Research Article

Effect of Various Growing Substrates on Growth and Development of Ponytail Palm (*Beaucarnea recurvata* Lem.)

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Abstract | The ponytail palm (*Beaucarnea recurvata* Lem.) is a member of the asparagaceae family and is used as an indoor and outdoor ornamental plant. In horticulture, using sustainable growing substrates is an appropriate method of environmental management and provides nutrients to the plants. The goal of this study was to use plant-based substrates as growing mediums for ponytail palm production. The research was conducted at Lalazar Nursery, Gardening Wing Estate Management, University of Agriculture, Faisalabad. There were eight treatments and each treatment was replicated three times, with three plants each. Different plant-based materials, including leaf compost, coco peat, and peat moss was used to ensure the quality growth and development of the ponytail palm. The experiment was arranged according to a completely randomized design (CRD). The collected data was analyzed using the Fisher's analysis of variance technique, and treatment means were compared using Tukey's test at a 5% probability level. The results regarding maximum plant height (86.05 cm), number of leaves per plant (58.33), leaf length (100.70 cm), leaf width (0.97 cm), fresh leaf weight (0.91 g), leaf total chlorophyll content (136.40 SPAD), photosynthetic rate (118.33 µmol m^2s^{-1}), transpiration rate (0.33 mmol m^2s^{-1}), epidermal cell area (1.00 $µm^2$), metaxylem cell area (0.45 $µm^2$), cortical thickness (7.50 µm) and xylem thickness (7.40 µm) were recorded in T_5 coco peat 50% + leaf compost 50% and T_6 peat moss 50% + leaf compost 50% showed maximum dry leaf weight (0.09 g). Maximum EC (5.3 dS/m), pH (8.5), N (2.1 %), P (43.3 ppm), and K (285.12 ppm) were observed in T_4 coco peat 50% + peat moss 50%. Minimum values regarding most parameters were studied in the control treatment (garden soil) due to poor chemical properties and the low availability of nutrients.

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Introduction

The Ponytail Palm, scientifically known as *Beaucarnea recurvata*, is a distinctive and fascinating plant that belongs to the Asparagaceae family. Despite its common name, it is not a true palm but rather a member of the Agave subfamily. Native to arid regions of Mexico, the Ponytail Palm has become a popular ornamental plant in many parts of the world due to its unique appearance, low maintenance requirements, and resilience (Youssef, 2014). Ponytail palm grows well in a range of soil conditions, whether in direct sunlight or slight shade. Plants need appropriate drainage because untreated soil makes their roots more susceptible to decay. Plants should be put outside gradually from indoors so they can get used to the change in temperature and light (Kawy *et al*., 2018). *Beaucarnea recurvata* is great for city gardens, beds and borders, rock gardens, Mediterranean gardens, or succulent gardens. It is ideal as an accent plant in decorative containers or dry forest-free areas (Walker, 2015).

Because of problems with drainage, insufficient aeration, and the presence of weed seeds, insects, and disease-carrying organisms, among other things, it is not advised to use regular soil as a substrate for containerized plant cultivation (Hussain *et al*., 2017). In the garden soil, plants will grow consistently, but after a few times, their leaves will start to turn yellow. This problem arises because of insufficient aeration and poor drainage. Furthermore, garden soil or silt contains many weeds and promotes soil-borne disease infestation. Second, the natural soil's texture and structure (particle size) provide a problem (Jacob *et al*., 2009). To enhance the growth of floricultural crops, both the provision of adequate growing media and the availability of nutrients are necessary. The plants grow well in a medium that is porous for root aeration and drainage and also performs the functions of water and nutrient retention. Recycling organic agricultural waste is an effective approach to environmental management (Chavada *et al*., 2017; Abad *et al*., 2002).

Peat moss is a good container substrate for greenhouse development due to its ideal physical properties of delayed decomposition, high water holding capacity, low bulk density, and high nutrient exchange capacity (Peng *et al*., 2018). Peat moss is an important organic material for the production of growth substrate, and it is the most extensively used substrate for the production of ornamental plants in nurseries, accounting for a large amount of the material used to produce ornamental plants (Khayyat *et al*., 2007). Previously study reported that peat moss is being used as a basic growing substrate for the development of ornamental plants and significantly increased the fresh and dry weight of foliage and higher number of roots was attained in growth substrates with peat moss (Altaf *et al*., 2021). The most common growth substrate for container plant production of perennial and annual ornamental plants is peat moss (Tariq *et al*., 2012).

Coconut husk, the main ingredient of coco peat, is known by the names coir fiber, coir fiber pith, coir dust, and simply coir (Razali *et al*., 2020). In order to grow horticulture crops, land is being used more frequently for infrastructure development, which reduces the availability of excellent-quality topsoil. Coconut husks are used to make coco coir, a typical soilless substrate in different regions (Norhasnan *et al*., 2021). It is advantageous as a media component due to its electrical conductivity, adequate pH, being more physically resistant, cation exchange capacity, slower decomposition, easier wetability, drainage, and other chemical properties. The unfavorable water-air interaction is caused by its high water retention capacity (Mariotti *et al*., 2020).

Leaf compost has been shown to be an effective alternative for rich carbohydrate substrates. They are renewable, abundant, cost-effective, and help solve pollution problems (Sarita *et al*., 2019; Chen and He, 2012). Organic matter has been demonstrated to improve aggregate stability, water drainage, water holding capacity, water infiltration, wind and water erosion resistance (Tejada *et al*., 2006). Because it serves as a natural source of nutrients, leaf compost is an important part of the growing medium for ornamental plants. Compost can provide a sufficient quantity of phosphate, potash, and minor components in the growing media, but in other cases, it is necessary to add more natural manure to the growing media, like bone meal, grass sand, or rock phosphate (Cheng *et al*., 2019).

Keeping in view the increasing market demand and significance of ornamental plants, a study was conducted to optimize substrate for plant production to diversify ornamental commodities in Pakistani markets for the promotion of the ornamental industry in

the country. The main purpose of this study was to evaluate soilless media as growing substrates for ponytail palm production to determine their effect on growth and development, as well as provide growers and nurserymen with low-cost, sufficient, and environment friendly alternatives to other expensive substrates. Peat moss, coco coir, and leaf compost were used as substrates in various ratios in this experiment. It was hypothesized that introducing these local substrates can enhance the growth and development of healthy plants that can be produced by growing on these substrates.

Materials and Methods

The present investigation was carried out at Lalazar Nursery Area, Gardening Wing Estate Management, University of Agriculture, Faisalabad which is located at 31° 25' 7.3740" N and 73° 4' 44.7924" E Faisalabad, Pakistan to evaluate the growth and quality performance of the Beaucarnea plant in soilless substrates. Plants were arranged from the well-reputed nursery of Faisalabad. Four different growing media, including soil, peat moss, coco peat, and leaf compost, were used as growing media for the quality growth of potted plants. There were total eight treatments, and each treatment was replicated three times, with three plants per replication. These growing substrates were manually filled in earthen pots (9 inches' diameter). The pots were arranged in a complete randomized design (CRD). Plants were placed under shade in a green house. Physiological parameters were measured from a single fully expanded leaf of each plant with the help of an IRGA meter (LCi-SD) for better observations. Analysis of all growth media in combination was also done for pH, EC, available nitrogen, phosphorous, and potassium at the Soil and Water Testing Laboratory District, Multan. The pH was measured using a digital ion analyzer meter. It was arranged by the Postharvest Lab, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. Electrical conductivity was measured with a conductivity meter, total nitrogen % by Kjeldahl's method following Chapman and Parker (1961), and accessible phosphorus (mg/L) by (Olsen *et al.*,1984). At 880 mU, the final reading was measured using a spectrophotometer. The available potassium (ppm) was measured using the flame photometric method with the equation, as per the methodology published by USS the Laboratory staff (1954).

Meq/1 of K = Meq/1 along with 50 mL sample × calibration curve

The treatments used in this study were as follows.

Treatment	Substrates
T_0	soil (control)
T_1	peat moss
T_2	coco peat
T_3	leaf compost
T_4	coco peat 50% + peat moss 50%
T_5	coco peat 50% + leaf compost 50%
T_6	peat moss 50% + leaf compost 50%
T_7	coco peat 33% + peat moss 33% + leaf compost 33%

Methodology of root anatomy

Root samples of ponytail palm were collected from each treatment; roots were preserved in 70% alcohol for analysis. The anatomical characteristics of ponytail palm roots were examined by following steps i.e., preservation of materials, sectioning of samples and staining by using standard procedure (Berhin *et al.*, 2019).

The statistical analysis of the generated data was analyzed by the use of software Statistix 8.1. Fisher's analysis of variance (ANOVA) technique and treatment means were compared using the Tukey's test at 5 percent probability level (Steel *et al.*, 1997).

Results and Discussion

Physio-Chemical Analysis

The physio-chemical analysis of growth substrate formulations revealed that coco peat 50% + peat moss 50% exhibited superior physio-chemical properties and provided the maximum amount of available plant nutrients compared to untreated plants. It is evident from (Table 1**)** that the lowest values of nutrients i.e., N (0.49 %), P (5.2 ppm), K (50 ppm) and the highest pH (8.5) and EC (3.77 dS/m) value were observed in control treatment (Garden soil). Minimum values of the nutrients regarding most parameters were studied in the control treatment due to poor chemical properties and the low availability of nutrients.

Morphological Parameters

Data regarding morphological parameters due to the effect of peat moss, coco peat, and leaf compost on ponytail palm was analyzed and is presented in (Table 2). It is evident from the results that T_5 (Coco Peat 50% + Leaf Compost 50%) has shown the maximum

plant height (86.05 cm), number of leaves per plant (58.33), leaf length (100.70 cm), leaf width (0.97 cm), fresh leaf weight (0.91 g), and dry leaf weight (0.09 g). Furthermore, the maximum dry leaf weight recorded in T_6 (peat moss 50% + leaf compost 50%) was 0.91 g. Results revealed that various levels of growing media affected ponytail palm, while the untreated control showed the lowest result among all treatments.

Table 1: *Physio-chemical Properties report of Growing Media.*

Growing media	EC (dS/m)	pH	N (%)	P (pmm)	K (pmm)
Garden Soil	3.77	8.5	0.49	5.2	50
Peat Moss	2.2	7.1	1.79	28	216
Cocopeat	1.9	7	0.39	7	68
Leaf Compost	2.2	6.8	1.27	30	213
Coco Peat 50% + Peat Moss 50%	2.8	6.9	2.17	23.4	285.12
Coco Peat 50% + Leaf Compost 50%	2.6	6.53	0.55	26.38	281.6
Peat Moss 50% + Leaf Compost 50%	2.1	7.2	0.69	43.3	250
Coco Peat 33% + Peat Moss 33% + Leaf Compost 33%	2.3	7.6	1.87	34.1	210

Source: *Soil and water testing laboratory district, Multan. Physio-Chemical Analysis.*

Physiological Parameters

The results statistically analyzed the mean values for different growing substrate treatments, as shown in Figures 1, 2 and 3. The results indicated that there was a significant difference among the mean values. It is shown that treatment T_5 with coco peat 50% + leaf compost 50% restrained all other treatments and has maximum chlorophyll content (136.40 SPAD), photosynthetic rate (118.33 mol $m^{-2}s^{-1}$), transpiration rate (0.33 mmol $m^{-2}s^{-1}$). The results predicted that various levels of growth substrates affected ponytail palm, with the untreated control showing the lowest result among all treatments.

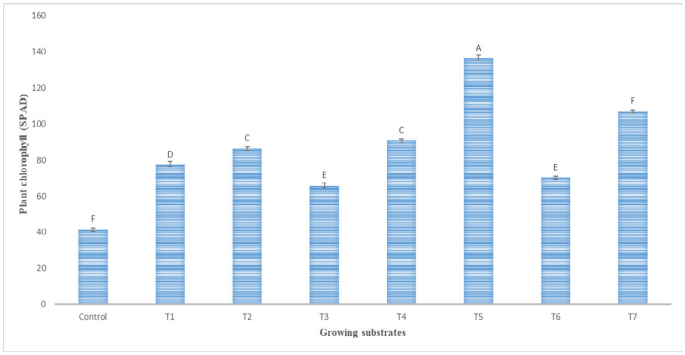

Figure 1: *Effect of various growth substrates on the chlorophyll content (SPAD) (nmol/cm) on Ponytail palm (Beaucarnea recuravata).*
T_0 (control), T_1 (peat moss), T_2 (coco peat), T_3 (leaf compost), T_4 (coco peat 50% + peat moss 50%), T_5 (coco peat 50% + leaf compost 50%), T_6 (peat moss 50% + leaf compost 50%), T_7 (coco peat 33% + peat moss 33% + leaf compost 33%). Error bars reflect the statistical significance at $P < 0.05$).

Table 2: *The effect of different growing substrates on morphological parameters of Ponytail palm (Beaucarnea recurvata).*

Treatment	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	Fresh leaf weight (g)	Dry leaf weight (g)
T_0 = control	55.31 ±1.25 G	34.00 ±0.33 G	26.22 ±0.70 H	0.25 +0.00 F	0.63 ±0.00 D	0.01 ±0.000 F
T_1 = peat moss	59.73 ±1.57 FG	37.66 ±0.88 FG	43.70 ±1.13 G	0.55 +0.01 C	0.82 ±0.01 BC	0.07 +0.001 C
T_2 = coco peat	77.17 ±1.54 BC	45.33 ±0.88 DE	67.52 ±1.09 F	0.16 + 0.01 G	0.86 ±0.01 AB	0.04 +0.002 E
T_3 = leaf compost	68.45 ±0.69 DE	51.66 ±0.88 BC	72.92 ±0.65 E	0.39 +0.01 D	0.76 ±0.00 C	0.08 +0.001 BC
T_4 = coco peat 50% + peat moss 50%	72.81 ±1.44 CD	48.33 ±0.88 CD	82.46 ±1.05 D	0.34 +0.00 DE	0.83 ±0.01 BC	0.05 +0.002 D
T_5 = coco peat 50% + leaf compost 50%	86.05 ±0.87 A	58.33 ±0.88 A	100.70 ±1.14 A	0.97 +0.01 A	0.91 ±0.02 A	0.08 +0.001 BC
T_6 = peat moss 50% + leaf compost 50%	81.53 ±1.38 AB	41.33 ±0.88 EF	88.08 ±0.61 C	0.67 +0.02 B	0.87 ±0.02 AB	0.09 +0.002 A
T_7 = coco peat 33% + peat moss 33% + leaf compost 33%	64.09 ±0.77 EF	54.66 ±0.88 AB	94.39 ±1.37 B	0.28 +0.01 EF	0.54 ±0.00 E	0.08 +0.002 AB

Means sharing the same case letter, for a parameter did not differ significantly at $P \leq 0.05$.

Table 3: *The effect of different growing substrates on anatomical parameters of Ponytail palm (Beaucarnea recurvata).*

Treatment	Epidermal cell area (µm²)	Metaxylem cell area (µm²)	Cortical thickness (µm)	Xylem thickness (µm)
T_0 = control	0.50 ±0.03 C	0.31 ±0.003 E	4.56 ±0.02 E	6.60 ±0.03 D
T_1 = peat moss	0.63 ±0.03 BC	0.34 ±0.003 D	6.06 ±0.08 C	7.13 ±0.03 B
T_2 = coco peat	0.66 ±0.03 B	0.36 ±0.005 CD	5.30 ±0.05 D	6.83 ±0.03 C
T_3 = leaf compost	0.30 ±0.05 D	0.38±0.005 C	6.63 ±0.08 BC	6.30 ±0.05 E
T_4 = coco peat 50% + peat moss 50%	0.63 ±0.03 BC	0.42±0.005 B	6.20 ±0.05 C	7.20 ±0.05 AB
T_5 = coco peat 50% + leaf compost 50%	1.00 ±0.05 A	0.45 ±0.003 A	7.50 ±0.05 A	7.40 ±0.05 A
T_6 = peat moss 50% + leaf compost 50%	0.50 ±0.05 BC	0.44 ±0.003 AB	6.50 ±0.05 BC	7.23 ±0.03 AB
T_7 = coco peat 33% +peat moss 33% + leaf compost 33%	0.30 ±0.05 D	0.42 ±0.005 B	6.80 ±0.05 B	6.76 ±0.03 CD

Means sharing the same case letter, for a parameter did not differ significantly at P ≤ 0.05.

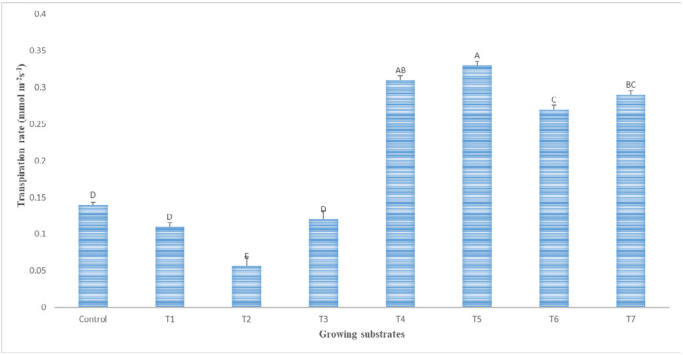

Figure 2: *Effect of various growth substrates on the transpiration rate (mmol $m^{-2}s^{-1}$) of Ponytail palm (Beaucarnea recuravata).*
T_0 (control), T_1 (peat moss), T_2 (coco peat), T_3 (leaf compost), T_4 (coco peat 50% + peat moss 50%), T_5 (coco peat 50% + leaf compost 50%), T_6 (peat moss 50% + leaf compost 50%), T_7 (coco peat 33% + peat moss 33% + leaf compost 33%). Error bars reflect the statistical significance at P < 0.05).

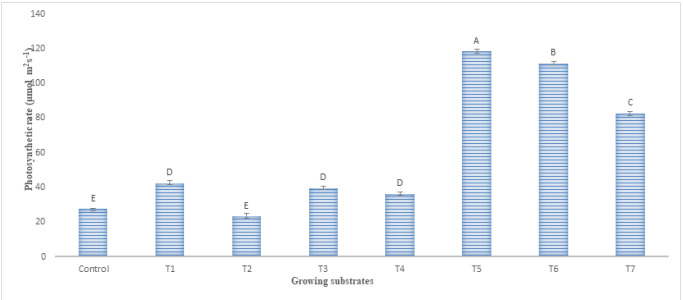

Figure 3: *Effect of various growth substrates on the photosynthetic rate (µmol m^2s^{-1}) of Ponytail palm (Beaucarnea recuravata).*
T_0 (control), T_1 (peat moss), T_2 (coco peat), T_3 (leaf compost), T_4 (coco peat 50% + peat moss 50%), T_5 (coco peat 50% + leaf compost 50%), T_6 (peat moss 50% + leaf compost 50%), T_7 (coco peat 33% + peat moss 33% + leaf compost 33%) . Error bars reflect the statistical significance at P < 0.05).

Root Anatomical Parameters

The data regarding root anatomical parameters due to the effect of peat moss, coco peat, and leaf compost on ponytail palm was analyzed and is presented in Table 3 and graphically presented in Figure 4. It is evident from the results that T_5 coco peat 50% + leaf compost 50% has maximum epidermal cell area (1.00 µm²), metaxylem cell area (0.45 µm²), cortical thickness (7.50 µm), xylem thickness (7.40 µm). Results envisaged that various levels of growing media affected ponytail palm, while the untreated control showed the lowest result among all treatments.

Physio-Chemical Analysis

In order to provide plants with the best possible growing conditions, it is crucial to understand and control the physiochemical characteristics of the potting medium. Researchers can promote healthy plant growth and obtain optimal yields by selecting media with appropriate properties and ensuring adequate management methods. The study reveals that nutrient-rich substrates bolstered the vegetative growth and quality traits of the plant under observation, aligning with earlier discoveries (Grassotti *et al.*, 2003). Another study observed that the organic amendment in the potting mixture increases the number of branches and enhances plant growth. Given the tight connection between nutrient intake and leaf count, media application may alter the number of leaves (Chitakunye *et al.*, 2023). A similar study found that the use of compost in the field synergistically increased soil organic matter (SOM), nutrient content, soil water holding capacity, and nutrient mobilization (Liu *et al.*, 2012). Previous study reported that, more leaf area and leaf area index due to more potassium present in leaf compost media that helps plants use water and resist drought (Farag and Zahran, 2014).

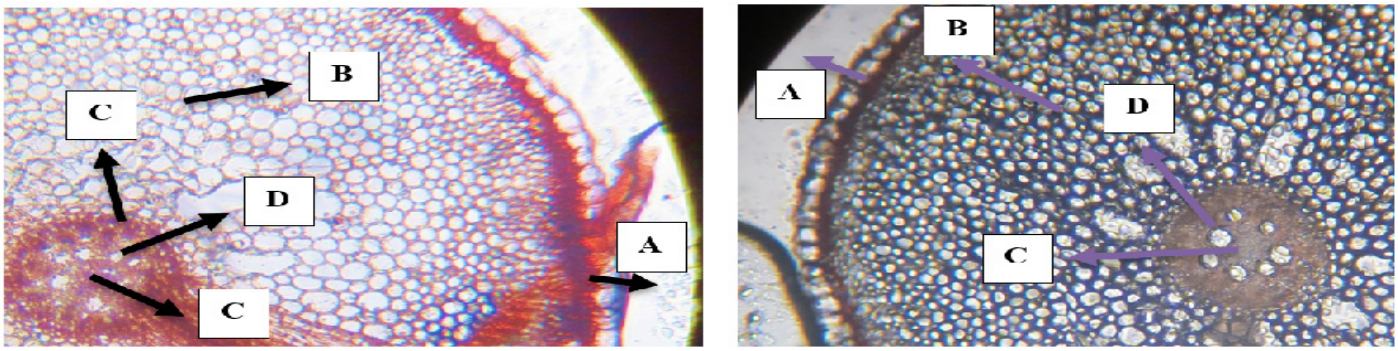

Figure 4: *Root Anatomical attributes of Ponytail palm.*
A *(Epidermal cell area µm²),* **B** *(Cortical thickness µm),* **C** *(Xylem thickness µm),* **D** *(Metaxylem cell area µm²).*

Morphological Parameters

The highest values of different morphological parameters were obtained by the T_5 treatment (Coco peat 50% + Leaf compost 50%) because both coco peat and leaf compost enhanced the nutrients availability and improve the growth of the plants. Coco peat has excellent water retention properties, ensuring that plants have access to moisture even during dry periods. It also helps to aerate the soil, prevent compaction, and promote root growth. According to a study, coco peat + leaf compost showed the maximum plant height, number of leaves per plant, root length, number of flowers, and flower diameter in stock (*Matthiola incana*) and geranium (*Pelargonium spp*) (Altaf *et al*., 2021). According to another study, under the influence of phosphorus regarding leaf area, number of leaves, and plant height, leaf compost was the most effective growing substrate in cyalamen plants (Inamoto *et al*., 2011). Lojo *et al*. (2019) conducted a similar study to determine the maximum growth of Impatiens in peat due to its favorable chemical properties, such as its high cation exchange capacity and its impact on leaf area. The results align with the findings of Zhang *et al*. (2012), who obtained significant results regarding fresh leaf weight in tomato and cucumber seedlings grown in coco peat. Therefore, it can assert that coco peat contributes organic matter and structure to the soil, thereby enhancing its structure and supplying essential nutrients (Treder, 2008). This article's findings cope with the findings of Naggar and Nasharty (2009), in which significant results regarding dry weight in *Hippeastrum vittatum* were obtained in sand and composted leaves.

Physio-Anatomical Parameters

The T_5 treatment (Coco peat 50% + Leaf compost 50%) achieved the highest values of different physiological parameters due to their natural pH buffering capacity, which can help stabilize soil pH levels. This is beneficial for plants, as it ensures that the pH remains within the optimal range for nutrient uptake and overall growth. These results are consistent with Warren *et al*. (2011) study, which examined the relationship between photosynthetic rates and leaf temperature. Numerous studies have reported a positive impact on the photosynthetic rate. An increase in photosynthetic rate might be due to higher chlorophyll contents, as photosynthesis depends on the chlorophyll contents of plants. Ahmad *et al*. (2018) conclude that chlorophyll facilitates photosynthesis, a crucial mechanism of plant physiology. Another study found that leaf compost greatly enhanced the water holding capacity of the media and improved the stomatal conductance, transpiration rate, leaf total chlorophyll contents and photosynthetic rate of geranium (*Pelargonium* spp) plants grown in pots (Altaf *et al*., 2021). According to Bolan *et al*. (2012), transpiration rate increases moisture level and total dry matter, which primarily drive the final plant's productivity and the plant's relationship with the environment. The highest values of different anatomical parameters were obtained by the T_5 treatment, in which (Coco peat 50% + Leaf compost 50%, because the presence of leaf and coconut coir in the growing medium can promote longer and denser root systems. These materials provide a favorable environment for root penetration and branching due to their fibrous structure, which offers physical support and facilitates root growth into the surrounding of soilless media (Riaz *et al*., 2008). Previous literature reported that soilless substrates significantly increased the vessels per bundle, the thickness of the lamina and its constituent tissues (upper and lower epidermis and mesophyll tissue), the length and width of the main vascular bundle, and the thickness of the phloem and xylem tissues in strawberry plants (Wanas and Khamis, 2021).

Conclusion and Recommendations

The effective evaluation of the aims of this research study can be concluded. The growth substrate mixture, including the combined effects of coco peat and leaf compost, showed the best results in comparison with all other growth substrates. Thus, the use of coco peat 50% + leaf compost 50% is suggested as an excellent soilless substrate for better growth and visual appearance of Ponytail palm (*Beaucarnea recurvate* Lem.). Further research can conclude an up-scaled composting experiment with larger compost pile volumes at the field trial for better growth of ornamental plants.

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Novelty Statement

The use of coco peat 50% + leaf compost 50% is suggested as an excellent soilless substrate for better growth and visual appearance of Ponytail palm (*Beaucarnea recurvate* Lem.).

Author's Contribution

Aimen Raza: Performed the experiment and collected data.
Muhammad Muzamil Ijaz: Helped in data collection and manuscript write-up.
Adnan Younis and Nasir A. Khan: Data analysis and proofreading.
Ahsan Akram, M.A. Salam Khan and M. Nadeem: Helped in relevant literature and format setting.

Conflict of interest
The authors have declared no conflict of interest.

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