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Growth Regulator and Plant Growth Promoting Rhizobacteria (PGPR Mix I) Treated Rooting Media for Rapid Propagation of Cut Foliage *Dracaena fragrans* 'Massangeana'

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Aim: The study aimed to identify an effective propagation method for cut-foliage *Dracaena fragrans* 'Massangeana' by evaluating different types of stem cuttings, root-promoting treatments and rooting substrates. Particular emphasis was placed on PGPR Mix I-enriched rooting media to accelerate root initiation, improve cutting establishment and increase the production of healthy planting material.

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Study Design: The experiment was conducted using a three-factor factorial completely randomised design (CRD) with 36 treatment combinations comprising three cutting types, four root-promoting treatments and three rooting media.
Place and Duration of Study: The experiment was conducted during 2025–2026 at the Department of Floriculture and Landscaping, College of Agriculture, Vellayani, to evaluate the effects of stem-cutting type, root-promoting treatments and rooting media on the rapid vegetative propagation of *Dracaena fragrans* 'Massangeana', an economically important ornamental plant.
Methodology: The experiment was conducted to standardise the propagation of *Dracaena fragrans* 'Massangeana' using different types of stem cuttings, root-promoting treatments and rooting media. Three cutting types, four root-promoting treatments (control, IBA at 2000 ppm, chitosan at 1000 ppm, and their combination) and three rooting media (coir pith + perlite, coir pith + perlite + PGPR mix I, and coir pith + FYM + AMF (Arbuscular Mycorrhizal Fungi) were evaluated. The treated cuttings were planted individually in 4 × 5-inch polybags and maintained under 50% shade. The experiment was laid out in a factorial completely randomised design (CRD) comprising 36 treatment combinations, with 10 cuttings per treatment and three replications, to assess the individual and interactive effects of the treatments on propagation.
Results: The study evaluated the influence of root-promoting treatments, cutting types and rooting media on the vegetative propagation of *Dracaena fragrans* 'Massangeana'. The parameters assessed included days to sprouting, survival percentage, percentage of sprouted cuttings, number of cuttings rooted, number of roots per cutting, root length, and root fresh and dry weights. Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip recorded the best results, followed by chitosan at 1000 ppm applied for 15 minutes, whereas the combined application of chitosan and IBA generally resulted in the poorest performance. Basal cuttings performed better than mini and terminal cuttings, exhibiting earlier sprouting, higher survival and sprouting percentages, and superior root development. Among the rooting media, coir pith and perlite (2:1) supplemented with Plant Growth-Promoting Rhizobacteria (PGPR) mix I consistently produced better results than the other media. Significant interactions were observed among the three factors, with basal cuttings treated with IBA at 2000 ppm and planted in PGPR mix I -enriched coir pith and perlite ($R_2 \times C_1 \times T_2$) emerging as the best treatment combination. This combination recorded the earliest sprouting (14 days), highest survival percentage (98.33%), maximum number of rooted cuttings (69.67), highest root number (14.17), longest roots (18.98 cm), and greatest root fresh and dry weights (2.25 g and 0.58 g, respectively). Overall, the findings demonstrate that the appropriate selection of cutting type, auxin treatment and rooting medium can substantially improve the propagation efficiency of *D. fragrans* 'Massangeana', with IBA-treated basal cuttings in PGPR mix I-enriched coir pith and perlite identified as the most effective combination.
Conclusion: The study concluded that basal cuttings (20 cm long with 12–17 nodes) treated with IBA at 2000 ppm for 1 minute and planted in coir pith + perlite (2:1) supplemented with PGPR mix I was the most effective combination for the rapid propagation of *Dracaena fragrans* 'Massangeana'. This treatment promoted the earliest sprouting (14 days), highest sprouting percentage (99%), highest rooting percentage (69.67%), greatest number of roots (14.17), longest roots (18.98 cm), and the highest root fresh and dry weights (2.25 g and 0.58 g, respectively). Thus, the standardized treatment offers a promising and efficient method for producing quality planting material of *D. fragrans* 'Massangeana' under humid tropical conditions.

Keywords: Dracaena fragrans 'Massangeana'; IBA; plant growth promoting rhizobacteria (PGPR mix I); rapid propagation; stem cuttings.

1. Introduction

Dracaena is a popular genus of ornamental foliage plants valued for indoor decoration and outdoor landscaping. The genus comprises slow-growing, semi-woody monocotyledonous shrubs in the family Asparagaceae. Its attractive foliage, ease of maintenance and adaptability have made Dracaena important to the national and international floriculture industries. Dracaena is ranked among the world's ten leading potted ornamental plants, reportedly occupying seventh place in global floriculture trends. Its elegant appearance and long-lasting foliage make it a popular choice for homes, offices and landscape gardens.

Many commercially valued Dracaena species are propagated by stem cuttings. Seed propagation is limited by the long juvenile period, low seed set under cultivation, and the lack of systematic information on seed set and germination potential. Consequently, commercially viable multiplication methods rely mainly on cuttings and micropropagation (Bhatia *et al*., 2025). Improving propagation efficiency and plant quality is important in commercial floriculture because these factors influence market value and demand. *Dracaena fragrans* 'Massangeana' (corn plant) is propagated vegetatively using hardwood and semi-hardwood stem cuttings, commonly referred to as canes. Under normal conditions, rooting takes 6–8 weeks, and the resulting plantlets grow slowly during the first year. Studies of dragon-fruit stem cuttings indicate that IBA treatment and rooting-medium composition can influence rooting performance (Amrutha, 2025). A further comparison of IBA and NAA treatments in dragon fruit documented differences in rooting, sprouting and cutting survival (Patel *et al*., 2026).

Successful rooting of stem cuttings depends on several factors, including the season of collection, age of the stock plant, cutting size, rooting substrate, irrigation, temperature, growth-regulator treatment and clone (Hartmann *et al.,* 2002). Plant growth regulators can promote root development, while warm temperatures, high humidity and indirect light provide favourable conditions for rooting. Plant growth-promoting rhizobacteria (PGPR) are increasingly used as eco-friendly biostimulants in ornamental crop production because they can improve nutrient uptake and plant growth while reducing reliance on synthetic chemicals. Studies have shown that PGPR can stimulate root initiation and development and improve shoot and root biomass, plant height, leaf area and flowering characteristics in ornamental plants.

In woody-plant cuttings, auxin is recognised as a key hormonal regulator of adventitious root formation (Liu *et al*., 2025). Work on mini-cuttings of *Ocotea odorifera* has also identified differences in rooting outcomes across IBA concentrations and collection seasons (da Luz *et al*., 2026). IAA-producing rhizobacteria have been associated with improved cutting-propagation efficiency in *Ceanothus velutinus* (Ganesh *et al*., 2024). Although cutting type, root-promoting treatments and rooting media are recognised as

important factors in vegetative propagation, their combined effects on stem-cutting establishment in *Dracaena fragrans* 'Massangeana' under the conditions considered in this study require direct comparative evaluation. In particular, it remains necessary to determine which treatment combination most effectively supports sprouting, survival and root development. The objective of this study was to evaluate the individual and interactive effects of basal, terminal and mini cuttings; four root-promoting treatments (control, IBA at 2000 ppm, chitosan at 1000 ppm, and chitosan combined with IBA); and three rooting media (coir pith + perlite, coir pith + perlite + PGPR mix I, and coir pith + FYM + AMF) on sprouting, survival and root development in *Dracaena fragrans* 'Massangeana'. PGPR mix I and AMF were procured from the Department of Agricultural Microbiology, College of Agriculture, Vellayani.

2. Materials and Methods

The experiment was conducted during 2025–2026 at the Department of Floriculture and Landscaping, College of Agriculture, Vellayani, to evaluate the effects of stem-cutting type, root-promoting treatments and rooting media on the rapid vegetative propagation of *Dracaena fragrans* 'Massangeana', an economically important ornamental plant. Healthy, vigorous three-year-old mother plants maintained under 50% shade served as the source of planting material. Three types of stem cuttings were used: basal and terminal cuttings, both 20 cm long and bearing approximately 12–17 nodes, and mini cuttings, 5–7 cm long, taken from the basal and terminal portions of shoots. The cuttings received one of four root-promoting treatments: distilled water as the control (R_1); IBA at 2000 ppm applied as a 1-minute dip (R_2); chitosan at 1000 ppm applied for 15 minutes (R_3); or chitosan at 1000 ppm combined with IBA at 2000 ppm (R_4). Three rooting media were evaluated: coir pith and perlite at 2:1 (T_1); coir pith and perlite at 2:1 supplemented with Plant Growth-Promoting Rhizobacterial consortium (PGPR) mix I (T_2); and coir pith and farmyard manure (FYM) at 1:1 supplemented with Arbuscular Mycorrhizal Fungi (AMF) at 10 g per polybag (T_3). PGPR mix I and AMF were procured from the Department of Agricultural Microbiology, College of Agriculture, Vellayani.

The treated cuttings were planted individually in 4 × 5-inch polybags containing the respective rooting media and maintained under 50% green shade netting to support root initiation and establishment. The experiment followed a factorial completely randomised design (CRD), with three cutting types, four root-promoting treatments and three rooting media, giving 36 treatment combinations (3 × 4 × 3). Each treatment comprised 10 cuttings and was replicated three times. This factorial design enabled assessment of the individual and interactive effects of cutting type, root-promoting treatment and rooting medium, with the aim of identifying suitable combinations for rapid and efficient propagation of *D. fragrans* 'Massangeana'.

3. Results and Discussion

Cutting performance varied significantly in response to the root-promoting treatments and rooting media. The parameters assessed were days to sprouting, survival percentage, percentage of cuttings that sprouted, number of cuttings rooted, number of roots per cutting, and root characteristics.

3.1 Sprouting Response in Cuttings

The initial sprouting response, measured as days to sprouting, survival percentage and percentage of cuttings that sprouted, is presented in Table 1. The analysis showed highly significant effects of root-promoting treatments, cutting type and rooting medium on all three parameters.

Table 1. Effect of root promoting growth regulators, type of cuttings and rooting media on days taken for sprouting, survival percentage and percentage of cuttings sprouted

Treatments	Days taken for sprouting	Survival %	% of cuttings sprouted
Root promoting growth regulators			
R_1-Control	26.41^{c} (5.13)	19.44^{c} (4.02)	28.33^{d} (4.75)
R_2- IBA 2000 ppm	15.89 ^{a} (3.98)	47.67^{a} (6.39)	55.89^{a} (6.80)
R_3-Chitosan 1000 ppm	20.81^{b} (4.56)	24.44^{b} (4.21)	40.52^{b} (5.61)
R_4-Chitosan 1000 ppm + IBA 2000 ppm	31.11 ^{d} (5.57)	4.67^{d} (1.73)	32.19^{c} (5.13)
SE(m)	0.02	0.02	0.02
CD	0.06	0.06	0.05
Type of cuttings			
C_1-Basal	22.19^{a} (4.67)	41.92^{a} (6.06)	63.78^{a} (7.92)
C_2-Terminal	25.00^{c} (4.95)	4.19^{c} (1.56)	7.06^{c} (2.11)
C_3-Mini cuttings	23.47^{b} (4.80)	26.06^{b} (4.64)	46.86^{b} (6.69)
SE(m)	0.02	0.02	0.01
CD	0.05	0.05	0.04
Rooting Media			
T_1- Coir pith + Perlite (2:1)	25.97^{a} (5.05)	18.97^{c} (3.56)	25.39^{c} (4.45)
T_2 - Coir pith + Perlite (2:1) + PGPR mix I	21.53^{c} (4.60)	32.72^{a} (5.03)	52.03^{a} (6.74)
T_3 - Coir pith + FYM (1:1) + AMF (10 g/ polybag)	23.17^{b} (4.78)	20.47^{b} (3.66)	40.28^{b} (5.53)
SE(m)	0.02	0.02	0.01
CD	0.05	0.05	0.04

3.1.1 Days Taken for Sprouting

Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) resulted in the earliest sprouting (15.89 days), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 20.81 days). The combined treatment of chitosan at 1000 ppm and IBA at 2000 ppm (R_4) showed delayed sprouting (31.11 days). Among cutting types, basal cuttings (C_1) sprouted earliest (22.19 days), followed by mini cuttings (C_3; 23.47 days), while terminal cuttings (C_2) took the longest (25.00 days). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) resulted in the earliest sprouting (21.53 days), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 23.17 days). Sprouting was latest in coir pith + perlite (2:1) alone (T_1; 25.97 days).

Significant two-way interactions (Figs. 1–3) and three-way interactions (Table 2) were also observed. Basal cuttings treated with IBA at 2000 ppm and planted in coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) sprouted earliest, at 14.00 days. In contrast, terminal cuttings treated with chitosan + IBA and planted in coir pith + perlite ($R_4 \times C_2 \times T_1$) took the longest to sprout (40.00 days). IBA can enhance the translocation of carbohydrates, other endogenous plant substances and nutrients to the rooting zone, supporting root initiation and development in layered shoots (Yeboah *et al*., 2014). In the present study, the combined use of a growth regulator and biofertiliser may have improved root and shoot traits by increasing the availability of growth-promoting substances. Earlier sprouting may reflect increased auxin activity, which can accelerate physiological processes and stimulate cell division in the bud region. A similar effect was reported in pomegranate cultivars Bhagwa and Ruby, where cuttings treated with IBA at 1500 ppm + NAA at 1500 ppm + Biomix sprouted earlier (8.60 and 7.80 days, respectively) and produced more sprouted cuttings (18.33 and 17.67, respectively), along with significantly higher values for other shoot traits.

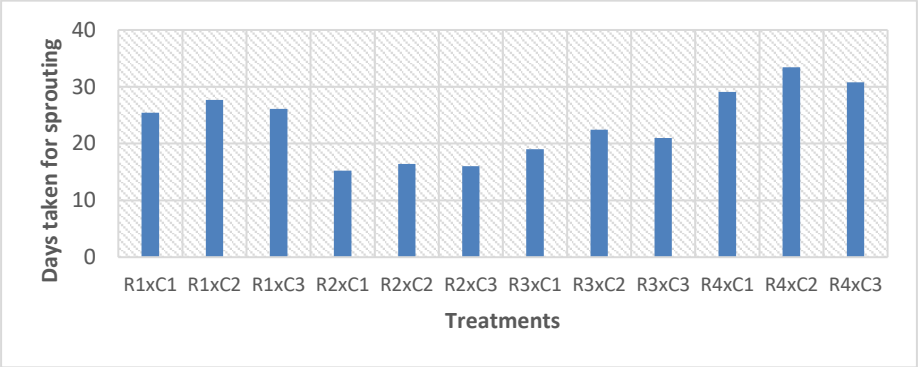


Fig. 1. Effect of root promoting growth regulators and type of cuttings on days taken for sprouting

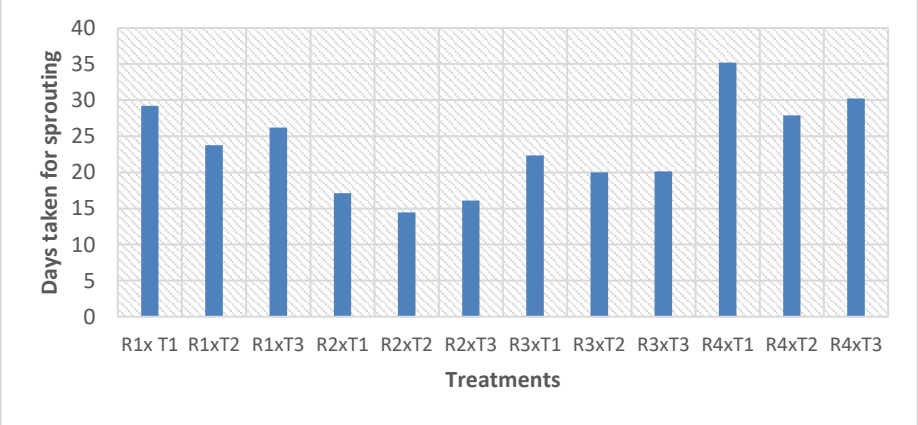


Fig. 2. Effect of root promoting growth regulators and rooting media on days taken for sprouting

3.1.2 Survival Percentage

For the main effects, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest survival percentage (47.67%), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 24.44%). The combined chitosan + IBA treatment (R_4) produced the lowest survival percentage (4.67%). Among cutting types, basal cuttings (C_1) had the highest survival percentage (41.92), followed by mini cuttings (C_3; 26.06), whereas terminal cuttings (C_2) had the lowest value (4.19). Among the rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) gave the highest survival percentage (32.72), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 20.47). Coir pith + perlite (2:1) alone (T_1) gave the lowest value (18.97).

Significant two-way (Figs. 4–6) and three-way interactions (Table 2) were also observed. The combination of basal cuttings treated with IBA at 2000 ppm and planted in coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) recorded the highest survival percentage

(98.33%). Beneficial microorganisms, including bacteria and mycorrhizal fungi, can improve plant water and nutrient uptake and thereby enhance survival rate. These findings are consistent with Mousa *et al*. (2019), who reported 100% survival in *Ficus elastica* var. decora air-layers treated with IBA at 3000 ppm in the girdled zone and combined with *Bacillus* or AMF in the rooting substrate. Ibrahim (2020) also reported 100% survival in detached rooted air-layers of *Dracaena marginata* treated with IBA at 300 ppm, phloroglucinol (PG) at 300 ppm and seaweed extract (SWE) at 2 ml/L, alone or in combination. These findings also highlight the potential benefits of combining auxins with beneficial microorganisms for survival and root and shoot development.

The rooting medium is an important determinant of successful cutting propagation. In this study, the coir pith–perlite mixture provided a balance between aeration and water-holding capacity, supporting oxygen availability, transpiration, nutrient uptake and growth during root initiation. Perlite improved aeration and might have favoured root initiation. Similarly, Mabizela *et al*. (2017) reported the highest survival of *Cyclopia subternata* stem cuttings in a bark-based rooting medium. Its lower water-holding capacity may have provided a favourable balance between aeration and moisture retention compared with the peat-based mixture.

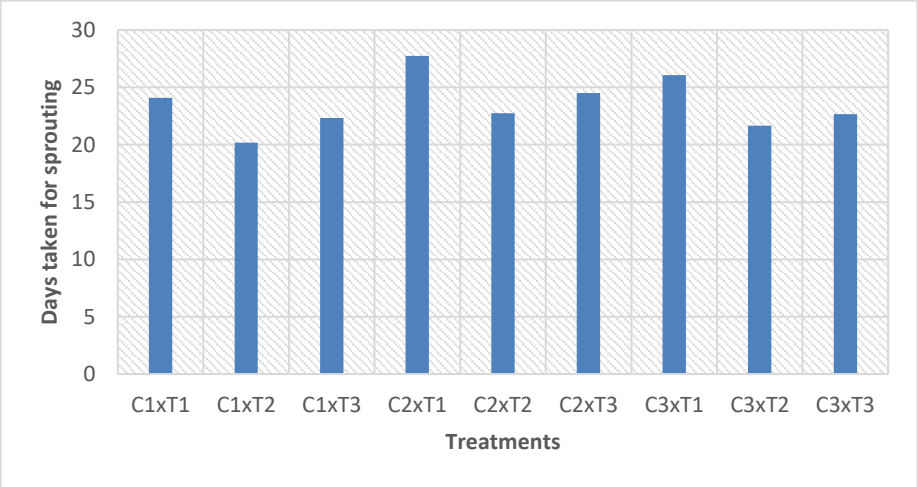


Fig. 3. Effect of type of cuttings and rooting media on days taken for sprouting

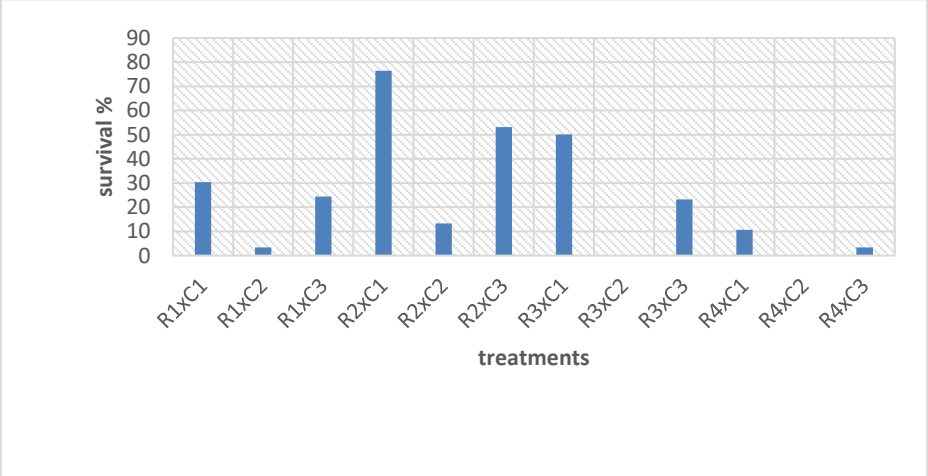


Fig. 4. Effect of root promoting growth regulators and type of cuttings on survival percentage

3.1.3 Percentage of Cuttings Sprouted

Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest percentage of sprouted cuttings (55.89%), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 40.52%). The control (distilled water, R_1) recorded the lowest percentage (28.33). Among cutting types, basal cuttings (C_1) recorded the highest percentage (63.78), followed by mini cuttings (C_3; 46.86); terminal cuttings (C_2) recorded the lowest value (7.06). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) recorded the highest percentage of sprouted cuttings (52.03), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 40.28). Coir pith + perlite (2:1) alone (T_1) recorded the lowest value (25.39).

Significant two-way (Figs. 7–9) and three-way interactions (Table 2) were also observed for the percentage of cuttings sprouted. The combination of IBA at 2000 ppm, basal cuttings and coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) recorded 99.00%

sprouting. This was statistically on par with IBA-treated basal cuttings in coir pith + FYM (1:1) + AMF at 10 g per polybag ($R_2 \times C_1 \times T_3$; 100.00%) and IBA-treated mini cuttings in coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_3 \times T_2$; 100.00%).

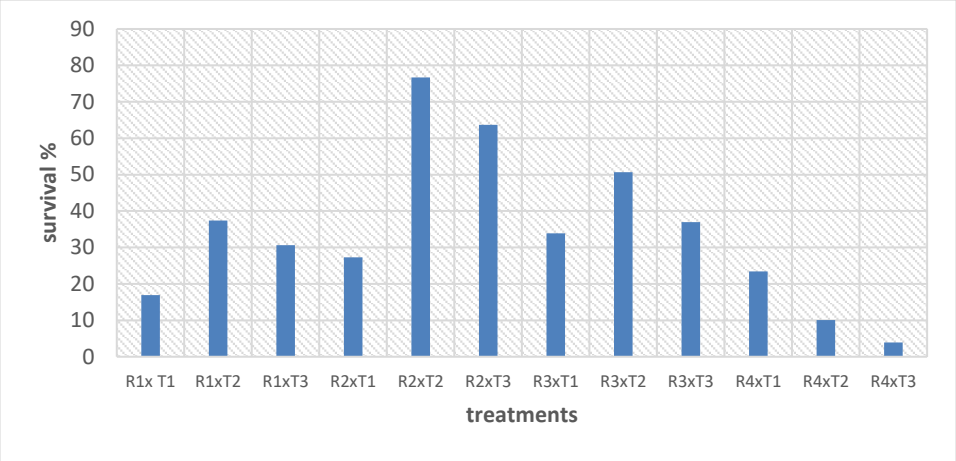


Fig. 5. Effect of root promoting growth regulators and rooting media on survival percentage

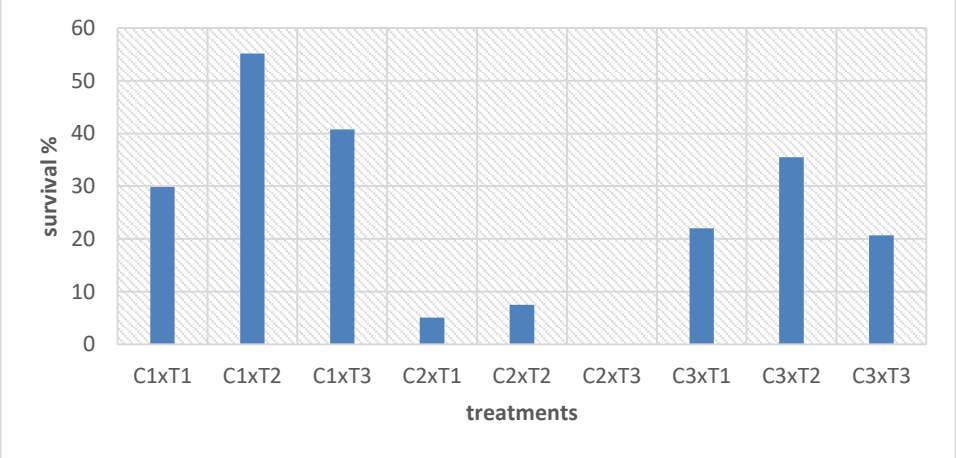


Fig. 6. Effect of type of cuttings and rooting media on survival percentage

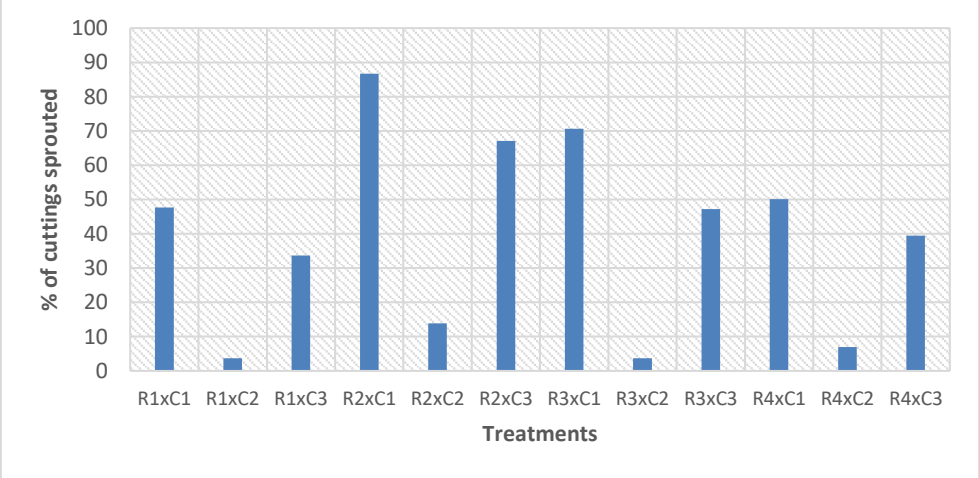


Fig. 7. Effect of root promoting growth regulators and type of cuttings on percentage of cuttings sprouted

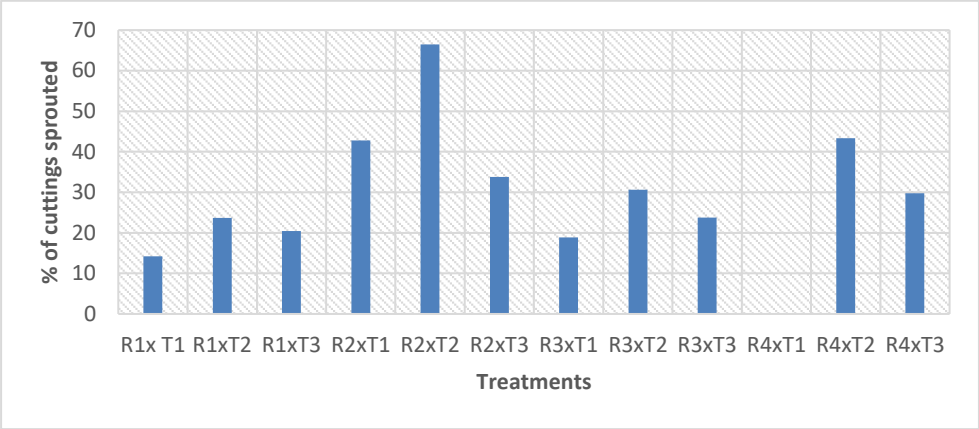


Fig. 8. Effect of root promoting growth regulators and rooting media on percentage of cuttings sprouted

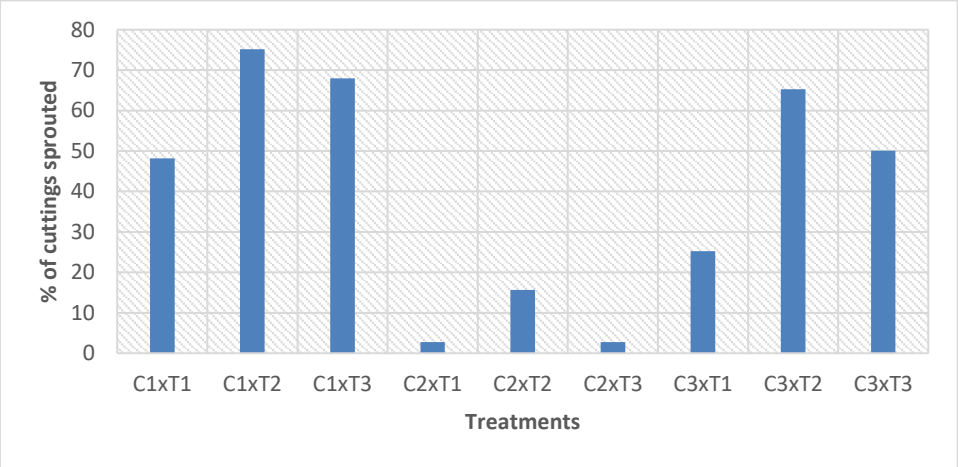


Fig. 9. Effect of type of cuttings and rooting media on percentage of cuttings sprouted

Table 2. Three-way interaction effects of root promoting growth regulators, type of cuttings and rooting media

AxBxC	Days taken for sprouting	Survival %	% of cuttings sprouted
R_1x C_1x T_1	28.00^{fgh} (5.29)	21.00^{kl} (4.64)	30.33^{h} (5.55)
R_1x C_1x T_2	22.00^{m} (4.69)	41.00^{g} (6.44)	61.00^{d} (7.84)
R_1x C_1x T_3	26.33^{hi} (5.13)	29.33^{j} (5.46)	51.67^{e} (7.22)
R_1x C_2x T_1	30.33^{cde} (5.51)	0.00^{p} (0.71)	0.00^{k} (0.71)
R_1x C_2x T_2	25.33^{ij} (5.03)	10.33^{o} (3.29)	11.00^{j} (3.39)
R_1 x C_2x T_3	27.33^{gh} (5.23)	0.00^{p} (0.71)	0.00^{k} (0.71)
R_1xC_3xT_1	29.33^{def} (5.42)	21.67^{k} (4.71)	20.33^{i} (4.56)
R_1xC_3xT_2	24.00^{ijk} (4.90)	19.67^{lm} (4.49)	40.33^{fg} (6.39)
R_1xC_3xT_3	25.00^{ijk} (5.00)	32.00^{i} (5.70)	40.33^{fg} (6.39)
R_2xC_1xT_1	16.33^{rs} (4.04)	60.00^{d} (7.78)	61.00^{d} (7.84)
R_2xC_1xT_2	14.00^{t} (3.74)	98.33^{a} (9.94)	99.00^{a} (9.97)
R_2xC_1xT_3	15.33^{s} (3.92)	71.00^{c} (8.46)	100.00^{a} (10.02)
R_2xC_2xT_1	17.00^{qr} (4.12)	20.33^{kl} (4.56)	0.00^{k} (0.71)
R_2xC_2xT_2	15.33^{s} (3.92)	19.67^{lm} (4.49)	30.67^{h} (5.58)
R_2xC_2xT_3	17.00^{qr} (4.12)	0.00^{p} (0.71)	11.00^{j} (3.39)
R_2xC_3xT_1	18.00^{pq} (4.24)	48.00^{f} (6.96)	21.00^{i} (4.64)
R_2xC_3xT_2	14.00^{t} (3.74)	81.33^{b} (9.05)	100.00^{a} (10.02)
R_2xC_3xT_3	16.00^{rs} (4.00)	30.33^{ij} (5.55)	80.00^{b} (8.97)
R_3xC_1xT_1	21.00^{mn} (4.58)	38.33^{h} (6.23)	60.33^{d} (7.80)
R_3xC_1xT_2	17.33^{pqr} (4.16)	61.00^{d} (7.84)	81.67^{b} (9.06)
R_3xC_1xT_3	18.67^{op} (4.32)	51.00^{e} (7.18)	70.00^{c} (8.40)
R_3xC_2xT_1	23.67^{kl} (4.86)	0.00^{p} (0.71)	11.00^{j} (3.39)
R_3xC_2xT_2	21.67^{m} (4.65)	0.00^{p} (0.71)	0.00^{k} (0.71)
R_3xC_2xT_3	22.00^{m} (4.69)	0.00^{p} (0.71)	0.00^{k} (0.71)

AxBxC	Days taken for sprouting	Survival %	% of cuttings sprouted
$R_3xC_3xT_1$	22.33^{lm} (4.72)	18.33^{m} (4.34)	30.33^{h} (5.55)
$R_3xC_3xT_2$	21.00^{mn} (4.58)	31.00^{ij} (5.61)	70.33^{c} (8.42)
$R_3xC_3xT_3$	19.67^{no} (4.43)	20.33^{kl} (4.56)	41.00^{f} (6.44)
$R_4xC_1xT_1$	31.00^{cd} (5.57)	0.00^{p} (0.71)	41.00^{f} (6.44)
$R_4xC_1xT_2$	27.33^{gh} (5.23)	20.33^{kl} (4.56)	59.00^{d} (7.71)
$R_4xC_1xT_3$	29.00^{efg} (5.38)	11.67^{n} (3.48)	50.33^{e} (7.13)
$R_4xC_2xT_1$	40.00^{a} (6.32)	0.00^{p} (0.71)	0.00^{k} (0.71)
$R_4xC_2xT_2$	28.67^{efg} (5.35)	0.00^{p} (0.71)	21.00^{i} (4.64)
$R_4xC_2xT_3$	31.67^{c} (5.63)	0.00^{p} (0.71)	0.00^{k} (0.71)
$R_4xC_3xT_1$	34.67^{b} (5.89)	0.00^{p} (0.71)	29.33^{h} (5.46)
$R_4xC_3xT_2$	27.67^{fgh} (5.26)	10.00^{o} (3.24)	50.00^{e} (7.11)
$R_4xC_3xT_3$	30.00^{cde} (5.48)	0.00^{p} (0.71)	39.00^{g} (6.28)
SE(m)	0.06	0.06	0.05
CD	0.17	0.17	0.14

The higher percentage of sprouted cuttings may be associated with increased cell division and elongation under IBA treatment, potentially acting in combination with growth-promoting biofertilisers. Barde *et al*. (2010) reported that IBA at 2000 ppm combined with phosphate-solubilising bacteria (PSB) produced the highest number of sprouted cuttings (2.80) in pomegranate. Similarly, Hakim *et al.* (2018) found the greatest number of sprouts in pomegranate cultivars Bhagwa and Ruby when higher concentrations of IBA and NAA (1500 ppm) were combined with biofertilisers, including PGPR, PSB and Biomix. These findings are consistent with the present results.

3.2 Number of Cuttings Rooted

The effects of root-promoting treatments, cutting type and rooting medium on the number of cuttings rooted are presented in Table 3. The analysis showed significant effects of all three factors. Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest number of rooted cuttings (21.37), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 6.96). The combined chitosan + IBA treatment (R_4) showed the lowest value (2.56). Among the cutting types, basal cuttings (C_1) had the highest number of rooted cuttings (17.19), followed by mini cuttings (C_3; 6.92), while terminal cuttings (C_2) had the lowest value (1.67). Among the rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) produced the highest number of rooted cuttings (19.61), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 6.17).

Significant two-way and three-way interactions (Table 4) were also detected. The combination of basal cuttings treated with IBA at 2000 ppm for 1 minute and planted in coir pith + perlite (2:1) + PGPR mix I recorded the highest number of rooted cuttings (69.67). Adventitious root formation is essential for successful cutting establishment and clonal propagation. The stimulatory effects of IBA on rooting and root growth have been described in previous studies (Kasem & Abd El-Baset, 2014). IBA may promote metabolite accumulation at the application site, stimulating cell division, cell elongation and root formation. In the present study, basal hardwood cuttings performed better than terminal semi-hardwood and mini cuttings under the 2000 ppm IBA treatment. Rooting behaviour is associated with the carbon-to-nitrogen (C:N) ratio in the basal tissue; an increase in this ratio may promote root initiation. This effect may be more pronounced in basal cuttings and enhanced by IBA treatment.

Higher IBA concentrations have also been associated with increased rooting. Attia *et al.* (2015) reported 72% rooting in tip-shoot cuttings of *D. marginata* treated with IBA at 1000 ppm, while Pushpamali *et al.* (2004) reported improved rooting in *D. sanderiana* cuttings treated with IBA at 2000 ppm. Bhatia *et al*. (2025) recorded 100% rooting and the earliest sprouting (18.58 days) in terminal cuttings of *Dracaena reflexa* treated with IBA at 200 ppm for 3 minutes; sprouting took 21.33 days in the control.

In rhizosphere associations, PGPR can colonise plant roots (Andrews & Harris, 2000), inhibit ethylene synthesis or mineralise nutrients (Steenhoudt & Vanderleyden, 2000), produce natural plant growth regulators such as indole-3-acetic acid (IAA) (Mishra *et al*., 2010), and stimulate cell division in root tips, causing changes in the outer root-cortex layers (Baset Mia *et al.,* 2010). Erturk *et al.* (2010) investigated PGPR effects on kiwifruit (*Actinidia deliciosa*) stem cuttings and reported rooting rates of 47.50% in semi-hardwood cuttings treated with *Bacillus* sp. RC03 and *Bacillus simplex* RC19, and 42.50% in hardwood cuttings treated with *Bacillus* sp. RC03. Dalda-Sekerci *et al.* (2024) reported that *Bacillus* strains increased rooting rates in rose cuttings by 50–60% compared with untreated cuttings. These findings support the present observation that PGPR Mix I in the rooting medium improved rooting, particularly in IBA-treated basal cuttings.

3.3 Number of Roots

The effects of root-promoting treatments, cutting type and rooting medium on root number are presented in Table 3. The analysis showed highly significant effects of all three factors. Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest number of roots (3.49), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 1.70). Basal cuttings (C_1) produced the highest number of roots (4.08), followed by mini cuttings (C_3; 0.94), while terminal cuttings (C_2) produced the fewest roots (0.49). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) recorded the highest number of roots (3.96), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 1.54).

Significant two-way and three-way interactions (Table 4) were also observed. The combination of IBA at 2000 ppm, basal cuttings and coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) produced the highest number of roots (14.17). Exogenous auxin

application can promote adventitious root initiation, increase root number, improve root quality and uniformity, and shorten the rooting period (Zheng *et al*., 2020).

Attia *et al.* (2015) likewise reported that IBA positively affected rooting percentage and root number in *Dracaena marginata* cuttings. Basal cuttings also produced significantly more roots than mid-shoot cuttings. Ibrahim (2020) found that *Dracaena marginata* air-layers treated with IBA at 300 ppm, alone or combined with phloroglucinol (PG) at 300 ppm and seaweed extract (SWE) at 2 ml/L, produced significantly more roots over two seasons than the control and other treatments. Similarly, Malaviya *et al*. (2023) reported that IBA at 2000 ppm increased root number in *D. marginata* cuttings. The root growth of basal cuttings under the treatments illustrated is shown in Plate 1.

3.4 Root Length (cm)

The effects of root-promoting treatments, cutting type and rooting medium on root length are presented in Table 3. The analysis showed highly significant effects of all three factors. IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the greatest root length (5.90), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 3.96). The combined chitosan + IBA treatment (R_4) produced the shortest roots (1.18). Among cutting types, basal cuttings (C_1) recorded the greatest root length (6.98), followed by mini cuttings (C_3; 1.97). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) recorded the greatest root length (6.98), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 2.84).

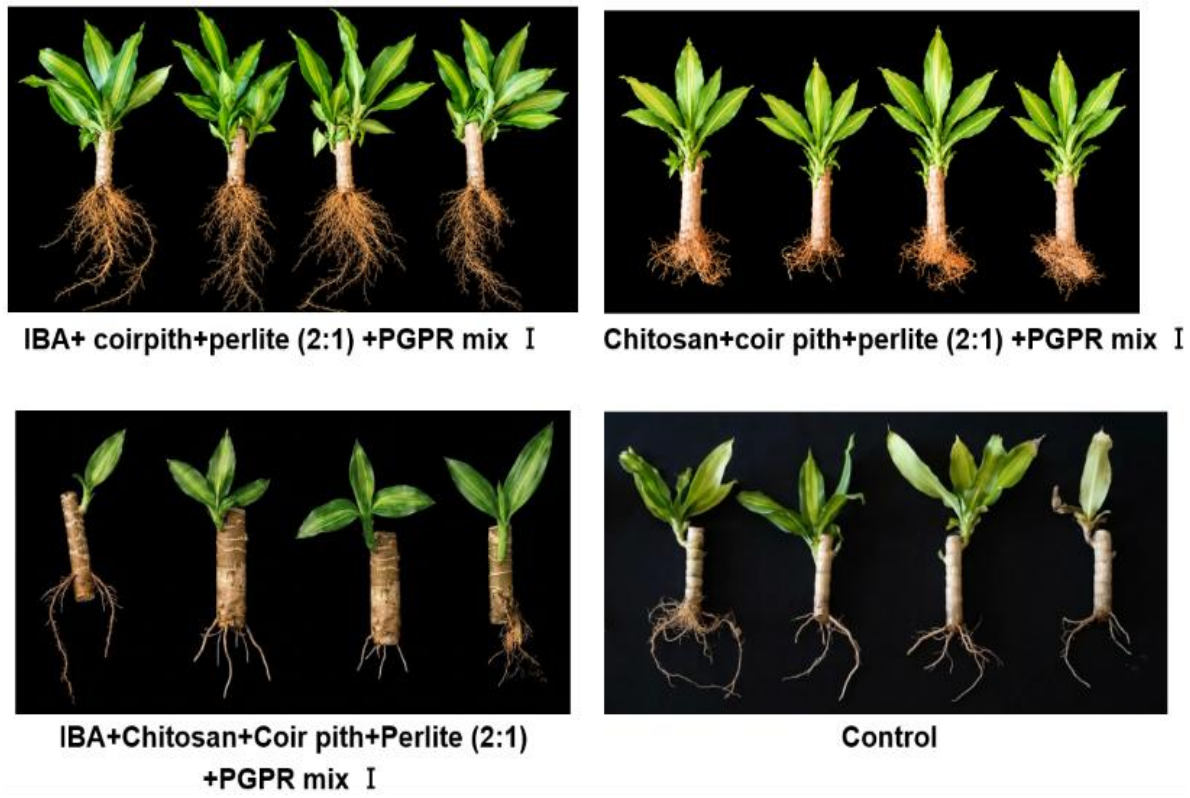


Plate 1. Root growth at 6 MAP in basal cuttings under different treatments

Significant two-way and three-way interactions (Table 4) were observed among treatments. The combination of IBA at 2000 ppm, basal cuttings and coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) produced the longest roots (18.98 cm). Increased root length in treated cuttings may be related to enhanced carbohydrate hydrolysis, metabolite accumulation at the auxin application site, protein synthesis, cell enlargement and cell division, as described by Strydom *et al*. (1960) for plum softwood stem cuttings.

Anit and Arquiza (1999) reported that IBA treatments increased root number in *Dracaena surculosa* 'Florida Beauty', although the roots were shorter. Attia *et al.* (2015) similarly found that basal cuttings of *Dracaena marginata* produced the highest number of roots per cutting, but root length was lower under different auxin treatments. In contrast, the present study found that IBA at 2000 ppm combined with coir pith + perlite (2:1) + PGPR Mix I produced both the greatest number of roots and the longest roots on basal cuttings. Root elongation may have been facilitated by the spaces provided by perlite and by the root-growth-promoting properties of PGPR Mix I. Ghimire *et al*. (2022) reported that IBA at 2000 ppm promoted root length in *Chrysanthemum indicum* cuttings, with responses influenced by cutting position and a well-aerated, well-spaced vermiculite–perlite (1:1) rooting medium.

3.5 Fresh Weight of Roots (g)

The effects of root-promoting treatments, cutting type and rooting medium on root fresh weight are presented in Table 3. The analysis showed highly significant effects of all three factors. Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest root fresh weight (0.64), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 0.23). The combined chitosan + IBA treatment (R_4) produced the lowest value (0.05). Basal cuttings (C_1) recorded the highest root fresh weight (0.48), followed by mini cuttings (C_3; 0.19), while terminal cuttings (C_2) recorded the lowest value (0.09). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) produced the highest root fresh weight (0.62), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 0.15).

Significant two-way and three-way interactions (Table 4) were also observed. The combination of IBA at 2000 ppm, basal cuttings and coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) recorded the highest root fresh weight (2.25 g).

Kaushik *et al.* (2025) reported that IBA at 2000 ppm improved root fresh and dry weights in *Hibiscus rosa-sinensis* stem cuttings, consistent with the present findings. Hashemabadi *et al.* (2026) likewise found that IBA treatment improved root fresh weight and other rooting traits in *Rosa damascene* cuttings. In *Dracaena marginata*, air-layers treated with PG, SWE, IBA + SWE, or IBA + PG + SWE produced the greatest root fresh weights per air-layer over two seasons compared with the control and other treatments, highlighting the potential of IBA and biostimulant treatments to improve root fresh weight.

In a study of adventitious rooting in *Dianthus caryophyllus*, Zheng *et al*. (2020) found that coir pith + perlite (1:1), together with exogenous auxin, increased the fresh and dry weights of induced roots, which they attributed to the substrate's high porosity. The improved rooting traits of *Dracaena* 'Massangeana' cuttings in the present study may similarly be associated with the coir pith–perlite substrate, which can provide suitable water-holding capacity, cation-exchange capacity and porosity for aeration.

3.6 Dry Weight of Roots (g)

The effects of root-promoting treatments, cutting type and rooting medium on root dry weight are presented in Table 3. The analysis showed highly significant effects of all three factors. Among the root-promoting treatments, IBA at 2000 ppm applied as a 1-minute dip (R_2) produced the highest root dry weight (0.21), followed by chitosan at 1000 ppm applied for 15 minutes (R_3; 0.03). The combined chitosan + IBA treatment (R_4) produced the lowest value (0.01). Basal cuttings (C_1) recorded the highest root dry weight (0.11), followed by mini cuttings (C_3; 0.04), whereas terminal cuttings (C_2) recorded the lowest value (0.03). Among rooting media, coir pith + perlite (2:1) + PGPR mix I (T_2) produced the highest root dry weight (0.12), followed by coir pith + FYM (1:1) + AMF at 10 g per polybag (T_3; 0.07).

Significant two-way and three-way interactions (Table 4) were also observed. The combination of IBA at 2000 ppm, basal cuttings and coir pith + perlite (2:1) + PGPR mix I ($R_2 \times C_1 \times T_2$) recorded the highest root dry weight (0.58 g). Ghimire *et al.* (2022) observed increasing root fresh and dry weights with increasing IBA concentration in *Chrysanthemum indicum* cuttings, supporting the positive association between IBA at 2000 ppm and root biomass. Malaviya *et al.* (2023) also reported increased root dry weight in *Dracaena marginata* cuttings treated with IBA at 2000 ppm. Similarly, Soliman *et al.* (2024) found that IBA improved root growth and dry root weight in *Sanchezia speciosa* stem cuttings.

Table 3. Effect of root promoting growth regulators, type of cuttings and rooting media on no. of cuttings rooted, no. of roots, root length (cm), fresh weight (g) and dry weight (g) of roots

Treatments	No. of cuttings rooted	Number of roots	Root length (cm)	Fresh wt. of roots (g)	Dry wt. of roots(g)
Root promoting growth regulators					
R_1	3.48^{c} (1.43)	1.03^{d} (1.05)	2.06^{c} (1.24)	0.09^{c} (0.76)	0.01^{c} (0.72)
R_2	21.37^{a} (3.42)	3.49^{a} (1.65)	5.90^{a} (2.03)	0.64^{a} (1.01)	0.21^{a} (0.83)
R_3	6.96^{b} (1.98)	1.70^{b} (1.26)	3.96^{b}(1.64)	0.23^{b} (0.83)	0.03^{b} (0.72)
R_4	2.56^{d} (1.32)	1.12^{c} (1.07)	1.18^{d}(1.09)	0.05^{d} (0.74)	0.01^{d} (0.71)
SE(m)	0.02	0.00	0.00	0.00	0.00
CD	0.05	0.01	0.01	0	0
Type of cuttings					
C_1	17.19^{a} (3.45)	4.08^{a} (1.92)	6.98^{a} (2.40)	0.48^{a} (0.95)	0.11^{a} (0.78)
C_2	1.67^{c} (1.03)	0.49^{c} (0.86)	0.87^{c} (0.92)	0.09^{c} (0.75)	0.03^{c} (0.72)
C_3	6.92^{b} (1.64)	0.94^{b} (1.00)	1.97^{b}(1.17)	0.19^{b} (0.80)	0.04^{b} (0.73)
SE(m)	0.02	0.00	0.00	0.00	0.00
CD	0.04	0.01	0.01	0	0
Rooting Media					
T_1	0.00^{c} (0.71)	0.00^{c} (0.71)	0.00^{c} (0.71)	0.00^{c} (0.71)	0.00^{c} (0.71)
T_2	19.61^{a} (3.55)	3.96^{a} (1.84)	6.98^{a} (2.33)	0.62^{a} (1.01)	0.12^{a} (0.78)
T_3	6.17^{b} (1.85)	1.54^{b} (1.22)	2.84^{b} (1.47)	0.15^{b} (0.79)	0.07^{b} (0.75)
SE(m)	0.02	0	0	0	0
CD	0.04	0.01	0.01	0	0

Table 4. Effects of three-way interaction on number of cuttings rooted, number of roots, root length (cm), fresh weight (g) and dry weight (g) of roots

AxBxC	No. of cuttings rooted	Number of roots	Root length (cm)	Fresh weight of roots (g)	Dry weight of roots (g)
$R_1xC_1xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_1xT_2$	20.00^{e} (4.52)	5.23^{e} (2.39)	10.17^{f} (3.27)	0.51^{g} (1.01)	0.06^{h} (0.75)
$R_1xC_1xT_3$	11.33^{f} (3.44)	4.00^{h} (2.12)	8.37^{h} (2.98)	0.31^{h} (0.90)	0.05^{i} (0.74)
$R_1xC_2xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_2xT_2$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_2xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_3xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_3xT_2$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_1xC_3xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_2xC_1xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_2xC_1xT_2$	69.67^{a} (8.38)	14.17^{a}(3.83)	18.98^{a} (4.41)	2.25^{a} (1.66)	0.58^{a} (1.04)
$R_2xC_1xT_3$	41.00^{c} (6.44)	4.17^{g} (2.16)	11.50^{d} (3.46)	0.77^{e} (1.13)	0.40^{c} (0.95)
$R_2xC_2xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_2xC_2xT_2$	20.00^{e} (4.53)	5.85^{d} (2.52)	10.45^{e} (3.31)	1.11^{c} (1.27)	0.21^{e} (0.84)
$R_2xC_2xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.22^{d} (0.85)
$R_2xC_3xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_2xC_3xT_2$	61.67^{b} (7.88)	7.24^{b} (2.78)	12.20^{c} (3.56)	1.63^{b} (1.46)	0.43^{b} (0.97)
$R_2xC_3xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_1xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_1xT_2$	31.33^{d} (5.64)	6.03^{e} (2.56)	15.23^{b} (3.97)	0.92^{d} (1.19)	0.09^{f} (0.77)
$R_3xC_1xT_3$	10.00^{g} (3.24)	5.20^{e} (2.39)	8.97^{g} (3.08)	0.53^{g} (1.01)	0.08^{g} (0.76)
$R_3xC_2xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_2xT_2$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_2xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_3xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_3xC_3xT_2$	21.33^{e} (4.67)	4.03^{gh}(2.13)	11.40^{d} (3.45)	0.63^{f} (1.06)	0.06^{h} (0.75)
$R_3xC_3xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_1xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_1xT_2$	11.33^{f} (3.44)	4.97^{f} (2.34)	5.30^{i} (2.41)	0.32^{h} (0.91)	0.05^{i} (0.74)
$R_4xC_1xT_3$	11.67^{f} (3.48)	5.13^{e} (2.37)	5.30^{i} (2.41)	0.17^{i} (0.82)	0.04^{j} (0.74)
$R_4xC_2xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_2xT_2$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_2xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_3xT_1$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_3xT_2$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
$R_4xC_3xT_3$	0.00^{h} (0.71)	0.00^{i} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{k} (0.71)
SE(m)	0.05	0.01	0.01	0	0
CD	0.15	0.03	0.04	0.01	0

4. Conclusion

The findings demonstrate that cutting type, root-promoting treatment and rooting medium were associated with differences in sprouting, survival and root development in *Dracaena fragrans* 'Massangeana'. Basal cuttings, 20 cm in length and bearing approximately 12–17 nodes, generally performed better than terminal and mini cuttings. Among the root-promoting treatments, indole-3-butyric acid (IBA) at 2000 ppm, applied as a one-minute dip, gave more favourable responses than chitosan at 1000 ppm or the combined chitosan–IBA treatment. The rooting medium comprising coir pith and perlite (2:1) enriched with PGPR mix I also performed well. The most favourable treatment combination comprised IBA-treated basal cuttings planted in this medium. It resulted in sprouting after 14 days, 98.33% survival, 99.00% sprouting, 14.17 roots per cutting, a root length of 18.98 cm, and root fresh and dry weights of 2.25 g and 0.58 g, respectively. These results identify a practical treatment combination for further evaluation and use in propagation under nursery conditions comparable to those of the present experiment.

5. Limitations

The experiment was conducted at one location under 50% shade using cuttings obtained from three-year-old mother plants. The treatments were limited to three cutting types, four root-promoting regimes and three substrates, and the reported responses therefore apply to the tested combinations. The study assessed sprouting, survival and rooting characteristics but did not establish performance across different nursery environments or subsequent production stages. Additional evaluation under other propagation conditions would help determine the consistency of the observed treatment responses.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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