical fertilizers and pesticides by improving plant resilience and nutrient uptake efficiency (Barrett et al. 2016). These agronomic advantages imply potential economic benefits through reduced input use and lower production costs.

However, adoption of cocodust nurseries by farmers depends largely on economic considerations rather than agronomic performance alone. Cocodust-based seedlings typically involve higher upfront costs due to tray-based production, nursery management, and growing media expenses. For smallholder farmers, such initial investments can act as a barrier unless they are compensated by substantial downstream savings and higher profitability. In Bangladesh, existing studies on vegetable production economics have largely focused on yield performance, technical efficiency, or gross returns, with limited attention to how improved nursery technologies affect the entire cost structure and net profitability at the farm level (Rahman et al. 2022; Yuan *et al.*, 2025).

Therefore, there remains a critical gap in empirical evidence regarding the economic productivity and cost–benefit performance of cocodust nursery systems under real farm conditions in Bangladesh. A comprehensive analysis that simultaneously considers input use, total production costs, and profitability across multiple vegetable crops is essential to assess whether cocodust nurseries constitute an economically viable and scalable solution. Against this background, the present study evaluates the economic viability of cocodust-based nurseries in vegetable farming in Bangladesh. Specifically, the objectives of this study are to: (i) compare input use and cost structures between cocodust-based and traditional soil-based nursery systems; (ii) assess the impact of cocodust nursery adoption on total production costs; and (iii) evaluate differences in economic productivity and profitability in terms of net returns across major vegetable crops. By providing robust farm-level evidence, this study aims to inform farmers, policymakers, and development organizations about the potential role of cocodust nurseries in improving the economic sustainability of vegetable production systems in Bangladesh.

2 Materials and Methods

2.1 Study area and sampling

The study was carried out in the Joypurhat district of northern Bangladesh, which falls within a major vegetable-growing area of the country. Field investigations were undertaken in three Upazilas of Joypurhat Sadar, Panchbibi, and Akklepur covered under the Rural Microenterprise Transformation Project (RMTP). These areas are dominated by smallholder vegetable producers and have experienced notable uptake of cocodust-based nursery practices. The site was purposively selected because cocodust nursery technology has been actively promoted and implemented in the region through the RMTP's Ecology Friendly Safe Vegetable and Crop Production and Marketing sub-project, facilitated by the JAKAS Foundation. This context provided an appropriate setting to evaluate the economic performance of cocodust nurseries under real farm conditions.

2.2 Research Design and Sample Selection

The study adopted a quantitative research design to evaluate the economic performance of cocodust-based nursery technology relative to traditional soil-based nursery practices in vegetable farming. The quantitative component was designed to facilitate a rigorous cost–benefit comparison. The study population comprised 80 vegetable farmers, purposively selected and evenly divided into two groups: cocodust nursery users (n = 40) and traditional nursery users (n =

40). Farmers in the cocodust group used cocodust-based seedlings for at least one full production season, ensuring adequate exposure to technology and reliable assessment of economic outcomes. The comparison group consisted of farmers who continued to rely exclusively on conventional soil-based nurseries. A stratified random sampling technique was employed to ensure representation across different farm sizes, income categories, and geographical locations within the study area. Stratification helped minimize selection bias and enhance the comparability of the two groups with respect to socio-economic characteristics. Sampling frames were prepared in close collaboration with field staff of the JAKAS Foundation, who maintain updated farmer databases under the Rural Microenterprise Transformation Project (RMTP). This approach ensured accuracy in farmer identification and consistency with project implementation records.

2.3 Quantitative data collection

Quantitative data were gathered through structured household surveys using a pre-tested digital questionnaire administered via KoboToolbox. The survey instrument was designed to capture detailed farm-level economic information, including:

- Farm and production characteristics, such as input use and cost components, including expenditures on seedlings, fertilizers, pesticides, irrigation, labor, intercultural operations, and structural inputs (e.g., poles and fencing)
- Total production cost per decimal (1 decimal = 0.01 acre), calculated by aggregating all variable and fixed cost components and
- Profitability indicators, derived from gross returns and net profit per decimal.

2.4 Crops studied

The analysis encompassed eight economically important vegetable crops that are highly sensitive to nursery management practices: tomato (*Solanum lycopersicum*), brinjal (*Solanum melongena*), chili (*Capsicum annuum*), cabbage (*Brassica oleracea* var. *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), bottle gourd (*Lagenaria siceraria*), bitter gourd (*Momordica charantia*), and country bean (*Lablab purpureus*). The inclusion of these crops allowed the study to capture a broad spectrum of vegetable production systems, representing multiple plant families such as Solanaceae, Brassicaceae, Cucurbitaceae, and Fabaceae as well as varying growth forms and management requirements. This diversity enhanced the robustness of the economic assessment of cocodust nursery technology across different crop types.

2.5 Statistical Analysis

All statistical analyses were conducted using R version 4.4.1 (R Core Team, 2024), with a primary emphasis on the quantitative assessment of economic productivity. Analyses were performed separately for each vegetable crop to capture crop-specific economic responses to nursery technology. For each crop, differences between cocodust nursery users (Yes) and traditional nursery users (No) were evaluated for key continuous variables, including individual cost components such as land preparation, seedling, fertilizer, pesticide, irrigation, labor, intercultural operations, and pole/fence, total production cost, and net profit per decimal. Costs were calculated on a per-decimal basis (1 decimal = 0.01 acre). The total production cost (TPC) was computed as the sum of all individual cost components:

$$TPC = C_{lp} + C_{sd} + C_f + C_p + C_{ir} + C_l + C_{lic} + C_{pf} \qquad (1)$$

where:

C_{lp}= land preparation cost, C_{sd}= seedling cost, C_f= fertilizer cost, C_p= pesticide cost, C_{ir}= irrigation cost, C_l= labor cost, C_{ic}= intercultural operation cost, C_{pf}= pole and fence cost.

The gross return (GR) was calculated as:

$$GR = Y \times P \qquad (2)$$

where:

Y= yield (kg per decimal), P= average market price of the crop (BDT per kg)

The net profit (NP) was derived using the following equation:

$$NP = GR - TPC \qquad (3)$$

Given the potential heterogeneity in farm management practices and unequal variance structures between groups, independent two-sample Welch's *t*-tests were applied for all continuous variables. Statistical significance was assessed at $P \leq 0.05$, and results are presented as mean ± standard error. All graphical outputs follow a consistent notation system in which bars sharing the same lowercase letter indicate no statistically significant difference, whereas different letters denote significant differences at $P \leq 0.05$. This standardized approach facilitates clear and robust comparison of economic performance indicators between cocodust-based and traditional nursery systems across vegetable crops.

3 Results

3.1 Land preparation cost

Land preparation cost per decimal was generally lower under cocodust-based nursery systems compared to traditional practices, although the magnitude and significance of the differences varied across crops (Fig. 1).

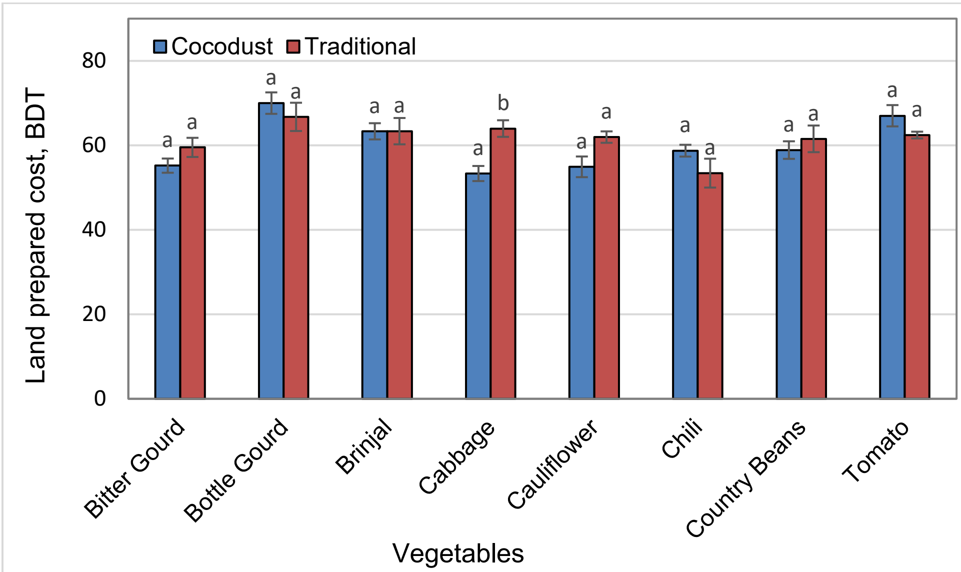

Fig. 1 Land preparation cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, cocodust users incurred a lower land preparation cost (8.3%) compared to traditional nursery users, but the difference was not statistically significant. In bottle gourd, land preparation cost under cocodust systems was 4.5% higher than traditional practices, while brinjal showed no difference between the two systems; neither difference was statistically significant. A statistically significant reduction was observed for cabbage, where cocodust adoption reduced land preparation cost by 17.2% compared to traditional nurseries. Similarly, country bean exhibited a significant reduction of 4.8% under cocodust systems. For cauliflower, cocodust users incurred 11.3% lower land preparation costs, but the difference was not statistically significant. In contrast, land preparation cost was higher under cocodust systems for chili (11.3%) and tomato (8.1%); however, these differences were not statistically significant.

3.2 Seedling cost

Seedling cost per decimal was consistently higher for cocodust-based nursery users compared to traditional nursery users across most vegetable crops, reflecting the additional expenses associated with tray-based production and cocodust growing media (Fig. 2).

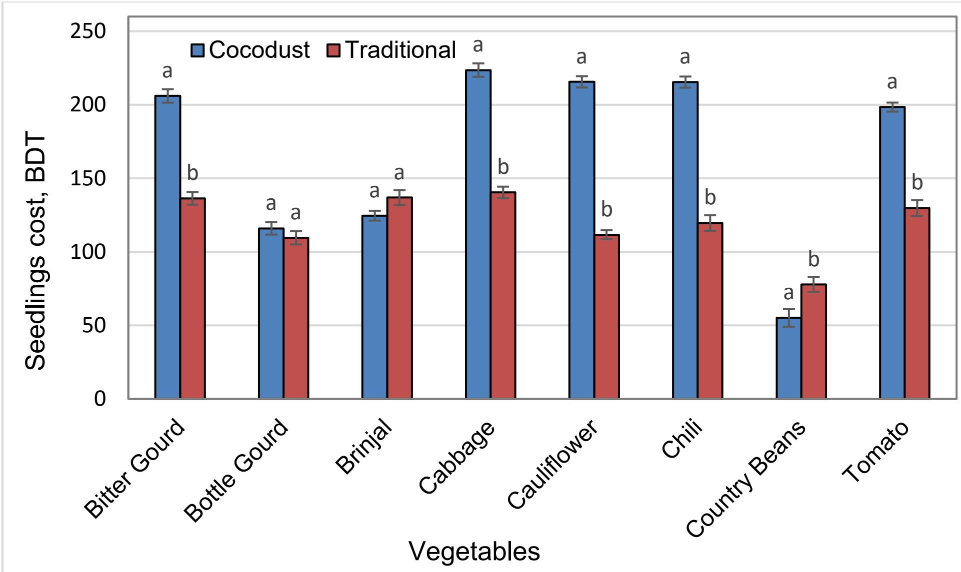

Fig. 2 Comparison of seedling cost (BDT per decimal) between cocodust-based and traditional nursery systems across selected vegetable crops. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, cocodust raised seedlings were 52% more expensive than those produced under traditional soil based nurseries. A similar pattern was observed for cabbage and cauliflower, where seedling costs increased by 60% and 93%, respectively, under cocodust systems. In chili, cocodust seedlings cost 79% more than traditional seedlings, while tomato exhibited a 52% increase in seedling cost under cocodust nursery use. In all these crops, the difference between nursery systems was supported by distinct letter groupings in the figure. In contrast, bottle gourd showed only a marginal increase in seedling cost of 6% under cocodust systems, and brinjal exhibited an 9% lower seedling cost compared to traditional nurseries. For both crops, the overlap in letter notation indicates that seedling costs were statistically comparable between nursery systems. Notably, country bean deviated from the general trend, as cocodust adoption resulted in a 30% reduction in seedling cost relative to traditional practices. The distinct letter notation confirms a clear difference between the two systems for this crop.

3.3 Fertilizer cost

Fertilizer cost per decimal was consistently and significantly lower for farmers using cocodust-based seedlings compared to traditional nursery users across all vegetable crops (Fig. 3), indicating improved nutrient use efficiency under cocodust systems.

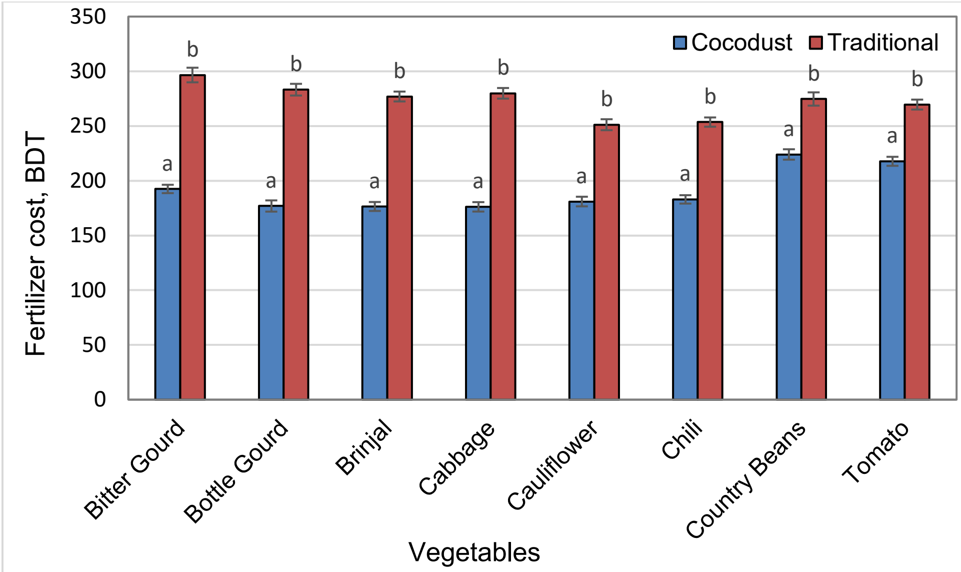

Fig. 3 Fertilizer cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, fertilizer expenditure under cocodust systems declined by 35% compared to traditional practices. Similar reductions were observed for bottle gourd (38%), brinjal (37%), and cabbage (37%), indicating markedly lower fertilizer requirements when cocodust raised seedlings were used. In cauliflower and chili, fertilizer costs were reduced by 28% under cocodust systems relative to traditional nurseries. Although the magnitude of reduction was slightly lower than that observed for cucurbit and brassica crops, the difference between nursery systems remained clearly evident in the figure. For country bean, fertilizer cost declined by 19% under cocodust adoption, while tomato showed a 19% reduction compared to traditional nursery practices. Despite being relatively smaller, these reductions further demonstrate the consistent fertilizer saving effect associated with cocodust nursery use.

3.4 Pesticide cost

Pesticide cost per decimal was generally lower for cocodust-based nursery users compared to traditional nursery users across most vegetable crops, reflecting reduced pest and disease incidence associated with healthier and more uniform seedlings (Fig. 4).

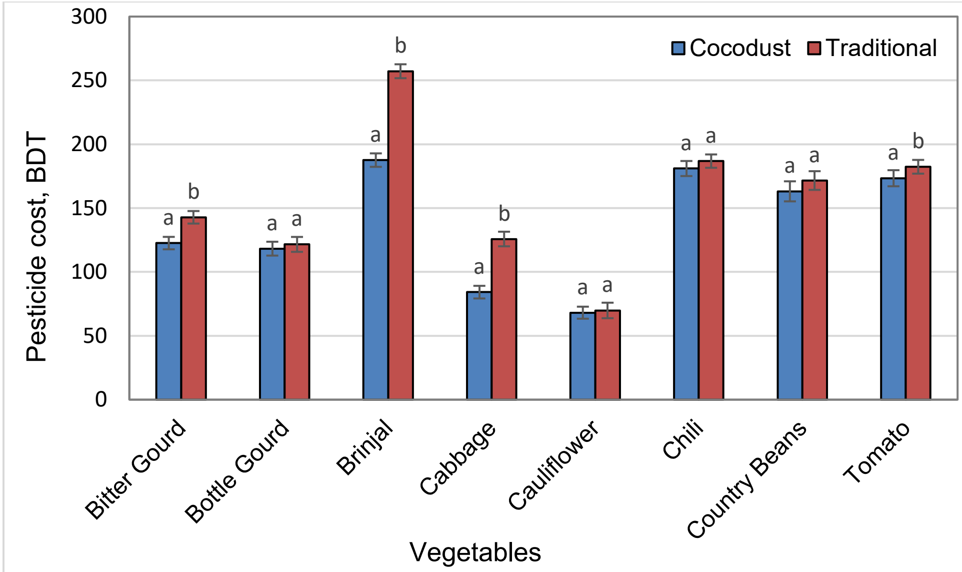

Fig. 4 Pesticide cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetable crops. Bars with different letters indicate significant differences at $P \leq 0.05$.

For brinjal, pesticide expenditure under cocodust systems was 27% lower than under traditional nursery practices (188 vs. 257 BDT), and the difference was statistically significant. A similarly strong and significant reduction was observed for cabbage, where pesticide cost declined by 33% under cocodust based cultivation (84 vs. 126 BDT). In bitter gourd, cocodust adoption resulted in a 14% lower pesticide cost compared to traditional practices (123 vs. 143 BDT), and the difference was also statistically significant. In contrast, bottle gourd and cauliflower showed no statistically significant difference in pesticide cost between cocodust and traditional nursery systems, despite small numerical reductions of 3% and 3%, respectively. Similarly, pesticide expenditure for chili and country bean remained statistically comparable between the two systems, with modest reductions of 3% and 5%, respectively. For tomato, pesticide cost under cocodust systems was 5% lower than under traditional nursery practices (173 vs. 182 BDT), and the difference was statistically significant, indicating a consistent reduction in pesticide use.

3.5 Irrigation cost

Irrigation cost per decimal varied across crops. However, cocodust nursery adoption generally resulted in lower irrigation expenditure compared to traditional nursery practices for most vegetables (Fig. 5), indicating improved water-use efficiency. For cabbage, irrigation cost under cocodust systems was 22% lower than under traditional nursery practices (49 vs. 63 BDT), and the difference was statistically significant. A similarly strong and significant reduction was observed for chili, where irrigation expenditure declined by 18% under cocodust based cultivation (75 vs. 92 BDT). In contrast, bitter gourd showed a 14% higher irrigation cost under cocodust systems (75 vs. 66 BDT), and the difference was statistically significant.

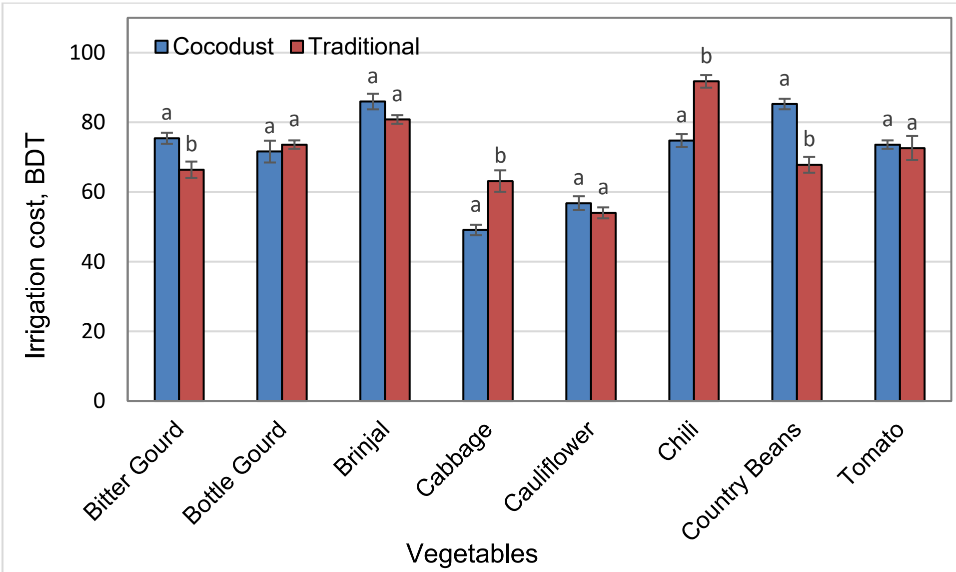

Fig. 5 Irrigation cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For country bean, irrigation cost increased by 25% under cocodust adoption (85 vs. 68 BDT), and this difference was also statistically significant. For bottle gourd, irrigation cost was 3% lower under cocodust systems, while brinjal showed a 6% higher irrigation cost compared to traditional practices. However, the differences for both crops were not statistically significant. In cauliflower and tomato, irrigation costs differed only marginally between nursery systems, with increases of 6% and 1.4%, respectively, and the differences were not statistically significant.

3.6 Pole and fence cost

Pole and fence cost per decimal was substantially lower for cocodust-based nursery users compared to traditional nursery users for crops requiring staking and structural support (Fig. 6), reflecting improved plant vigor and reduced need for repeated support installation.

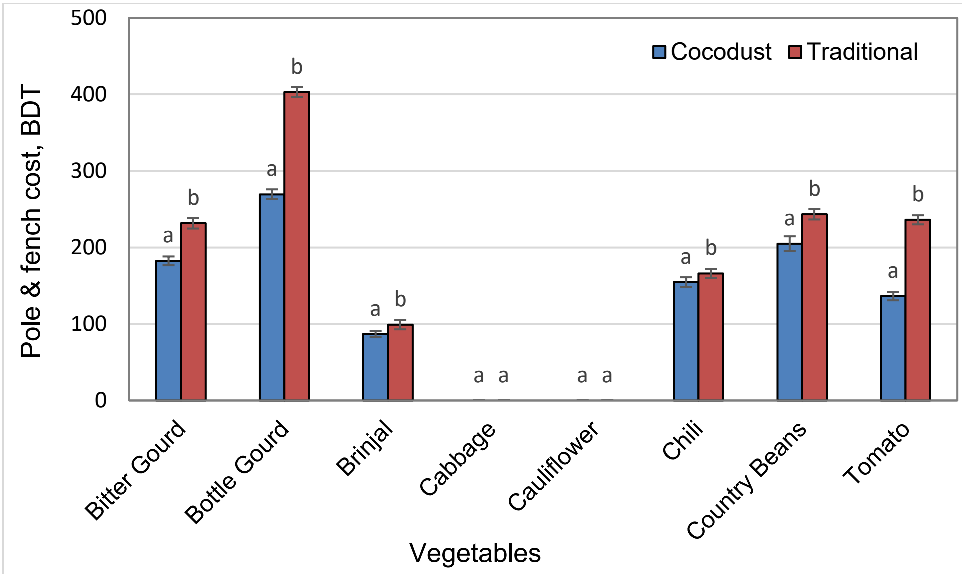

Fig. 6 Pole and fence cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, cocodust adoption reduced pole and fence cost by 21% compared to traditional practices, and the difference was statistically significant. A much larger and significant reduction was observed for bottle gourd, where pole and fence cost declined by 33% under cocodust systems (269 vs. 403 BDT). In brinjal, cocodust based cultivation reduced pole and fence cost by 12% compared to traditional nurseries, and the difference was statistically significant. Similarly, tomato exhibited a pronounced and significant reduction of 42% in pole and fence cost under cocodust systems. For chili, pole and fence cost was 7% lower under cocodust systems. However, the difference was not statistically significant. In country bean, cocodust adoption reduced pole and fence cost by 16% and the difference was statistically significant. As expected, cabbage and cauliflower did not incur pole or fence costs under either nursery system, as these crops do not require staking.

3.7 Labor cost

Labor cost per decimal was significantly lower for cocodust-based nursery users compared to traditional nursery users across all vegetable crops (Fig. 7), indicating substantial labor-saving effects associated with cocodust nursery technology.

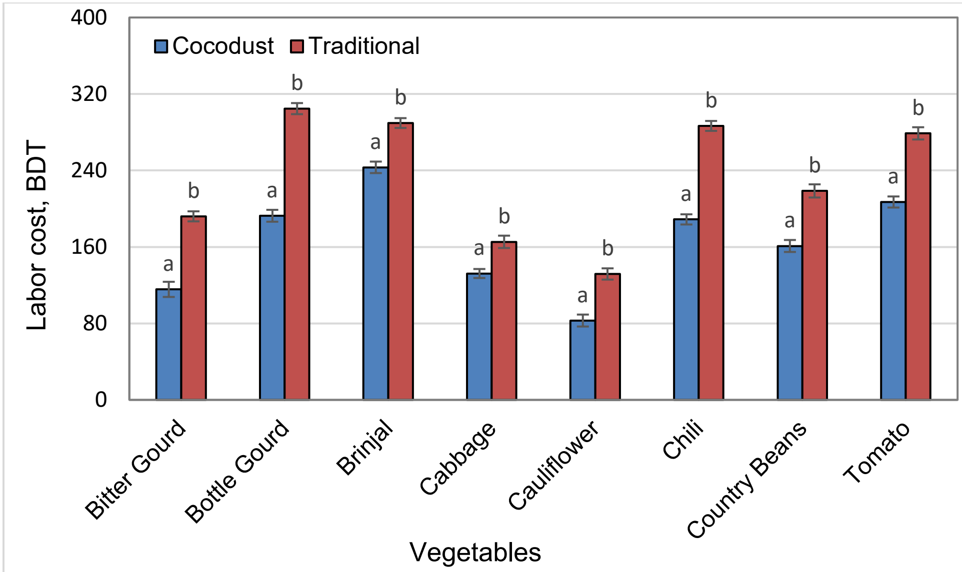

Fig. 7 Labor cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, labor expenditure under cocodust systems was 40% lower than under traditional nursery practices, and the difference was statistically significant. A similarly large and significant reduction was observed for bottle gourd, where labor cost declined by 37% under cocodust adoption. In brinjal, cocodust based cultivation reduced labor cost by 16% compared to traditional nurseries, and the difference was statistically significant. For cabbage, labor expenditure decreased by 20% under cocodust systems, showing a statistically significant reduction. A pronounced reduction was also evident for cauliflower, where labor cost under cocodust systems was 37% lower than traditional practices and the difference was statistically significant. In chili, cocodust adoption resulted in a 34% reduction in labor cost, which was also statistically significant. For country bean, labor cost declined by 27% under cocodust systems and the difference was statistically significant. Similarly, tomato exhibited a 26% significant reduction in labor cost with cocodust nursery use.

3.8 Intercultural operation cost

Intercultural operation cost per decimal was substantially lower for cocodust-based nursery users compared to traditional nursery users across all vegetable crops (Fig. 8), indicating reduced management intensity under cocodust systems.

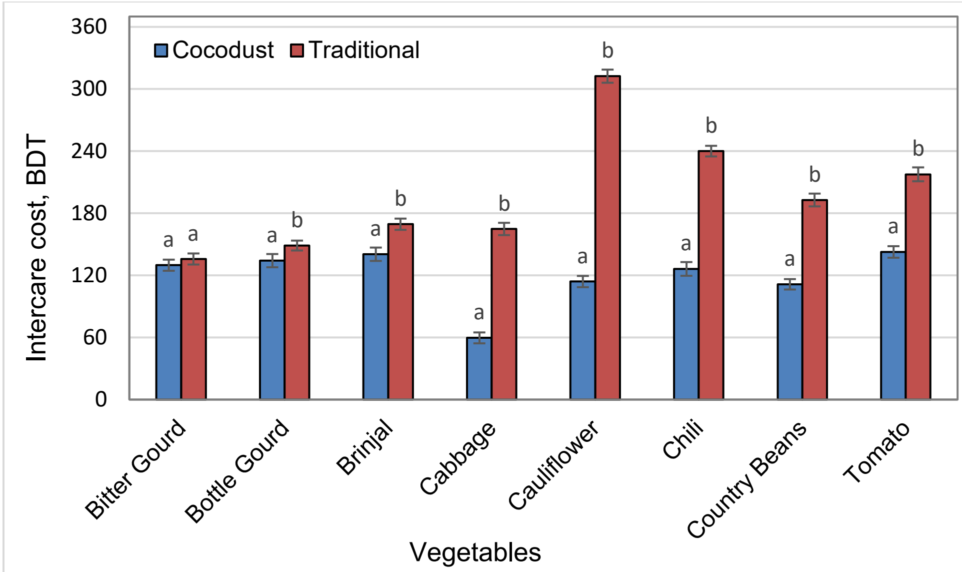

Fig. 8 Intercultural operation cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, intercultural operation cost under cocodust systems was 4% lower than under traditional practices. However, the difference was not statistically significant. In contrast, bottle gourd exhibited a 10% reduction in intercultural operation cost under cocodust systems, and the difference was statistically significant. A similar significant reduction was observed for brinjal, where cocodust adoption reduced intercultural cost by 17% compared to traditional nurseries. A very pronounced and significant reduction was recorded for cabbage, with intercultural operation cost declining by 64% under cocodust systems. Likewise, cauliflower showed a 64% significant reduction, reflecting substantially lower management requirements under cocodust based cultivation. For chili, intercultural operation cost was reduced by 48% under cocodust systems, and the difference was statistically significant. In country bean, cocodust adoption lowered intercultural cost by 43% also showing a statistically significant difference. Similarly, tomato exhibited a 34% reduction in intercultural operation cost under cocodust systems and the difference was statistically significant.

3.9 Total production cost

Total production cost per decimal was consistently and significantly lower for cocodust-based nursery users compared to traditional nursery users across all vegetable crops (Fig. 9), reflecting the cumulative effect of reductions in multiple input cost components.

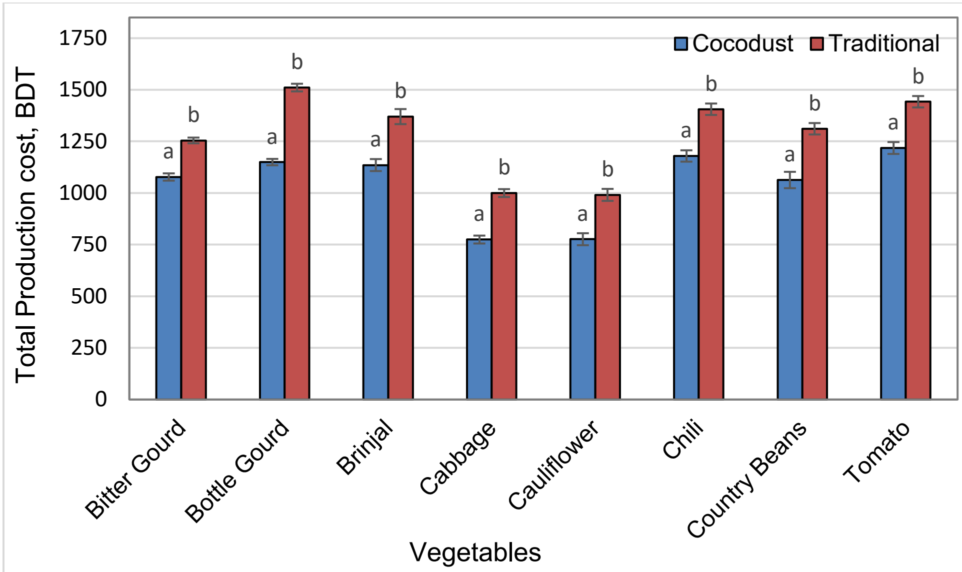

Fig. 9 Total production cost (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, total production cost under cocodust systems was 14% lower than under traditional nursery practices, and the difference was statistically significant. A larger and significant reduction was observed for bottle gourd, where cocodust adoption reduced total production cost by 24% compared to traditional practices. In brinjal, cocodust based cultivation lowered total production cost by 17%, and the difference was statistically significant. Similarly, cabbage exhibited a pronounced and significant reduction of 23% in total production cost under cocodust systems. For cauliflower, total production cost declined by 22% under cocodust adoption, showing a statistically significant difference. In chili, cocodust based cultivation reduced total production cost by 16% compared to traditional nurseries, and the difference was statistically significant. In country bean, cocodust adoption resulted in a 19% significant reduction in total production cost. Likewise, tomato showed a 16% statistically significant reduction in total production cost under cocodust systems.

3.10 Net profit

Net profit per decimal was significantly higher for cocodust-based nursery users compared to traditional nursery users across all vegetable crops (Fig. 10), reflecting the combined effects of lower total production costs and improved productivity.

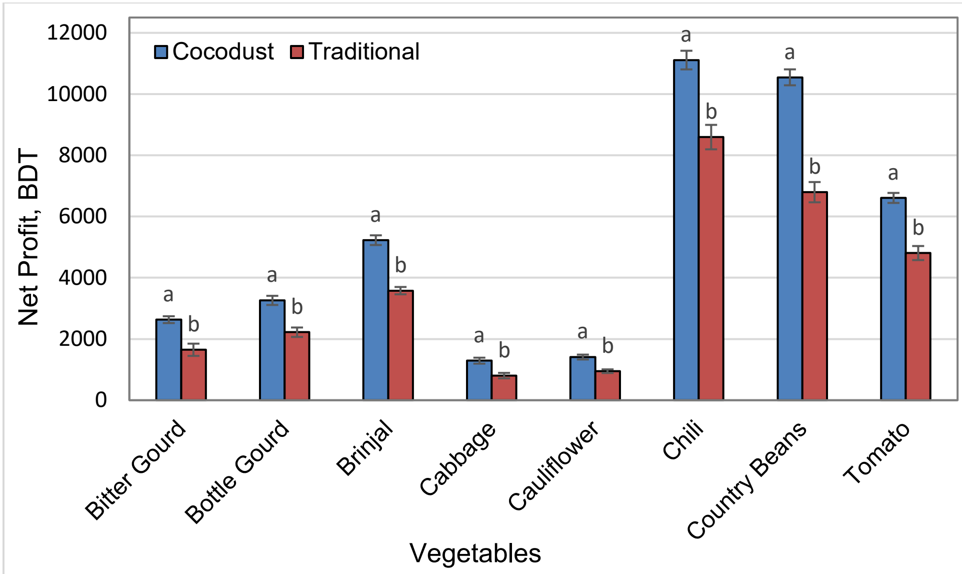

Fig. 10 Net profit (BDT per decimal) for cocodust-based and traditional nursery systems across selected vegetables. Bars with different letters indicate significant differences at $P \leq 0.05$.

For bitter gourd, net profit under cocodust systems was 60% higher than under traditional nursery practices (2632 vs. 1648 BDT), and the difference was statistically significant. A similar and significant increase was observed for bottle gourd, where cocodust adoption increased net profit by 47% compared to traditional practices (3261 vs. 2221 BDT). In brinjal, cocodust based cultivation resulted in a 46% statistically significant increase in net profit. For cabbage, net profit increased by 61% under cocodust systems, showing a statistically significant improvement. A comparable pattern was observed for cauliflower, where cocodust adoption increased net profit by 49% compared to traditional nursery systems, and the difference was statistically significant. For chili, cocodust based cultivation generated a 29% significant increase in net profit. Likewise, country bean exhibited a pronounced and significant net profit increase of 55% under cocodust systems. In tomato, cocodust adoption increased net profit by 37% compared to traditional nursery practices and the difference was statistically significant.

4 Discussion

This study provides a rigorous economic evaluation of cocodust nursery technology in vegetable production systems of northern Bangladesh. By comparing cocodust-based seedling management with conventional soil-based nurseries across multiple crops, the results demonstrate clear economic advantages associated with cocodust adoption. These advantages arise through multifactor cost savings and enhanced profitability at the production level, supporting broader efforts to improve smallholder vegetable farming efficiency.

4.1 Land Preparation Cost

Cocodust nursery adoption did not uniformly reduce land preparation costs across all vegetables, with significant decreases observed only in selected crops such as cabbage and country bean. These results are aligned with previous observations that improved seedling vigor can reduce the need for intensive soil tillage and repeated soil preparation (Haque et al., 2008). Strong, healthy seedlings require less soil manipulation to ensure establishment, particularly for crops with relatively uniform transplant performance (Ellis et al., 1995). However, for other crops, comparable land preparation costs indicate that initial soil preparation remains driven largely by field conditions and agronomic practices rather than by seedling quality alone.

4.2 Seedling Cost

Seedling cost per decimal was generally higher under cocodust systems for most crops, reflecting the additional investment in tray-based production and high-quality growing media. This pattern confirms previous findings that soilless and controlled nursery systems often incur greater upfront costs (Haque et al., 2008). However, the economic logic for adopting higher-cost seedlings is compelling when viewed through the lens of production efficiency and long-term profitability: healthier seedlings typically exhibit stronger root systems, reduced transplant shock, and higher survival rates, which translate into downstream savings and yield stability (Mariotti et al., 2020, Evans et al., 1996).The notable exception for country bean, where cocodust seedling cost was lower, suggests crop-specific labor or material dynamics that merit further agronomic investigation.

4.3 Fertilizer and Pesticide Cost

One of the most consistent economic benefits of cocodust seedlings was observed in fertilizer and pesticide expenditure. Across all crops, cocodust users realized substantial reductions in fertilizer cost (18–38%) compared to traditional users. This aligns with evidence showing that seedlings with improved root architecture and vigor utilize nutrients more efficiently, requiring less supplemental fertilizer to achieve similar or higher yields (Valenzuela et al., 2024). Lower pesticide costs for crops such as brinjal, cabbage, and bitter gourd reflect reduced pest and disease incidence, likely owing to healthier early growth and reduced exposure to soil-borne pathogens

(Barrett et al., 2016). These reductions not only benefit the bottom line but also align with sustainable intensification goals by minimizing agrochemical inputs.

4.4 Irrigation and Structural Input Cost

The effects of cocodust adoption on irrigation cost were crop-specific. Significant reductions in crops such as cabbage and chili suggest improved water-use efficiency and root establishment, which have also been documented in soilless media studies (Gruda et al., 2019). Conversely, comparable or slightly higher irrigation costs in other crops may reflect field-level water management decisions that are independent of seedling origin. Pole and fence costs were significantly lower for climbing and vine crops under cocodust systems, indicating reduced labor and material inputs necessary to support plant structures. This outcome likely results from more uniform and predictable plant growth requiring less corrective staking. Similar structural cost savings have been reported where improved seedling quality reduces crop management burdens (Dash et al., 2020).

4.5 Labor and Intercultural Operation Cost

Labor cost was one of the largest contributors to total cost savings under cocodust systems, with reductions ranging from 16% to 40% across crops. Labor-intensive tasks such as weeding, gap filling, and routine cultural operations were consistently lower for cocodust users. This finding is consistent with research showing that uniform, vigorous seedlings reduce the need for repeated interventions and associated labor (Dash et al., 2020). Intercultural operation costs also declined markedly, particularly for cabbage, cauliflower, chili, and country bean, underscoring the role of cocodust seedlings in reducing the frequency and intensity of crop management tasks.

4.6 Total Production Cost

The aggregate effect of component-wise cost savings resulted in a consistent and statistically significant reduction in total production cost across all vegetables studied, demonstrating that cocodust nursery adoption delivers economic benefits beyond isolated input adjustments. In the present study, total production cost declined by approximately 14% in bitter gourd and by nearly 24% in bottle gourd, reflecting the cumulative impact of lower fertilizer, pesticide, labor, intercultural operation, irrigation, and structural input costs. Similar patterns have been reported in studies on cocodust and other coir-based growing media, which show that improved seedling vigor and root system development enhance nutrient uptake efficiency and reduce the need for repeated field interventions (Evans et al., 1996; Gruda, 2019).

From an economic perspective, these findings indicate that the higher upfront investment in cocodust-based seedlings is effectively offset by downstream cost savings, leading to a net reduction in total production cost. This outcome is consistent with economic theories of agricultural technology adoption, which posit that farmers adopt innovations when gains from improved efficiency and reduced management intensity outweigh additional initial costs (Feder et al., 1985; Feder et al., 2004). Moreover, the observed reductions in chemical and labor inputs align with recent evidence emphasizing the role of renewable substrates such as coconut coir in promoting more efficient, resource-conserving horticultural production systems (Barrett et al., 2016; Gruda et al., 2019). Together, these results reinforce the conclusion that cocodust nursery technology enhances cost efficiency while supporting sustainable intensification in vegetable farming.

4.7 Net Profit

The most compelling outcome of this study is the consistent and substantial increase in net profit across all vegetable crops following the adoption of cocodust-based nursery technology. Profit gains ranged from approximately 30% in chili to over 60% in country bean and cabbage, underscoring the strong economic advantage of cocodust nurseries across diverse crop types. These improvements were driven by the combined effects of significantly lower total production costs and enhanced crop performance, rather than by yield increases alone.

The observed profitability gains are consistent with earlier evidence indicating that investments in improved nursery and seedling management can generate high economic returns by reducing downstream input requirements and management intensity (Mariotti et al., 2020; Gruda, 2019). In the present study, reductions in fertilizer, pesticide, labor, intercultural operation, irrigation, and structural input costs collectively outweighed the higher initial seedling expenditure, resulting in a clear net financial benefit for cocodust users. This finding reinforces the economic rationale that technology adoption decisions in smallholder agriculture are shaped by overall profitability rather than by isolated cost components (Feder et al., 1985). The magnitude and consistency of net profit increases observed across crops align with findings from Bangladesh and other developing country contexts, where improved nursery technologies and input-use efficiency have been shown to expand farm margins and stabilize income (Kabir et al., 2019; Hasan et al., 2020). Higher net returns enhance farmers' capacity to absorb production risks, reinvest in farm operations, and maintain household consumption during periods of price or climate variability. As such, cocodust nursery adoption not only improves short-term profitability but also contributes to income resilience and long-term livelihood sustainability for smallholder vegetable producers. Moreover, the uniform profitability gains across vegetables with differing growth habits and management requirements suggest that cocodust-based nursery systems are economically robust and broadly applicable. This robustness strengthens incentives for wider adoption and supports the case for integrating cocodust nursery technology into extension programs aimed at promoting sustainable and commercially viable vegetable farming systems.

5 Conclusions

This study provides robust empirical evidence on the economic viability of cocodust-based nursery technology in vegetable farming systems of Bangladesh. Across eight major vegetable crops, cocodust adoption consistently improved economic performance by reducing key production costs, including fertilizer, pesticide, labor, irrigation, intercultural operations, and structural inputs, despite higher initial seedling costs. These cost savings translated into significantly lower total production costs and substantial increases in net profit, confirming the economic superiority of cocodust nurseries over traditional soil-based practices. Given the consistent reductions in production costs and significant increases in net profit across crops, cocodust-based nursery technology should be promoted as a core component of sustainable vegetable production systems in Bangladesh. Policy support in the form of targeted training, strengthened extension services, and initial input assistance can accelerate adoption among smallholder farmers, enhance farm profitability, and contribute to more efficient and environmentally responsible vegetable production.

COMPETING INTERESTS DISCLAIMER:
Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated or analyzed during the current study are available from the corresponding author upon reasonable request.

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