



Original Research

Transforming horticultural productivity with organic manures in geotextile vertical farming

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Abstract

This study investigated sustainable, space-efficient cultivation strategies in urban agricultural systems. Specifically, it evaluated the effectiveness of organic manure-based substrates in geotextile pockets for enhancing the growth and yield of selected leafy and spice crops under vertical farming conditions. The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from December 2019 to April 2020, using a Randomized Complete Block Design with three replications. Four substrate treatments were tested in geotextile pockets: T1 (control), T2 (2 kg vermicompost + 2 kg soil per pocket), T3 (1.5 kg vermicompost + 0.5 kg coco fibre + 2 kg soil per pocket), and T4 (2 kg kitchen compost + 2 kg soil per pocket). Mint, chili, and Indian spinach were grown, and data were recorded on growth, yield components, and total yield. Significant variation was observed among treatments for most growth and yield traits across all three crops. For mint, the highest yield per plant (151.40 g) was obtained from T3, while the lowest (80.00 g) was recorded in the control (T1). In chili, T3 produced the highest fruit yield (88.43 g plant⁻¹), which differed significantly from the other treatments. The lowest fruit yield (24.00 g plant⁻¹) was obtained from T1 and was statistically similar to T4 (29.67 g plant⁻¹). For Indian spinach, T3 again yielded the highest (290.66 g plant⁻¹), compared to the lowest yield (71.33 g plant⁻¹) under T1. The combination of vermicompost, coco fibre, and soil in geotextile pockets consistently enhanced the growth and yield of mint, chili, and Indian spinach. This indicates that this organic substrate mix is a promising option for productive and sustainable vertical horticulture in urban environments.

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1. Introduction

Urban agriculture is increasingly recognized as a viable strategy to enhance food and nutrition security, especially in densely populated cities with limited arable land (Hassan *et al.*, 2021). Rooftop and vertical farming systems offer opportunities to utilize underused urban spaces for producing fresh vegetables and spices close to consumers, while also improving microclimates and environmental quality (Gumble *et al.*, 2015; Despommier, 2013). In Bangladesh, particularly Dhaka, land fragmentation, high land prices, and rapid urbanization constrain conventional horticultural expansion, creating a strong need for innovative, space-efficient production systems (Alam, 2018). Vertical cultivation using geotextile structures presents a promising option, as it enables multi-layered crop production, reduces land footprint, utilizes building facades or narrow spaces, and can potentially mitigate urban heat island effects (Kalantari *et al.*, 2018).

Within such intensive systems, the choice of growing medium and nutrient source is central to plant establishment, growth, and yield (Shathy *et al.*, 2018). Organic manures, including vermicompost, kitchen compost, and green manures, not only supply essential macro- and micronutrients but also improve substrate structure, water-holding capacity, and microbial activity (Adekiya *et al.*, 2019). Vermicompost is known to contain plant growth-promoting

substances, humic acids, and beneficial microorganisms that can stimulate root growth, nutrient uptake, and overall vigor in horticultural crops (Kumar *et al.*, 2022). Coco fiber, or cocopeat, widely used as a soilless substrate component, enhances aeration and moisture retention, which is particularly important in confined root zones such as pockets or containers in vertical systems (Islam *et al.*, 2021). Kitchen compost and other recycled organic wastes represent readily available household resources that can support nutrient recycling and reduce solid-waste pressure in urban areas when appropriately used in urban farming systems (Liu *et al.*, 2021).

Horticultural crops like mint (*Mentha* spp.), chili (*Capsicum* spp.), and Indian spinach (*Basella alba* L.) are well-suited to vertical farming in geotextile pockets due to their relatively shallow root systems, frequent harvests, and high market value. Mint and Indian spinach contribute important vitamins, minerals, and bioactive compounds to urban diets, while chili is both a staple spice and a cash crop in Bangladesh. Previous work has shown that integrating organic manures and bio-fertilizers can improve growth, essential-oil content, and herbage yield in aromatic and leafy species such as *Mentha* (Aćimović and Miljković, 2025). Similarly, organic manures, vermicomposting, and bio-fertilizers have been reported to enhance growth and yield attributes in chili and other solanaceous vegetables (Dalim *et al.*, 2026). However, suboptimal substrate composition or nutrient management in vertical structures can still lead to poor vegetative growth, reduced yield, and lower quality, thereby undermining the potential advantages of these intensive systems (Islam *et al.*, 2021).

Previous studies in rooftop and protected cultivation have demonstrated that organic amendments such as vermicompost,

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composted wastes, and coco-based substrates can significantly enhance the growth and yield of vegetables in container systems (Mejia et al., 2022). Nevertheless, there is limited information on how specific combinations of vermicompost, coco fiber, kitchen compost, and soil perform in vertically arranged geotextile pockets across different crop types, particularly under the climatic and management conditions of Dhaka. Moreover, comparative data on the productivity of mint, chili, and Indian spinach grown together in the same geotextile vertical system and managed with different organic manure-based substrates are scarce. Addressing these gaps will help optimize substrate formulations that are both agronomically effective and locally feasible for small-scale urban farmers and household gardeners.

This study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to evaluate organic manure-based substrates in a geotextile vertical farming system. The experiment focused on three horticultural crops—mint, chili, and Indian spinach—comparing a control substrate with mixtures containing vermicompost, coco fiber, and kitchen compost in vertically arranged geotextile pockets. By assessing the growth, yield components, and yield of each crop under these treatments, the study aims to identify organic substrate combinations that can enhance productivity and support sustainable, resource-efficient horticulture in urban environments, thereby contributing to climate-resilient urban food systems in Bangladesh.

2. Materials and Methods

2.1 Ethical approval statement

This study focused exclusively on cultivated horticultural plants (mint, chili, and Indian spinach) grown under experimental conditions. It did not involve human participants, animal subjects, or endangered/protected plant species. According to the guidelines of the Institutional Research Ethics Committee of Sher-e-Bangla Agricultural University, such agronomic field and pot experiments are exempt from formal ethical review. An exemption and approval of the experimental plan were obtained and documented under reference number SAU/HORT/2024-2025/GEOTEX-01.

2.2 Experimental site, soil and climate

The study was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during the Rabi season from December 2024 to April 2025. The experimental site is located at approximately 24°09' N latitude and 90°34' E longitude, at an elevation of about 8.4 m above mean sea level (Figure 1). This area lies within Bangladesh's subtropical monsoon zone, where 70–80% of annual rainfall occurs during the southwest monsoon (Kharif) months, leading to hot, humid, and cloudy conditions. In contrast, the Rabi season (approximately October–March) is characterized by comparatively scanty rainfall, cooler temperatures, and abundant sunshine, which are favorable for winter vegetable cultivation (Alamgir et al., 2015). Monthly mean temperature, relative humidity, and rainfall during the crop-growing period were obtained from the Bangladesh Meteorological Department, Agargaon, Dhaka-1212, Bangladesh.

The soil of the experimental field belongs to the Tejgaon series, classified as Deep Red Brown Terrace Soil (Kumar et al., 2019) under the Madhupur Tract Agro-Ecological Zone (AEZ-28). Before initiating the experiment, a composite soil sample was collected from multiple points of the experimental area at a depth of 0–15 cm. The sample was air-dried, gently ground, passed through a 2 mm sieve, and analyzed for selected physical and chemical properties at the Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka, following standard procedures (Kumar et al., 2019). The soil was sandy loam in texture, containing 26% sand, 43% silt, and 31% clay, with a pH of 5.9 and an organic matter content of 0.78%.

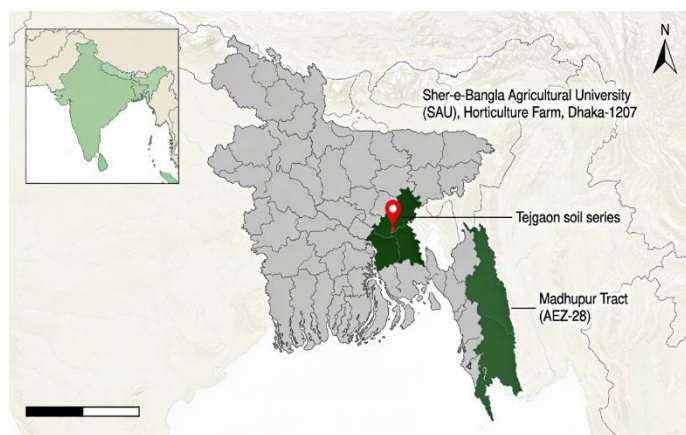


Figure 1. Research site location.

2.3 Plant materials

Three horticultural crops were selected as test species: mint, chili, and Indian spinach. Stem cuttings of mint (*Mentha* spp.) were collected from the rooftop garden of FABLAB, SAU. Seeds of chili (*Capsicum frutescens* L.), variety 'BARI Morich-1', were obtained from the Bangladesh Agricultural Research Institute (BARI), Gazipur. This variety is a dwarf, high-yielding type released by BARI. Seeds of Indian spinach (*Basella alba* L.), variety 'BARI Puishak-2', characterized by green stems, were also collected from BARI. These crops were chosen for their suitability for vertical cultivation and potential for frequent harvests.

2.4 Vertical structure and experimental treatments

A vertical wooden frame, measuring 7 × 4 ft (height × width), was fabricated and covered with a polythene sheet on the back and sides to protect the structure from rain and moisture. Durable, eco-friendly geotextile cloth was used to sew planting pockets, arranged in a grid, on the front of the frame. Each pocket was designed to hold approximately 4 kg of growing medium.

The experiment utilized a single-factor treatment structure with four organic manure-based growing media per pocket: T1: Control (soil only); T2: 2 kg vermicompost + 2 kg soil; T3: 1.5 kg vermicompost + 0.5 kg coco fiber + 2 kg soil; T4: 2 kg kitchen compost + 2 kg soil.

Well-decomposed vermicompost and kitchen compost were prepared and supplied by the SAU composting facility. Coco fiber was purchased from a commercial supplier in Dhaka and pre-moistened before mixing. All growing media were thoroughly homogenized before filling the pockets.

According to manufacturer and laboratory reports, vermicompost contained 1.5–2.0% N, 0.9–1.7% P, and 1.5–2.4% K (ACI Fertilizer, 2016). Coco fiber contained 0.41% N, 0.81% P, and 1.32% K. The kitchen compost (Anumar compost) contained 8.6% organic carbon, had a C:N ratio of 6.8:1, and contained 0.5% P and 0.56% K (Islam et al., 2021).

2.5 Experimental design and layout

The experiment utilized a Randomized Complete Block Design (RCBD) with three replications. Each 7 × 4 ft vertical structure served as one block, and all four treatments (T1–T4) were randomly assigned to pockets within each block. Each pocket contained 4 kg of its designated growing medium (Figure 2). For each treatment × replication combination, an equal number of pockets were planted with mint, chili, and Indian spinach, ensuring that all crops experienced the same vertical position and exposure conditions within the structure.

2.6 Soil media preparation

Before preparing the media mixtures, surface soil from the experimental plot was sun-dried for one week. It was then repeatedly cross-plowed and laddered to break clods and remove stubble, weeds, and plant residues. The prepared soil was then mixed with

organic manures in the following proportions for each pocket: T2: 2 kg vermicompost + 2 kg soil; T3: 1.5 kg vermicompost + 0.5 kg coco fiber + 2 kg soil; T4: 2 kg kitchen compost + 2 kg soil.

Mixing was done on a clean floor until a uniform texture was obtained. The media were then filled into geotextile pockets to a consistent bulk volume. This approach followed and adapted methods used in previous studies on organic substrate mixtures for horticultural crops in containers or vertical systems.

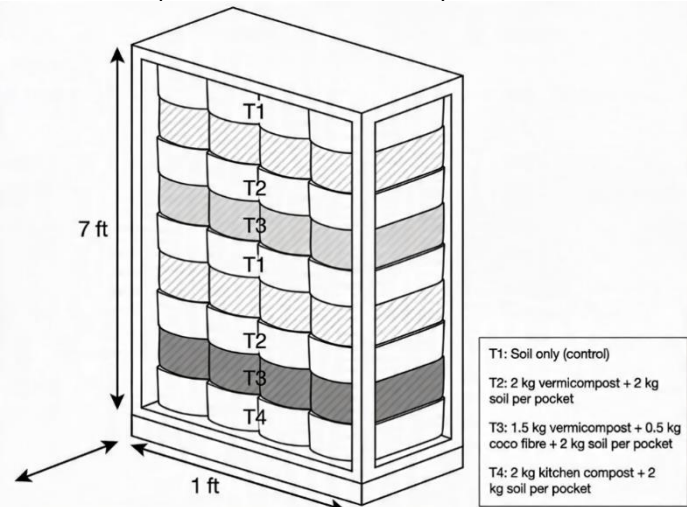


Figure 2. Layout of experimental plot.

2.7 Crop establishment and management

Seeds for chili and Indian spinach were sown on a well-prepared seedbed on December 3, 2024. The seedbed was lightly irrigated after sowing to ensure proper germination, with seedlings emerging around December 10, 2024. Healthy, uniform chili and Indian spinach seedlings were transplanted into geotextile pockets on January 20, 2025, in the late afternoon to minimize transplanting shock. Immediately after transplanting, light irrigation was applied to aid seedling establishment. Stem cuttings of mint were planted directly into their designated pockets on January 19, 2025.

Intercultural operations, including irrigation, weeding, and plant protection, were carried out uniformly for all treatments. Irrigation was provided as needed to maintain the media near field capacity, taking care to avoid waterlogging. Weeds emerging around the base and in the pockets were removed manually. Pest and disease management relied on recommended cultural and mechanical practices, and no synthetic chemical fertilizers were applied to maintain consistency with the organic management regime.

Basic tools used included standard 1.5 L manual hand sprayers (China) for irrigation and plant protection, and a digital balance (model: EK-600i, A&D Company, Japan) for yield measurements.

2.8 Data collection

For each crop, three plants per treatment per replication (n = 3) were randomly selected from the central pockets and tagged for data collection, avoiding border pockets to minimize edge effects. Growth and yield attributes were recorded at 20, 50, and 75 days after transplanting (DAT) for chili and Indian spinach, and at corresponding days after planting for mint.

The recorded parameters included plant height (cm), number of branches per plant, number of leaves per plant, leaf area, and canopy size (cm). Additionally, the number of fruits per plant was recorded for chili, and the number of branches per plant for mint and Indian spinach. At harvest, the fresh herbage yield of mint and Indian spinach (g plant⁻¹) and the fresh fruit yield of chili (g plant⁻¹) were measured using the aforementioned digital balance. Yield data were subsequently converted to per-pocket or per-structure values as required.

2.9 Statistical analysis

All recorded data were subjected to an analysis of variance (ANOVA) appropriate for a randomized complete block design (RCBD) to determine the significance of treatment effects. Statistical analyses were performed using Statistix 10 software (Analytical Software, Tallahassee, FL, USA). When F-values were significant, treatment means were separated using Tukey's honest significant difference (HSD) test at 5% and 1% probability levels, following procedures similar to those used by Adekiya et al. (2019). Results are presented as mean values, and significance levels are indicated where appropriate.

3. Results and Discussion

3.1 Growth and yield responses of mint (Mentha spp.)

3.1.1 Growth attributes

Plant height of mint responded significantly to the organic manure treatments at all observation dates (25, 50, and 75 DAT). Plants grown in T3 (1.5 kg vermicompost + 0.5 kg coco fiber + 2 kg soil per pocket) were the tallest (13.23, 16.67, and 15.00 cm at 25, 50, and 75 DAT, respectively), whereas the shortest plants (4.00, 5.47, and 5.33 cm) were observed in the control (T1) (Table 1). The superiority of T3 can be attributed to the combined effects of vermicompost and coco fiber, which improve soil structure, water-holding capacity, and nutrient availability, thereby supporting more vigorous shoot growth (Adekiya et al., 2019). Similar increases in mint plant height under vermicompost and organic nutrient regimes were reported by Dalim et al. (2026), who noted that vermicompost in combination with other organic inputs enhanced vegetative growth in chili species.

The number of leaves per plant also varied significantly among treatments (Table 1). T3 produced the highest leaf numbers (151.33, 296.00, and 221.33 leaves plant⁻¹ at 25, 50, and 75 DAT, respectively), while T1 recorded the lowest values (54.67, 157.00, and 96.67 leaves plant⁻¹). Higher leaf production in T3 reflects improved nutrient supply and moisture conditions, which favor continuous leaf initiation and expansion. Vermicompost is known to supply readily available nutrients along with plant growth-promoting substances and beneficial microbes, which together stimulate leaf proliferation and enhance canopy development (Dahiya et al., 2020). Kumar et al. (2022) and Kumar et al. (2025) similarly reported that combining organic inputs such as FYM, vermicompost, and biostimulants significantly increased leaf number and herbage yield in Japanese mint (Mentha arvensis).

Canopy size followed the same trend, with T3 showing the maximum canopy spread (15.03, 16.13, and 15.07 cm at 25, 50, and 75 DAT) and T1 the minimum (6.57, 11.00, and 9.67 cm) (Table 1). A larger canopy indicates more efficient interception of light and higher photosynthetic area, which ultimately supports higher biomass accumulation. The improvement in canopy size under T3 is consistent with reports that organic amendments, especially vermicompost combined with porous organic substrates like coir, enhance root growth and water status, leading to more extensive foliage (Younis et al., 2022).

Table 1. Effect of different organic manures on plant height and leaf number of mint.

T	Plant height at different DAT (cm)			Number of leaves per plant at different DAT			Canopy size per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	4.00 _d	5.47 _d	5.33 _d	54.67 _d	157.00	96.67 _d	6.57 _c	11.00	9.67 _c
T ₂	10.1 _{0^b}	12.6 _{0^b}	11.03 _b	139.33 _b	255.67 _b	202.00 _b	10.1 _{7^b}	13.33 _b	11.77 _b
T ₃	13.2 _{3^a}	16.6 _{7^a}	15.00 _a	151.33 _a	296.00 _a	221.33 _a	15.0 _{3^a}	16.13 _a	15.07 _a
T ₄	6.63 _c	8.07 _c	7.67 _c	75.33 _c	171.67 _c	132.33 _c	7.77 _c	12.00 _{bc}	10.67 _{bc}
LSD _{0.05}	1.78	2.18	2.24	11.69	20.91	15.32	1.92	2.07	1.99
CV%	10.5 ₂	10.1 ₈	11.50	5.56	4.76	4.70	9.74	7.92	8.46

T=Treatments; In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2 kg Vermicompost and 2 kg soil per pocket; T₃- 1.5 kg Vermicompost, 0.5 kg coco fiber and 2 kg soil per pocket; T₄- 2 kg Kitchen compost and 2 kg soil per pocket

3.1.2 Leaf morphology and yield

Leaf length and breadth of mint were significantly influenced by the treatments (Table 2). T₃ consistently produced the longest leaves (2.60, 3.17, and 2.80 cm at 25, 50, and 75 DAT, respectively) and the widest leaves (1.87, 2.37, and 2.02 cm). In contrast, T₁ resulted in the smallest leaf dimensions and was statistically similar to T₄ on most observation dates. The larger leaf size observed under T₃ may be attributed to improved nutrient uptake and turgor maintenance, leading to enhanced cell expansion. Previous studies have demonstrated that vermicompost, particularly when combined with other organic inputs, increases leaf size and leaf area in mint and other herbs. This, in turn, improves photosynthetic capacity and essential oil yield (Adekiya et al., 2019).

The number of branches per plant also significantly increased with the application of organic manure (Table 2). T₃ exhibited the highest number of branches (24.67, 49.67, and 42.33 branches plant⁻¹ at 25, 50, and 75 DAT, respectively), whereas T₁ showed the lowest branching (6.67, 17.00, and 12.67 branches plant⁻¹). Branching is closely linked to nutrient availability, especially nitrogen. While excessive or deficient nitrogen can disrupt vegetative growth, balanced organic sources provide a gradual nutrient release that promotes steady branching (Stewart et al., 2000). The positive effects of vermicompost and organic manures on branching in mint align with the findings of Suresh et al. (2018), who reported enhanced branch number and herbage yield in *Mentha* under organic nutrient management.

Table 2. Effect of different organic manures on leaf morphology of mint.

T	Number of branches per plant at different DAT			Length of leaves per plant at different DAT (cm)			Breadth of leaves per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	6.67 _d	17.00 _d	12.67 _d	1.47 _c	2.10 _c	1.87 _c	1.13 _c	1.4 _c	1.17 _c
T ₂	15.6 _b	40.67 _b	30.33 _b	2.17 _{ab}	2.60 _b	2.30 _b	1.43 _b	2.0 _b	1.73 _b
T ₃	24.6 _a	49.67 _a	42.33 _a	2.60 _a	3.17 _a	2.80 _a	1.87 _a	2.3 _a	2.02 _a
T ₄	9.67 _c	22.33 _c	17.33 _c	2.07 _b	2.47 _{bc}	2.20 _{bc}	1.23 _{bc}	1.6 _c	1.38 _c
LSD ₀₅	2.49	3.99	3.45	0.49	0.37	0.36	0.20	0.2	0.23
CV%	8.82	6.16	6.72	11.8	7.18	8.07	7.13	7.6	7.41

T=Treatments; In a column means having similar letters are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2 kg Vermicompost and 2 kg soil per pocket; T₃- 1.5 kg Vermicompost, 0.5 kg coco fiber and 2 kg soil per pocket; T₄- 2 kg Kitchen compost and 2kg soil per pocket

Total fresh herbage yield of mint exhibited marked differences among treatments (Table 2). T₃ produced the highest total yield per plant (151.40 g), followed by T₂ (132.40 g), T₄ (91.53 g), and T₁ (80.00 g). The superiority of T₃ reflects the cumulative effects of improved plant height, branching, leaf number, leaf size, and canopy expansion (Figure 3). Similar yield advantages under vermicompost-based management have been documented in mint and other aromatic crops, where vermicompost and biofertilizers increased herbage yield, essential oil content, and overall plant vigor compared with control or solely mineral fertilization (Hassan et al., 2021). These results confirm that a mixture of vermicompost and coco fiber is highly suitable for mint cultivation in vertical geotextile systems.

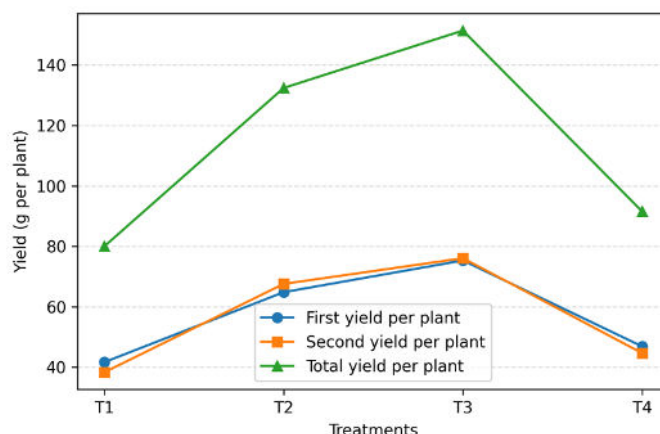


Figure 3. Effect of different organic manures on mint yield. (T₁: Control; T₂: 2 kg vermicompost and 2 kg soil per pocket; T₃: 1.5 kg vermicompost, 0.5 kg coco fiber, and 2 kg soil per pocket; T₄: 2 kg kitchen compost and 2 kg soil per pocket).

3.2 Growth and yield responses of chilli (*Capsicum frutescens* L.)

3.2.1 Vegetative growth

Plant height of chilli increased significantly with organic manure treatments at all growth stages (Table 3). The tallest plants (16.20, 41.73, and 48.50 cm at 25, 50, and 75 DAT, respectively) were recorded in T₃, while T₁ produced the shortest plants (7.03, 10.33, and 15.67 cm). Vermicompost-rich substrates likely enhanced root development and nutrient uptake, resulting in taller plants. This observation agrees with Kumar et al. (2022), who reported higher chilli plant height in vermicompost-treated plots compared with the control. Similar positive responses of chilli to vermicompost and organic combinations have been highlighted by Dalim et al. (2026).

The number of leaves per plant showed a parallel response pattern (Table 9). T₃ consistently produced the highest leaf numbers (35.00, 69.00, and 91.67 leaves plant⁻¹ at 25, 50, and 75 DAT, respectively), whereas T₁ recorded the lowest (10.00, 21.33, and 33.67 leaves plant⁻¹) (Table 3). The increased leaf number in vermicompost treatments has been attributed to enhanced nutrient supply and microbial activity, which stimulate vegetative growth and canopy development (Adekiya et al., 2019). Leaf length and breadth were also significantly improved by T₃ (Table 3), with the longest leaves (8.70, 12.07, and 14.17 cm) and widest leaves (2.80, 2.87, and 2.90 cm) recorded in this treatment, while T₁ had the smallest values. A larger leaf area under vermicompost-based substrates has been reported in several chilli studies and is generally associated with higher photosynthetic capacity and yield (Hosseinzadeh et al., 2018).

Table 3. Effect of different organic manures on plant height of chilli.

T	Plant height at different DAT (cm)			Number of leaves per plant at different DAT			Canopy size per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	7.03 _c	10.3 ₃	15.6 ₇	10.00 _d	21.33 _c	33.67 _d	6.00 _d	10.67 _c	14.07 _c
T ₂	10.60 _b	26.6 ₃	33.3 ₃	24.33 _b	47.33 _b	68.33 _b	12.3 ₃	20.00 _b	24.00 _b
T ₃	16.20 _a	41.7 ₃	48.5 ₀	35.00 _a	69.00 _a	91.67 _a	17.0 ₀	27.00 _a	33.17 _a
T ₄	10.00 _b	13.9 ₀	18.0 ₀	13.00 _c	27.00 _c	49.67 _c	10.0 ₀	14.00 _c	18.33 _c
LSD ₀₅	2.00	3.86	4.25	2.47	5.74	6.32	2.13	3.60	5.62
CV%	9.17	8.34	7.36	5.99	6.98	5.20	9.42	10.06	12.57

T=Treatments; In a column means having similar letters are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2 kg Vermicompost and 2 kg soil per pocket; T₃- 1.5 kg Vermicompost, 0.5 kg coco fiber and 2kg soil per pocket; T₄- 2 kg Kitchen compost and 2 kg soil per pocket

Branch number and canopy size of chili followed similar trends (Table 4). T₃ produced the highest branch numbers (6.00, 10.33, and

14.67 branches per plant) and the largest canopy size (17.00, 27.00, and 33.17 cm at 25, 50, and 75 DAT), while T1 showed the lowest branching and canopy spread. Vermicompost has been shown to increase lateral branching and canopy development in hot pepper by improving nutrient status, chlorophyll content, and soil physical conditions (El-Mogy et al., 2024). The present findings align with these reports and underscore the suitability of vermicompost-based mixtures for promoting robust chili growth in vertical systems.

Table 4. Effect of different organic manures on the number of branches per plant, leaf length, and leaf breadth of chili.

T	Number of branches per plant at different DAT			Length of leaves per plant at different DAT (cm)			Breadth of leaves per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	0.00 _d	2.00 ^c	6.33 ^d	5.00 ^c	6.00 ^c	7.00 ^c	1.50 ^d	1.5 ^{3 d}	1.57 ^d
T ₂	2.33 _b	6.33 ^b	10.33 _b	7.67 _{ab}	9.00 _b	10.1 _{0 b}	2.20 _b	2.2 _{7 b}	2.33 ^b
T ₃	6.00 _a	10.33 _a	14.67 _a	8.70 _a	12.0 _{7 a}	14.1 _{7 a}	2.80 _a	2.8 _{7 a}	2.90 ^a
T ₄	1.67 ^c	3.00 ^c	8.00 ^c	6.00 _{bc}	7.67 _{bc}	8.67 _{bc}	1.80 _c	1.9 _{3 c}	1.97 ^c
LSD _{0.05}	0.56	1.21	1.49	1.74	2.30	2.41	0.28	0.2	0.24
CV%	11.2 ₃	11.17	7.58	12.7 ₆	13.2 ₆	12.0 ₇	6.82	4.7 ₂	5.54

T=Treatments; In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2 kg Vermicompost and 2 kg soil per pocket; T₃- 1.5 kg Vermicompost, 0.5 kg coco fiber and 2 kg soil per pocket; T₄- 2 kg Kitchen compost and 2 kg soil per pocket

3.2.2 Yield and yield components

Yield-contributing characteristics of chili were significantly influenced by the treatments (Table 5). Days to first flowering were reduced from 43 days in T1 to 31 days in T3, indicating that vermicompost plus coco fiber promoted earlier reproductive development. Earlier flowering under organic nutrient management has been reported by El-Mogy et al. (2024), who found that vermicompost and organic boosters advanced flower initiation in chili.

Single fruit weight, fruit length, and total fruit weight per plant all responded positively to vermicompost treatments. Although differences in single fruit weight were not statistically large, T3 recorded the highest average weight (3.00 g fruit⁻¹), comparable to T2 (2.87 g fruit⁻¹), while T1 had the lowest (1.91 g fruit⁻¹). Fruit length was significantly increased in T3 (8.10 cm) compared with T1 (3.23 cm), reflecting improved nutrient supply and plant vigor. Most importantly, total fruit weight per plant was highest in T3 (88.43 g), followed by T2 (68.23 g), whereas T1 and T4 produced much lower yields (24.00 and 29.67 g plant⁻¹, respectively) (Table 5).

Similar yield improvements with vermicompost have been documented for chili and hot pepper in field and pot experiments, where vermicompost increased fruit number, fruit weight, and total yield compared with control or solely mineral fertilization (Castellanos et al., 2017). These effects are generally attributed to improved soil structure, higher cation exchange capacity, enhanced microbial activity, and slow release of nutrients from vermicompost, all of which support sustained growth and reproductive performance (Liu et al., 2021).

3.3 Growth and yield responses of Indian spinach (*Basella alba* L.)

3.3.1 Vegetative growth

Indian spinach responded strongly to organic manure treatments. Plant height significantly increased with T3 at all observation dates (14.33, 46.67, and 31.50 cm at 25, 50, and 75 DAT, respectively), whereas T1 recorded the lowest heights (6.17, 18.50, and 12.43 cm; Table 6). Vermicompost combined with coco fiber likely improved root growth, aeration, and moisture retention, which are critical for rapid vegetative expansion in leafy vegetables (Islam et al., 2021).

Table 5. Effect of different organic manures on yield-contributing characteristics and yield of chili.

Treat-ments	First flowering (days)	Single fruit weight (g)	Fruit length (cm)	Fruits weight per plant (g)
T ₁	43.00 ^a	1.91 ^b	3.23 ^c	24.00 ^c
T ₂	39.00 ^b	2.87 ^a	5.90 ^b	68.23 ^b
T ₃	31.00 ^c	3.00 ^a	8.10 ^a	88.43 ^a
T ₄	40.00 ^{ab}	2.00 ^b	3.67 ^c	29.67 ^c
LSD _{0.05}	3.61	0.29	1.02	8.41
CV%	4.73	6.01	9.74	8.01

In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2 kg Vermicompost and 2 kg soil per pocket; T₃- 1.5 kg Vermicompost, 0.5 kg coco fiber and 2 kg soil per pocket; T₄- 2 kg Kitchen compost and 2 kg soil per pocket.

The number of leaves per plant showed a similar response pattern (Table 6). T3 produced the highest leaf numbers (13.67, 34.00, and 26.67 leaves plant⁻¹ at 25, 50, and 75 DAT, respectively), while T1 had the fewest leaves (5.67, 14.67, and 9.00 leaves plant⁻¹). Increased leaf production under organic amendments has been reported for Malabar spinach and other leafy crops when compost and vermicompost are applied, leading to higher edible biomass and better nutritional quality (Liu et al., 2021; Islam et al., 2021).

The canopy size of Indian spinach was also significantly greater in T3 (19.83, 24.23, and 23.07 cm at 25, 50, and 75 DAT, respectively) than in T1 (7.37, 9.87, and 8.13 cm; Table 17). A larger canopy ensures greater light interception and higher photosynthetic capacity, directly contributing to yield. Organic amendments have been shown to increase canopy spread and fresh weight in leafy vegetables under low-input systems (Dahiya et al., 2023).

Table 6. Effect of different organic manures on plant height, leaf number, and canopy size of Indian spinach.

T	Plant height at different DAT (cm)			Number of leaves per plant at different DAT			Canopy size per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	6.17 ^d	18.50 _d	12.4 _{3 d}	5.67 _c	14.67 _d	9.00 ^d	7.37 _d	9.87 ^d	8.13 ^d
T ₂	10.67 _b	39.82 _b	26.3 _{3 b}	10.3 _{3 b}	28.67 _b	18.33 _b	14.9 _{7 b}	18.00 _b	16.40 _b
T ₃	14.33 _a	46.67 _a	31.5 _{0 a}	13.6 _{7 a}	34.00 _a	26.67 _a	19.8 _{3 a}	24.23 _a	23.07 _a
T ₄	8.52 ^c	25.33 _{0 c}	17.0 _{0 c}	8.67 _b	19.33 _c	11.67 _c	10.2 _{3 c}	12.43 _c	10.53 _c
LSD _{0.05}	1.05	3.41	4.34	1.91	4.27	2.62	1.97	2.54	1.55
CV%	5.27	5.24	9.97	9.99	8.84	8.01	7.55	7.89	5.34

T=Treatments; In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2kg Vermicompost and 2kg soil per pocket; T₃- 1.5kg Vermicompost, 0.5 kg coco fiber and 2kg soil per pocket; T₄- 2kg Kitchen compost and 2kg soil per pocket.

Leaf length and breadth were maximized in T3 and minimized in T1 (Table 7). Specifically, T3 exhibited leaf lengths of 12.33, 13.50, and 10.97 cm and leaf breadths of 9.13, 11.27, and 10.00 cm at 25, 50, and 75 DAT, respectively, while T1 consistently produced markedly smaller leaves. These findings align with studies on *Basella alba*, where organic amendments like compost and biochar increased leaf area and chlorophyll content, leading to higher yield and improved quality (Liu et al., 2021).

The number of branches per plant followed a similar pattern (Table 7), with T3 producing the highest number (3.67, 5.00, and 4.33 at 25, 50, and 75 DAT) and T1 the lowest (0.67, 1.33, and 1.00). Increased branching contributes to a greater number of leaf-bearing stems and, consequently, higher edible biomass. Similar increases in branching due to vermicompost and compost have been reported for leafy vegetables grown in homestead or rooftop gardens (Islam et al., 2021).

Table 7. Effect of different organic manures on the number of branches, leaf length, and breadth of Indian spinach.

T	Number of branches per plant at different DAT			Length of leaves per plant at different DAT (cm)			Breadth of leaves per plant at different DAT (cm)		
	25	50	75	25	50	75	25	50	75
T ₁	0.67 _d	1.33 ^a	1.00 ^c	5.77 _d	6.57 _d	5.33 _d	2.43 _d	3.20 _d	2.22 _d
T ₂	2.33 _b	3.67 ^b	2.67 ^b	10.6 _{0^b}	11.7 _{0^b}	9.67 _b	6.20 _b	7.47 _b	6.53 _b
T ₃	3.67 _a	5.00 ^a	4.33 ^a	12.3 _{3^a}	13.5 _{0^a}	10.9 _{7^a}	9.13 _a	11.2 _{7^a}	10.0 _{0^a}
T ₄	1.33 _c	2.67 ^c	1.33 ^c	7.43 _c	8.37 _c	7.33 _c	4.77 _c	6.03 _c	5.12 _c
LSD _{0.05}	0.37	0.48	0.39	1.51	1.78	1.29	0.83	1.29	1.22
CV%	9.48	7.66	8.39	8.36	8.87	7.80	7.37	9.25	10.2 ₂

T=Treatments; In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2kg Vermicompost and 2kg soil per pocket; T₃- 1.5kg Vermicompost, 0.5 kg coco fiber and 2kg soil per pocket; T₄- 2kg Kitchen compost and 2kg soil per pocket.

3.3.2 Yield of Indian spinach

Total fresh yield per plant of Indian spinach varied significantly among treatments (Table 8). T₃ produced the highest total yield (290.66 g plant⁻¹), followed by T₂ (213.00 g plant⁻¹) and T₄ (125.33 g plant⁻¹), while T₁ recorded the lowest yield (71.33 g plant⁻¹). The yield advantage of T₃ reflects its superior performance in plant height, leaf number, leaf size, branching, and canopy spread. These results are consistent with earlier studies demonstrating that compost and vermicompost derived from household organic wastes significantly increase plant height, leaf number, biomass, and yield in leafy vegetables grown in kitchen gardens and rooftop systems (Islam et al., 2021).

Table 8. Effect of different organic manures on the yield of Indian spinach.

Treatments	First yield per plant (g)	Second yield per plant (g)	Total yield (g)
T ₁	36.00 _d	35.33 _d	71.33 _d
T ₂	113.00 _b	100.00 _b	213.00 _b
T ₃	154.33 _a	136.33 _a	290.66 _a
T ₄	64.00 _c	61.33 _c	125.33 _c
LSD _{0.05}	21.64	16.26	28.63
CV%	11.80	9.78	8.18

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Where, T₁- Control; T₂- 2kg Vermicompost and 2kg soil per pocket; T₃- 1.5kg Vermicompost, 0.5 kg coco fiber and 2kg soil per pocket; T₄- 2kg Kitchen compost and 2kg soil per pocket.

4. Conclusions

The geotextile vertical farming system, which utilizes organic substrates, improved the growth and yield of mint, chili, and Indian spinach compared to soil alone. The vermicompost–coco fiber–soil mixture (T₃) consistently produced the most vigorous plants, exhibiting greater canopy development and fresh biomass than both the control and kitchen-compost treatments. These results suggest that combining nutrient-rich vermicompost with porous, moisture-retentive coco fiber creates a favorable root environment in confined vertical pockets, thereby enhancing nutrient and water uptake. Practically, vermicompost-based substrates—especially vermicompost combined with coco fiber—appear promising for productive, space-efficient vertical horticulture in urban Bangladesh. This approach could contribute to household food security while simultaneously recycling organic wastes. Future research should extend these findings across different seasons and locations, and evaluate substrate biology, nutrient dynamics, product quality, and economic returns under farmer-managed conditions.

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Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Any additional materials, including raw datasets and analysis codes, can be provided for non-commercial academic use subject to institutional policies.

Informed consent statement

Not applicable.

Conflict of interest

The authors declare that they have no competing interests. No author has any financial or personal relationships that could inappropriately influence or bias the content of this paper.

Authors' contribution

Conceptualization and experimental design: Anzuman Rahman Nitu and Abul Hasnat M Solaiman. **Field experimentation and data collection:** Anzuman Rahman Nitu, Sohel Rana Mazumder and Abul Hasnat M Solaiman. **Data curation, statistical analysis, and interpretation:** Abul Hasnat M Solaiman. **Drafting of the manuscript:** Anzuman Rahman Nitu and Sohel Rana Mazumder; **critical revision and editing:** all authors. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

References

- Acimović M and Miljković A, 2025. Systematic evaluation of rosemary essential oil in aromatherapy practice: A review. *Natural Product Communications*, 20(11): 1–14. <https://doi.org/10.1177/1934578X251399774>
- Adekiya AO, Agbede TM, Aboyeji CM, Dunsin O and Ugbe JO, 2019. Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Saudi Society of Agricultural Sciences*, 18(2): 218–223. <https://doi.org/10.1016/j.jssas.2017.05.005>
- Alam MJ, 2018. Rapid urbanization and changing land values in mega cities: Implications for housing development projects in Dhaka, Bangladesh. *Bandung: Journal of the Global South*, 5: 2. <https://doi.org/10.1186/s40728-018-0046-0>
- Alamgir M, Shahid S, Hazarika MK, Nashrullah S, Harun SB and Shamsudin S, 2015. Analysis of meteorological drought pattern during different climatic and cropping seasons in Bangladesh. *Journal of the American Water Resources Association*, 51(5): 1261–1279. <https://doi.org/10.1111/jawr.12276>
- Castellanos JZ, Cano-Rios P, García-Carrillo EM, Olalde-Portugal V, Preciado-Rangel P, Ríos-Plaza JL and García-Hernández JL, 2017. Hot pepper (*Capsicum annum* L.) growth, fruit yield, and quality using organic sources of nutrients. *Compost Science and*

- Utilization, 25: S70–S77. <https://doi.org/10.1080/1065657X.2017.1362673>
- Dahiya S, Rana MK, Khedwal RS and Chaudhary A, 2023. Significance of plant canopy maintenance in crop yield. *International Journal of Environment and Climate Change*, 13(8): 2265–2272. <https://doi.org/10.9734/ijec/2023/v13i82191>
- Dalim HM, Helal MGJ, Chowdhury MK, Rahman S, Mazumder SR, Hossain MI and others, 2026. Beyond mono fertilization: Mixed fertilization enhances productivity and quality of chili (*Capsicum frutescens*). *PLoS ONE*, 21(3): e0331538. <https://doi.org/10.1371/journal.pone.0331538>
- Despommier D, 2013. *The vertical farm: Feeding the world in the 21st century*. New York: Thomas Dunne Books.
- El-Mogy MM, Adly MA, Shahein MM, Hassan HA, Mahmoud SO and Abdeldaym EA, 2024. Integration of biochar with vermicompost and compost improves agro-physiological properties and nutritional quality of greenhouse sweet pepper. *Agronomy*, 14(11): 2603. <https://doi.org/10.3390/agronomy14112603>
- Gumble J, Berghage R and Stearns D, 2015. Production and financial analyses of the rotating living wall, an urban agricultural system. *Journal of Environmental Protection*, 6(9): 1029–1041. <https://doi.org/10.4236/jep.2015.69091>
- Hassan N, Solaiman AHM, Arefin A, Islam R and Hayder S, 2021. Efficacy of vermicompost and biochar on the growth and yield of green cabbage. *Asian-Australasian Journal of Bioscience and Biotechnology*, 6(2): 68–74. <https://doi.org/10.3329/aajbb.v6i2.56142>
- Hosseinzadeh SR, Amiri H and Ismaili A, 2018. Evaluation of photosynthesis, physiological, and biochemical responses of chickpea (*Cicer arietinum* L. cv. Pirouz) under water deficit stress and use of vermicompost fertilizer. *Journal of Integrative Agriculture*, 17(11): 2426–2437. [https://doi.org/10.1016/S2095-3119\(17\)61874-4](https://doi.org/10.1016/S2095-3119(17)61874-4)
- Islam R, Solaiman AHM, Kabir MH, Arefin SMA, Azad MOK, Siddique MH and others, 2021. Evaluation of lettuce growth, yield, and economic viability grown vertically on unutilized building wall in Dhaka City. *Frontiers in Sustainable Cities*, 3: 582431. <https://doi.org/10.3389/frsc.2021.582431>
- Kalantari F, Mohd Tahir O, Akbari Joni R and Fatemi E, 2018. Opportunities and challenges in sustainability of vertical farming: A review. *Journal of Landscape Ecology*, 11: 35–60. <https://doi.org/10.2478/jlecol-2018-0004>
- Kumar S, Singh R and Patel A, 2022. Vermicompost effect on soil and field crops: A review. *Pharma Innovation Journal*, 11(11): 2565–2569. <https://doi.org/10.22271/tpi.2022.v11.i11ae.17113>
- Kumar U, Rashid H, Tithi NH and Mia MY, 2019. Status of soil properties in relationship with soil pH in Madhupur tract of Tangail district in Bangladesh. *Progressive Agriculture*, 30(3): 282–287. <https://doi.org/10.3329/pa.v30i3.45153>
- Kumar V, Walia SS, Pal Kalra V, Kaur T, Gaber A, Alshehri MA and Hossain A, 2025. Organic manure combined with biofertilizer influences the growth, herb yield, oil content and soil health of Japanese Mentha (*Mentha arvensis* L.). *Journal of Plant Nutrition*, 48(16): 2796–2814. <https://doi.org/10.1080/01904167.2025.2499134>
- Liu C, Lu M, Cui J, Li B and Fang C, 2014. Effects of straw carbon input on carbon dynamics in agricultural soils: A meta-analysis. *Global Change Biology*, 20(5): 1366–1381. <https://doi.org/10.1111/gcb.12517>
- Mejía PA, Ruiz-Zubiate JL, Correa-Bustos A, López-López MJ and Salas-Sanjuán MD, 2022. Effects of vermicompost substrates and coconut fibers used against the background of various biofertilizers on the yields of *Cucumis melo* L. and *Solanum lycopersicum* L. *Horticulturae*, 8(5): 445. <https://doi.org/10.3390/horticulturae8050445>
- Shathy SN, Mazumder SR, Solaiman AHM, Arefin SMA, Tasnim Z and Chakma B, 2024. Influence of various growing media on growth and yield performance of potted pakchoi: A comparative analysis. *International Journal of Business and Social Science Research*, 12(2): 29–35. <https://doi.org/10.55706/ijbssr12121>
- Stewart DPC, Cameron KC and Cornforth IS, 2000. Release of sulphate, sulphur, potassium, calcium and magnesium from spent mushroom compost under field conditions. *Biology and Fertility of Soils*, 31(2): 128–133. <https://doi.org/10.1007/s003740050358>
- Suresh V, Fetricia JP and Saranya V, 2018. Effect of FYM, coirpith, vermicompost, humic acid and Panchagavya on growth and yield of mint (*Mentha arvensis*). *Horticulture International Journal*, 2(6): 417–419. <https://doi.org/10.15406/hij.2018.02.00088>
- Younis A, Ahsan M, Akram A, Lim KB, Zulfiqar F and Tariq U, 2022. Use of organic substrates in sustainable horticulture. In: *biostimulants for crop production and sustainable agriculture*. Wallingford: CAB International, pp. 122–138. <https://doi.org/10.1079/9781789248098.0009>

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