
Survival and growth of selected ornamental crops in different soilless growing media in an Outdoor Modular Green Wall System

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Cedillo, N. O., Sanchez Jr., F. C., Aguilar, E. A. and Pangga, G. V. (2026). Survival and growth of selected ornamental crops in different soilless growing media in an Outdoor Modular Green Wall System. *International Journal of Agricultural Technology* 22(5):2061-2080.

Abstract Soilless growing media composed of coconut coir dust and vermicompost (2:1), with or without the addition of vermiculite and coconut husk-enriched biochar, supported high survival rates across all ornamental species studied, ranging from 83% to 89%. Among the four species, Purple Heart (*Tradescantia pallida*) and Croton (*Codiaeum variegatum*) showed the highest suitability for vertical wall planting, with 96% and 67% survival rates, respectively. In contrast, survival was lowest in coconut coir dust alone (30%) and in commercial potting medium (24%). Combining coconut coir dust and vermiculite alone also resulted in a moderately low survival rate (63%). Growth parameters, including leaf count, leaf area, plant height, plant and root fresh and dry weights, canopy cover, and chlorophyll content, were generally improved in Mayana (*Coleus scutellarioides*), Croton (*Codiaeum variegatum*), Lantana (*Lantana camara*), and Purple Heart (*Tradescantia pallida*) by media treatments containing vermicompost, with or without vermiculite and biochar, indicating that these soilless combinations enhance plant performance.

Keywords: Croton, Living wall system, Purple heart, Vertical gardening

Introduction

Living walls, also known as green walls or vertical gardens, have become increasingly popular because of their aesthetic appeal, environmental benefits, and potential to improve indoor and outdoor air quality (Wesolowska and Laska, 2019). A living wall system is a form of green infrastructure where plants are cultivated vertically on walls or other upright surfaces, supported by different types of growing media and irrigation methods (Manso and Gomes, 2015; Perez *et al.*, 2014). While many plant types can be used in living walls, ornamental plants are often preferred for their attractive foliage, flowers, and coloration (Baran and Gultekin, 2017).

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The effectiveness of a living wall system largely relies on the conditions in which the plants are grown, especially the kind of growing media used. Soilless growing media, typically a mixture of peat moss, vermiculite, perlite, and/or other materials, have been found to be effective for growing plants in a living wall system (Manso and Gomes, 2015). The choice of soilless media can affect plant growth and performance, as well as the overall success of the living wall system (Manso and Gomes, 2015; Wang *et al.*, 2022).

This study aimed to assess the performance of selected ornamental plants grown in different soilless growing media within an outdoor modular green wall system. Specifically, it sought to identify the most suitable media for promoting each plant species' healthy growth and survival. The results are intended to inform the development of effective living wall systems and support the broader application of green infrastructure in urban settings.

Materials and methods

The experiment was conducted from February to July 2022 at the Ornamental Crops Nursery, Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños. It lasted five months and allowed comprehensive observation and data collection on the growth and performance of the four selected ornamental plant species under different soilless growing media treatments.

Plant materials

Four species of ornamental plants – Mayana (*Coleus scutellarioides* (L.) Benth.), Croton (*Codiaeum variegatum* (L.) Rumph. Ex A. Juss.), Lantana (*Lantana camara* L.), and Purple heart (*Tradescantia pallida* (Rose) D.R. Hunt) – were used for the experiment. The Museum of Natural History, University of the Philippines Los Baños, identified and verified these species. They are among the recommended plants for outdoor vertical gardening systems because they tolerate full sun, limited water, and limited nutrients.

To ensure uniformity of the initial planting materials, plant cuttings of these species were taken with specific measurements and leaf counts. In Mayana, 1-inch cuttings with three remaining leaves were used. For Croton, 4-inch cuttings with four remaining leaves were used. For Lantana, 1-inch cuttings with three remaining leaves were used, and for Purple Heart, 2-inch cuttings with two remaining leaves were used. All cuttings were initially propagated in a 1:1 mix of garden soil and coconut coir dust.

Croton propagation started one week earlier than the other plant species. This was because Croton takes longer to root, about four weeks. After the initial week, Mayana, Lantana, and Purple Heart cuttings were propagated and allowed to root for three weeks.

This timing strategy ensured all plant species were simultaneously ready to transplant into different soilless growing media treatments. After transplanting, the plants were established for a week before being placed on the outdoor vertical walls to prevent transplant shock.

Treatments

Six soilless growing media treatments were used in the experiment: T1 – Coconut coir dust (Control); T2 – Commercial Potting Medium (Ramgo); T3 – Coconut coir dust and vermicompost (2:1); T4 – Coconut coir dust and vermiculite (2:1); T5 – Coconut coir dust, vermicompost, and vermiculite (2:1:1); and T6 – Coconut coir dust, vermicompost, vermiculite, and coconut husk-enriched biochar (2:1:1:1). These coconut coir dust-based soilless media combinations were selected based on the results of an initial study conducted on the effects of various soilless media on the growth and quality of the ornamental foliage plant *Aglaonema commutatum* 'Siam Aurora'.

The coconut coir dust was treated to reduce its tannin content. It was soaked in water for two weeks, drained, and wrung out, then soaked in fresh water for another two weeks before being drained and wrung out again. After one month of soaking, the coir was sun-dried before being used as a growing medium.

Samples of each growing media component were submitted to the Central Analytical Service Laboratory at the National Institute of Molecular Biology and Biotechnology, University of the Philippines Los Baños, for NPK analysis.

Experimental setup

The experiment followed a Randomized Complete Block Design (RCBD) with six soilless growing media treatments and five replications per treatment, resulting in 30 experimental units (vertical walls). Individual vertical garden hanging pots measuring 11.8cm x 10.0cm x 9.3cm (L x W x H) were filled with the corresponding growing media treatment.

Each vertical wall measured 152.2cm x 92.0cm (L x W) and was established in an open field to expose the plants to natural outdoor conditions and sufficient direct sunlight (Figure 1). The 30 vertical walls were randomly arranged in the experimental area. Within each vertical wall, the four plant species, Mayana (*Coleus scutellarioides*), Croton (*Codiaeum variegatum*),

Lantana (*Lantana camara*), and Purple Heart (*Tradescantia pallida*), were randomly arranged by block per row (elevation), such that each species was represented in each block. Each vertical wall contained five sample plants per species. The vertical wall served as the experimental unit, with five vertical walls representing the five replications of each growing media treatment.



a



b



c

Figure 1. Experimental Setup of Vertical Garden Hanging Pots and Placement of Vertical Walls: (a) Front View, (b) Side View, and (c) Close-up View

Growing conditions

The plants were cultivated in an open field at the Ornamental Crops Nursery, Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños (Figure 1). The experimental site had an average peak light intensity of approximately 42,445 lux. Throughout the study, the total rainfall amounted to 762.4mm, with the rainiest months being April, June, and July, each with over 100mm of rainfall. Throughout the study period, the average relative humidity ranged from 79% to 85%. Using the Sunken Pan method, the evaporation rate ranged from 84.4mm to 145.7mm. The mean

temperature ranged from 26.5°C to 28.8°C. The environmental conditions at the experimental site were generally suitable for the plant species under investigation.

Management practices

Plants were watered daily with 100 mL of water per plant. Fertilizer was manually applied twice during the experiment: one month and three months after initial planting. A controlled-release fertilizer, specifically, Ramgo Nutricote (13+11+11+2MgO+TE), was used, with each plant receiving one teaspoon (equivalent to 5 grams) of fertilizer. Table 1 details the nutrient composition of Ramgo Nutricote.

Table 1. Guaranteed Analysis of the nutrient content of Ramgo Nutricote Controlled Release Fertilizer

Nutrient	Content (%)
Total Nitrogen (N)	13.0
Ammoniacal Nitrogen	6.5
Nitrate Nitrogen	6.5
Water Soluble Phosphates (P2O5)	11.0
Water Soluble Potash (K2O)	11.0
Water Soluble Magnesium (Mg)	2.0
1.2% Water Soluble Magnesium (Mg)	0.02
Water Soluble Boron (B)	Not more than 1%
Water Soluble Chlorine	0.05
Water Soluble Copper (Cu)	0.20
Chelated Iron (Fe)	0.06
Water Soluble Manganese (Mn)	0.02
Water Molybdenum (Mo)	0.015

Information Source: Data obtained from the Ramgo Nutricote Controlled Release Fertilizer bottle.

Sevin® WP 85 was applied twice throughout the study when insects appeared. A concentration of 60 tablespoons per 16 Liters was used, following the instructions on the packaging for ornamental crops.

Data gathered

Leaf count

Leaves were counted, including new leaf tips and sprouts. Data were gathered every month.

Leaf area

Leaf area was measured monthly using the mobile application ‘Petiole’ developed by Petiole LTD. This app was referenced in multiple research papers, including publications in *Frontiers in Plant Science*, *MDPI Plants*, *bioRxiv*, *European Journal of Forest Research*, *Environmental and Experimental Botany*, etc.

Plant height

Plant height was measured monthly with a ruler, from the base to the highest point of the plant.

Canopy cover

Canopy cover was assessed monthly using the mobile application ‘Canopeo’, developed by Oklahoma State University. This application quantifies the percentage canopy cover of live green vegetation based on downward-facing photos taken with a mobile device.

Survival rate

At the end of the 5-month growth period, the plants' survival status (alive or dead) was monitored. Survival data were recorded as binary outcomes (1 for alive, 0 for dead) and analyzed using logistic regression with a binomial distribution in R statistical software.

Plant fresh weight

Plant fresh weight was measured at the end of the experiment by weighing the plants immediately after removing the growing medium and surface moisture.

Plant dry weight

Plant dry weight was obtained by oven-drying the plants for 48 hours and weighing them. This accounted for the plants' high-water content.

Root fresh weight

Root fresh weight was measured at the end of the experiment by separating the roots from the plant tops, removing the growing medium, and weighing the roots immediately after removing surface moisture.

Root dry weight

Root dry weight was determined after oven-drying the roots for 48 hours before weighing, following the same procedure used for plant dry weight measurements.

Leaf tissue analysis

At the end of the experiment, leaves from each treatment were submitted for NPK analysis at the Central Analytical Service Laboratory, National Institute of Molecular Biology and Biotechnology, University of the Philippines Los Baños.

Chlorophyll content

Chlorophyll concentration was measured using a SPAD meter, which provides rapid, accurate, and non-destructive measurements of leaf chlorophyll content, often used to indicate chloroplast development, photosynthetic capacity, leaf nitrogen content, or general plant health.

Statistical analysis

All growth-related parameters, including leaf count, leaf area, plant height, canopy cover, fresh and dry weights (plant and root), and chlorophyll content, were subjected to Analysis of Variance (ANOVA) to determine significant differences among the six soilless growing media treatments. Where significant differences were detected, Tukey's Honestly Significant Difference (HSD) test was used for post hoc comparison of means at a 5% significance level.

Survival data, recorded as binary outcomes (alive or dead), were analyzed using logistic regression under a Generalized Linear Model (GLM) framework with a binomial distribution. Tukey's HSD was applied to the estimated marginal means from the logistic regression to determine treatment differences.

All statistical analyses were conducted separately for each plant species to account for species-specific responses to the growing media. Data analyses were performed using R statistical software.

Results

Meteorological data

Meteorological data were obtained from the National Agromet Station at the University of the Philippines Los Baños. Throughout the study, the total rainfall amounted to 762.4mm, with the rainiest months being April, June, and July, each with over 100mm of rainfall. Throughout the study period, the average relative humidity ranged from 79% to 85%. Using the Sunken Pan method, the evaporation rate ranged from 84.4mm to 145.7mm. The mean temperature ranged from 26.5°C to 28.8°C (Figure 2). The environmental conditions at the

experimental site were generally suitable for the plant species under investigation.

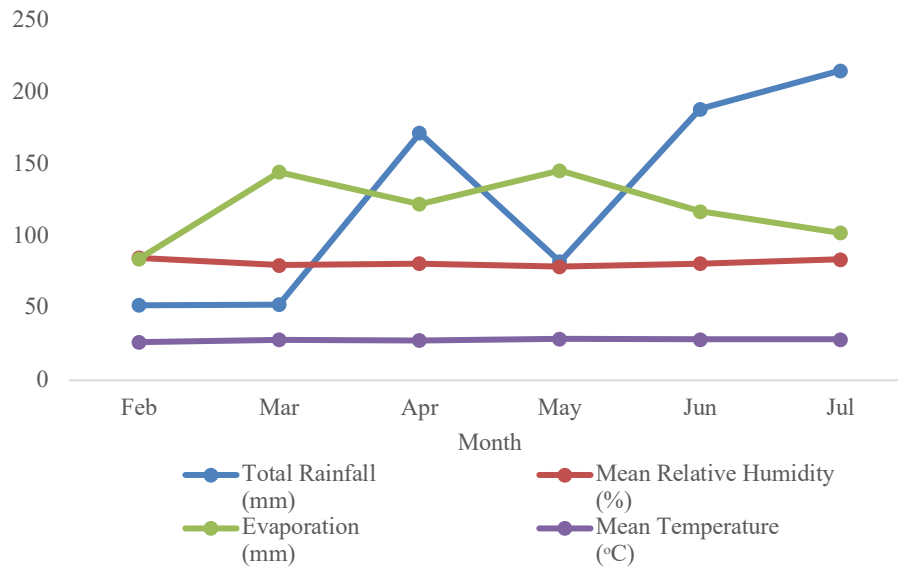


Figure 2. Meteorological data obtained from the National Agromet Station, University of the Philippines Los Baños, from February to July 2022
Evaporation data obtained through the Sunken Pan method.

Analysis of water nutrients

The irrigation water analysis showed low nitrate, phosphorus, and potassium (Table 2), suggesting that the irrigation water alone may not have supplied enough nutrients for the optimal growth of the ornamental crops examined in the study. The water's limited nutrient content highlights the need to supplement nutrients through the growing media.

Table 2. Nutrient Analysis of Irrigation Water

Sample	NO3 (ppm)	P (ppm)	K (ppm)
Water	0.036 ± 0.002	0.064 ± 0.002	11.99 ± 0.30

Nutrient analysis of media

The data represented the nutrient analysis results of the individual components of the different soilless growing media used in the study (Table 3). The data showed that the commercial soilless growing medium had relatively

low nitrogen content compared to biochar and vermicompost. Phosphorus content was moderately high, while potassium content was relatively low compared to biochar and vermiculite.

Table 3. Nutrient Analysis of Soilless Growing Media

Sample	%N (w/w)	P (ppm)	K (ppm)
Commercial	0.31 ± 0.01	1,924 ± 35	160.79 ± 4.78
Biochar	1.61 ± 0.09	1,524 ± 33	505.30 ± 32.77
Vermicompost	0.81 ± 0.01	28,534 ± 992	13.52 ± 0.54
Vermiculite	0.03 ± 0.00	ND	227.00 ± 1.81
Coconut coir dust	0.09 ± 0.01	35.07 ± 3.37	51.53 ± 0.96

Commercial – Ramgo Potting Medium (composed of coconut coir dust, burnt rice hull, and perlite); Biochar – Coconut husk-enriched biochar

Coconut husk-enriched biochar showed significantly higher nitrogen content than other growing media components. Phosphorus content was slightly lower than that of the commercial medium but still relatively high, and potassium content was significantly higher than that of the other growing media components. Vermicompost showed moderate nitrogen content, higher than the commercial medium but lower than biochar. The phosphorus content was exceptionally high, indicating a rich source of phosphorus. Potassium content was relatively low compared to the other media. Vermiculite showed the lowest nitrogen content among all the media. Phosphorus was not detected in this medium, suggesting it was not a significant source. The potassium content was relatively high compared to some media. Coconut coir dust showed a low nitrogen content, like vermiculite. The phosphorus content was relatively low compared to other media. The potassium content was also low compared to other media, but higher than vermicompost.

Survival rate

Among the soilless growing media combinations used, T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1); T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk-enriched biochar (2:1:1:1), and T3 – Coconut coir dust: Vermicompost (2:1) had the highest survival rates of 89%, 85%, and 83%, respectively, regardless of the ornamental species used. It was followed by T4 – Coconut coir dust: Vermiculite (2:1) with a 63% survival rate. The commercial potting medium (T2) had the lowest survival rate (24%), which did not differ statistically from the control treatment of Coconut coir dust alone (T1), with a 30% survival rate (Figure 3).

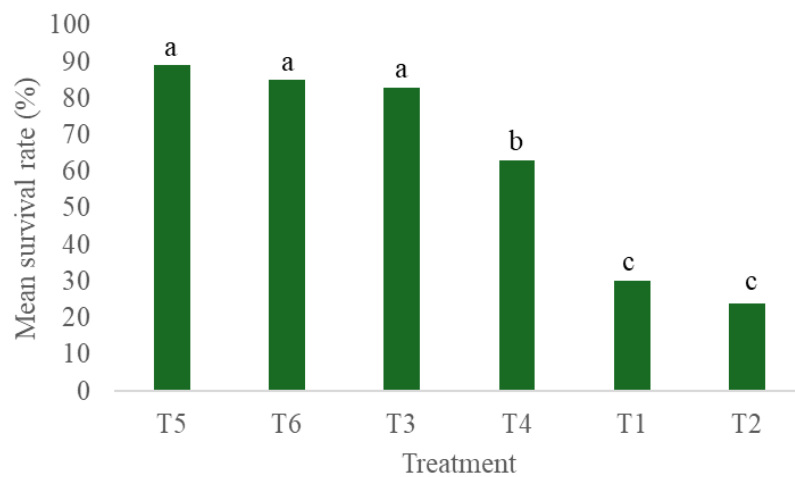


Figure 3. Mean survival rate across different soilless growing media combinations, regardless of ornamental crop species. Bars with the same letter are not significantly different at the 5% significance level, based on Tukey-adjusted comparisons following logistic regression (GLM with binomial family) T1 – Coconut coir dust (Control), T2 – Commercial potting medium, T3 – Coconut coir dust: Vermicompost (2:1), T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1) and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1)

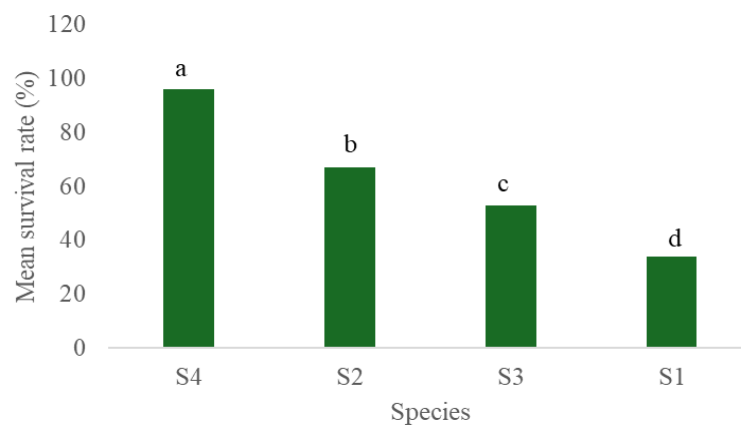


Figure 4. Mean survival rate across ornamental crop species, regardless of soilless growing media. Bars with the same letter are not significantly different at the 5% significance level, based on Tukey-adjusted comparisons following logistic regression (GLM with binomial family) S1 – Mayana (*Coleus scutellarioides*), S2 – Croton (*Codiaeum variegatum*), S3 – Lantana (*Lantana camara*), S4 – Purpleheart (*Tradescantia pallida*)

Purpleheart had the highest survival rate (96%), followed by Croton (67%), Lantana (53%), and Mayana, which had the lowest survival rate (34%), regardless of soilless growing media (Figure 4).

Growth parameters

Mayana (*Coleus scutellarioides*)

Mayana showed high mortality rates, with only a 34% survival rate regardless of soilless growing media, as shown in Figure 4. The irrespective of ornamental species, T1 – Coconut coir dust (Control), T2 – Commercial potting medium, and T4 – Coconut coir dust: Vermiculite (2:1) were the highest mortality rates, thus statistical analysis of the growth parameters was only compared for T3 – Coconut coir dust: Vermicompost (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) as also shown in Figure 3 and Table 4.

Table 4. Post Hoc Test Results using Tukey’s HSD for Leaf Area and Plant Dry Weight of Mayana

Treatment	Leaf Area	Plant Dry Weight (g)
T3	6.8b	19.2b
T5	7.4a	24.8a
T6	6.3c	20.6ab
p-value	<2e-16***	0.0145*

Note. Different letters denote significant differences among the treatments.

T1, T2, and T4 were excluded from the statistical analyses due to high mortality rates.

Growth parameters showed that leaf area and plant dry weight varied significantly across treatments. This suggested that the soilless growing media substantially affected leaf area and plant dry weight. Other parameters such as leaf count, plant height, plant canopy, plant fresh weight, root fresh weight, root dry weight, chlorophyll content, and number of flowers did not differ significantly. The post hoc analysis using Tukey's Honestly Significant Difference (HSD) test revealed that T5 had the highest leaf area and plant dry weight. On the other hand, T6 did not differ significantly from T5 in terms of plant dry weight (Table 4).

The leaf tissue analysis provided insights into the nutrient composition of Mayana plants in different soilless growing media. The analysis showed consistent nitrogen and phosphorus levels across treatments, with no substantial differences. However, potassium levels varied significantly, with T5 having the highest content, followed by T6 and T3 (Table 5). Therefore, the greater

availability of potassium in T5 may have contributed to increased leaf area and plant dry weight in Mayana plants.

Table 5. NPK Analysis of Mayana Leaf Tissue grown in different soilless growing media

Treatment	%N (w/w)	P (ppm)	K (ppm)
T3	1.82 ± 0.01	4763 ± 231	6552 ± 465
T5	1.62 ± 0.03	4865 ± 316	9118 ± 388
T6	1.71 ± 0.04	4829 ± 78	6819 ± 192

Note. Due to high mortality in T1, T2, and T4, insufficient leaf samples were available for NPK analysis. Consequently, NPK analysis was conducted only for T3, T5, and T6.

Croton (*Codiaeum variegatum*)

Croton showed moderately high mortality rates, with only a 67% survival rate regardless of soilless growing media (Figure 4). The irrespective of ornamental species, T1 – Coconut coir dust (Control), and T2 – Commercial potting medium was the highest mortality rates; thus, statistical analysis of the growth parameters was only compared for T3 – Coconut coir dust: Vermicompost (2:1), T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) (Figure 3, Table 6).

Table 6. Post Hoc Test Results using Tukey's HSD of Croton growth parameters in different soilless growing media treatments

Treatment	Leaf Count	Plant Height (cm)	Plant Fresh Weight (g)	Root Fresh Weight (g)	Root Dry Weight (g)	Plant Canopy (%)	Plant Dry Weight (g)	Chlorophyll
T3	168.6a	41.7a	81.7ab	73.2a	13.1a	0.6b	23.6b	40.4b
T4	110.7b	35.0b	63.5b	58.6b	10.7b	1.0ab	23.5b	42.2ab
T5	159.9a	41.2a	92.5a	73.1a	13.2a	1.2a	29.2a	41.2b
T6	157.2a	39.2ab	97.2a	69.2a	12.5ab	1.2a	30.2a	49.7a
p-value	0.00037 4 ***	0.0026 **	0.00084 2 ***	0.0019 7 **	0.0090 6 **	0.0011 4 **	7.34e-08 ***	0.007 **

Note. Different letters denote significant differences among the treatments.

T1 and T2 were excluded from the statistical analyses due to high mortality rates.

Statistical analysis revealed significant differences among the treatments for all growth parameters except leaf area (Table 6). The post hoc analysis using Tukey's Honestly Significant Difference (HSD) test revealed that Treatments T3 – Coconut coir dust: Vermicompost (2:1), T5 – Coconut coir dust:

Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) consistently resulted in significantly higher leaf count, plant height, plant fresh weight, root fresh weight, and root dry weight compared to Treatment T4 – Coconut coir dust: Vermiculite (2:1) (Table 6). These findings suggest that coconut coir dust and vermicompost, either alone (T3) or with vermiculite (T5) and coconut husk-enriched biochar (T6), positively influenced various aspects of Croton plant growth.

The different soilless growing media also significantly affected canopy size. Treatments T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk-enriched biochar (2:1:1:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T4 – Coconut coir dust: Vermiculite (2:1) resulted in larger plant canopies than T3 – Coconut coir dust: Vermicompost (2:1) ($p < 0.05$) (Table 6). This suggests that adding vermiculite and coconut husk-enriched biochar to the growing media increased foliage coverage and spread.

In contrast, including vermicompost, vermiculite, and coconut husk-enriched biochar in the growing media significantly affected Croton plant dry weight. Treatments T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) and T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1) showed significantly greater dry weight compared to treatments T3 – Coconut coir dust: Vermicompost (2:1) and T4 – Coconut coir dust: Vermiculite (2:1) ($p < 0.05$) (Table 6), indicating that the use of this soilless media combination led to a significant accumulation of dry biomass in the plants.

On the other hand, the combination of coconut coir dust and vermiculite, either alone (T4) or in conjunction with coconut husk-enriched biochar (T6), positively influenced chlorophyll synthesis and content in the leaves of Croton plants ($p < 0.05$) (Table 6).

Lantana (*Lantana camara*)

Lantana showed moderately high mortality rates, with only a 53% survival rate regardless of soilless growing media (Figure 4). Irrespective of ornamental species, T1 – Coconut coir dust (Control), and T2 – Commercial potting medium have the highest mortality rates; thus, statistical analysis of the growth parameters was only compared for T3 – Coconut coir dust: Vermicompost (2:1), T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) (Figure 3 and Table 7).

Growth parameters showed that only chlorophyll content varied significantly across treatments (Table 7). This suggested that the soilless growing media had a substantial effect on chlorophyll. Other parameters, such as leaf

count, plant height, plant canopy, plant fresh weight, plant dry weight, root fresh weight, root dry weight, and number of flowers, did not differ significantly.

The post hoc analysis using Tukey's HSD test revealed that T4 – Coconut coir dust: Vermiculite (2:1) had notably higher chlorophyll content compared to treatments T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T3 – Coconut coir dust: Vermicompost (2:1) ($p < 0.05$) (Table 7). These results indicate that combining coconut coir dust and vermiculite in the growing medium influenced chlorophyll synthesis and content in Lantana leaves.

Table 7. Post Hoc Test Results using Tukey's HSD for Chlorophyll Content of Lantana

Treatment	Chlorophyll
T3	36.6b
T4	40.4a
T5	37.7b
T6	37.9b
p-value	6.14e-05 ***

Note. Different letters denote significant differences among the treatments.

Table 8. Post Hoc Test Results using Tukey's HSD of Purple Heart growth parameters in different soilless growing media treatments

Treatment	Leaf Count	Plant Height (cm)	Plant Dry Weight (g)	Root Dry Weight (g)	Chlorophyll	Number of Flowers
T2	117.5a	22.5a	16.4ab	8.4ab	82.5a	10.2a
T3	75.5b	24.5a	14.5ab	5.6b	74.3ab	3.8b
T4	84.9b	16.1b	16.8a	7.9b	77.3ab	2.6b
T5	81.0b	22.9a	17.6a	7.1b	79.5ab	2.3b
T6	87.4b	22.2a	12.6b	11.3a	72.0b	3.3b
p-value	0.000142 ***	4.76e-05 ***	0.00614 **	0.000297 ***	<2e-16 ***	7.04e-16 ***

Note. Different letters denote significant differences among the treatments.

T1 was excluded from the statistical analysis of all parameters due to high mortality rates.

Purple Heart (*Tradescantia pallida*)

Purple Heart showed the lowest mortality rates, with a 96% survival rate regardless of soilless growing media (Figure 4). Irrespective of ornamental species, T1 – Coconut coir dust (Control) was among the highest mortality rates; thus, statistical analysis of the growth parameters was only compared for T2 – Commercial Potting Medium (Ramgo), T3 – Coconut coir dust: Vermicompost (2:1), T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust:

Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) (Figure 3 and Table 8).

The statistical analysis revealed varying levels of significance for growth parameters. Leaf count, plant height, plant dry weight, root dry weight, chlorophyll content, and number of flowers differed significantly among treatments (Table 8), indicating that the soilless growing media mixes influenced these growth parameters. In contrast, plant fresh weight and root fresh weight did not differ statistically.

The post hoc analysis using Tukey's Honestly Significant Difference (HSD) test revealed that T2 – Commercial Potting Medium (Ramgo) had a significantly higher leaf count compared to treatments T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1), T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T3 – Coconut coir dust: Vermicompost (2:1) ($p < 0.05$) (Table 8). It indicated that the Commercial Potting Medium (T2), composed of coconut coir dust, burnt rice hull, and perlite, promoted higher leaf production and development in Purple heart plants.

T2 – Commercial Potting Medium (Ramgo), along with T3 – Coconut coir dust: Vermicompost (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) showed significantly greater plant height as compared to T4 – Coconut coir dust: Vermiculite (2:1) ($p < 0.05$) (Table 8), indicating that the Commercial potting medium (T2) and the soilless growing media mixes with vermicompost alone (T3), or with added vermiculite (T5), and coconut husk enriched biochar (T6) influenced the vertical growth and stature of Purple heart plants.

T2 – Commercial Potting Medium (Ramgo) and T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), T4 – Coconut coir dust: Vermiculite (2:1), and T3 – Coconut coir dust: Vermicompost (2:1) showed significantly greater plant dry weight than T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) ($p < 0.05$) (Table 8). This suggests that Commercial potting medium (T2) and the soilless growing media mixes with either coconut coir dust and vermicompost alone (T3), vermiculite alone (T4), and the combination of all three components (T5) significantly affected dry biomass accumulation in the plants.

In terms of root dry weight, both T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) and T2 – Commercial Potting Medium (Ramgo) were significantly higher values as compared to T4 – Coconut coir dust: Vermiculite (2:1), T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), and T3 – Coconut coir dust: Vermicompost (2:1) ($p < 0.05$)

(Table 8), indicating that Commercial potting medium (T2) and the combinations of coconut coir dust, vermicompost, vermiculite, and coconut husk enriched biochar (T6) promoted greater accumulation of dry biomass in the roots of Purple heart plants.

T2 – Commercial Potting Medium (Ramgo), along with T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1), T4 – Coconut coir dust: Vermiculite (2:1), and T3 – Coconut coir dust: Vermicompost (2:1), exhibited significantly higher chlorophyll content compared to T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1) ($p < 0.05$) (Table 8). This finding indicates that Commercial potting medium (T2) and the soilless growing media mixes, specifically coconut coir dust and vermicompost (T3) or coconut coir dust and vermiculite (T4), or the combination of these three components (T5), played a role in the synthesis and content of chlorophyll in Purple heart plant leaves.

The number of flowers were significantly differed among the treatments, with T2 – Commercial Potting Medium (Ramgo) having a significantly higher number of flowers compared to treatments T3 – Coconut coir dust: Vermicompost (2:1), T6 – Coconut coir dust: Vermicompost: Vermiculite: Coconut husk enriched biochar (2:1:1:1), T4 – Coconut coir dust: Vermiculite (2:1), and T5 – Coconut coir dust: Vermicompost: Vermiculite (2:1:1) ($p < 0.05$) (Table 8). It indicated that the Commercial Potting Medium (T2) influenced Purple heart plants' flowering behavior and reproductive output.

Discussion

Results showed that Coconut coir dust alone (T1) and Commercial Potting Medium (T2) treatments showed very low survival rates of 30% and 24%, regardless of plant species. Purple Heart had the highest survival rate (96%) among the plant species used in the study, followed by Croton (67%). Purple Heart was an exceptionally resilient ornamental crop that can endure suboptimal and unfavorable conditions, including limited water and nutrients and inhibitory compounds such as tannins in coconut coir dust (Dewi *et al.*, 2020). Croton, on the other hand, is also highly adaptable, tolerates a wide range of soil types, and thrives in part shade with high drought tolerance (Black, 1997). Coconut coir dust is present in significant amounts in both the Coconut coir dust alone treatment (T1) and the Commercial potting medium (T2), which consisted of coconut coir dust mixed with small quantities of burnt rice hull and perlite. The packaging did not provide the specific proportions of components in T2. On the other hand, the soilless growing media combinations containing coconut coir dust, vermicompost, vermiculite, and coconut husk-enriched biochar (T3, T5,

and T6) demonstrated high survival rates of 83-89% regardless of plant species, except for the combination of coconut coir dust and vermiculite alone (T4), which showed a moderately low survival rate of 63%.

Different crop species respond differently to varying combinations of soilless growing media. However, most growth parameters in Mayana, Croton, Lantana, and Purple Heart showed a positive effect from the soilless growing media combinations of coconut coir dust and vermicompost, either alone (T3) or with added vermiculite (T5) and coconut husk-enriched biochar (T6).

The soilless growing media combinations of coconut coir dust and vermicompost, alone or with vermiculite and coconut husk-enriched biochar, provided a unique environment promoting plant growth. Coconut coir dust retains moisture effectively, ensuring a steady water supply for plant roots (Prasad, 1997; Patricia *et al.*, 1997). Vermiculite and coconut husk-enriched biochar increase the porosity of the growing media, enhancing water retention and facilitating root respiration through improved aeration (Lehmann, 2007; Indrasumunar and Gresshoff, 2013).

Combining coconut coir dust, vermicompost, vermiculite, and coconut husk-enriched biochar may have improved drainage by maintaining a well-structured growing medium with sufficient pore space. Organic matter in coconut coir dust and vermicompost acted as a nutrient reservoir, slowly releasing essential nutrients for plant uptake (Ramnarain *et al.*, 2019; Asiah *et al.*, 2004). Vermiculite and coconut husk-enriched biochar prevented nutrient leaching and prolonged nutrient availability (Haraz *et al.*, 2020).

Coconut coir dust and vermicompost have a natural pH close to neutral, buffering the growing media against pH fluctuations and optimizing nutrient uptake by plant roots (Evans *et al.*, 1996; Ramnarain *et al.*, 2019). Vermicompost and coconut husk-enriched biochar introduced beneficial microorganisms to the growing media, supporting nutrient cycling, organic matter decomposition, and pathogen suppression. These microorganisms fostered a favorable soil ecosystem that promoted plant growth (Sinha *et al.*, 2011; Chauhan and Singh, 2015; Ramnarain *et al.*, 2019; Asiah *et al.*, 2004).

The positive effect on the growth parameters observed in these soilless growing media combinations is attributed to the physical characteristics of each component, such as water and nutrient retention capacity. These characteristics ensure a consistent supply of essential resources for healthy plant growth. The well-structured growing media facilitated root development by allowing easy root penetration, oxygen access, and the establishment of a robust root system for enhanced nutrient uptake and overall plant vigor.

Beneficial microorganisms in vermicompost and coconut husk-enriched biochar further improved nutrient availability and suppressed harmful pathogens,

enhancing plant health (Sinha *et al.* 2011; Chauhan and Singh 2015; Ramnarain *et al.*, 2019; Asiah *et al.*, 2004). The pH buffering capacity of coconut coir dust and vermicompost maintained optimal pH levels, preventing nutrient deficiencies or toxicities that could hinder plant growth (Evans *et al.*, 1996; Ramnarain *et al.*, 2019).

In summary, combining coconut coir dust, vermicompost, vermiculite, and coconut husk-enriched biochar in the soilless growing media created a balanced and favorable environment for plant growth. These components' physical and chemical properties worked synergistically to provide adequate moisture, aeration, drainage, nutrients, and beneficial microbial interactions. Among the ornamental species tested, Purple Heart and Croton proved most suitable for vertical planting.

Acknowledgements

The authors thank the University of the Philippines Los Baños (UPLB) for funding support, and the Crop Production and Management and Postharvest and Seed Sciences Divisions of the Institute of Crop Science, College of Agriculture and Food Science, UPLB, for providing access to facilities and resources. The authors are also grateful to Mr. Michael D. Barotea for assistance with setting up and conducting the experiment, and to Mr. Joseph Nyl B. Milante and Mr. Nilo Quillooy for helping construct the vertical walls.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 4 May 2025, Revised: 10 September 2026, Accepted: 13 September 2026)