International Journal of Horticultural Science 2025, 31: 37-43.
https://doi.org/10.31421/ijhs/31/2025/15461

Impact of different growing media on propagation of bougainvillea (*Bougainvillea* spp.) through hardwood stem cuttings in Chitwan, Nepal

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Summary: An experiment was conducted in Rampur, Chitwan, Nepal, in a Randomized Complete Block Design (RCBD) with five treatments: T1 (sand:soil, 1:1) [control], T2 (sand:cocopeat:perlite, 1:1:1), T3 (perlite:sand, 1:1), T4 (sand:cocopeat, 1:1), and T5 (peat moss:perlite, 1:1). Each treatment was replicated four times with a total of 300 planted cuttings. The key parameters evaluated were sprouting percentage, shoot growth (length, leaf number, and branch number), and root development (length, number, fresh, and dry biomass). Analysis of data was done using R-Studio, and Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level. The results revealed that peat moss:perlite (1:1) demonstrated the highest shoot growth with shoot length of 6.00, 14.38 and 28.78 cm at 30, 60, and 90 Days After Planting (DAP) respectively. Leaf number were 6.25, 13.12, and 19.57, while branch numbers were 1.76, 2.00, and 2.18 at the same intervals., Additionally, the fresh root weight was recorded 8.74 g. Sand:cocopeat:perlite (1:1:1) recorded the highest sprouting percentage (81.66%) and root length (17.11 cm), while sand:cocopeat (1:1) achieved the highest root number (18.37) and dry root weight (0.99 g). Perlite:sand (1:1) exhibited moderate performance with sprouting percentage 69.99%, and root length 12.56 cm. In contrast, control (sand:soil) showed the least favorable results with the lowest sprouting percentage (58.33%), the fewest number of roots (7.81), and the minimum root length (9.73). This study concludes that peat moss:perlite (1:1) is the most effective growing medium for bougainvillea propagation, offering a practical solution to enhance rooting success and growth performance. Sand:cocopeat (1:1) with maximum dry weight of root and maximum number of roots emerged as a reliable alternative, proving the effectiveness of the medium.

Panthi, S., Pant, M., Chand, R., Devkota, T. (2025): Impact of different growing media on propagation of bougainvillea (*Bougainvillea* spp.) through hardwood stem cuttings in Chitwan, Nepal. International Journal of Horticultural Science 2025, 31: 37-43. https://doi.org/10.31421/ijhs/31/2025/15461

Key words: Bougainvillea propagation, peat moss, perlite, root development, sprouting percentage

Introduction

Bougainvillea spp. is a highly valued climbing flowering shrub in tropical and subtropical regions, admired for its vibrant bract colors, unique leaf characteristics, substantial plant size, and versatility as a popular perennial ornamental crop in floriculture. The main method of vegetative proliferation for Bougainvillea is through stem cutting. Propagation of the *Bougainvillea* spp. is done by hardwood and semi-hardwood cutting. Problems in container gardening often arise from soil compaction, which reduces water retention, drainage, aeration, and root penetration. Commercial nurseries need consistent growing media for high quality plants. Good aeration and water holding capacity are essential for root development (Khayyat & Salehi, 2007). Issues with root cutting often lead to large financial losses (Fadwa & Yahia, 2014). Much effort has been made to enhance the rooting of cuttings in ornamental plants such as Bougainvillea. It is often acknowledged that the rooting medium is essential for rooting plant cuttings (Atangana et al., 2006). The choice and preparation of growing media for nursery plant production are critical to the health and growth of plants. No single rooting medium is suitable for cuttings because the needs vary according to the species, type of cutting, season, and method of propagation (Hartmann et al., 2002). Root initiation can be accelerated using quality rooting material in conjunction with a rooting hormone. Therefore, the experiment aimed to assess the root formation of *Bougainvillea* spp. Under different growing media to enhance its establishment success. The lack of ability to form adventitious roots by cutting occurs routinely in Bougainvillea and presents a challenge to vegetative propagation (Celine et al., 2006). Furthermore, plants generated via air layering are scarce and require more labor and expertise (Ahmad et al., 2007). Conversely, traditional sexual reproduction is challenging (Cerveny & Gibson, 2006). Due to ideal environmental circumstances, *Bougainvillea* spp. may propagate year-round in the terai region (the southern plains of Nepal). However, sandy soil in the middle terai limits propagation because it cannot support the evapotranspiration requirements of young leaves that lack or have immature roots. Due to space constraints, ornamental nurseries in Kathmandu import bougainvillea from India, which causes the entry of invasive pathogens and diseases transmitted through soil (Shrestha et al., 2023). When placed in containers, most soil types become compacted, leading to decreased water-holding capacity, poor drainage, reduced aeration, slower water infiltration, and restricted root penetration. Growing media is therefore essential to producing high-quality Bougainvillea plants (Singh et al., 2020). Therefore, this study aimed to evaluate the effects of different growing media on the rooting and growth performance of Bougainvillea hardwood cuttings under field conditions in Chitwan, Nepal.

Materials and methods

Research site

The experiment was conducted at the horticultural farm of Agriculture and Forestry University (AFU), Rampur, Chitwan (***Figure 1***). It is 10 kilometers west of Bharatpur, the district headquarters of Chitwan, in Nepal's inner terai region. The site is located at 27.64 °N latitude and 84.35 °E longitude, with an elevation of 228 meters above sea level. The region experiences a humid subtropical climate, with summer temperatures reaching 43 °C and winter temperatures dropping to 2–3 °C. The average annual rainfall exceeds 1500 mm, predominantly during the monsoon season (mid-June to mid-September). The research was conducted from the first week of April to the last week of July 2024.

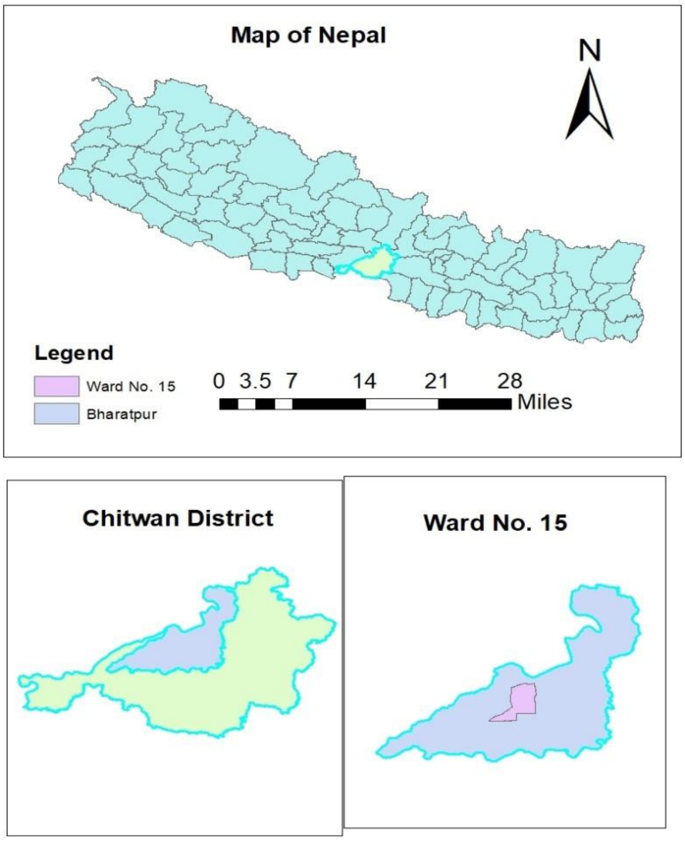

Figure 1. Map of Nepal showing research site.
(Created using ArcGIS Pro Software

Weather Condition

The data show that temperature decreases slightly towards the end of the experiment after the initiation of precipitation. At the beginning of the research period, there was lower relative humidity, which was seen as highly fluctuating during the entire research period. There was lower precipitation at the beginning of the research period, and precipitation was higher towards the end of the experiment. During the research period, the average maximum temperature was 38.61 °C, while the average minimum temperature was recorded 12.74 °C. The average relative humidity was 39.06%, and the average precipitation was 3.42 mm (***Figure 2***).

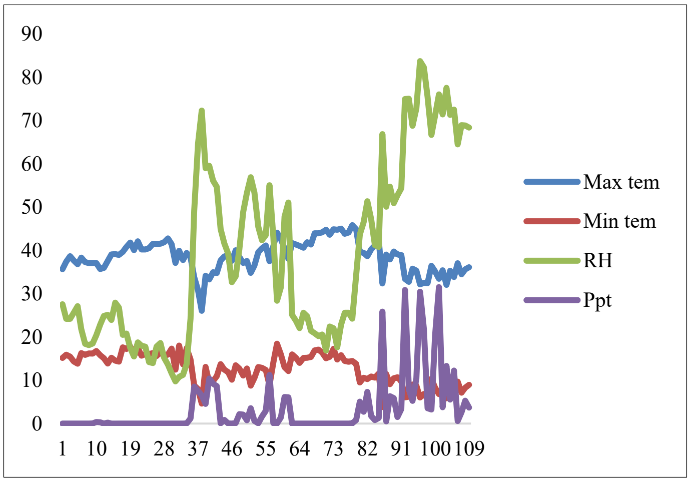

Figure 1. Weather condition during research period
(Source: NASA POWER, 2024)

Experimental details

Experimental design

The experiment was carried out under field conditions. Five treatments and four replications were employed in a randomized complete block design (RCBD). Twenty experimental units, each consisting of 15 polybags, were established, resulting in 300 hardwood stem cuttings.

Treatment details

In the experiment, five treatments were used: T1 (Sand:Soil, 1:1), T2 (Sand:Cocopeat:Perlite, 1:1:1), T3 (Perlite:Sand, 1:1), T4 (Sand:Cocopeat, 1:1) and T5 (Peat moss:Perlite, 1:1) (***Table 1***).

Table 1. Treatment details

Treatments	Treatment details
T1	Sand: Soil(1:1)[control]
T2	Sand:Cocopeat:Perlite(1:1:1)
T3	Perlite: Sand(1:1)
T4	Sand: Cocopeat(1:1)
T5	Peat moss:Perlite(1:1)

Field layout

The size of an individual experimental unit was 50 cm × 40 cm, and the number of experimental units was 20. Net experimental area was 6 m × 4.1 m (24.6 m²). The distance between two replications was 1 meter, and the distance between two plots was 0.5 m. There were 15 plants per plot and 300 plants in the experimental area. Plant-to-plant distance was 10 cm, and row-to-row distance was 15 cm. Border distance was kept at 5 cm (***Figure 3***).

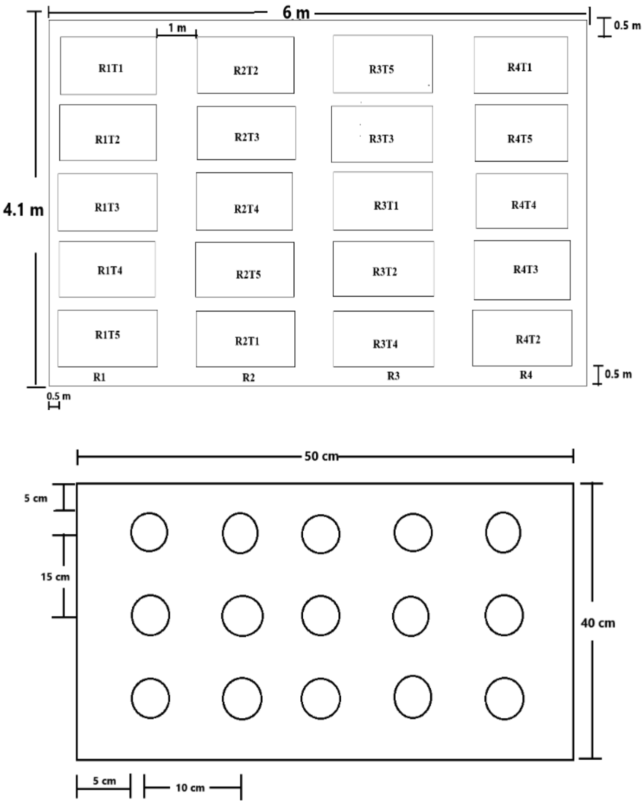

Figure 2. Layout of experimental field.

Planting details

The study included five different growing media treatments obtained from the horticulture laboratory at the Agriculture and Forestry University. Each growing medium was prepared by thoroughly mixing the respective components to ensure homogeneity before filling the polybags. Hardwood stem cuttings, each measuring 12 cm in length, were collected from mature, healthy *Bougainvillea* spp. plants. The basal portion of each cutting was trimmed at a slant to maximize rooting potential. These cuttings were then planted at a uniform depth in polybags containing the assigned growing media.

Data to be recorded

The data regarding shoot parameters were the total number of sprouted plants, the number of leaves per cutting, the number of branches per cutting, shoot length, and the sprouting percentage. The data on root parameters were the length per cutting, the number of roots per cutting, and the fresh and dry weight of roots per cutting.

The following parameters were recorded:

1. Sprouting percentage: The sprouting percentage was determined by counting the total number of emerged plants in each growing medium, and was calculated using the following formula:

$$\text{Sprouting }\% = \frac{\mathit{Number\ of\ sprouting\ cuttings}}{\mathit{Total\ cuttings\ planted}} \times 100$$

2. Shoot length (cm): Shoot length was measured from base to tip using a ruler.

3. Number of leaves per cutting: The total number of leaves of sample plants from each replication were counted.

4. Branch number: The total branches of sample plants from each replication were counted.

5. Number of roots per cutting: Sample plants from each treatment were carefully uprooted and thoroughly washed with tap water to eliminate mud and media particles from the roots. They were then placed on tissue paper to dry and absorb excess moisture. Once dried, the total number of roots was counted.

6. Root length (cm): The longest root length, from apex to tip, was measured with a ruler.

7. Fresh weight of root (g): Fresh root weights of sample plants in each replication were measured with the help of an electric balance.

8. Root dry weight (g): After taking fresh root weights, they were kept in the oven at 72 °C for 72 hours in the oven to dry out. Using an electric balance, dry weight was determined.

Parameters related to shoot were measured at 30, 60, and 90 days after planting (DAP), while root parameters were assessed 90 days after planting.

Data analysis

All the recorded data were systematically arranged based on the treatments and various observed parameters. Experimental data were analyzed by analysis of variance (ANOVA) using R Studio 4.3.3 with the software package Agricolae. Duncan's multiple range test (DMRT) was done at a probability level of 0.05, where the effects of the treatments were significant at a 5% level of probability (Gomez & Gomez, 1984). Bar diagrams were prepared using MS Excel.

Results and discussion

The data about different root and shoot parameters as influenced by different growing media are presented in ***Tables 2-3***, respectively. Hardwood cuttings planted in these media showed significantly better results compared to the control group in terms of rooting characteristics, including sprouting percentage, shoot length, leaf count, branch count, root number, root length, fresh root weight, and dry root weight.

Effects of different growing media on sprouting percentage

The analysis revealed a statistically significant influence of the growing media on the sprouting percentage of hardwood cuttings. As presented in ***Table 2***, the sprouting percentage of *Bougainvillea* spp. cuttings ranged from 58.33% to 81.66%. The highest sprouting percentage (81.66%) was recorded in the sand:cocopeat:perlite (1:1:1) mixture. The sprouting percentages for peat moss:perlite (1:1), perlite:sand (1:1), and sand:cocopeat (1:1), with values of 74.99%, 69.99%, and 66.66% respectively, were statistically similar, while the lowest sprouting percentage (58.33%) was observed in the control group.

These findings may be attributed to the combination of sand and perlite with cocopeat, which facilitates rapid root growth and provides immediate anchorage to immature roots (Singh et al., 2020). This mixture potentially aids in retaining air, moisture, and nutrients, releasing them as required by the plants (Singh et al., 2020). The superior physical and nutritional properties of the mixture, containing both organic matter (peat) and mineral substances (perlite), may enhance the sprouting and growth of cuttings compared to media composed solely of organic or mineral substances (Rymbai et al., 2012).

Table 2. Effect of growing media on sprouting and root parameters of Bougainvillea hardwood cuttings (Chitwan, Nepal, 2024).

Treatments	Sprouting percentage	Number of roots	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
Sand:Soil(Control)	58.33^{d}	7.81^{c}	9.73^{c}	4.15^{d}	0.31^{c}
Sand:Cocopeat:Perlite(1:1:1)	81.66^{a}	12.81^{b}	17.11^{a}	5.25^{cd}	0.61^{b}
Perlite:Sand(1:1)	69.99^{bc}	9.50^{bc}	12.56^{b}	6.33^{bc}	0.54^{b}
Sand:Cocopeat(1:1)	66.66^{c}	18.37^{a}	13.17^{b}	7.26^{b}	0.99^{a}
Peat moss:Perlite(1:1)	74.99^{b}	12.73^{b}	14.65^{b}	8.74^{a}	0.66^{b}
LSD(0.05)	6.14	3.73	2.06	1.39	0.15
$SE_m(\pm)$	0.89	0.54	0.29	0.20	0.022
F-Probability	<0.001	<0.001	<0.001	<0.001	<0.001
CV%	5.67	19.77	9.96	14.29	16.42
Grand Mean	70.33	12.24	13.44	6.34	0.62

Note: Treatment means separated by DMRT and columns represented by the same letter(s) are non-significant at the 5% level of significance; LSD: Least Significant Difference; SEm: Standard error of the mean deviation; CV: Coefficient of Variation; g: gram; cm: centimeters

Table 2. Effect of growing media on shoot development of Bougainvillea hardwood cuttings (Chitwan, Nepal, 2024).

Treatments	Shoot length (cm)			Leaf number			Branch number		
	30DAP	60DAP	90DAP	30DAP	60DAP	90DAP	30DAP	60DAP	90DAP
Sand:Soil(Control)	3.49^{c}	9.49^{bc}	20.37^{c}	4.76^{bc}	8.50^{b}	13.81^{b}	1.22^{cd}	1.33^{b}	1.53^{b}
Sand:Cocopeat:Perlite(1:1:1)	3.88^{c}	9.06^{c}	16.55^{d}	3.98^{cd}	8.14^{b}	13.88^{bc}	1.28^{c}	1.46^{b}	1.65^{b}
Perlite:Sand(1:1)	4.61^{b}	11.22^{b}	24.69^{b}	5.39^{ab}	10.12^{b}	16.17^{ab}	1.46^{b}	1.77^{a}	2.06^{a}
Sand:Cocopeat(1:1)	2.75^{d}	6.94^{d}	12.17^{e}	3.19^{d}	5.75^{c}	12.24^{c}	1.16^{d}	1.25^{b}	1.56^{b}
Peat moss:Perlite(1:1)	6.00^{a}	14.38^{a}	28.78^{a}	6.25^{a}	13.12^{a}	19.57^{a}	1.76^{a}	2.00^{a}	2.18^{a}
LSD(0.05)	0.42	1.86	1.16	1.00	2.00	3.57	0.08	0.24	0.31
$SE_m(\pm)$	0.06	0.27	0.16	0.14	0.29	0.51	0.012	0.035	0.045
F-Probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.01
CV%	6.70	11.85	3.69	13.79	14.27	15.33	4.01	10.13	11.26
Grand Mean	4.14	10.22	20.51	4.71	9.13	15.13	1.37	1.56	1.8

Note: Treatment means separated by DMRT and columns represented by the same letter(s) are non-significant at the 5% level of significance; LSD: Least Significant Difference; SE_m: Standard error of the mean deviation; CV: Coefficient of Variation; cm: centimeters

The results can also be explained by the properties of cocopeat, which is low in nitrogen, calcium, and magnesium but high in phosphorus and potassium. Phosphorus is beneficial for plants as it promotes root growth and development (Gohil et al., 2018), partly by supporting metabolic processes associated with auxin activity and cell wall biosynthesis (Gohil et al., 2018). It may also contribute to lignin formation, providing structural support during early root development (Aparna et al., 2021). These results align with previous findings on the effect of potting media on *Bougainvillea* spp. propagation (Singh et al., 2020).

Effect of different growing media on shoot growth

Shoot growth parameters varied significantly among treatments, as shown in ***Table 3***. The highest shoot lengths at 30, 60, and 90 DAP were recorded in the peat moss:perlite (1:1) treatment. This was followed by perlite:sand (1:1), with values of 4.61 cm, 11.22 cm, and 24.69 cm, respectively. The lowest shoot length was observed in sand:cocopeat (1:1), measuring 2.75 cm, 6.94 cm, and 12.17 cm at the same time points. However, control and sand:cocopeat:perlite (1:1:1) were statistically similar at 30 and 60 days after planting, indicating that these two growing media have similar effects on shoot growth.

Similarly, the maximum leaf number per plant (6.25, 13.12, 19.57) was recorded in the peat moss:perlite (1:1) followed by (5.39, 10.12, 16.17) in perlite:sand (1:1), and the minimum leaf number per plant (3.19, 5.75, 12.24) was recorded in sand:cocopeat (1:1). Control, sand:cocopeat:perlite (1:1:1) and perlite:sand (1:1) did not differ significantly. However, perlite:sand (1:1) produced a higher mean leaf number than the other two.

The branch number across all the treatments exhibited significant differences as shown in ***Table 3***. Significantly, the maximum branch number per plant (1.76, 2.00, 2.18) was observed in peat moss:perlite (1:1), followed by (1.46, 1.77, 2.06) perlite:sand (1:1), and the minimum branch number per plant (1.16, 1.25, 1.56) was recorded in sand:cocopeat (1:1).Control and sand:cocopeat:perlite (1:1:1) exhibited statistical similarity at 30, 60, and 90 days after planting. Similarly, perlite:sand (1:1) and peat moss:perlite (1:1) were statistically similar at 60 and 90 days after planting.

This result suggests that the combination of peat moss and perlite provided optimal physical conditions and sufficient nutrients for enzymatic and biochemical activation in cuttings, thereby promoting shoot growth (Wazir et al., 2003). The superiority of peat moss may be attributed to its high cation exchange capacity, fibrous structure that minimizes nutrient leaching, and favorable physical properties, including high water retention, low bulk density, and high porosity (AI, 2016). When combined with other media, it enhances root development and shoot growth (Rasul et al., 2025). Perlite, commonly added to organic components like peat moss, increases aeration and porosity, making it especially beneficial for container-grown trees (AI, 2016). Due to its balanced physical and chemical properties, such as appropriate density, porosity, air capacity, water retention, pH, electrical conductivity, and carbon-to-nitrogen ratio, peat moss remains a preferred planting medium for various horticultural species (Abad et al., 2001).

Peat moss, combined with perlite, enhances nutrient availability by absorbing water up to eight times its weight at saturation (Hahn et al., 2001). Its high cation exchange capacity and fibrous structure help retain nutrients, reducing leaching and supporting root development. Rich in nitrogenous compounds and phosphates, peat moss plays a crucial role in protein synthesis, amino acid formation, and RNA production, all essential for cell division and new cell formation (Weisman et al., 1995). Perlite improves aeration, facilitating gas exchange for roots and ensuring sustained nutrient release over time (Markoska et al., 2020). These findings align with Sardoei & Rahbarian (2014), who reported increased photosynthetic pigments and carotenoid content in ornamental plants grown in peat moss-based media. Similar results were observed by Bosila et al. (2010) in Bougainvillea, Khandaker et al. (2018) in *Petunia grandiflora*, and El-Sabagh et al. (2023) in *Euphorbia milii*.

Effect of different growing media on number of roots

The number of roots per cutting across all the treatments is statistically significant, as shown in ***Table 2***. The sand:cocopeat (1:1) mixture had the most roots (18.37). Sand:cocopeat:perlite (1:1:1) and peat moss:perlite (1:1) with values of 12.81 and 12.73, respectively, were statistically similar, indicating that these media provide roughly the same environment for root growth. Perlite:sand (1:1) produced fewer roots than sand:cocopeat:perlite (1:1:1) and peat moss:perlite (1:1), implying poor root growth but better than the control. The minimum number of roots per cutting was observed in the control (sand:soil, 1:1).

The better result recorded in sand:cocopeat (1:1) for the number of roots might be due to superior properties of sand and cocopeat as compared to other media; a similar result was observed by Shrestha et al. (2023). Cocopeat enhances apical meristem activity and stimulates cambial division, while its decomposed organic matter improves pore spaces, water retention, and microbial activity, leading to optimal root growth (Wazir et al., 2003; Fagge & Manga, 2011). Its high water-holding capacity facilitates nutrient absorption, increasing primary, secondary, and overall root formation per cutting. Additionally, cocopeat may regulate endogenous IAA distribution, promoting meristematic cell differentiation into root primordia and boosting root numbers (Rubasinghe et al., 2009). For Bougainvillea growers in Nepal, a propagation protocol combining sand and cocopeat with Rootex C could enhance local production and reduce imports (Shrestha et al., 2023). These findings align with previous studies on Bougainvillea (Shrestha et al., 2023; Bosila et al., 2010; Singh et al., 2020), Ficus species (Nagwa, 2007), and African Marigold (Aparna et al., 2021).

Effect of different growing media on root length

The growing media had significant influence on the root length per plant, as demonstrated in ***Table 2***. The maximum root length, measuring 17.11 cm, was recorded in the sand:cocopeat:perlite mixture (1:1:1). The root lengths in the perlite:sand (1:1), sand:cocopeat (1:1), and peat moss:perlite (1:1) combinations were statistically similar. The minimum root length, measuring 9.73 cm, was observed in the control group.

This may be due to fact that perlite media and cocopeat work together to promote cambial division and apical meristematic activities (Singh et al., 2020). Maximum root growth is achieved through improved pore spaces, water-holding capacity, and microbial activity brought about by decomposed organic matter (Wazir et al., 2003). Cocopeat's high porosity and coarse texture facilitate nutrient and water movement, supporting better root development (Singh et al., 2020). Its lower particle density increases the medium's surface area and water-holding capacity, improving nutrient absorption and leading to longer roots (Rubasinghe et al., 2009). A well-aerated medium further enhances root penetration and metabolic activity, accelerating root formation and growth (Gopale & Zunjarrao, 2011). These findings align with findings of Singh et al. (2020) in Bougainvillea, Aparna et al. (2021) in African Marigold, Awang et al. (2010) in *Celosia cristata,* and Mane et al. (2008) in *Arabidopsis thaliana*.

Effect of different media on fresh and dry weight of root

The fresh weight of roots per cutting varied significantly depending on the growing medium, as shown in ***Table 2***. The highest fresh weight of root was observed in peat moss:perlite (8.74 g). Fresh weight of roots in perlite:sand (6.33 g) and sand:cocopeat (7.26 g) were statistically similar, while fresh weight of root in sand:soil (4.15 g) and sand:cocopeat:perlite (5.25g) were also statistically similar. The control group had lowest fresh weight of roots (4.15 g). Similarly, different growing media significantly affected the dry weight of roots per plant. The highest dry weight of root was observed in sand:cocopeat (0.97 g). Dry weight of root in sand:cocopeat:perlite (0.61 g), perlite:sand (0.54 g), and peat moss:perlite (0.66 g) were statistically similar. The lowest dry weight of root (0.31 g) was observed in control.

This result indicates that peat moss:perlite and sand:cocopeat media yielded the maximum fresh and dry root weight. This may be due to the improved aeration and drainage provided by inorganic components like sand and perlite, combined with the high water-holding capacity, disease resistance, and nutrient-rich properties of organic media such as peat moss and cocopeat (Kaushal & Kumari, 2020)

Peat moss substrate enhances aeration conditions (more porous, suitable moist conditions, good infiltration, and aeration) with generating a bigger root system stimulating greater water uptake by root and shoot nutrition uptake (Rabeea et al., 2013). According to recent research, perlite rooting media produced favorable outcomes in terms of rooting ratio, root length, and root weight (Doğan et al., 2016). In this study, aeration and water-holding capacity interacted positively in the peat-moss–perlite mixture, enabling it to produce the highest root fresh weight among all substrates. (Nguyen et al., 2022). Cuttings planted in peat and perlite medium with better fresh weight of root were associated with proper water-holding capacity of the medium for a longer period (Ercişli et al., 2002).

The high water-holding capacity of cocopeat enhances nutrient absorption, leading to increased development of primary, secondary, and total roots per cutting (Rubasinghe et al., 2009). This may explain the highest dry root weight observed in cocopeat based media (Aparna et al., 2021). Additionally, Singh et al. (2020) reported that shoot growth was most favorable in sand and cocopeat media, followed closely by sand:cocopeat:perlite media.

Conclusions

The effectiveness of different growing media varied significantly, influencing root and shoot development in bougainvillea cuttings. Among the media used, peat moss:perlite (1:1) demonstrated the longest shoot length, highest leaf and branch numbers, and greatest fresh root weight, making it the most effective option. Cocopeat combined with sand and the sand:cocopeat:perlite mix exhibited moderate performance but showed comparatively lower shoot growth. In contrast, perlite:sand and sand:soil resulted in reduced root development, with sand:soil (control) performing the poorest overall. Based on these findings, peat moss:perlite, sand:cocopeat:perlite, and sand:cocopeat mixtures are recommended for optimal bougainvillea propagation using hardwood stem cuttings.

Acknowledgements

We wish to express our deep gratitude to Prof. Dr. Kalyani Mishra Tripathi, Agriculture and Forestry University, Rampur, Chitwan, for providing the necessary guidelines. We thank the Agriculture and Forestry University for providing the laboratory.

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