Research Article

Optimizing Palm Seedling Growth through Soil Amendment Trials and its Economic Return via Cost-Benefit Ratio Analysis

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Abstract | Growth media is one the most noticeable and significant input of pot grown ornamental. In present study, we used various growing media with different soil amendments to identify the best growing media for palm seedlings along with its benefits cost ratio (BCR). Seedlings of three palm species (Phoenix palm, Lady palm and Alexandria palm) were grown in different soil amendments i.e., Control (Gardens Soil + Sand + Silt) soil amended with peat moss (50% Peat moss + 25% Garden soil + 25% Silt) soil amended with leaf mould (50% Leaf mould + 25% Garden soil + 25% Silt) and soil amended with bagasse (50% Bagasse + 25% Garden soil + 25% Silt). Among different soil amendments, the best growth and developments of palm species were observed in in soil amendment with 50% peat moss as compared with other soil amendments while lesser development was observed in control. Furthermore, BCR results showed that the palm plants grown in the peat moss is having a greater number of BCR as compared with the BCR of leaf mould and bagasse. Based on findings of the current study, it can be concluded that soil amended with peat moss (50%) has positive effect on growth and development of palm species and is more economical.

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Introduction

Ornamental plants grown in potted plants have a variety of cultural inputs. One of the most noticeable and significant inputs is the use of growth media. Role of potting or growing media and nutrition are playing crucial role in the development as well as growth of ornamental plants (Tariq *et al*., 2012; Yasmeen *et al*., 2012; Younis *et al*., 2013). There is evidence that mediums such as peat play a leading role in the quality and the production of perennials well as the container growing ornamental plants (Riaz *et al*., 2015). Medium for better growth potted plants should be the best composition and drainage of good, less in soluble salts and sufficient capacity to exchange water. Vectors with this characteristic can be developed through various combinations of corrections. The basic components of special media are considered organic, purple, peat moss, clay and sand (Hartmann *et al*., 2002). The best medium provides sufficient support or anchor for the plant, which acts as a reservoir of water, where plant nutrients help to spread oxygen to the roots of the plant, and gas exchange occurs between the outer atmosphere and the plant roots (Abad *et al*., 2002). The physical and chemical properties of the medium, including the available ability, texture, structure and pH of basic nutrients such as potassium, phosphorus and nitrogen, are key factors for the improvement of plant growth and development. Medium nutrient adequacy and the nature of the medium are key to improved production, including plant and flower production, flower quality and maximum size of flowers (Riaz *et al*., 2008). High-quality media is an investment in plant quality and growth.

There are a variety of materials, including rice shells, peat, soil, purple sand, sand and stone casting for the production of ornamental plants (Silva *et al*., 2017). Clay has the greatest water retention and communication capacity, while sand costs less and has the largest inorganic correction. In this regard, peat is considered to be an appropriate organic substance, the base for the preparation of potted plants, which is highly valued when planting potted plants in nurseries (Ribeiro *et al*., 2007). Composting leaves or leaf molds increase the significance of the growth medium by reducing the pH of the soil, and maximize nutrient solubility. Sometimes organic materials are considered less fertilizer releases, but they improve soil fertility, help stimulate root development, and improve mineralization by inducing biological conditions and microbial activity (Suresh *et al*., 2004). Similarly, perlite is a naturally occurring inorganic, non-renewable silicon rock that is produced by mining grinding and its particle size is desirable. It is an important substrate for improving plant growth and development (Owen, 2013). It was observed that mixed media could improve the production of ornamental plants (Kakoei and Salehi, 2013).

Palm trees are evergreen, mainly tropical plants (could also be known as Arecase) in the palm family. Over 2,500 species of palm trees are found in world. Most Palms are tree-like, with single trunks and either fan shaped (palmate) or feather shaped (pinnate) with compound leaves. The larger palm tree play major role in landscapes and smaller palms are grown in containers particularly as indoor plants. Palms, due to their adaptability in diverse climates are important member of landscape planting design and their usage are not only restricted to interior-plant scaping in homes but as a focal point in public open space such as park and gardens, businesses or shopping malls (Broschat *et al*., 2014). Additionally, they are also used as architectural status, specimens or hedges, and aesthetically fulfilled purposes (Broschat and Meerow, 2000). The most common plant species grown in Peshawar region are Phoenix Plan, Lady Palm and Alexandria Palm and are used in this experiment. Phoenix Palm (*Phoenix canariensis*) is commonly used landscape palm. Its origin is from Asia especially South China, Vietnam and Laos. The lady palm (*Rhapis excelsa)* is commonly indoor broad leaf or fan palm. It is native to Taiwan and southern china. It is first grown intensively by Japan and then became more popular in Europe. Alexandria Palm (*Archontophoenix alexandrae*) is another most popular landscape palm. It is native to Eastern Australia especially to coastal rainforests. Palm plants has a great importance as an ornamental plant and have potential benefits as indoor plant and specimen plant. To standardize media for palm seedlings grown in Peshawar, palm species were grown in various soil amendments and their performance was investigated for optimum growth and development along with the estimation of benefits cost ratio.

Materials and Methods

A pot experiment was conducted in ornamental plants nursery, Department of Horticulture, University of Agriculture Peshawar, Pakistan, during in the year 2019 (5th March to 15th Nov). Mature seedlings of three palm species Phoenix palm, Lady palm and Alexandria palm were transplanted into 8×12 inches bags filled with different soil amendments i.e. Control (Gardens Soil + Sand + Silt) Soil Amended with Peat moss (50% Peat moss + 25% Garden soil + 25% Silt), Soil Amended with Leaf mould (50% Leaf mould + 25% Garden soil + 25% Silt), and Soil Amended with Sugarcane residue (50% Bagasse + 25% Garden soil + 25% Silt) and their growth parameters were studied (Figure 1). The experimental design was simple CRD (completely randomized design) and repeated thrice. A separate ANOVA was generated for each palm specie grown in different growing media and the treatment means were separated by LSD test.

Figure 1: *Experimental scheme representing palm seedling grown in different soil amendments.*

Growth and development of palm species

The morphological responses of three different palm species were observed in various soil amendments. Data was collected on 3 randomly selected plants from every treatments in all replications. The transplanted seedlings, after the maturation, were observed for plant shoot and root growth and development parameters. Shoot related parameters such as Plant height (cm) was observed with measuring tape from the base of the stem to apical meristems, Stem diameter (mm) with vernier caliper around the stem of the plants, number of leaves plant^{-1} through naked eye observations, leaf area (cm^2) through leaf area meter, and chlorophyll index (SPAD) by SPAD meter. Similarly, root growth and development parameters like number of roots plant^{-1} was observed through naked eye observations by uprooting the plants, Root Fresh weight (g) was weighed on digital balance, and Root Dry weight (g) by drying in the sun and then weighing on digital balance. The root dry matter content was also measured from the average fresh root weight and average dry root weight of the mature palm plants using the following formula:

Root Dry matter content (%) = (Average dry root weight) / (Average fresh root weight) × 100

Determination of benefits cost ratio

The benefit cost ratio for palm plants, in three different experiments were estimated using the following formula.

Benefits Cost Ratio (BCR) = (No. of grown plants survived × Price per plant) / (No. of seedlings × Price per seedling) + (weight of media used ×Price per Kg) + Tranportstion cost)

Data analysis

The collected data were subjected to statistical analysis using Statistix 8.1 software. A two-factor analysis of variance (ANOVA) was performed, and mean comparisons were conducted using the Least Significant Difference (LSD) test at a significance level of α= 0.05, as described by Jalal *et al.* (2020). Additionally, a correlation heat map was created utilizing Pearson correlation with a p-value threshold of 0.05, employing the web-based SRplot tool (https://www.bioinformatics.com.cn/srplot).

Results and Discussion

Plant height (cm)

Plant height of Phoenix palm and Lady Palm was significantly ($P \leq 0.05$) affected by soil amendments but there was a non-significant relation found in Alexandria Palm. The multiple comparison of the mean data revealed that in Phoenix palm, the maximum plant height (44.80 cm) was found in palm specie grown in soil amendment with 50% peat moss followed by the plant height (42.80 cm) for the palm specie grown in soil amendments with 50% leaf mould while the minimum plant height (40.13 cm) was observed in control. Similarly, in Lady palm, the maximum plant height (44.80 cm) of palm specie grown in soil amendment with 50% peat moss followed by the plant height (42.80 cm) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum plant height (40.13 cm) was recorded in control. Consistently, in Alexandria palm, the maximum plant height (51.77 cm) of palm specie grown in soil amendment with 50% peat moss followed by the plant height (49.43 cm) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum plant height (44.50 cm) was observed in control (Table 1).

Plant height increased greater in soil amendment with peat moss than soil amendment with leaf mould. This might be due to the availability of growing nutrients to the palm plant seedlings and drainage allowing the palm seedlings to grow more efficiently. The same results were previously been reported by Mohamed (2008) for grown in various growing media.

Table 1: *Shoot morphology of palm seedling grown in different soil amendments.*

		Plant height	Stem diameter	Number of leaves plant^{-1}	Leaf area	Chlorophyll index
Phoenix palm	Control	40.13b	9	7.77	539.26	31.07b
	Peat moss (50%)	44.80a	12.77	9.33	631.29	54.23a
	Leaf mould (50%)	42.80a	12.03	8.9	618.9	49.27a
	Bagasse (50%)	40.47b	10.23	8.33	574.97	42.80a
	F value	9.89	1.68	1.53	0.43	7.99
	P value	**	NS	NS	NS	**
Lady palm	Control	41.8	9.33	8.77	676.86c	32.60c
	Peat moss (50%)	49.9	15.17	10.03	778.46a	55.40a
	Leaf mould (50%)	46.47	10.7	9.43	748.76ab	49.63a
	Bagasse (50%)	44.23	10.13	9	709.16bc	40.83b
	F value	3.82	3.82	2.41	11	22.6
	P value	NS	NS	NS	**	***
Alexandria palm	Control	44.5	10	3	765.90d	40.77
	Peat moss (50%)	51.77	16.23	3.57	948.89a	57.3
	Leaf mould (50%)	49.43	13.37	3	845.36b	53.63
	Bagasse (50%)	48.43	10.7	2.56	803.74c	51.53
	F value	1.05	3.74	0.75	191	1.9
	P value	NS	NS	NS	***	NS

He observed that the growing media with peat moss has the better impact on plant height of Areca palm. The same results for the growing media with peat moss were also reported by Nazir *et al.* (2017), while testing its effect on Ravenea palm.

Stem diameter (mm)

Soil amendments has significantly ($P \leq 0.05$) affected the stem diameter of Lady palm but there was a non-significant relation found in Phoenix palm and Alexandria Palm. The multiple comparison of the mean data revealed that in Lady palm, the maximum stem diameter (15.17 mm) of palm specie grown in soil amendment with 50% peat moss followed by the stem diameter (10.70 mm) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum stem diameter (9.33 mm) was noticed in control. Similarly, in Phoenix palm, the maximum stem diameter (12.77 mm) was found in palm specie grown in soil amendment with 50% peat moss followed by the stem diameter (12.03 mm) for the palm specie grown in soil amendments with 50% leaf mould while the minimum stem diameter (9.00 mm) was noticed in control. Consistently, in Alexandria palm, the maximum stem diameter (16.23 mm) of palm specie grown in soil amendment with 50% peat moss followed by the stem diameter (13.37 mm) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum stem diameter (10.00 mm) was noticed in control (Table 1).

Stem diameter is the promising growth parameter for plants and is much important for the better pot production. The results of the current study to obtain the better soil amendment for the growth of palm species are in conformity with Nazir *et al.* (2017) as they concluded that the soil amendments improve the nutritional efficiency and have a positive impact on the growth parameters of Ravenea palm. To further revealed that Nazir *et al.* (2017) the growing medium with peat moss has proven to be a better growing media for palm. The same was also previously been reported by (Bronick and Lal. 2005; Rivenshield and Bassuk, 2007; Celik *et al.*, 2010).

Number of leaves plant^{-1}

Upon the statistical analysis of the data, it was revealed that there was a non-significant relation of soil amendments with number of leaves per plant in Phoenix palm, Lady palm and Alexandria Palm. However, in Phoenix palm, the maximum number of leaves per plant (9.33) was found in palm specie grown in soil amendment with 50% peat moss followed by the number of leaves per plant (8.90) for the palm specie grown in soil amendments with 50% leaf mould while the minimum number of leaves per plant (7.77) was noticed in control. Similarly, in Lady palm, the maximum number of leaves per plant (10.03) of palm specie grown in soil amendment with 50% peat moss followed by the number of leaves per plant (9.43) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum number of leaves per plant (8.77) was noticed in control. Consistently, in Alexandria palm, the maximum number of leaves per plant (3.57) of palm specie grown in soil amendment with 50% peat moss followed by the number of leaves per plant (3.00) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum number of leaves per plant (2.56) was noticed in soil amendments with 50% of Bagasse (Table 1).

Number of leaves per plant is different in various the palm species depends upon the palm plant species and architecture and an important parameter for the better growth of plant providing more photosynthetic energy and play a vital role in the growth parameters of palm. This could be mainly affected by the nutrients availability and better substrate. Growing medium could affect all the growth parameters including number of leaves per plant and due to the positive correlation with the nutrients uptake,and regularly the growing media leads the palm plants are encourage for better plant growth. These findings are closely related to those previously reported by Nazir *et al*. (2017), who working on Areca palm both of their researchers finding are in with the current study.

Leaf area (cm²)

Results revealed that soil amendments has significantly ($P \leq 0.05$) affected the leaf area of Lady palm and Alexandria palm, however, there was a non-significant relation of soil amendments with leaf area of Phoenix palm. The multiple comparison of the mean data revealed that in Lady palm, the maximum leaf area (778.46 cm^2) of palm specie grown in soil amendment with 50% peat moss followed by the leaf area (748.76 cm^2) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum leaf area (676.86 cm^2) was noticed in control. Similarly, in Phoenix palm, the maximum leaf area (631.29 cm^2) was found in palm specie grown in soil amendment with 50% peat moss followed by the leaf area (618.90 cm^2) for the palm specie grown in soil amendments with 50% leaf mould while the minimum leaf area (539.26 cm^2) was noticed in control. Besides, in Alexandria palm, the maximum leaf area (948.89 cm^2) of palm specie grown in soil amendment with 50% peat moss followed by the leaf area (845.36 cm^2) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum leaf area (765.90 cm^2) was noticed in control (Table 1).

In current study, the leaf area was greatly affected by the various soil amendments. The soil amended with peat moss (50%) and leaf mould (50%) have shown better results with refered to leaf area. As described by Nazir *et al*. (2017) and Mohamed, 2008 that the growing medium could provide a better aeration and nutrients uptake for the plants to improve its growth parameters. Palm species could uptake more essential nutrients from the soil when grown in a growing medium with soil amendments like peat moss. The current results are in close conformity with Sardoei and Rahbarian (2014) who stated that the soil amended with peat moss were noticed with significant effect on palm specie.

Chlorophyll index (SPAD)

Results revealed that soil amendments has significantly ($P \leq 0.05$) affected the chlorophyll index of Phoenix palm and Lady Palm, however, there was a non-significant relation of soil amendments with chlorophyll index of Alexandria palm. The multiple comparison of the mean data revealed that in Phoenix palm, the maximum chlorophyll index (54.23) was found in palm specie grown in soil amendment with 50% peat moss followed by the chlorophyll index (49.27) for the palm specie grown in soil amendments with 50% leaf mould while the minimum chlorophyll index (31.07) was noticed in control. Similarly, in Lady palm, the maximum chlorophyll index (55.40) of palm specie grown in soil amendment with 50% peat moss followed by the chlorophyll index (49.63) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum chlorophyll index (32.60) was noticed in control. While, in Alexandria palm, the maximum chlorophyll index (57.30) of palm specie grown in soil amendment with 50% peat moss followed by the chlorophyll index (53.63) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum chlorophyll index (40.77) was noticed in control (Table 1).

Leaf chlorophyll is a key indicator of leaf greenness, which is often used to check nutrient deficiencies in leaves (Ali *et al*., 2017). Chlorophyll is very important as it is responsible for harvesting light during photosynthesis (Croft *et al*., 2017). It also provides an indication of nutritional status (Martinez and Guiamet, 2004). It was earlier reported by Rahbarian and Sardoei (2014) that for the better improvement of plant performance, the better growing media should be used, and the soil amendment with peat moss (50%) shown a better performance with refered to leaf chlorophyll index of *Ficus benjamina*. The results of Rahbarian and Sardoei (2014) are very much in line with the current study in respect of all growth parameters including chlorophyll index.

Number of roots plant⁻¹

Results revealed that soil amendments have significantly ($P \leq 0.05$) affected the number of roots per plant of Phoenix palm, Lady palm and Alexandria palm. The multiple comparison of the mean data revealed that in Phoenix palm, the maximum number of roots per plant (12.00) was found in palm specie grown in soil amendment with 50% peat moss followed by the number of roots per plant (10.67) for the palm specie grown in soil amendments with 50% leaf mould while the minimum number of roots per plant (6.67) was noticed in control. Similarly, in Lady palm, the maximum number of roots per plant (14.00) of palm specie grown in soil amendment with 50% peat moss followed by the number of roots per plant (11.33) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum number of roots per plant (8.00) was noticed in control. Consistently, in Alexandria palm, the maximum number of roots per plant (14.67) of palm specie grown in soil amendment with 50% peat moss followed by the number of roots per plant (12.00) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum number of roots per plant (8.00) was noticed in control (Table 2).

Various soil amendments has significantly affected the number of roots of palm plants. The number of roots has shown an increased trend in soil amended with peat moss (50%) in the current study. As earlier reported by Seman *et al.* (2018) that for the better growth of palm plants, better soil and combination of growing media should be used. The results of the current study for the number of roots are in conformity with (Seman *et al*., 2018; Rahbarian and Sardoei, 2014; Mohamed, 2018).

Root fresh weight (g)

Statistical analysis of the data revealed that soil amendments have significantly ($P \leq 0.05$) affected the root fresh weight of Phoenix palm, Lady palm and Alexandria palm. The multiple comparison of the mean data revealed that in Phoenix palm, the maximum root fresh weight (13.67 g) was found in palm specie grown in soil amendment with 50% peat moss

Table 2: *Root morphology of palm seedling grown in different soil amendments.*

		Number of roots plant^{-1}	Root fresh weight	Root dry weight	Root dry matter content
Phoenix palm	Control	6.67c	7.00c	4.33c	58.31
	Peat moss (50%)	12.00a	13.67a	8.33a	61.37
	Leaf mould (50%)	10.67ab	12.33ab	7.00ab	56.84
	Bagasse (50%)	8.33bc	10.67b	5.67bc	53.03
	F value	9.7	16.6	5.08	0.33
	P value	**	***	*	NS
Lady palm	Control	8.00c	8.67c	4.67c	53.17
	Peat moss (50%)	14.00a	15.33a	9.33a	61.04
	Leaf mould (50%)	11.33ab	13.67ab	7.33b	54.02
	Bagasse (50%)	9.00bc	11.33bc	6.33bc	56.13
	F value	8.29	12.1	13.7	0.66
	P value	**	**	**	NS
Alexandria palm	Control	8.00c	8.67b	5.00b	53.87
	Peat moss (50%)	14.67a	18.33a	10.00a	56.6
	Leaf mould (50%)	12.00b	16.00a	9.00a	57.69
	Bagasse (50%)	8.67c	14.67a	8.33a	58.23
	F value	31.4	6.8	4.57	0.04
	P value	***	*	*	NS

followed by the root fresh weight (12.33 g) for the palm specie grown in soil amendments with 50% leaf mould while the minimum root fresh weight (7.00 g) was noticed in control. Similarly, in Lady palm, the maximum root fresh weight (15.33 g) of palm specie grown in soil amendment with 50% peat moss followed by the root fresh weight (11.33 g) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum root fresh weight (8.67 g) was noticed in control. Consistently, in Alexandria palm, the maximum root fresh weight (18.33 g) of palm specie grown in soil amendment with 50% peat moss followed by root fresh weight (16.00 g) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum root fresh weight (8.67 g) was noticed in control (Table 2).

Different soil amendments has significantly affected the root fresh weight of palm species It is reported by number of researchers that for better plant growth, the nutrients availability in the growing medium and its uptake by the plant roots are very conical. Various combination of growing medium could greatly affect the plnat growth parameters in which roots are the very much important. The soil amended with peat moss has a significant impact on the palm plants regarding root fresh weight. The findings of the current study are also previously confirmed by (Seman *et al*., 2018, Rivenshield and Bassuk. 2007, Rahbarian and Sardoei, 2014; Mohamed, 2008).

Root dry weight (g)

Results revealed that soil amendments have significantly ($P \leq 0.05$) affected the root dry weight of Phoenix palm, Lady palm and Alexandria palm. The multiple comparison of the mean data revealed that in Phoenix palm, the maximum root dry weight (8.33 g) was found in palm specie grown in soil amendment with 50% peat moss followed by the root dry weight (7.00 g) for the palm specie grown in soil amendments with 50% leaf mould while the minimum root dry weight (4.33 g) was noticed in control. Similarly, in Lady palm, the maximum root dry weight (9.33 g) of palm specie grown in soil amendment with 50% peat moss followed by the root dry weight (7.33 g) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum root dry weight (4.67 g) was noticed in control. Consistently, in Alexandria palm, the maximum root dry weight (10.00 g) of palm specie grown in soil amendment with 50% peat moss followed by root dry weight (9.00 g) for the palm varieties grown in soil amendments with 50% leaf mould while the minimum root dry weight (5.00 g) was noticed in control (Table 2).

Various soil amendment has a positive impact on the root dry weight of palm varieties. The root dry weight of the palm species are increased by the soil amendment with peat moss. Soil amended with peat moss (50%) has better impact on the root dry weight of palm. This might be due to the availability of growing nutrients to the palm plant seedlings and drainage allowing the palm seedlings to grow more efficiently and the number of roots increased. The results of the current study are in great conformity with Seman *et al*. (2018) and Rahbarian and Sardoei (2014).

Root dry matter content (%)

Results revealed that soil amendments have non-significant effect on the root dry matter content of Phoenix palm, Lady palm and Alexandria palm. However, in Phoenix palm, the maximum root dry matter content (61.37 %) was found in palm specie grown in soil amendment with 50% peat moss while the minimum root dry matter content (56.84 %) was noticed in in soil amendments with 50% leaf mould. Similarly, in Lady palm, the maximum root dry matter content (61.04 %) of palm specie grown in soil amendment with 50% peat moss while the minimum root dry matter content (53.17 %) was noticed in control. Consistently, in Alexandria palm, the maximum root dry matter content (58.23%) of palm specie grown in soil amendment with 50% bagasse while the minimum root dry matter content (53.87 %) was noticed in control (Table 2).

Root dry matter content is an important parameters for estimating the biomass and nutrients uptake capacity of plants. In current study the root dry matter contents were high in the pam varieties grown in soil amended with peat moss. The current results are greatly in accordance with Seman *et al*. (2018) who concluded that different combination of growing media affect the root dry matter and an increased dry matter content was recorded for growing media in combination with peat moss.

Correlation of shoot and root morphology

To further get a better understanding and show the relationship for all the above ground and below ground parameters of different palm seedling grown

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in different soil amendments, a correlation heat map was created utilizing Pearson correlation with a p-value threshold of 0.05 to show the negative and positive correlation among all the studied parameters (Figure 2). The results declared that all the parameters (Plant height (PH), Stem diameter (SD), Number of leaves plant-1 (NL), Leaf area (LA), Chlorophyll index (CI), Number of roots plant-1 (NR), Root fresh weight (RFW), Root dry weight (RDW), Root Dry Matter content (RDM)) were significantly having positive correlation among them except PH, SD, and NL. PH and SD have showed negative correlation with NL, while NL have showed negative correlation LA, CI, RFW and RDW.

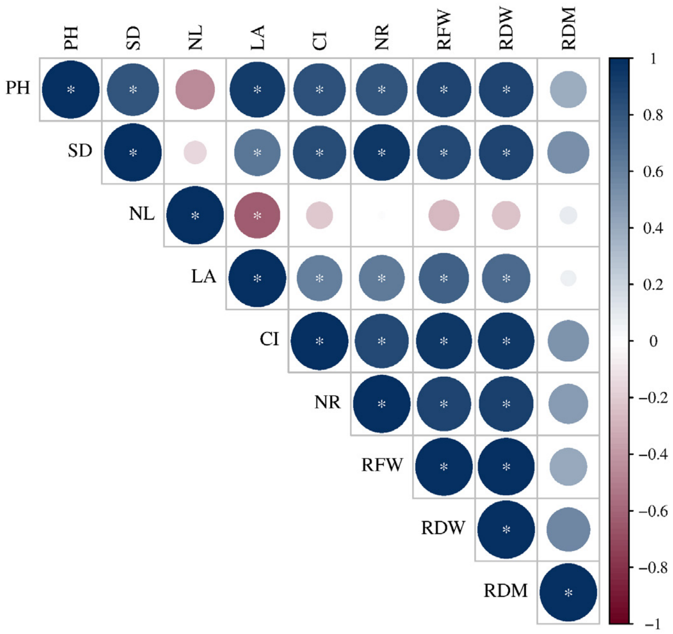

Figure 2: *Correlation of shoot and root morphology of palm seedling grown in different soil amendments. Plant height (PH), Stem diameter (SD), Number of leaves plant^{-1} (NL), Leaf area (LA), Chlorophyll index (CI), Number of roots plant^{-1} (NR), Root fresh weight (RFW), Root dry weight (RDW), Root Dry Matter content (RDM).*

Determination of benefits cost ratio (BCR)

The details of the benefits cost ratio are given in the Table 3 while the calculated benefits cost ratio for all the medium used for growing palm plants is given in Table 4. BCR results showed that the palm plants grown in the peat moss is having a greater number of BCR (1.54) as compared with the BCR of leaf mould (1.40) and bagasse (1.27). These results indicated that the palm plants grown in the planting medium of peat moss is more economical having greater BCR and should be recommended for growing of better production of palm species as compared with the other medium.

Table 3: *Estimated benefit cost ratio (BCR) details according to the proposed formula.*

Details for BCR	Peat moss	Leaf mould	Bagasse
No. of seedlings sown.	27	27	27
No. of grown palm plants survived	27	25	23
Market Price per seedling sown	Rs. 200		
Market price per grown plant survived	Rs. 450	Rs. 400	Rs.380
Weight of medium used	25 kg	25 kg	25 kg
Price of medium used per kg	Rs.80	Rs.50	Rs.40
Transportation cost	Rs.500	Rs.500	Rs.500

Table 4: *Estimated benefit cost ratio (BCR).*

Detail	Symbolized	Peat moss	Leaf mould	Bagasse
No. of grown palm plants survived × Market price per plant	B	12150	10000	8740
No. of grown seedlings sown × Market price per seedling	C1	5400	5400	5400
Weight of medium used × Price per kg	C2	2000	1250	1000
Transportation cost	C3	500	500	500
Total C (C1+C2+C3)	C	7900	7150	6900
BCR	B/C	1.54	1.40	1.27

Conclusions

Based on the analyzed data and results, it could be concluded that soil amended with peat moss (50%) has a significant impact on growth and development of all the selected palm species. Soil amended with peat moss (50%) is more economical and shows the best performance among all other soil amendments. Soil amendment with peat moss (50%) is more economical for growing palm species in agro-climatic conditions of Peshawar.

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Novelty Statement

Soil amendment with 50% of peat moss has a significant impact on the growth performance of palm seedlings, and it is more economical for palm growers.

Author's Contribution

Niqab Hussain: Conducted the research work and wrote the original draft of the manuscript.
Syed Qaisar Ali Shah and Iqrar Hussain: Helped the first author in data collection, analysis, and in the development of the manuscript.
Noor-ul-Amin: Supervised the research work and edited the final version of the paper.
All the authors are agreed to the final version of the manuscript.

Generative AI and AI-assisted technology statement
No generative AI and AI-assisted technology has been used in the development of this research article.

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

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