jotaf **Journal of Tekirdag Agricultural Faculty**
Tekirdağ Ziraat Fakültesi Dergisi

Ocak/January 2025, 22(1)
Başvuru/Received: 15/08/23
Kabul/Accepted: 08/10/24
DOI: 10.33462/jotaf.1341534

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http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Investigation of the Effects of Rooting Medium and IBA Concentration on Rooting and Shoot Development of Bougainvillea (*Bougainvillea* spp.) Cuttings

Begonvil (*Bougainvillea* spp.) Çeliklerinin Köklenme ve Sürgün Gelişimi Üzerine, Köklendirme Ortamı ve IBA Konsantrasyonunun Etkilerinin Araştırılması

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Abstract

In this study, the effect of different rooting mediums (peat moss, peat + sand, peat + loam) and IBA (indole-3-butyric acid) concentration was investigated on hardwood cuttings taken from *Bougainvillea glabra*, *Bougainvillea spectabilis*, and *Bougainvillea* x *buttiana* species. The cuttings were treated with 0, 1000, 2000 and 3000 mg/l IBA. Statistical evaluation was performed according to a randomized block experimental design with three factors and three repetitions. The results showed that *Bougainvillea* x *buttiana* cuttings had the highest number of roots, root fresh weight, longest shoot length, and shoot fresh weight. Cuttings grown in 100% peat medium had the highest rooting percentage, root number, root dry weight, leaf number, and shoot fresh weight. Regarding IBA concentrations, the cuttings treated with 3000 ppm IBA had the highest number of roots, root length, and root fresh weight. Furthermore, in all of the *Bougainvillea* species, the highest rooting percentage and leaf number were observed in cuttings treated with 2000 ppm IBA. Notably, *Bougainvillea* x *buttiana* cuttings treated with 1000 ppm IBA dose and planted in peat medium provided the longest shoot length, highest shoot fresh weight, and shoot dry weight. In conclusion, the findings show that the growing medium has a statistically significant effect on the rooting and root quality of cuttings and that it would be useful to investigate various rooting hormones, dasages and rooting media to increase rooting and shoot development. Considering growing medium plays a crucial role in plant growth, it can be stated that further improvements in rooting and growth can be realized via utilizing the enhanced physical and chemical properties of peat-based mixtures.

Keywords: *Bougainvillea*, IBA, Ornamental plants, Plant propagation, Rooting medium

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Atıf: Rasul, A. T., Ak, B. E., Abdurrahman, Y. A., Hatipoğlu, İ. H. (2025). Begonvil (*Bougainvillea* spp.) çeliklerinin köklenme ve sürgün gelişimi üzerine, köklendirme ortamı ve IBA konsantrasyonunun etkilerinin araştırılması. *Tekirdağ Ziraat Fakültesi Dergisi,* 22(1): 18-34

Citation: Rasul, A. T., Ak, B. E., Abdurrahman, Y. A., Hatipoğlu, İ. H. (2025). Investigation of the effects of rooting medium and IBA concentration on rooting and shoot development of bougainvillea (*Bougainvillea* spp.) Cuttings. *Journal of Tekirdağ Agircultural Faculty,* 22(1): 18-34.

Öz

Bu çalışmada, *Bougainvillea glabra*, *Bougainvillea spectabilis* ve *Bougainvillea* x *buttiana* türlerine ait sert odun çelikleri için farklı köklendirme ortamlarının (turba yosunu, turba yosunu + tın (1:1), turba + kum (1:1)) ve IBA (indol-3-bütirik asit) konsantrasyonunun etkisi araştırılmıştır. Çeliklere 0 (Kontrol), 1000, 2000 ve 3000 mg/l seviyelerinde IBA uygulanmıştır. İstatistiksel değerlendirme, tesadüf bloklarında üç faktörlü ve üç tekrarlı, deney olarak tasarlanmıştır. Sonuçlar, *Bougainvillea* x *buttiana* çeliklerinin en fazla kök sayısına, kök taze ağırlığına, en uzun sürgün uzunluğuna ve sürgün taze ağırlığına sahip olduğunu göstermiştir. Yalnızca turba yosunu ortamında yetiştirilen çeliklerde en yüksek köklenme yüzdesine, kök sayısına, kök kuru ağırlığına, yaprak sayısına ve sürgün taze ağırlığına ulaşıldığı belirlenmiştir. IBA konsantrasyonlarının etkisine bakıldığında, 3000 ppm IBA uygulanan çeliklerin en yüksek kök sayısına, kök uzunluğuna ve kök taze ağırlığına sahip olduğu görülmüştür. Ayrıca Begonvil türlerinin tamamında en yüksek köklenme yüzdesi ve yaprak sayısının 2000 ppm IBA uygulanan çeliklerden sağlandığı görülmüştür. Özellikle, 1000 ppm IBA dozu ile muamele edilen ve yalnızca turba yosunu bulunan ortamına dikilen *Bougainvillea* x *buttiana* çeliklerinden en uzun sürgün uzunluğu, en yüksek sürgün taze ağırlığı ve sürgün kuru ağırlığı sağladığı belirlenmiştir. Sonuç olarak, bulguların genel değerlendirmesi, yetiştirme ortamının çeliklerde köklenme yeteneği ve kök kalitesi üzerinde istatistiksel olarak önemli bir etkiye sahip olduğunu ve köklenme ve sürgün gelişimini arttırmak için çeşitli köklendirme hormonlarının, dozlarının ve köklendirme ortamlarının araştırılmasının faydalı olacağını göstermektedir. Yetiştirme ortamının bitki büyümesinde çok önemli bir rol oynadığı göz önüne alındığında, turba yosunu bazlı karışımların gelişmiş fiziksel ve kimyasal özelliklerden yararlanılarak köklenme ve büyümede daha fazla olumlu sonuç alınabileceği söylenebilir.

Anahtar Kelimeler: Begonvil, IBA, Süs bitkileri, Bitki yetiştiriciliği, Köklendirme ortamı

1. Introduction

Nyctaginaceae family comprises 300-400 species of trees, shrubs, and herbaceous plants grouped into approximately 30 genera (Mabberley, 1997). Among them, the *Bougainvillea* genus includes 14 species. *Bougainvillea* is a popular tropical and subtropical ornamental plant commonly grown in containers in cooler climates during summer, and it can be overwintered or replanted annually (Gilman, 1999). The name "*Bougainvillea*" is derived from Louis Antoine de Bougainville, a French sailor and military leader who first observed the Brazilian plant in 1768 (Kobayashi et al., 2007). This climbing plant with thorns grows chaotically and can reach heights of up to nine meters. It is frequently used as a hedge, barrier, or slope cover, effectively covering large and challenging-to-maintain areas, preventing weed growth (Eed et al., 2015).

Bougainvillea is a versatile ornamental plant, suitable for hanging baskets, containers, and bonsai (Kobayashi et al., 2007; Rasul et al., 2021). Its popularity has grown due to urbanization, landscape horticulture, pollution and drought resistance, easy maintenance compared to other plants, and numerous applications (Singh, 2017). Additionally, it has gained attention for planting in heavy industrial areas and traffic islands to mitigate pollutants and greenhouse gases (Chauhan et al., 2016).

The *Bougainvillea* plant is utilized as a traditional treatment for digestive disorders in Mandsaur, India. *Bougainvillea glabra* has shown antidiarrheal activity linked to its antimicrobial properties. The genus *Bougainvillea* is known for its presence of anti-diabetic compounds. For optimal growth, *Bougainvillea* plants require full sun, high light density, and well-drained, acidic soil with specific temperature ranges. Reproduction is mainly achieved through stem cuttings.

The onset of urbanization, the emergence of environmental problems, and the longing of people who are away from nature for green areas have increased the importance of ornamental plants and forest trees (Gencer Gokce et al., 2022). There are some problems in plant propagation methods in the ornamental plant breeding sector, and it becomes extremely important to determine the appropriate propagation techniques of plants (Ak et al., 2022). The choice of a suitable propagation medium is crucial for successful rooting of cuttings. It provides an ideal environment for root development and nutrient uptake (Laubscher and Ndakidemi, 2008; Ak et al., 2021). A proper growing medium allows plants to extract water and nutrients effectively from the soil, contributing to healthy root systems (Landis et al., 1990). The quality of the rooting medium significantly influences rooting percentage and root quality (Kumar et al., 2015). It's essential to ensure adequate moisture and aeration in the medium for successful cutting establishment. While various propagation media exist, not all are suitable for all plant varieties and environmental conditions. Factors like plant type, season, use of growth-promoting compounds, and interactions between these elements affect the effectiveness of the propagation process (Dirr and Heuser, 1987; Ak et al., 2021). The most effective propagation method varies based on the plant type, cutting type, season, and the propagation facility used. Techniques such as misting fog and polyethylene tunnels are sometimes employed to control environmental conditions like air, temperature, relative humidity, and light during propagation (Beyl and Trigiano, 2016).

IBA (Indole-3-butyric acid) is a type of auxin that plays a crucial role in promoting the growth of adventitious roots in plants. Auxin is essential for plant propagation as it regulates various developmental processes, including stem elongation, early root formation, callus production, enzyme induction, and flowering, fruit, and leaf senescence. The rooting potential of certain plant species varies significantly based on the season when stem cuttings are taken, rather than a specific calendar date (Hartmann et al., 1997). Additionally, factors like the age of the mother tree and the use of plant growth regulators influence the rooting process of cuttings (Altoé et al., 2011; De Oliveira et al., 2015). It was determined that only the use of IBA during the rooting stages increased the number of roots (Öcalan et al., 2023).

Bougainvilleas are generally propagated by cuttings, but rooting failure is observed when propagated by hardwood cuttings. Auxin must be used to promote rooting (Akyiğit and Baktır, 1989; Ibironke, 2019). Rooting percentages of cuttings in Bougainvillea plants are low. This may cause economic losses (De Klerk et al., 1999). In this context, the hormones IBA, IAA and NAA are recommended, but due to the availability, accessibility and cost of supply of auxins, the study focused on determining the appropriate concentration of a single hormone.

The main objectives of this study are to compare the rooting ability of hardwood cuttings of three different *Bougainvillea* species (*Bougainvillea glabra*, *Bougainvillea spectabilis*, and *Bougainvillea* x *buttiana*). It was

aimed to determine the suitable environment and appropriate IBA concentration for hardwood cuttings of three different Bougainvillea plant species.

2. Materials and Methods

2.1. Material

The study was carried out in the plastic house of the Horticulture Department at the Directorate General of Agriculture in Duhok Governorate, located at 36° 51′42" N, 42° 56′13" E, and at an altitude of 522 m. The research was conducted from 15th February to 30th May 2021.

In the study, 3 different *Bougainvillea* species were used as plant material. The characteristics of these plants are explained in the following paragraphs.

Bougainvillea glabra is an evergreen climber with elliptical leaves that are green or variegated and have a glossy shine. The plant produces bracts in various sizes and shapes, usually triangular and mauve or purple, sometimes white. The bracts grow along the branches and at the branch tips, with blooms ranging in color from white to cream. The plant has short thorns with a curled point, and green-leaf types exhibit rapid growth with a spreading habit.

Bougainvillea spectabilis is distinguished by its sticky stems and leaves. The large, ovate leaves have hairs on the underside and rippled edges. The small flowers are cream-colored, while the bracts come in dark pink, red, or purple shades. The species exhibits an intense growth habit with vibrant bracts appearing both above and below the branches. Thorns on this plant can be large and curved.

Bougainvillea hybrids, specifically *B.* x *buttiana*, display dark pink or red bracts and short, straight thorns. The plant's open growth habit requires regular trimming to maintain a bushy appearance. These hybrids are known for blooming multiple times a year on average (Kobayashi et al., 2007).

The brand of peatmoss used is Greenterra®. The sand size used in this study is 0.2 - 0.5 mm (*Figure 1*).

Figure 1. Growing media used in the research

Table 1. Some physical and chemical properties of the propagation media.

Media	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	pH	EC (dS/m)	OM(%)	WHC(%)
Peat moss	-	-	-	6.47	0.74	74.70	70.00
Peat + Sand (1:1)	711.70	141.10	147.20	7.10	0.19	7.86	65.00
Peat + Loam (1:1)	500.50	303.30	191.70	7.15	0.265	11.35	52.00

OM: Organic matter,
WHC: Water Holding Capacity
The g/kg ratios in the table are determined according to dry weight.

In *Table 1*, various chemical and physical characteristics of samples were collected from three different growth mediums were presented. Texture analysis of media, including sand, silt, and clay content, was conducted using the

hydrometer method proposed by Bouyoucos (1962). pH and EC measurements were performed following the procedures outlined by Page et al. (1982). Organic matter content in the soil was assessed using soil analysis methods provided by Black et al. (1965).

2.2. Methods

In this study, the rooting response of three *Bougainvillea* species to different propagation media and varying IBA concentrations were investigated. Cuttings of the species were obtained in January from plants grown in the gardens of floriculture nurseries in the Department of Horticulture in Duhok province.

All cuttings that were cut were 20 cm and had 10 to 12 buds. These cuttings were taken from branches that were 2 years old. The cuttings were kept in a damp cloth in cold storage until February. The fresh weight is taken, then placed in a nylon bag inside a paper bag and dried in the oven for 48 hours at a temperature of 70 degrees Celsius the dry weight is taken. This process is carried out in the laboratories of the College of Agriculture at the University of Duhok. Irrigation is done according to soil dryness and use elecronic soil tester.

The cuttings from these species were treated with four different IBA concentrations (0, 1000, 2000, and 3000 mg l^{-1}). The cuttings were kept in the hormone for 10 seconds. All cuttings were at length 20 cm, and cut out a slant shape and put in 2/3 of the cuttings in the rooting media after it has been treated with rooting hormone. Subsequently, they were planted in black plastic pots of 28cm height×24cm dimensions, filled with three different media, that is, a peat moss and two peat moss-based mixtures. The peat moss-based mixtures were prepared using peat moss and sand in a ratio of 1:1 by volume and peat moss and loam in a ratio of 1:1 by volume.

Both the cuttings and the planting media were sterilized using Beltanol L 50% at a concentration of 1 ml l^{-1}.

In this experiment, a factorial Randomized Complete Block Design (RCBD) with three factors was employed, resulting in a total of (3 × 3 × 4) = 36 different treatments. Each treatment was replicated three times, and in each replication, there were eight cuttings per pot, resulting in a total of (3 × 3 × 4 × 3 × 8) = 864 cuttings for all species combined and 288 cuttings for each individual species.

At the end of the experimental period, the number of cuttings that had successfully developed roots was recorded, and these numbers were then converted into percentages for all the experiments.

After each experiment, the researchers recorded the number of visible roots formed on each cutting and measured the longest root length in centimeters from the base to the tip of the longest root using a ruler. The roots produced on the cuttings were then separated, placed in paper bags, and dried in an oven at 70°C for 48 hours. Once dried, the roots were weighed precisely using a balance. Moreover, the researchers counted the number of shoots that sprouted from the cuttings for each treatment and replication. The length of the shoots on the rooted cuttings was measured with a ruler and centimeter. Additionally, the number of leaves that developed on the cuttings was recorded for each treatment and replication.

The data from the experiments were analyzed using the SAS program (Anonymous, 2001), with means compared through Duncan's Multiple Range Test at a confidence level of less than 5%.

3. Results and Discussion

3.1. Rooting percentage (%)

The interaction between species and growing media affects significantly the rooting percentage of the cuttings. The highest rooting percentage (90.42%) was observed in the interaction of cuttings planted in peat moss medium, while the lowest percentage (66.67%) was found in peat moss + loam medium. Regarding IBA treatment, *B. glabra* cuttings treated with 1000 and 2000 mg L^{-1} IBA exhibited the highest rooting percentages of 85.00% and 84.72%, respectively. *B. spectabilis* cuttings with 0 mg L^{-1} IBA showed the lowest percentage of 61.11%. The interaction between growth media and IBA also played a significant role in rooting. The highest percentage (94.44%) observed in cuttings treated with 2000 mg L^{-1} IBA and planted in peat moss, while the lowest value (56.94%) was recorded in peat moss + loam medium.

Regarding the tree factor interactions between media, species and IBA dosages, the highest rooting percentage (100%) was observed in *B. glabra* cuttings planted in peat moss and treated with 2000 mg L^{-1} of IBA, indicating a successful rooting response. On the other hand, the lowest rooting percentage (50%) was recorded for untreated

cuttings of *B. spectabilis* planted in peat moss + loam medium, indicating a less favorable rooting outcome in this specific combination.

Table 2. Propagation media and IBA concentrations' effect on the rooting percentage of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				
		0ppm	1000ppm	2000ppm	3000ppm	Species x Media
B. glabra	Peat	87.50cd	92.50bc	100.00a	81.67d-f	90.42a
	Peat+Sand	79.17ef	87.50cd	58.33i	83.33de	77.08bc
	Peat+Loam	50.00j	75.00fg	95.83ab	75.00fg	73.96c
B. spectabilis	Peat	79.17ef	79.17ef	95.83ab	95.83ab	87.50a
	Peat+Sand	54.17ij	75.00ef	87.50cd	79.17ef	73.96c
	Peat+Loam	50.00j	87.50cd	66.67h	75.00fg	69.79d
B. x *buttiana*	Peat	79.07ef	66.67h	87.50cd	75.00fg	77.06bc
	Peat+Sand	83.33de	75.00fg	79.17ef	79.17ef	79.17b
	Peat+Loam	70.83gh	70.83gh	58.33i	66.67h	66.67e
	Peat+Sand	72.22f	79.17cd	75.00ef	80.56cd	
	Peat+Loam	56.94g	77.78de	73.61f	72.22f	
						Species means
Species × IBA Conc.	*B. glabra*	72.22 ef	85.00a	84.72a	80.00bc	80.49a
	B. spectabilis	61.11g	80.56bc	83.33ab	83.33ab	77.08b
	B. x buttiana	77.74cd	7083f	75.00de	73.61ef	74.30c
						Media means
Media × IBA Conc.	Peat	81.91bc	79.44cd	94.44a	84.17b	84.99a
	Peat+Sand	72.22f	79.17cd	75.00ef	80.56cd	76.74b
	Peat+Loam	56.94g	77.78de	73.61f	72.22f	70.14c
IBA conc. means		69.69c	78.80b	81.02a	78.98b	-

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

Table 3. Propagation media and IBA concentrations' effect on roots number of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	9.99r	16.38i-l	13.54m-q	13.12n-q	13.26de	
	Peat+Sand	11.46qr	12.61o-q	14.00l-p	11.47qr	12.38e	12.03c
	Peat+Loam	5.78s	11.92p-r	14.17l-p	9.88r	10.44f	
B. spectabilis	Peat	16.19j-l	21.01d-f	21.93c-e	28.69a	21.96a	
	Peat+Sand	15.25j-n	16.17j-l	19.23f-h	20.22e-g	17.72c	17.15b
	Peat+Loam	6.27s	16.93h-k	15.28j-n	15.88j-m	13.59d	
B. x *buttiana*	Peat	20.15e-g	23.28b-d	22.37c-e	23.66bc	22.37a	
	Peat+Sand	17.65h-j	17.29h-j	21.38c-f	23.29b-d	19.90b	20.10a
	Peat+Loam	18.64g-i	14.55k-o	13.94l-p	24.97b	18.03c	
Species × IBA Conc.	*B. glabra*	9.08g	13.64de	13.90d	11.49f		
	B. spectabilis	12.57ef	18.03c	18.81c	21.60b	Media means	
	B. x buttiana	18.81c	18.37c	19.23c	23.97a		
Media × IBA Conc.	Peat	15.44e	20.22b	19.28bc	21.82a	19.19a	
	Peat+Sand	14.79e	79.17cd	18.20c	18.33c	16.67b	
	Peat+Loam	10.23f	77.78de	14.46e	16.91d	14.02c	
IBA conc. means		13.00c	16.68b	17.32b	19.02a	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

3.2. Root number per cutting

The results presented in *Table 3* demonstrate that the species, growth media, and IBA concentrations all have significant effects on the number of roots formed on the cuttings. According to species main effect, *B.* x *buttiana* had the highest number of roots per cutting (20.10), while *B. glabra* had the lowest (12.03). The peat moss medium resulted in the maximum number of roots per cutting (19.19), while the medium containing peat moss + loam (1:1) had the lowest number (14.02). Treatment with 3000 mg L^{-1} IBA led to a significant increase in the number of roots per cutting (19.02) compared to the untreated cuttings (13 roots) (*Figure 2*). The interactions between species and propagation media, species and IBA concentrations, and propagation media and IBA concentrations also showed significant differences in the number of roots formed on the cuttings. The highest root number was observed in *B*. x *buttiana* cuttings planted in peat moss medium with 3000 ppm IBA treatment (22.37 roots), while the lowest number was in *B. glabra* cuttings planted in peat moss + loam medium (10.44 roots). Triple interaction effects also revealed significant differences, with *B. spectabilis* cuttings planted in peat moss medium with 3000 mg L^{-1} IBA showing the highest root number (28.69 roots), and *B. glabra* cuttings planted in peat moss + loam medium and untreated (0 ppm) having the lowest root number.

Figure 2. Effects of IBA concentrations on root number

3.3. Length of longest root per cutting

The data in the *Table 4* indicated that main effect of *Bougainvillea* species were significant on the longest roots length, the cuttings of *B. glabra* and B. x *buttiana* had the longest root length (26.54 and 26.00 cm) respectively when compared with cuttings of *B. spectabilis* which gave a shorter root length (24.41 cm). The roots produced on cuttings planted in peat moss medium provided the longest root length (26.18cm) in comparison with the shorter root length (24.99 cm) for Peatmoss + Loam (1:1) medium. IBA concentration (3000) mg L-1 showed the highest root length (26.30 cm) which was significant with control (24.78 cm). It was concluded from the results of the dual interaction between species and propagation media the excellence of cuttings of *B. glabra* planted in alone peat moss medium which gave the longest roots (27.33 cm) in comparison to minimum roots length (23.53 cm) were found on cuttings of *B. spectabilis* planted in medium contained peatmoss + loam (1:1). From the interaction between species and IBA concentrations, the significantly highest length root was found from Cuttings *B. glabra* treated with 3000 mg L^{-1} IBA (28.12 cm) in comparison with the least root length (24.11 cm) from 2000 mg L^{-1} of *B. spectabilis* cuttings. The results for a dual-action of propagation medium and concentrations of IBA cleared that the cuttings planted in peat moss medium and treated with 3000 mg L^{-1} of IBA provided the significantly highest root length (26.98 cm) while the minimum root length (24.03 cm) were shown in the control treatment 0 mg L^{-1} in peatmoss + loam media (1:1). For triple interaction among all three studied factors, the significant highest length of roots (29.56 cm) was noticed for *B. glabra* cuttings that were planted in peatmoss medium and treated

with 3000 mg L^{-1} of IBA which was different importantly with all interactions while the minimum length of roots (22.66 cm) was for same species cuttings that planted in peatmoss + loam (1:1) and treated with 0 mg L^{-1} of IBA.

The data presented in *Table 4* shows that the length of roots on *Bougainvillea* cuttings is influenced by the species, propagation media, and IBA concentrations. *B. glabra* and B. x *buttiana* cuttings had the longest roots (26.54 cm and 26.00 cm, respectively) compared to *B. spectabilis* (24.41 cm). Peat moss medium resulted in longer roots (26.18 cm) compared to peatmoss + loam (1:1) medium (24.99 cm). The highest IBA concentration (3000 mg L^{-1}) showed the longest root length (26.30 cm), significantly different from the control (24.78 cm). The dual interaction between species and propagation media revealed that *B. glabra* cuttings in peat moss had the longest roots (27.33 cm) while *B. spectabilis* cuttings in peatmoss + loam (1:1) had the shortest (23.53 cm). In the dual interaction between species and IBA concentrations, *B. glabra* cuttings treated with 3000 mg L^{-1} IBA had the longest roots (28.12 cm), whereas *B. spectabilis* cuttings treated with 2000 mg L^{-1} had the shortest (24.11 cm). The interaction between propagation media and IBA concentrations showed that cuttings in peat moss treated with 3000 mg L^{-1} IBA had the longest roots (26.98 cm), while the control treatment in peatmoss + loam media (1:1) had the shortest (24.03 cm). For the triple interaction among all factors, the longest roots (29.56 cm) were observed in *B. glabra* cuttings planted in peatmoss medium and treated with 3000 mg L^{-1} of IBA, significantly different from all other interactions, while the shortest roots (22.66 cm) were found in *B. glabra* cuttings in peatmoss + loam (1:1) medium and treated with 0 mg L^{-1} of IBA.

Table 4. Propagation media and IBA concentrations' effect on the longest root length (cm) of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	27.07a-f	28.26a-d	24.41d-h	29.56a	27.33a	
	Peat+Sand	23.65e-h	25.97a-h	29.33ab	28.99a-d	26.81ab	26.54a
	Peat+Loam	22.66h	26.67a-h	26.07a-h	26.51a-h	25.48a-c	
B. spectabilis	Peat	24.71d-h	26.80a-g	24.20d-h	24.11e-h	24.95b-d	
	Peat+Sand	24.90d-h	23.92e-h	25.23c-h	24.95d-h	24.75cd	24.41b
	Peat+Loam	24.07e-h	23.61e-h	22.91gh	23.54e-h	23.53d	
B. x *buttiana*	Peat	27.04a-g	26.71a-h	24.00e-h	27.26a-e	26.25a-c	
	Peat+Sand	24.10e-h	27.40a-e	25.51a-h	26.22a-h	25.81a-c	26.00a
	Peat+Loam	25.36b-h	23.00f-h	29.22a-c	26.23a-h	25.95a-c	
Species × IBA Conc.	*B. glabra*	24.46cd	26.97ab	26.61a-c	28.12a		
	B. spectabilis	24.56cd	24.78b-d	24.11d	24.20d	Media means	
	B. x buttiana	25.50b-d	25.70b-d	26.24a-d	26.57a-c		
Media × IBA Conc.	Peat	26.27a-c	27.26a	24.20cd	26.98a	26.18a	
	Peat+Sand	24.22cd	25.76a-d	26.69a	26.49ab	25.79ab	
	Peat+Loam	24.03d	24.43b-d	26.07a-d	25.43a-d	24.99b	
IBA conc. means		24.78b	25.82ab	25.65ab	26.30a	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

3.4. Fresh weight of roots

The data in *Table 5* reveals that the species, propagation media, and IBA concentrations were significant for the fresh weight of roots per cutting in *Bougainvillea*. B. x *buttiana* had the highest root fresh weight (3.39 g) while *B. glabra* had the lowest (1.89 g). Peatmoss + loam medium resulted in the highest root fresh weight (2.71 g) while peatmoss + sand (1:1) had the lowest (2.35 g). IBA concentration at 3000 mg L-1 showed the highest fresh weight of roots (2.76 g) compared to the control (1.95 g). In the dual interaction, B. x *buttiana* cuttings in peat moss medium had the maximum fresh weight (3.61 g) while *B. glabra* cuttings in peatmoss and peatmoss + sand (1:1) had the least (1.63 g). For the interaction between species and IBA concentrations, B. x *buttiana* cuttings treated with 3000 mg L-1 had the highest fresh weight (4.17 g) compared to *B. glabra* cuttings treated with the same concentration (1.59 g). In the dual interaction between media and IBA concentrations, cuttings in peatmoss + loam (1:1) treated with 2000 and 3000 ppm had the highest fresh weight of roots (3.04 g and 3.17 g) respectively, while the control in peatmoss medium had the lowest (1.86 g). The triple interaction showed that B. x *buttiana* cuttings treated with 3000 ppm of IBA and planted in peatmoss and peatmoss + loam (1:1) had significantly the

highest fresh weight of roots (4.45 g and 4.52 g) respectively, while *B. glabra* cuttings treated with the same concentration in peatmoss + sand (1:1) had the lowest (1.07 g).

Table 4. Propagation media and IBA concentrations' effect on root frest weight (g) of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	1.69k-m	1.53lm	1.60k-m	1.71k-m	1.63f	
	Peat+Sand	1.87j-m	1.61k-m	1.99i-l	1.07n	1.63f	1.89c
	Peat+Loam	1.46mn	3.41d-f	2.75gh	1.99i-l	2.40d	
B. spectabilis	Peat	1.68k-m	2.37hi	1.99i-l	1.74k-m	1.95e	
	Peat+Sand	1.43mn	2,03i-k	1.82j-m	2.82g	2.02e	2.17b
	Peat+Loam	1.48mn	2.66gh	3.09fg	2.99fg	2.55d	
B. x *buttiana*	Peat	2.22ij	3.74cd	4.03bc	4.45a	3.61a	
	Peat+Sand	3.09fg	4.22ab	2.68gh	3.55de	3.39b	3.39a
	Peat+Loam	3.32d-f	1.61k-m	3.28ef	4.52a	3.18c	
Species × IBA Conc.	*B. glabra*	1.67f	2.18e	2.11e	1.59f		
	B. spectabilis	1.53f	2.35de	2.30de	2.52d	Media means	
	B. x buttiana	2.88c	3.19b	3.33b	4.17a		
Media × IBA Conc.	Peat	1.86d	2.55b	2.54b	2.63b	2.39b	
	Peat+Sand	2.13c	2.62b	2.16c	2.48b	2.35b	
	Peat+Loam	2.09cd	2.56b	3.04a	3.17a	2.71a	
IBA conc. means		1.95c	2.57b	2.58b	2.76a	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

Table 5. Propagation media and IBA concentrations' effect on root dry weight (g) of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	0.397no	0.487k-n	0.357no	0.610h-l	0.463ef	
	Peat+Sand	0.363no	0.413m-o	0.530i-n	0.413m-o	0.430f	0.467c
	Peat+Loam	0.293o	0.593h-m	0.500j-n	0.643g-l	0.508d-f	
B. spectabilis	Peat	0.640g-l	0.763c-h	0.473k-o	0.647g-l	0.631c	
	Peat+Sand	0.353no	0.730d-h	0.4633-o	0.593h-m	0.535de	0.584b
	Peat+Loam	0.350no	0.660g-k	0.677f-j	0.660g-k	0.587cd	
B. x *buttiana*	Peat	0.367no	0.927bc	1.850a	0.847c-f	0.998a	
	Peat+Sand	0.620h-l	0.903b-d	0.710e-i	0.813c-g	0.787b	0.849a
	Peat+Loam	0.823c-g	0.387no	0.873c-e	1.063b	0.787b	
Species × IBA Conc.	*B. glabra*	0.351h	0.498fg	0.462fg	0.556ef		
	B. spectabilis	0.448g	0.718cd	0.538e-g	0.633de	Media means	
	B. x buttiana	0.603e	0.739c	1.144a	0.908b		
Media × IBA Conc.	Peat	0.468gh	0.726bc	0.893a	0.701b-d	0.697a	
	Peat+Sand	0.446h	0.682cd	0.568ef	0.607de	0.576c	
	Peat+Loam	0.489f-h	0.547e-g	0.683cd	0.789b	0.627b	
IBA conc. means		0.455c	0.651b	0.715a	0.699ab	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

3.5. Dry weight of roots

The dry weight of roots per cutting in different *Bougainvillea* species was significantly differed, with B. x *buttiana* cuttings showing the highest dry weight (0.849 g) and *B. glabra* cuttings having the least dry weight (0.467 g). Planting cuttings in peat moss medium resulted in the highest dry weight of roots (0.697 g), while peat moss + sand (1:1) medium had the lowest weight (0.576 g). Treatment with 2000 mg L^{-1} IBA significantly increased the dry weight of roots (0.715 g) compared to untreated cuttings (0 mg L^{-1} IBA, 0.455 g). Dual interactions revealed that *B.* x *buttiana* cuttings in peat moss medium had the highest dry weight (0.998 g), and *B. glabra* cuttings in peat moss + sand (1:1) had the least dry weight (0.430 g). Additionally, *B.* x *buttiana* cuttings treated with 2000 mg L^{-1} IBA showed the highest dry weight (1.144 g) in interaction, while *B. glabra* cuttings with 0 mg L-1 IBA exhibited the lowest dry weight (0.351 g). The triple interaction indicated that *B.* x *buttiana* cuttings planted in peat moss and treated with 2000 mg L^{-1} IBA had the highest dry weight (1.850 g), while *B. glabra* cuttings in peat moss + loam (1:1) with 0 mg L^{-1} IBA showed the lowest weight (0.293 g).

3.6. Shoot number per cutting

The results presented in *Table 6* show that the number of shoots per cutting was affected by the factors studied. *B. spectabilis* species had the highest number of shoots (2.81) per cutting, while *B.* x *buttiana* had the lowest (2.24). Cuttings planted in peatmoss and peatmoss + loam (1:1) media produced the highest number of shoots (2.54 and 2.57, respectively) compared to the lowest number (2.34) in peatmoss + sand (1:1) medium. Untreated cuttings with 0 mg L^{-1} IBA had the maximum number of shoots (2.64), significantly higher than cuttings treated with 1000 and 3000 mg L^{-1} IBA (2.42 and 2.41, respectively). Regarding dual interactions, *B. spectabilis* cuttings in peatmoss + loam (1:1) medium had the highest number of shoots (2.92), while *B.* x *buttiana* cuttings in peatmoss + sand (1:1) had the lowest (2.18). The highest number of shoots from dual interactions between species and IBA doses was found in *B. spectabilis* cuttings treated with 3000 ppm of IBA (2.92), while B. x *buttiana* cuttings treated with 1000 mg L^{-1} IBA had the lowest (1.98). The interaction of peatmoss + loam (1:1) medium and 0 mg L^{-1} IBA resulted in the highest number of shoots (2.75), while peatmoss + sand (1:1) medium and 1000 mg L^{-1} IBA showed the lowest (2.15). In the triple interaction, the highest number of shoots (3.24) was observed in *B. spectabilis* cuttings planted in peatmoss + loam (1:1) medium and treated with 3000 mg L^{-1} IBA, while the lowest number (1.72) was found in *B. glabra* cuttings treated with the same IBA treatment and planted in peatmoss + sand (1:1) medium.

Table 6. Propagation media and IBA concentrations' effect on shoot number per cutting of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	2.74b-f	2.56c-I	2.33e-l	2.53c-j	2.54bc	
	Peat+Sand	2.54c-i	2.29f-m	2.39d-l	1.72o	2.23de	2.41b
	Peat+Loam	2.67b-h	2.66b-h	2.44d-l	2.02k-o	2.45b-d	
B. spectabilis	Peat	3.00a-c	3.08ab	2.69b-g	2.83a-e	2.90a	
	Peat+Sand	2.75b-f	2.41d-l	2.61b-i	2.69b-g	2.62b	2.81a
	Peat+Loam	2.89a-d	2.81a-f	2.72b-g	3.24a	2.92a	
B. x *buttiana*	Peat	2.22g-n	2.38d-l	1.97l-o	2.17h-o	2.19e	
	Peat+Sand	2.03j-o	1.75no	2.81a-f	2.13i-o	2.18e	2.24c
	Peat+Loam	2.69b-g	1.80m-o	2.50c-k	2.37e-l	2.34c-e	
Species × IBA Conc.	*B. glabra*	2.65b-d	2.50c-e	2.39d-f	2.09gh		
	B. spectabilis	2.88ab	2.77ab	2.67a-c	2.22a	Media means	
	B. x buttiana	2.31e-g	1.98h	2.43c-f	2.51a-c		
Media × IBA Conc.	Peat	2.65ab	2.67ab	2.33c-e	2.51a-c	2.54a	
	Peat+Sand	2.44b-d	2.15e	2.60a-c	2.18de	2.34b	
	Peat+Loam	2.75a	2.42b-d	2.56a-c	2.54a-c	2.57a	
IBA conc. means		2.64a	2.42b	2.50ab	2.41b	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

3.7. Leaves number per cutting

The results presented in *Table 7* indicate that the effects of factors were significant with regard to number of leaves per cutting. Cuttings of *B. spectabilis* had the highest number of leaves (59.76) when treated with 2000 mg L^{-1} IBA, while the lowest number (47.85) was observed with 3000 mg L^{-1} IBA treatment. In terms of dual interactions, *B. spectabilis* cuttings planted in peatmoss medium showed the highest number of leaves (74.76) compared to other interactions, especially when *B. glabra* cuttings were planted in peatmoss + loam (1:1) medium, resulting in the lowest number of leaves (31.27). The number of leaves per cutting for *B. glabra* cuttings varied with different IBA concentrations, with the highest number (70.00) observed with 2000 mg L^{-1} IBA treatment and the lowest number (35.34) with 3000 mg L^{-1} IBA treatment. Additionally, when cuttings were planted in peatmoss medium and treated with 1000 mg L^{-1} IBA, the highest number of leaves per cutting (75.64) was obtained, while the lowest number (34.10) was observed for cuttings planted in peatmoss + loam (1:1) and treated with 2000 mg L^{-1} IBA. The largest number of leaves (97.33) was noticed in the triple interaction of *B. glabra* cuttings treated with 2000 mg L^{-1} IBA and planted in peatmoss + sand (1:1) medium, whereas the lowest number (31.63) was seen with *B. spectabilis* cuttings treated with the same concentration of IBA and planted in peatmoss + loam (1:1) medium.

Table 7. Propagation media and IBA concentrations' effect on leaves number per cutting of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	68.73ef	73.68de	77.46cd	49.07k-m	67.23b	
	Peat+Sand	49.92j-l	61.94gh	97.33a	35.19pq	61.10c	53.20b
	Peat+Loam	32.89q	35.22pq	35.21pq	21.77r	31.27g	
B. spectabilis	Peat	73.13de	90.00b	71.06e	6486fg	74.76a	
	Peat+Sand	57.37hi	50.93jk	81.82c	62.47gh	6315c	59.62a
	Peat+Loam	52.49i-k	35.91pq	31.63q	43.77m-o	40.95f	
B. x *buttiana*	Peat	38.85op	63.25g	55.29ij	52.66i-k	52.51d	
	Peat+Sand	47.45k-m	40.84n-p	52.61i-k	49.21k-m	47.53e	47.09c
	Peat+Loam	45.00l-n	32.80q	35.47pq	51.63jk	41.23f	
Species × IBA Conc.	*B. glabra*	50.51de	56.95c	70.00a	35.34h		
	B. spectabilis	60.99b	58.95bc	61.50b	57.03c	Media means	
	B. x buttiana	43.77g	45.63fg	47.79ef	51.17d		
Media × IBA Conc.	Peat	60.24c	75.64a	67.93b	55.53d	64.84a	
	Peat+Sand	51.58e	51.24e	77.25a	48.96e	57.26b	
	Peat+Loam	43.46f	34.64h	34.10h	39.06g	37.82c	
IBA conc. means		52.48c	53.84b	59.76a	47.85d	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

3.8 Shoots fresh weight

The results from *Table 8* show significant variations in fresh shoot weight among *Bougainvillea* species. *B.* x *buttiana* cuttings had the highest fresh shoot weight (22.07 g) compared to *B. glabra* cuttings (10.62 g). Planting cuttings in peatmoss medium resulted in the highest fresh shoot weight (16.94 g), while peatmoss + loam (1:1) medium had the lowest weight (12.71 g). IBA concentrations of 2000 and 3000 mg L^{-1} produced the maximum fresh shoot weight (16.33 g and 16.01 g) respectively, significantly higher than the control (12.47 g). In terms of dual interactions, B. x *buttiana* cuttings planted in peatmoss medium showed the highest fresh shoot weight (24.40 g), while *B. glabra* cuttings in peatmoss + loam (1:1) had the lowest weight (7.98 g). Similarly, *B.* x *buttiana* cuttings treated with 3000 mg L^{-1} IBA had the highest fresh shoot weight (25.69 g), whereas *B. glabra* cuttings treated with the same concentration of IBA had the lowest weight (8.76 g). Cuttings planted in peatmoss and treated with 1000 mg L^{-1} IBA showed the highest fresh shoot weight (20.32 g), while peatmoss + loam (1:1) medium without IBA treatment had the lowest weight (11.36 g). In the triple interaction, *B.* x *buttiana* cuttings in

peatmoss and treated with 1000 mg L^{-1} IBA exhibited the highest fresh shoot weight (30.59 g), while *B. glabra* cuttings in peatmoss + loam (1:1) and treated with 3000 mg L^{-1} IBA had the lowest weight (6.37 g).

Table 8. Propagation media and IBA concentrations' effect on shoot fresh weight of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	11.23l-n	12.75i-l	12.39j-l	9.98no	11.59d	
	Peat+Sand	10.35m-o	11.21l-n	17.72g	9.93no	12.30d	10.62c
	Peat+Loam	7.06qr	9.94no	8.54o-q	6.37r	7.98f	
B. spectabilis	Peat	13.71h-k	17.63g	14.17h-j	13.80h-k	14.83c	
	Peat+Sand	12.08k-m	12.68i-l	18.04fg	15.59h	14.60c	12.97b
	Peat+Loam	9.39n-p	9.66no	7.50p-r	11.35l-n	9.47e	
B. x *buttiana*	Peat	14.73hi	30.59a	25.99c	26.28c	24.40a	
	Peat+Sand	19.70ef	21.75d	20.97de	22.15d	21.14b	22.07a
	Peat+Loam	17.62g	14.79h	21.69d	28.63b	20.68b	
Species × IBA Conc.	*B. glabra*	9.55f	11.30e	12.88d	8.76f		
	B. spectabilis	11.73e	13.32d	13.23d	13.58d	Media means	
	B. x buttiana	17.35c	22.38b	22.88b	25.69cd		
Media × IBA Conc.	Peat	13.23fg	20.32a	17.51c	16.69cd	16.94a	
	Peat+Sand	14.04f	15.21e	18.91b	15.89de	16.01b	
	Peat+Loam	11.36h	11.46h	12.57g	15.45e	12.71c	
IBA conc. means		12.47c	15.66ab	16.33a	16.01a	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

Table 9. Propagation media and IBA concentrations' effect on shoot dry weight of hardwood cuttings of three Bougainvillea species

Species	Media	IBA Concentrations				Species x Media	Species means
		0ppm	1000ppm	2000ppm	3000ppm		
B. glabra	Peat	3.42h-l	3.41h-l	3.15i-m	2.82k-n	3.20d	
	Peat+Sand	2.56l-n	3.11j-m	4.42e-g	2.20mn	3.07d	2.87c
	Peat+Loam	1.88n	3.07j-m	2.38mn	2.04n	3.07d	
B. spectabilis	Peat	4.10e-I	4.98e	3.91f-j	3.98f-j	4.24c	
	Peat+Sand	3.13j-m	3.80g-j	4.80ef	4.51e-g	4.06c	3.79b
	Peat+Loam	3.62g-k	2.82k-n	2.25mn	3.60g-k	3.08d	
B. x *buttiana*	Peat	4.32e-h	9.58a	7.62b	6.87bc	7.10a	
	Peat+Sand	5.99cd	6.65cd	5.90d	6.43cd	6.24b	6.57a
	Peat+Loam	5.84d	4.39e-g	6.31cd	8.97a	6.38b	
Species × IBA Conc.	*B. glabra*	2.62f	3.20e	3.31e	2.35f		
	B. spectabilis	3.62de	3.87d	3.65de	4.03d	Media means	
	B. x buttiana	5.38c	6.87b	6.61b	7.42a		
Media × IBA Conc.	Peat	3.95de	5.99a	4.89bc	4.56bc	4.85a	
	Peat+Sand	3.89de	4.52bc	5.04b	4.38cd	4.46b	
	Peat+Loam	3.78e	3.43e	3.65e	4.87bc	3.93c	
IBA conc. means		3.74b	4.65a	4.53a	4.60a	-	

According to the Duncan Multiple Range Test, means with the same letter for every factor and interactions are not statistically different at the 5% level.

The available results from *Tables 2* to *9* consistently show that the use of alone peat moss as a propagation medium provides better outcomes compared to other media for various characteristics. It leads to significantly higher rooting percentage (84.99%), more roots per cutting (19.19 roots), longer root length per cutting (26.18 cm), greater root dry

weight (0.697 g), longer shoots length per cutting (34.55 cm), more leaves per cutting (64.84), higher fresh weight of shoots (16.94 g), and higher dry weight of shoots (4.85 g).

The findings from various studies (Bosila et al., 2010; Abdulrahman, 2012; Hasan and Hammo, 2021; Mehmood et al., 2013) consistently confirm that peat moss is an excellent medium for promoting high rooting rates and improving root characteristics in various plant cuttings. Peat moss has been shown to enhance root length, dry weight of roots, and number of shoots, shoot length, and overall plant growth. Its physical and chemical properties, such as high-water retention, low bulk density, and high porosity, contribute to its effectiveness as a growth medium. Additionally, when combined with other media, peat moss can further enhance its physical qualities, resulting in improved plant rooting and growth. The fertility of the medium also plays a crucial role in nutrient absorption and plant growth, especially regarding nitrogen and other essential elements. Overall, the choice of growth medium is a vital component of the propagation system, significantly influencing rooting ability and root quality in cuttings.

The results presented in *Tables 2*, *6*, and *7* demonstrate that treating the cuttings with 2000 mg L-1 IBA led to a significant increase in rooting percentage, number of leaves per cutting, and dry weight of roots. These findings are in line with previous studies conducted by Hammo et al. (2013), Kuldeep et al. (2013), Wagh et al. (2013), and Çorbacı et al. (2023) on various plant species, which also showed positive effects of IBA on rooting and plant growth. Similarly, *Tables 2* and *4* show that the application of 3000 mg L-1 IBA resulted in the highest number of roots per cutting, longest root length. These observations are supported by the research of Ashok and Ravivarman (2020) and Youssef (2020) on different plant cuttings, including *Bougainvillea* and *Ficus benjamin*. Additionally, *Table 9* indicates that the highest length of the longest shoot per cutting was achieved with 1000 mg L-1 IBA, consistent with the findings of Yeshiwas et al. (2015) and Mehraj et al. (2013) on rose and *Bougainvillea* cuttings, respectively. Overall, plant hormones, particularly auxins like IBA, play a crucial role in the cutting propagation process, influencing root development, cell division, elongation, and differentiation, as well as other growth and developmental processes in plants.

On the other hand, *B. glabra* species resulted in the highest rooting percentage per cutting (80.49%) according to *Table 2*. The greatest length of the longest root was found in *B. glabra* (26.54 cm) and B. x *buttiana* (26.00 cm) species, as indicated in *Table 4*. Moreover, *B. spectabilis* showed the maximum number of shoots per cutting (2.81 shoots) and leaves number per cutting (59.62 leaves) as shown in *Tables 6* and *7*, respectively. In summary, B. x *buttiana* cuttings generally outperformed the other species in terms of rooting ability, root and shoot characteristics, while *B. glabra* exhibited the highest rooting percentage. *B. spectabilis*, on the other hand, showed superior performance in terms of shoot and leaf development.

The ability of stem cuttings to produce adventitious roots can vary significantly among different plant species (Beyl and Trigiano, 2016). The success of woody species in cutting reproduction is often associated with the availability of reserve components, especially carbohydrates, in the stem, providing the necessary energy for root development (Stuepp et al., 2017).

Regarding the longest root length per cutting, *B. glabra* and *B.* x *buttiana* species performed noticeably better than *B. spectabilis*, similar to the differences observed in stem cuttings of *Actinidia deliciosa* and *Actinidia arguta* (Peticila et al., 2016). The improvement in root length can be attributed to genetic factors and the number of leaves. Genetic factors play a crucial role in establishing a robust root system, while the number of leaves contributes to food production and translocation of nutrients to support root growth (Osterbye, 1970). The influence of plant species is evident in the highest number of shoots and leaves produced by *B. spectabilis* cuttings, consistent with the results of Banjara (2017) on Terminalia species. A well-developed root system supports the growth of new shoots by ensuring efficient transport of water and nutrients from the propagation media to the developing plant (Mewar and Naithani, 2016). The plant hormone cytokinin also plays a role in regulating cell division and differentiation during leaf and shoot growth (Efroni et al., 2013).

Noiton et al. (1992) suggested that the plant hormone ABA (abscisic acid) could be one of the factors hindering root production in difficult-to-root plants. Swamy et al. (2002) studied the relationship between the amount of natural auxins and their function in cuttings, as well as the presence of accessible forms of carbohydrates and nitrogenous elements at the cutting's base, which can influence the rooting process and other properties. Additionally, the formation of shoots on cuttings before root development, due to favorable environmental factors, may lead to the release of cytokinins from these shoots, encouraging the development of buds on cuttings, as mentioned by Abdlqader (1999).

When roots develop on cuttings, they provide the necessary water and nutrients for shoot development and growth.

4. Conclusions

According to the obtained data, *Bougainvillea* x *buttiana* cuttings showed significant superiority in terms of rooting characteristics. The highest number of roots, fresh and dry root weight, longest shoots, and shoot weight were recorded for *Bougainvillea* x *buttiana*. On the other hand, *Bougainvillea glabra* had the highest rooting percentage, while *Bougainvillea spectabilis* had the highest number of shoots and leaves. Peat moss medium generally demonstrated the best rooting performance. It resulted in the highest number of roots, dry root weight, leaves number, fresh shoot weight, and dry shoot weight. Peat moss + loam (1:1) provided the highest fresh root weight, and alone peat moss and peat moss + sand (1:1) produced the longest roots and shoots, respectively. Different IBA concentrations significantly affected rooting. Treatment with 3000 mg L-1 IBA resulted in the highest number of roots and fresh root weight. 2000 mg L-1 IBA treatment led to the highest rooting percentage and leaves number, while 1000 mg L-1 IBA treatment produced the longest shoots. Root dry weight was highest at 2000 and 3000 mg L-1 IBA treatments, whereas fresh and dry shoot weights were highest at 2000, 3000, and 1000 mg L-1 IBA treatments, respectively. Overall, the best results were obtained with *Bougainvillea* x *buttiana* cuttings planted in peat moss medium and treated with 1000 mg L-1 IBA. *Bougainvillea glabra* cuttings planted in peat moss medium and treated with 2000 and 3000 mg L-1 IBA showed the highest rooting percentage and longest roots, respectively. *Bougainvillea spectabilis* cuttings treated with 3000 mg L-1 IBA in peat moss medium and peat moss + loam (1:1) medium produced the highest number of roots and shoots, respectively.

The conducted experiment provides valuable recommendations for the propagation of *Bougainvillea* species:

- *Bougainvillea* x *buttiana* is the preferred species for propagation over *Bougainvillea glabra* and *Bougainvillea spectabilis* due to its superior rooting capability and higher success rate.
- The use of auxin (IBA) treatment is recommended for enhancing the rate of rooting in cuttings, especially at higher concentrations. IBA promotes physiological processes within the cuttings, leading to improved rooting and shoot development.
- Planting the cuttings in alone peat moss medium yields favorable results. Ensuring proper environmental conditions, such as temperature and relative humidity, is crucial for successful rooting.
- Future research should focus on the individual effects of various factors on the rooting process and shoot development. Analyzing all cutting components, including hormones, can provide valuable insights.
- Investigating the impact of the wounding process on cuttings' success is essential to understand its beneficial and harmful effects.
- Exploring the use of other types of auxins, such as IAA and NAA, and combining them with IBA, may lead to even better results in rooting cuttings of *Bougainvillea* species.
- Experimenting with various media types and mixtures for propagating cuttings of *Bougainvillea* can help optimize the rooting process and overall plant development. By considering these recommendations, horticulturists and researchers can improve the propagation success of *Bougainvillea* species and potentially enhance their cultivation and commercial applications.

Acknowledgment

This work was not supported financially by any organization.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authorship Contribution Statement

Concept: Rasul, A. T., Ak, B. E.; Design: Rasul, A. T., Ak, B. E, Abdulrahman Y. A., Hatipoğlu İ. H.; Data Collection or Processing: Rasul, A. T., Abdulrahman Y. A.; Statistical Analyses: Rasul, A. T., Hatipoğlu İ. H.; Literature Search: Rasul, A. T., Hatipoğlu İ. H.; Writing, Review and Editing: Rasul, A. T., Ak, B. E, Abdulrahman Y. A., Hatipoğlu İ. H.

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