Original Research Article

Assessing the agronomic benefits and adoption potential of cocodust seedling nurseries in vegetable systems in Bangladesh

Abstract

Seedling quality is a key determinant of vegetable crop productivity. However, conventional soil-based nursery practices in Bangladesh are often associated with high seedling mortality, soil-borne diseases, and excessive use of agrochemicals. This study evaluated the agronomic performance and adoption potential of cocodust-based seedling nurseries compared with traditional soil-based practices across eight major vegetable crops in northern Bangladesh using a farm-level comparative approach involving 80 farmers. Cocodust application significantly increased yields of bitter gourd (17%), bottle gourd (18%), brinjal (23%), chili (23%), country bean (44%), and tomato (25%), while yield increases in cabbage (15%) and cauliflower (12%) were not statistically significant. Across all crops, seedling mortality was reduced by 68–82% under cocodust-based nurseries. Harvesting time was significantly shortened for all crops, with reductions of 8–15% in most cases and reaching 43–47% in chili and country bean. Cocodust use was associated with significantly reduced chemical fertilizer application in bitter gourd and marginally in tomato, and with reduced pesticide use in bitter gourd, country bean, and tomato, while organic fertilizer use remained high irrespective of nursery practice. Incidence of soil-borne diseases was significantly lower in bottle gourd and cauliflower under cocodust-based nurseries. Overall, cocodust-based seedling nurseries improved vegetable productivity, reduced early-stage seedling losses, shortened production cycles, and lowered reliance on chemical inputs in selected crops, highlighting cocodust as a low-cost and environmentally sustainable option for smallholder vegetable production systems.

Keywords: Cocodust; Seedlings; Vegetable productivity; Disease incidence

1 Introduction

Vegetable cultivation is a cornerstone of food security, nutrition, and rural livelihoods in Bangladesh, contributing significantly to agricultural GDP and employment (BBS, 2023). Despite rapid sectoral growth, productivity at the farm level remains constrained by a critical bottleneck: the quality of seedlings at the inception of the crop cycle (Dash et al., 2020b). Predominant traditional nursery practices rely on repeatedly used topsoil, leading to nutrient depletion, soil fatigue, and a high prevalence of soil-borne pathogens such as *Pythium* spp. and *Fusarium oxysporum* (Mohanto et al., 2019). Compensatory and often excessive use of chemical fertilizers and pesticides exacerbates these problems, resulting in a vicious cycle of poor seed germination, weak seedling growth, high transplant mortality, and ultimately, suboptimal yield and declining soil health. This scenario not only undermines farmer profitability but also heightens environmental degradation and production risks in the face of climatic variability (Hossain et al., 2022; Rahman & Zhang, 2018).

In response, soilless cultivation media have emerged globally as sustainable alternatives for quality seedling production. Among these, cocodust (cocopeat), a processed, biodegradable byproduct of coconut (*Cocos nucifera*) husks, has garnered significant attention. Its excellent physical and chemical properties including a high water-holding capacity (retaining 600–800%

of its weight), optimal air-filled porosity, a near-neutral pH (5.5–6.8), and a naturally low pathogen load create an ideal, controlled rhizosphere for early plant development (Abad et al., 2002; Kumarasinghe et al., 2016). Unlike traditional soil, cocodust provides uniform aeration and moisture regulation, preventing waterlogging and drought stress, which are primary causes of damping-off and poor root establishment. Its sterile and inert nature minimizes the risk of soil-borne diseases and weed competition from the outset. Furthermore, cocodust exhibits a favorable cation exchange capacity (CEC), allowing for efficient nutrient retention and release, thereby enhancing fertilizer-use efficiency and promoting robust seedling vigor, uniformity, and biomass accumulation (Asaduzzaman et al., 2022). From a systemic perspective, the use of this renewable agricultural waste product supports circular economy principles, reduces pressure on topsoil extraction, and aligns with climate-resilient agriculture by enabling consistent seedling production irrespective of seasonal soil quality fluctuations.

International and regional studies substantiate these advantages, indicating that cocodust-based nurseries can enhance germination rates, accelerate growth cycles, improve transplant survival, and significantly reduce dependency on chemical inputs (Dash et al., 2020a). In Bangladesh, initiatives like the Rural Microenterprise Transformation Project (RMTP) have begun promoting cocodust nurseries as a transformative pathway toward ecological intensification aiming to simultaneously boost productivity, farmer income, and environmental sustainability. However, while the agronomic advantages of cocodust are supported by station-level research, there is a scarcity of comprehensive, farm-level comparative studies within Bangladesh's dominant smallholder farming contexts. Crucially, the adoption of any agricultural innovation depends not only on its measurable performance but also on farmers' perceptions and experiences (Uddin et al., 2021). A systematic assessment that integrates quantitative agronomic data with qualitative insights into farmer perspectives is therefore essential to evaluate the real-world impact and scalability of the technology.

This study addresses this gap by conducting a comparative evaluation of the cocodust nursery model against traditional soil-based practices in the vegetable-growing district of Joypurhat, Northern Bangladesh. The study has two primary objectives: (1) to quantitatively assess the agronomic performance of cocodust seedlings in terms of yield, mortality, crop duration, and input use efficiency across eight major vegetable crops, and (2) to qualitatively analyze farmer perceptions and experiences to understand the drivers and barriers influencing the technology's adoption potential. The findings aim to provide robust evidence to guide policy, extension services, and investment decisions for scaling up sustainable vegetable seedling production systems in Bangladesh and similar agro-ecological regions.

2 Materials and Methods

2.1 Study Area

The study was conducted in Joypurhat district, located in the northern agro-ecological zone of Bangladesh. Specifically, the research focused on the operational areas of the Rural Microenterprise Transformation Project (RMTP) in Joypurhat Sadar, Panchbibi, and Akklepur Upazilas. This region is characterized by intensive smallholder vegetable farming and was selected due to the active promotion and adoption of cocodust nursery technology under the RMTP's "Ecology Friendly Safe Vegetable and Crop Production and Marketing" sub-project, implemented by the JAKAS Foundation.

2.2 Research Design and Sample Selection

A comparative mixed-methods design was employed, with a study population of 80 vegetable farmers strategically divided into two groups: Cocodust users (n=40), who had utilized cocodust-based seedlings for at least one production season, and Traditional Practice Farmers (n=40), who continued to use conventional soil-based nursery methods. A stratified random sampling technique was applied to ensure representation across different socio-economic strata and geographical locations within the project area, with farmer lists finalized in collaboration with field staff from the JAKAS Foundation to ensure accuracy.

2.3 Data Collection

Data were collected between October to November 2025, employing the following tools: Structured Household Surveys utilized a pre-tested digital questionnaire, deployed via KoboToolbox, to collect quantitative data. It captured Farm & Production Characteristics, including landholding size and tenure status; Agronomic and Economic Parameters, such as detailed input costs (fertilizer, pesticide), total production cost per decimal (1 decimal = 0.01 acre), yield (kg/decimal), seedling mortality rate (%), and harvesting time (days from transplanting); and Perceived Changes, namely self-reported changes in chemical fertilizer, pesticide, and organic compost use over the preceding two years, and the incidence of soil-borne diseases. The Qualitative Component consisted of open-ended questions within the survey to capture farmers' opinions on the specific qualities of cocodust versus traditional seedlings, supplemented by Key Informant Interviews (KIIs) conducted with nursery operators, agricultural extension officers, and project staff to contextualize the findings and understand systemic enablers and constraints.

2.4 Crop Selection

The study focused on eight economically significant and nursery-sensitive vegetable crops: 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*). This selection ensured the assessment covered a diverse range of plant families (Solanaceae, Brassicaceae, Cucurbitaceae, Fabaceae) and growth habits.

2.5 Statistical Analysis

All analyses were performed in R 4.4.1 (R Core Team, 2024). For each crop, differences between cocodust application (Yes) and control (No) were evaluated separately for yield, cost components, total cost, net profit, harvesting time, and seedling mortality. For each variable within each crop, an independent two-sample Welch's t-test (unequal variance) was conducted at a significant level of $P \leq 0.05$. Responses on chemical fertilizer use, pesticide use, organic/compost use and soil-borne diseases were treated as categorical variables, with missing values retained as a separate category. Percentages were calculated for each crop under cocodust application (Yes) and non-application (No) and displayed using 100% stacked bar charts. Associations between cocodust use and response variables were assessed for each crop using Chi-square tests of independence. Statistical significance was determined at $P \leq 0.05$. Results are presented as mean ± standard error (SE). Qualitative data from open-ended responses and KIIs were transcribed, coded, and analyzed thematically to identify recurring patterns related to perceived benefits, challenges, and adoption motivations. In figures, treatments sharing the same lowercase letter indicate no significant difference, while different letters indicate significant differences ($P \leq 0.05$).

3 Results

3.1 Effect of Cocodust Application on Yield performance

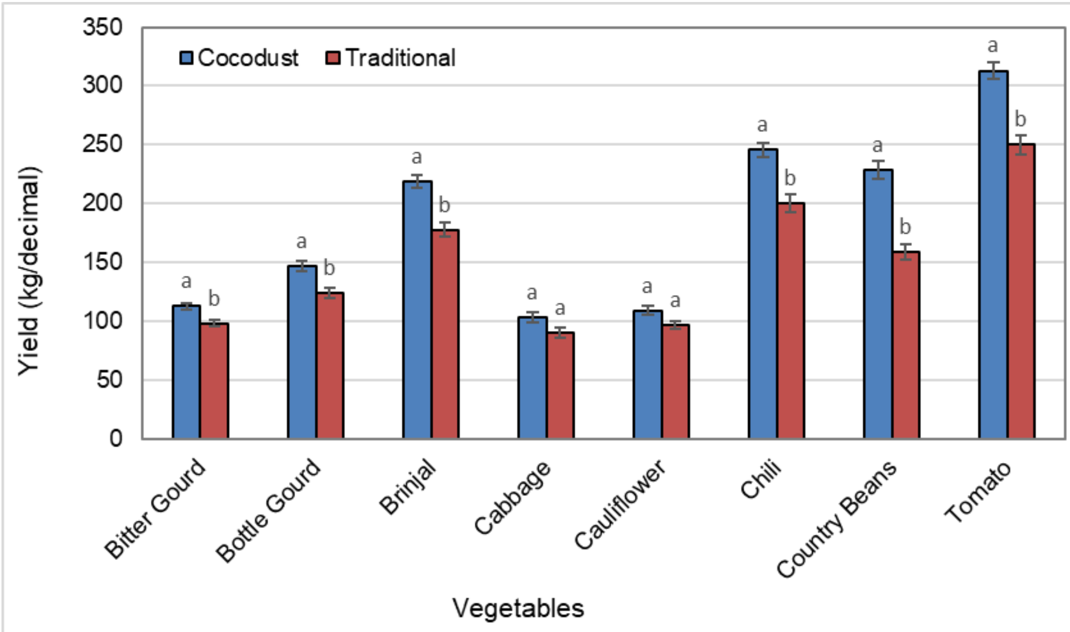

Fig. 1 Effect of cocodust application on yield of different vegetable crops. Bars represent mean ± SE of yield for cocodust-treated and traditional plots. Differences within each crop were tested using an independent two-sample Welch's t-test. Different lowercase letters indicate significant differences at $P \leq 0.05$, while the same letters indicate no significant difference.

Mean yield was higher under cocodust application than in the traditional for all studied crops as shown in Fig.1. Yield increased from 98 to 113 kg per decimal in bitter gourd, representing a 17% increase, from 124 to 147 kg per decimal in bottle gourd, corresponding to an 18% increase, and from 178 to 219 kg per decimal in brinjal, showing a 23% increase. These increases were statistically significant. Furthermore, Chili yield increased significantly from 200 to 246 kg per decimal, representing a 23% increase, while country beans showed the largest yield increase, rising from 159 to 228 kg per decimal, equivalent to a 44% increase. Tomato yield also increased significantly, from 250 to 313 kg per decimal, corresponding to a 25% increase.

However, in cabbage and cauliflower, yield increased from 90 to 103 kg per decimal, equivalent to a 15% increase, and from 97 to 109 kg per decimal, corresponding to a 12% increase, respectively. However, the differences observed between these two crops were not statistically significant.

3.2 Effect of Cocodust Application on Seedling Mortality

Mean seedling mortality was lower under cocodust application than in the traditionla for all studied crops, as shown in Fig. 2. In bitter gourd, seedling mortality decreased from 14 to 5%, corresponding to a 68% reduction. In bottle gourd, mortality declined from 12 to 3%, representing a 73% reduction, while in brinjal it decreased from 21 to 4%, equivalent to an 82% reduction. These reductions were statistically significant. In cabbage and cauliflower, seedling mortality decreased from 11 to 3%, corresponding to a 77% reduction, and from 11 to 3%, representing a 74% reduction, respectively. The reductions observed for both crops were statistically significant.

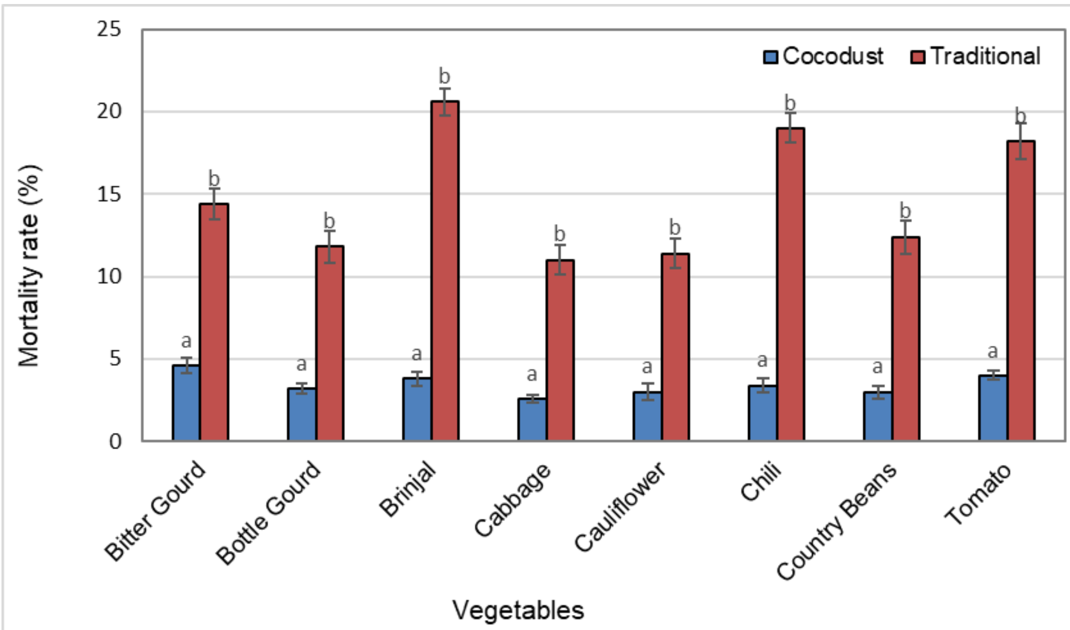

Fig. 2 Effect of cocodust application on seedling mortality of different vegetable crops. Bars represent mean ± SE of yield for cocodust-treated and traditional plots. Differences within each crop were tested using an independent two-sample Welch's t-test. Different lowercase letters indicate significant differences at $P \leq 0.05$, while the same letters indicate no significant difference.

Chili exhibited a marked reduction in seedling mortality from 19 to 3%, equivalent to an 82% reduction, while country beans showed a decrease from 12 to 3%, corresponding to a 76% reduction. In tomato, seedling mortality declined from 18 to 4, representing a 78% reduction. All reductions observed for these crops were statistically significant.

3.3 Effect of Cocodust Application on Harvesting Time

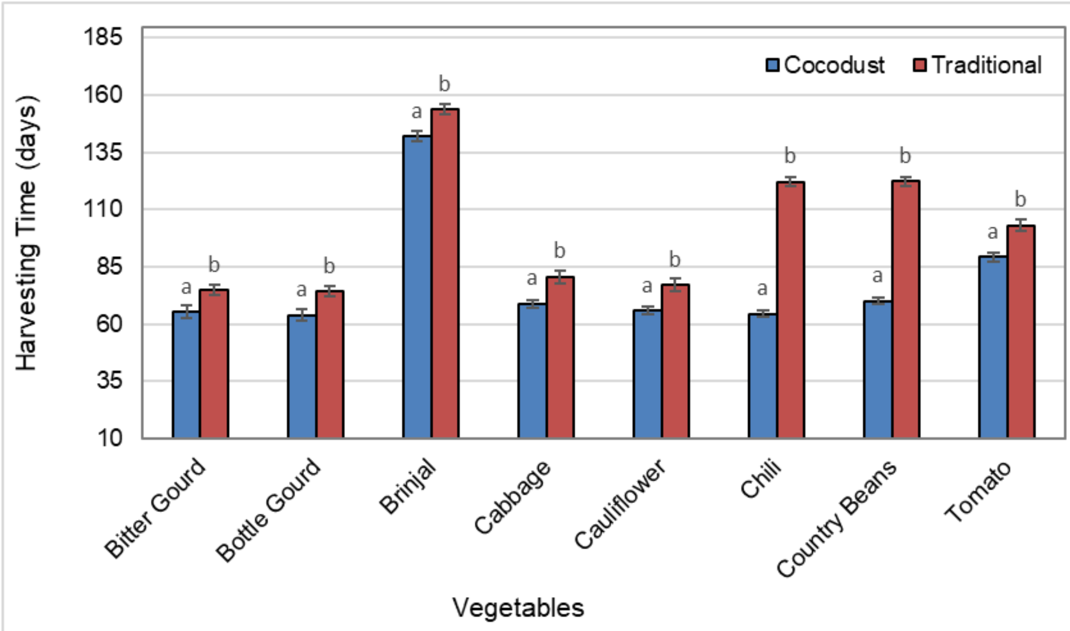

Fig. 3 Effect of cocodust application on harvesting time of different vegetable crops. Bars represent mean ± SE of yield for cocodust-treated and traditionla plots. Differences within each crop were tested using an independent two-sample Welch's t-test. Different lowercase letters indicate significant differences at $p \leq 0.05$, while the same letters indicate no significant difference.

Mean harvesting time was shorter under cocodust application than in the traditional for all studied crops, as shown in Fig. 3. Harvesting time decreased from 75 to 66 days in bitter gourd, representing a 13% reduction, from 74 to 64 days in bottle gourd, corresponding to a 14% reduction, and from 154 to 142 days in brinjal, showing a 8% reduction. These reductions were statistically significant. In cabbage and cauliflower, harvesting time decreased from 81 to 69 days, equivalent to a 15% reduction, and from 77 to 66, corresponding to a 14% reduction, respectively. These differences were statistically significant.

Chili exhibited a substantial reduction in harvesting time from 122 to 65 days, representing a 47% reduction, while country beans showed a decrease from 122 to 70 days, equivalent to a 43% reduction. Tomato harvesting time also decreased from 103 to 89 days, corresponding to a 14% reduction. All reductions observed for these crops were statistically significant.

3.4 Changes in Chemical Fertilizer Use

Table 1 Results of Chi-square tests $P \leq 0.05$, assessing the association between cocodust application (Yes vs. No) and changes in chemical fertilizer use across crops. The table presents crop-wise test statistics and *p*-values based on the distribution of response categories (increased, unchanged, slightly decreased, and much decreased). * indicates $P < 0.05$ and ns = not significant.

Crop	**Change in Chemical fertilizer use**		**Change in Pesticide use**		**Change in Organic/compost use**		**Presence of soil-borne diseases**	
	Chi-square	**p-value**	**Chi-square**	**p-value**	**Chi-square**	**p-value**	**Chi-square**	**p-value**
Bitter Gourd	3.750	0.05*	6.667	**0.03***	0.000	1.00 ns	1.905	0.17 ns
Bottle Gourd	0.625	0.43 ns	0.625	0.43 ns	0.000	1.00 ns	6.667	**0.04***
Brinjal	3.800	0.15 ns	0.417	0.52 ns	0.000	1.00 ns	3.800	0.15 ns
Cabbage	4.800	0.19 ns	0.000	1.00 ns	0.000	1.00 ns	3.800	0.15 ns
Cauliflower	1.905	0.17 ns	1.905	0.17 ns	2.500	0.28 ns	10.000	**0.01***
Chili	10.000	0.01 ns	1.905	0.17 ns	0.000	1.00 ns	1.143	0.57 ns
Country Bean	1.905	0.17 ns	6.800	**0.03***	0.000	1.00 ns	1.905	0.17 ns
Tomato	7.333	0.06*	6.667	**0.03***	0.000	1.00 ns	2.000	0.37 ns

Cocodust application was significantly associated with reduced chemical fertilizer use in Bitter gourd, where all cocodust users reported slightly or much decreased fertilizer application, whereas non-users more frequently reported increased use (Fig. 4; Table 1). In Tomato, cocodust use similarly resulted in universal fertilizer reduction among users, while responses among non-users were more heterogeneous, including increased, unchanged, and decreased fertilizer application; this association was marginally significant.

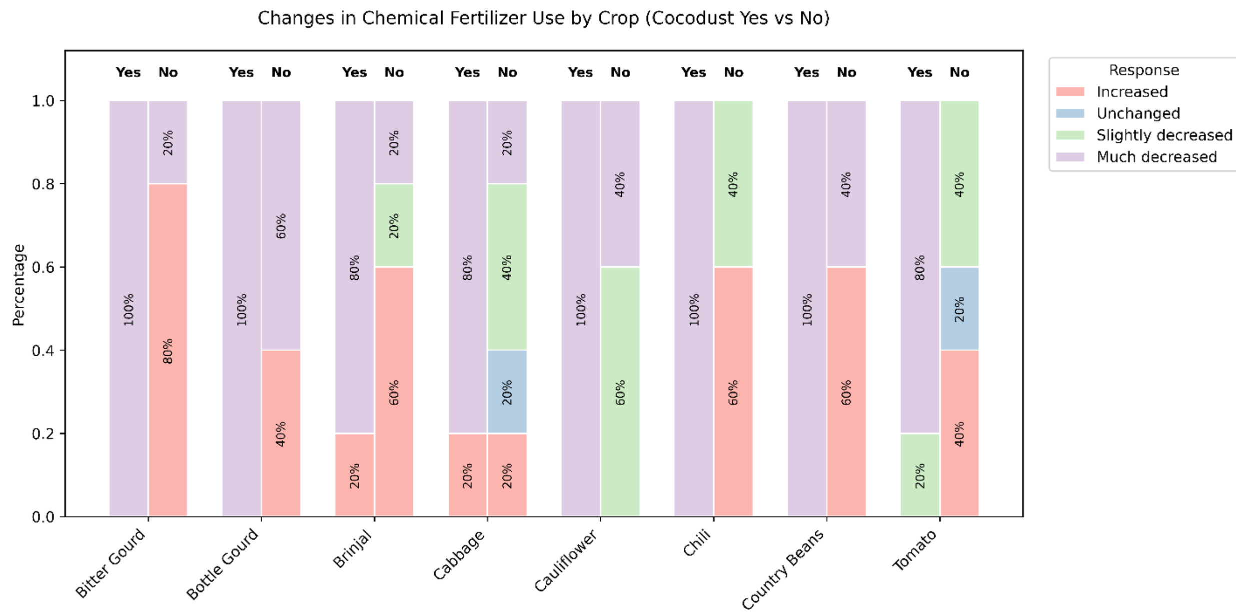

Fig. 4 Percentage distribution of farmers' responses on changes in chemical fertilizer use across crops under cocodust application (Yes) and non-application (No). Stacked bars represent the proportions of responses categorized as increased, unchanged, slightly decreased, and much decreased for each crop. Percentages are shown within each bar segment.

For Bottle gourd and Country bean, cocodust users consistently reported reduced fertilizer input, whereas non-users more often reported increased application; however, these differences were not statistically significant. In Brinjal and Cabbage, the majority of cocodust users (≥80%) reported reduced fertilizer use, while responses among non-users were more variable, but no significant associations were detected. In Cauliflower, fertilizer use declined uniformly irrespective of cocodust application, resulting in no detectable association. Likewise, in Chili, cocodust use was descriptively associated with complete fertilizer reduction among users, while non-users predominantly reported increased fertilizer application; however, this relationship was not statistically significant.

3.5 Changes in Pesticide Use

Across crops, cocodust application was generally associated with a shift toward reduced pesticide use, as reflected by higher proportions of farmers reporting slightly or much decreased pesticide application compared with non-users (Fig. 5; Table 1).

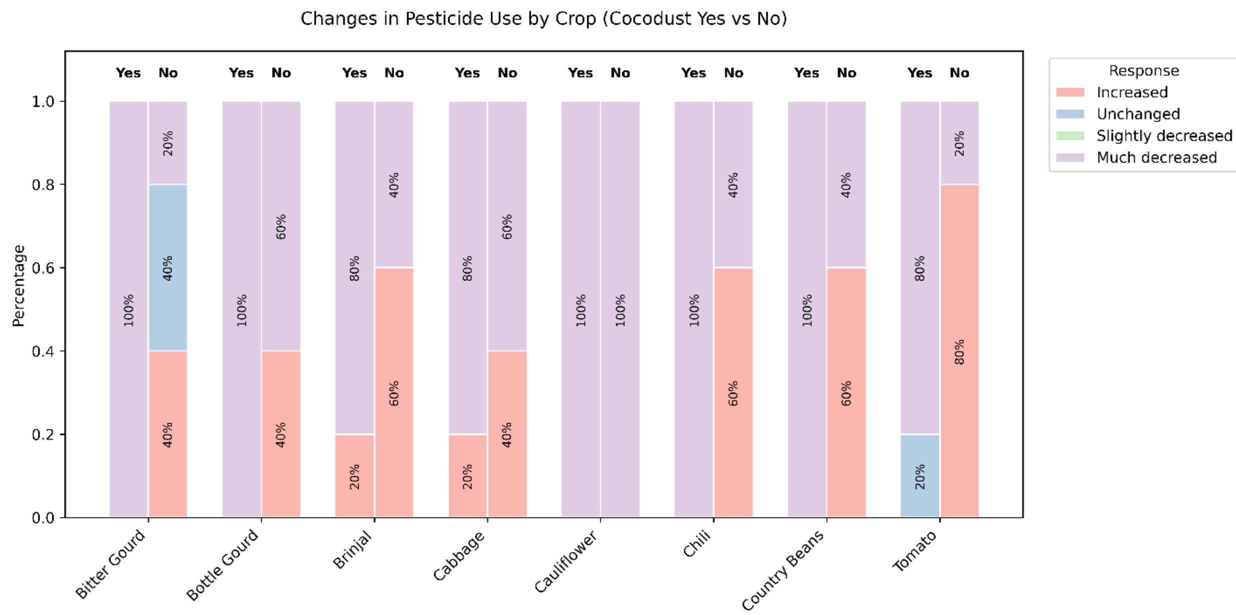

Fig. 5 Percentage distribution of farmers' responses on changes in pesticide use across crops under cocodust application (Yes) and non-application (No). Stacked bars illustrate the proportions of responses indicating increased, unchanged, slightly decreased, and much decreased pesticide use for each crop, with percentages displayed within bar segments.

Cocodust application was significantly associated with changes in pesticide use in Bitter gourd, Country bean, and Tomato (Fig. 5; Table 1). In Bitter gourd, all cocodust users reported reduced pesticide application (100% slightly or much decreased), whereas among non-users, 40% reported increased use and 40% reported unchanged use. In Country bean, pesticide use declined universally among cocodust users (100%), while 60% of non-users reported increased pesticide application. Similarly, in Tomato, all cocodust users reported reduced pesticide use (100%), compared with 80% of non-users reporting increased application.

For Bottle gourd, Brinjal, Cabbage, Cauliflower, and Chili, cocodust users generally showed a higher proportion of reduced pesticide use compared with non-users; however, these differences were not statistically significant ($p > 0.05$), indicating that the observed trends were not consistent enough to demonstrate a clear association.

3.6 Changes in Organic Fertilizer Use

Cocodust application was associated with increased use of organic fertilizer across crops, as indicated by a greater proportion of farmers reporting increased or unchanged organic fertilizer application compared with non-users (Fig. 6; Table 1).

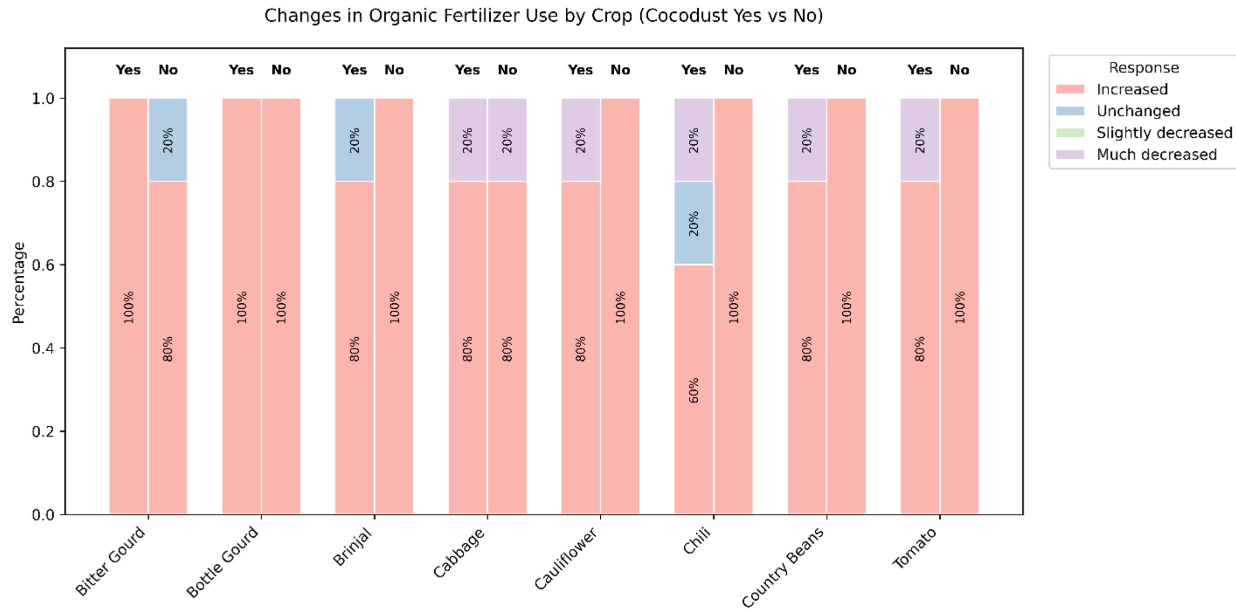

Fig. 6 Percentage distribution of farmers' responses on changes in organic fertilizer use across crops under cocodust application (Yes) and non-application (No). Stacked bars show the relative proportions of increased, unchanged, slightly decreased, and much decreased organic fertilizer use for each crop, with percentages presented within bar segments.

Across all crops, cocodust application was not significantly associated with changes in organic or compost fertilizer use ($p > 0.05$; Fig. 6; Table 1). Nevertheless, organic fertilizer use was consistently high among both cocodust users and non-users. In Bitter gourd, Bottle gourd, Cauliflower, Country bean, and Tomato, 80–100% of farmers in both groups reported increased organic fertilizer application.

Similarly, in Brinjal and Cabbage, approximately 80% of farmers reported increased organic fertilizer use regardless of cocodust application, with only a small proportion reporting unchanged or reduced use. In Chili, increased organic fertilizer use was reported by 60% of cocodust users and all non-users, again indicating widespread adoption across management practices. Overall, the similarity in response patterns between cocodust-applied and non-applied groups explains the absence of statistically significant differences in organic fertilizer use among crops.

3.7 Changes in Soil-Borne Disease Incidence

Cocodust application was significantly associated with soil-borne disease incidence in Bottle gourd and Cauliflower (Fig. 7; Table 1). In Bottle gourd, all cocodust users reported a low incidence of soil-borne disease, whereas among non-users, disease incidence was substantially higher, with 60% of farmers reporting elevated disease levels. In Cauliflower, cocodust users consistently reported reduced disease incidence, while non-users predominantly reported intermediate disease levels (80%), indicating a clear reduction in disease pressure associated with cocodust application.

For Bitter gourd, Brinjal, Cabbage, Chili, Country bean, and Tomato, cocodust users generally exhibited a higher proportion of reduced disease incidence compared with non-users; however, these differences were not statistically significant ($p > 0.05$). Although descriptive trends suggested lower disease pressure under cocodust application in several crops, the observed variability was insufficient to establish a consistent statistical association.

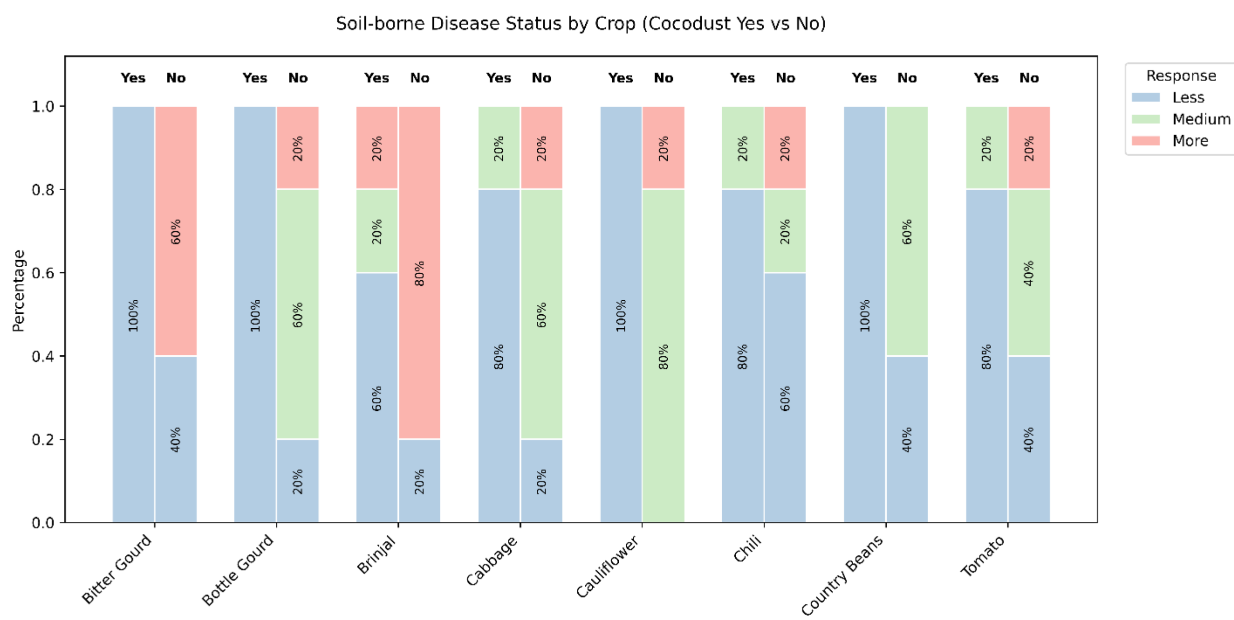

Fig. 7 Percentage distribution of farmers' responses on soil-borne disease incidence across crops under cocodust application (Yes) and non-application (No). Stacked bars represent the proportions of responses classified as less, medium, and more disease occurrence for each crop, with percentages displayed within each segment.

Overall, cocodust application tended to lower reported soil-borne disease incidence across crops, with the magnitude and statistical significance of effects differing by crop.

4. Discussion

The present study demonstrates that cocodust application can substantially improve vegetable production performance while reducing reliance on chemical inputs and lowering soil-borne disease incidence, although the magnitude and statistical significance of these effects were crop-specific. Overall, cocodust consistently enhanced yield, reduced seedling mortality, shortened harvesting time, and was associated with favorable shifts in fertilizer and pesticide use patterns, supporting its potential as a sustainable substrate amendment in vegetable production systems.

4.1 Yield Improvement, Seedling Establishment, and Crop Development

The significant yield increases observed in bitter gourd, bottle gourd, brinjal, chili, country bean, and tomato under cocodust application are consistent with growing evidence that coconut coir–based substrates enhance soil physical conditions, including aeration, water-holding capacity, and root-zone porosity, thereby improving crop growth and productivity (Abad et al., 2005). Improved root development and nutrient uptake efficiency under cocodust-treated conditions likely contributed to the observed yield gains, particularly in crops that are sensitive to soil compaction and excess moisture stress. Recent studies have shown that coir-based amendments promote more extensive root systems and improve nutrient-use efficiency by stabilizing soil moisture and enhancing rhizosphere conditions (Savvas & Gruda, 2018).

The absence of statistically significant yield responses in cabbage and cauliflower suggests that crop-specific root architecture and nutrient requirements may influence responsiveness to cocodust application. Brassica crops often exhibit comparatively lower sensitivity to changes in substrate physical structure, which may explain their weaker response to cocodust amendments, as reported under different organic and soilless substrate systems (Raviv & Lieth, 2008).

In addition to yield enhancement, cocodust application substantially reduced seedling mortality across all crops, highlighting a critical benefit during early crop establishment. Coconut coir substrates are known to create a favorable microenvironment for seedlings by maintaining uniform moisture availability while reducing waterlogging and associated root stress (Blok et al., 2017; Evans et al., 1996). Improved seedling survival likely facilitated more rapid and uniform stand establishment, which in turn contributed to the shorter harvesting times observed under cocodust application. Earlier crop maturity has been linked to improved early vigor and root-zone conditions in coir-amended systems (Gruda et al., 2023).

The advancement of harvest timing under cocodust application has important agronomic and economic implications, particularly for fast-growing vegetables such as chili and country bean, where early market entry can substantially increase profitability. Similar reductions in crop duration have been reported in vegetable systems using organic substrates that enhance early growth dynamics and reduce establishment stress (Savvas & Gruda, 2018).

4.2 Impacts of Cocodust on Fertilizer, Pesticide Use, and Soil-Borne Disease Dynamics

Cocodust application was associated with reduced reliance on chemical fertilizers and pesticides in several crops, although the strength and consistency of these effects varied by crop. Statistically significant or marginally significant reductions in chemical fertilizer use observed in bitter gourd and tomato are consistent with evidence that coconut coir–based substrates improve nutrient retention, buffer nutrient release, and enhance nutrient-use efficiency in the root zone (Arenas et al., 2002; Gruda et al., 2023; Meerow, 1994). Improved soil structure and moisture regulation under cocodust amendment likely reduced nutrient losses through leaching, thereby lowering the need for frequent chemical fertilizer application. The absence of consistent significance across all crops suggests that fertilizer reduction responses are crop-specific and influenced by inherent nutrient demand and existing fertilization regimes, as reported in diversified vegetable systems (Diacono & Montemurro, 2011; Evans et al., 1996; Prakash et al., 2021; Sabatino, 2020).

Similarly, the significant reductions in pesticide use observed in bitter gourd, country bean, and tomato indicate that cocodust application may indirectly reduce pest pressure. Improved plant vigor, enhanced root development, and reduced abiotic stress are known to increase crop tolerance to pest and disease attack, thereby lowering dependence on chemical pest control inputs (Altieri & Nicholls, 2003; Kabato et al., 2025). However, the lack of significant pesticide-use reductions in other crops suggests that cocodust alone is unlikely to replace integrated pest management practices and should be considered a complementary rather than standalone strategy for pesticide reduction.

In contrast, cocodust application did not significantly influence organic or compost fertilizer use across crops. High levels of organic fertilizer application were reported irrespective of cocodust use, indicating that farmers' decisions regarding organic nutrient inputs are largely governed by established management practices, input availability, and broader soil fertility strategies rather than substrate amendment alone. Similar observations have been reported in systems where improvements in soil physical properties do not necessarily translate into changes in farmer nutrient management behavior (Gruda et al., 2023; Raviv, 2013).

Beyond input-use efficiency, cocodust application conferred clear benefits for soil health through the suppression of soil-borne diseases in selected crops. The significant reduction in disease incidence observed in bottle gourd and cauliflower aligns with previous studies demonstrating that coconut coir can limit soil-borne pathogens by improving aeration, reducing excessive moisture, and fostering beneficial microbial communities that compete with or antagonize pathogenic organisms (Chromkaew et al., 2023; Noble & Coventry, 2005; Van der Sloot et al., 2024). The absence of statistically significant disease suppression in other crops suggests that the effectiveness of cocodust against soil-borne diseases is likely pathogen-specific and influenced by crop type and environmental conditions, a pattern widely reported in organic substrate and compost-amended systems (Bonanomi et al., 2010; M. Uddin et al., 1970).

Overall, these findings highlight the multifaceted role of cocodust application in improving input-use efficiency and soil health, while underscoring the importance of crop-specific management strategies and complementary agronomic practices to fully realize its benefits.

4.3 Implications for sustainable vegetable production

Collectively, these findings indicate that cocodust application can play a meaningful role in improving productivity and sustainability in vegetable-based cropping systems. By enhancing yield, reducing seedling mortality, shortening production cycles, and lowering dependence on chemical fertilizers and pesticides in selected crops, cocodust contributes to more resource-efficient and environmentally friendly production. However, the crop-specific nature of several responses underscores the need for tailored recommendations rather than uniform application across all vegetable crops.

5. Conclusion

This study demonstrates that cocodust application can substantially enhance vegetable production performance while contributing to more sustainable input management, although responses were crop-specific. Cocodust use significantly improved yield, reduced seedling mortality, and shortened harvesting time in several crops, indicating clear benefits for early crop establishment and overall productivity. These effects were most pronounced in bitter gourd, bottle gourd, brinjal, chili, country bean, and tomato, whereas responses in cabbage and cauliflower were comparatively limited.

Cocodust application was also associated with reduced reliance on chemical fertilizers and pesticides in selected crops, highlighting its potential to improve input-use efficiency. Although reductions in chemical fertilizer and pesticide use were not uniformly significant across all crops, consistent descriptive trends toward lower agrochemical dependence were observed. In contrast, organic fertilizer use remained largely unaffected by cocodust application, suggesting that farmer nutrient management practices were driven primarily by existing management strategies rather than substrate amendment alone.

Importantly, cocodust application contributed to reduced soil-borne disease incidence in bottle gourd and cauliflower, underscoring its role in improving soil health and plant resilience. Together, these findings indicate that cocodust can function as an effective organic substrate amendment that enhances crop performance while supporting environmentally sustainable production practices.

Overall, cocodust represents a promising, low-cost, and environmentally friendly amendment for vegetable-based cropping systems. However, given the observed crop-specific responses, future research should focus on optimizing application rates, evaluating long-term soil health impacts, and integrating cocodust use with complementary nutrient and pest management strategies to maximize its agronomic and environmental benefits.

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.

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