Volume: 8, Issue: I, (June, 2026), pp 59-68
foa.rjt.ac.lk/sljae

SRI LANKAN JOURNAL OF AGRICULTURE AND ECOSYSTEMS eISSN: 2673-1401

SLJAE

ORIGINAL ARTICLE

Effects of Synthetic and Natural Root-Promoting Substances on Adventitious Rooting of *Syzygium campanulatum* Korth. Softwood Cuttings

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DOI: https://doi.org/10.4038/sljae.v8i1.178

Abstract

Syzygium campanulatum Korth., commonly known as Christina is an ornamental shrub widely used in landscape horticulture. Its propagation through stem cuttings is limited by low rooting efficiency and prolonged root initiation. This study evaluated the effects of synthetic and natural root-promoting substances on adventitious rooting in softwood cuttings. A pot experiment was conducted following a completely randomized design (CRD) with 12 treatments and three replicates. Treatments included a synthetic auxin (indole-3-butyric acid, IBA), natural biostimulants (aloe vera gel, aloe vera pieces, bee honey, cinnamon powder, aspirin solution, and coconut water), combinations of selected natural substances, and water-only control. The rooting medium was a sterilized mixture of river sand and coir dust (2:1 v/v). The highest survival (92.3%) and rooting percentage (66.7%) were recorded in IBA-treated cuttings, followed by aloe vera pieces (83.3% survival; 33.3% rooting). The synthetic auxin IBA significantly outperformed other treatments in terms of root number, total root length, and fresh root biomass. Among natural substances, aloe vera pieces were the most effective, even though they were inferior to IBA. The coconut water–based combinations promoted high callus elongation, while only callus formation occurred in other treatments. Cost analysis showed that aloe vera pieces (LKR 6.50 per surviving cutting) were more economical than IBA (LKR 7.87 per surviving cutting). These results indicate that IBA is the most effective rooting agent, while aloe vera pieces offer a cost-effective natural alternative. Further research is recommended to optimize concentrations, application methods, and combinations of natural substances and to evaluate their effectiveness under varying environmental conditions.

Keywords*: Aloe vera, indole-3-butyric acid (IBA), natural biostimulants, softwood cuttings, Syzygium campanulatum.*

Date of Submission: 26.06.2025

Date of Acceptance: 26.05.2026

1. Introduction

S. campanulatum, commonly known as Christina or Red Lip *Syzygium*, is a popular evergreen ornamental shrub in Family Myrtaceae. It is widely used in landscape gardening due to its striking orange-red emerging leaves and dense canopy, making it ideal for hedges and topiary designs in tropical urban environments (Roseli et al. 2010). Propagation of Christina can be achieved through seeds, air layering, or stem cuttings; however, stem cuttings are the most preferred method for maintaining uniformity in foliage colour and plant shape (Hartmann et al. 2011).

Despite this advantage, the species is considered difficult to root, exhibiting low rooting percentages and prolonged root initiation periods. This challenge is attributed to physiological dormancy, insufficient endogenous auxins, and the nature of woody cuttings, which generally respond poorly under standard nursery conditions (Hartmann et al. 2011). Rooting success in cuttings depends on several factors, including the physiological status of the mother plant, the type of cutting, the rooting medium, and especially the presence of rooting hormones like auxins (Hartmann et al. 2011).

Synthetic auxins such as IBA and naphthalene acetic acid (NAA) have been widely used to stimulate adventitious root formation in woody plants by promoting cell differentiation and elongation at the basal end of cuttings (Ahmad et al. 2016; Jamal Uddin et al. 2020). However, concerns over the cost, environmental safety, and accessibility of synthetic chemicals have led to growing interest in natural alternatives derived from plant-based or biological sources.

Several natural substances have been reported to enhance rooting in stem cuttings. For instance, aloe vera gel contain bioactive compounds including salicylic acid and gibberellins, which may stimulate root development and protect against microbial infections (Al Sherif 2017). Coconut water is rich in phytohormones such as cytokinins, auxins, gibberellins, and other growth-promoting compounds, making it a commonly used natural additive in plant tissue culture and propagation (Yong et al. 2009). Cinnamon extract shows antimicrobial effects at wounds and boosts rooting with auxins in Melaleuca viminalis cuttings (Hameed & Adil 2019). Aspirin (acetylsalicylic acid) is a synthetic analogue of salicylic acid, a known plant hormone involved in stress response and root stimulation (Pallag et al. 2014).

While studies show these natural substances enhance root development, few have compared them with synthetic auxins in challenging-to-root species like *S. campanulatum* under tropical conditions. Therefore, this study aimed to evaluate the rooting performance and cost-effectiveness of IBA and selected natural root-promoting substances (aloe vera, bee honey, cinnamon, coconut water, and aspirin) for propagation of Christina stem cuttings.

2. Materials and Methods

The experiment was conducted over a period of five months (January to May 2021) at Bulathkohupitiya, Kegalle, Sri Lanka (7.08°N, 80.34°E; elevation: 169 m amsl, Low Country Wet Zone (WL1) agro-ecological region). This location receives an annual rainfall of 2000–2500 mm, with average temperature ranging from 25–32°C and relative humidity between 64% and 87% (WorldWeatherOnline 2021).

The study was conducted using a completely randomized design (CRD) comprising 12 treatments, each with three replicates. Each replicate consisted of a pot containing four stem cuttings. The treatments comprised IBA, several natural alternatives, and a control, as detailed in Table 1.

Table 1: Treatments and application methods for ***S. campanulatum*** stem cuttings

Treatment	Description	Application method
T1	Control (well water)	Basal 1 cm of cuttings was immersed in well water for 2 min.
T2	IBA rooting powder (synthetic auxin)	Basal 5 mm was dipped in IBA rooting powder for 5 s; excess was tapped off (Akwatulira et al. 2011).
T3	Aloe vera gel	50 g fresh gel was blended with 5 mL distilled water; basal 1 cm was immersed for 2 min (Shidiki et al., 2019).
T4	Aloe vera pieces	A 2 cm^2 piece of aloe leaf was gently attached onto the basal 5 mm.
T5	Bee honey (undiluted)	Basal 1 cm was dipped in 50 mL pure bee honey for 2 min (Dunsin et al. 2016).
T6	Cinnamon powder	Basal 5 mm was dipped in cinnamon powder for 5 s.
T7	Aspirin solution (1000 ppm)	50 mg aspirin dissolved in 50 mL distilled water; the basal 1 cm was immersed for 2 min.
T8	Coconut water	Fresh tender coconut water; basal 1 cm was immersed for 2 min.
T9	Bee honey + coconut water (1:1 v/v)	Equal volume from each was mixed; the basal 1 cm was immersed in the solution for 2 min.
T10	Aloe vera gel + coconut water (1:1 v/v)	Equal volumes were mixed; basal 1 cm was immersed in the solution for 2 min.
T11	Cinnamon powder + coconut water	Basal 1 cm was dipped in coconut water for 2 min, followed by the application of cinnamon powder (5 mm).

The rooting medium was composed of a 2:1 (v/v) blend of river sand and coir dust, which was steam-sterilized at 70 °C for 45 min to ensure the elimination of potential pathogens. Following sterilization, the medium was moistened and allowed to equilibrate overnight before planting.

Softwood stem cuttings were collected early in the morning (6.00–7.00 a.m.) from two healthy, disease-free *S. campanulatum* mother plants. The cuttings were trimmed to 10 cm in length, each retaining four leaves. A slanting cut was made just below a node at the basal end using a sterile blade to increase the rooting surface, and the leaf area was reduced by transversely halving each leaf. All cuttings were then dipped in a 3 g/L Captan® solution for 1 min as a preventive antifungal treatment and stored in water until application of their respective treatments. After the treatments described in Table 1 were applied, four cuttings per replicate were inserted 2 cm deep into the rooting medium within plastic pots. These pots were then randomly placed inside a basic, inexpensive polythene propagation chamber built from a bamboo frame and covered with 125-micron transparent polythene. Humidity was maintained by periodically misting both the chamber and the rooting medium as required.

Starting one month after planting, a foliar nutrition solution (Albert's solution, 2000 ppm) was applied at three-days interval with a hand sprayer. After two months, the following parameters were recorded (Table 2).

Table 2: List of measurements

Measurement	Units	Remarks
Survival percentage	%	(No of surviving cuttings / No of total cuttings planted) × 100

- Survival percentage (%)
- Rooting percentage (%) =
  (Number of rooted cuttings / Total number of cuttings planted) × 100
- Number of roots per cutting
- Total root or callus length per cutting (cm)- The total length of roots produced by a cutting was measured when adventitious roots were present. In treatments where rooting did not occur, the length of callus tissue formed at the basal end of the cutting was measured instead. Measurements were recorded in centimeters using a ruler.
- Fresh weight of roots per cutting (g)
- Cost-effectiveness (LKR per surviving cutting)

Data were analyzed using analysis of variance (ANOVA) in R version 4.1.2 (R Core Team, 2021) after verifying the assumptions of normality and homogeneity of variance, and treatment means were compared using the Least Significant Difference (LSD) test at a 5% significance level.

3. Results and Discussion

3.1 Survival Percentage

A significant variation was observed in the survival of cuttings across treatments ($p < 0.05$) (Fig. 1). The highest survival rate was recorded in the IBA treatment (92.3%), followed by those propagated with aloe vera pieces (83.3%) and cinnamon powder combined with coconut water (83.3%). Notably, treatments involving bee honey and aspirin + coconut water showed poor survival, with the former exhibiting no survival.

This superior performance of IBA aligns with findings of Rakibuzzaman et al. (2018), who reported enhanced survival in *Stevia rebaudiana* cuttings treated with IBA. Cinnamon powder may have supported cutting survival through its volatile bioactive constituents, including terpenes and oxygenated terpenoids identified in Cinnamomum zeylanicum, which are known to possess antimicrobial and antioxidant properties that may reduce microbial infection at the cut surface and protect regenerating tissues (Jayaprakasha et al. 2002). Coconut water is also reported to contain cytokinins, sugars, minerals, and small amounts of growth-promoting substances that may support metabolic activity and cell viability during rooting (Al Sherif 2017; Yong et al. 2009). Collectively, these factors may explain the comparatively higher survival and establishment observed in these natural treatments, although their effects were lower than those obtained with IBA.

Conversely, the failure of undiluted bee honey to support survival may be due to its high viscosity and osmotic potential, which can facilitate water removal from the cuttings. Similarly, the poor performance of the aspirin + coconut water treatment may be attributed to potential phytotoxic effects of excessive acetylsalicylic acid, as previously observed in *Triticum aestivum* under controlled conditions (Pallag et al. 2014); though this effect may vary between species and treatment concentrations.

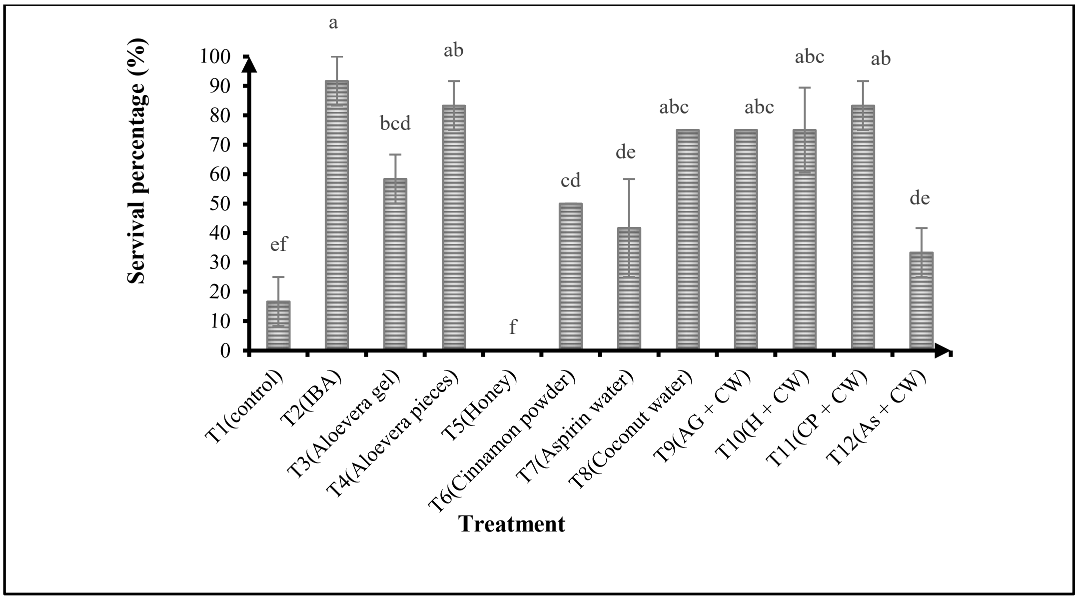

Figure 1. Survival percentage of *Syzygium campanulatum* softwood cuttings at 2 months after planting as affected by different natural and synthetic root-promoting substances.
Treatment codes and descriptions: T1 – Control (well water); T2 – IBA rooting powder (synthetic auxin); T3 – Aloe vera gel; T4 – Aloe vera pieces; T5 – Bee honey (undiluted); T6 – Cinnamon powder; T7 – Aspirin solution (1000 ppm); T8 – Coconut water; T9 – Bee honey + coconut water (1:1 v/v); T10 – Aloe vera gel + coconut water (1:1 v/v); T11 – Cinnamon powder + coconut water; T12 – Aspirin + coconut water (50 mg in 50 mL). Means followed by the same letter are not significantly different at the $\alpha = 0.05$ significance level

3.2 Rooting Response

3.2.1 Rooting Percentage

Rooting occurred exclusively in two treatments: IBA (66.7%) and aloe vera pieces (33.3%) (Fig. 2). All other treatments produced callus tissue without subsequent root emergence. The strong rooting response to IBA aligns with previous findings demonstrating the effectiveness of synthetic auxins in inducing adventitious roots in difficult-to-root woody ornamentals such as *Synsepalum dulcificum* and *Hylocereus undatus* (Ahmad et al. 2016; Chen et al. 2012).

The moderate rooting obtained from aloe vera-treated cuttings may be attributed to the slow localized release of bioactive compounds, including gibberellins, salicylic acid, and trace amounts of auxin, which accumulate at wounded sites and may facilitate root initiation (Al Sherif 2017). In contrast, aloe vera gel applied as a blended dip did not induce rooting, suggesting that the method of application influences the stability, concentration, and bioavailability of active constituents.

The failure of other natural treatments to promote rooting likely reflects insufficient concentration of active compounds or limited uptake at the cutting base. *S. campanulatum* is generally regarded as difficult to root due to its inherently low generative capacity (Hartmann et al. 2011).

3.2.2 Number of Roots per Cutting

The IBA treatment produced a significantly higher number of roots per cutting compared to aloe vera. This result aligns with previous studies on *Hylocereus undatus* and *Warburgia ugandensis*, where IBA similarly enhanced root proliferation (Ahmad et al. 2016; Akwatulira et al. 2011). The superior performance of IBA is attributed to its ability to stimulate cell division and elongation in the basal meristem, thereby promoting the formation and development of adventitious roots (Hartmann et al. 2011).

3.2.3 Total Root or Callus Length per Cutting

Cuttings treated with IBA exhibited the highest total root length (5.89 ± 0.65 cm), followed by those treated with aloe vera pieces (2.78 ± 0.25 cm). In contrast, all other treatments resulted in callus formation only (Fig. 3). This difference reflects the role of IBA in initiating root primordia and promoting root elongation (Hartmann et al. 2011). Interestingly, the bee honey treatment did not induce even callus formation. This may be attributed to honey's strong antimicrobial properties, which could suppress microbial communities or physiological responses necessary for wound healing and callus induction. However, further investigation under controlled conditions is required to verify this effect.

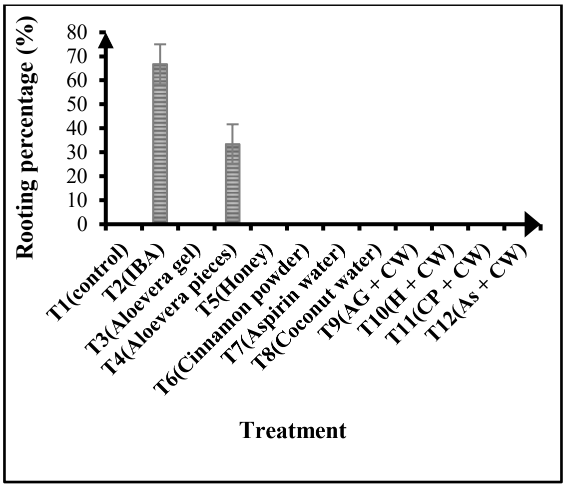

Figure 2: Rooting percentage of *Syzygium campanulatum* softwood cuttings as affected by different natural and synthetic root-promoting substances.
Treatment codes and descriptions: T1 – Control (well water); T2 – IBA rooting powder (synthetic auxin); T3 – Aloe vera gel; T4 – Aloe vera pieces; T5 – Bee honey (undiluted); T6 – Cinnamon powder; T7 – Aspirin solution (1000 ppm); T8 – Coconut water; T9 – Bee honey + coconut water (1:1 v/v); T10 – Aloe vera gel + coconut water (1:1 v/v); T11 – Cinnamon powder + coconut water; T12 – Aspirin + coconut water (50 mg in 50 mL).
Means followed by the same letter are not significantly different at the α = 0.05 significance level.

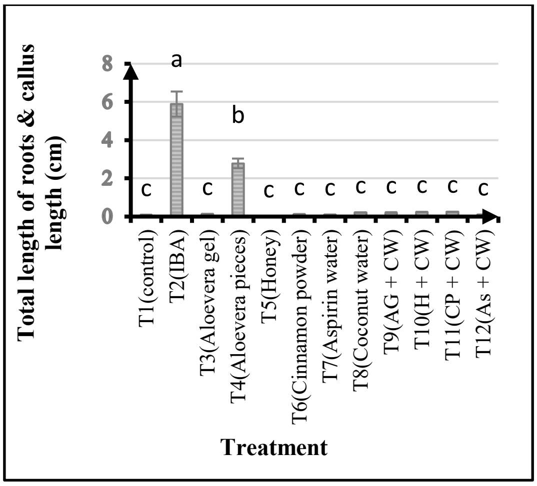

Figure 3: Total length of roots (T2 and T4) or callus tissue (all other treatments) of *Syzygium campanulatum* softwood cuttings as affected by different natural and synthetic root-promoting substances.
Treatment codes and descriptions: T1 – Control (well water); T2 – IBA rooting powder (synthetic auxin); T3 – Aloe vera gel; T4 – Aloe vera pieces; T5 – Bee honey (undiluted); T6 – Cinnamon powder; T7 – Aspirin solution (1000 ppm); T8 – Coconut water; T9 – Bee honey + coconut water (1:1 v/v); T10 – Aloe vera gel + coconut water (1:1 v/v); T11 – Cinnamon powder + coconut water; T12 – Aspirin + coconut water (50 mg in 50 mL).
Means followed by the same letter are not significantly different at the α = 0.05 significance level.

3.2.4 Fresh Root Weight

IBA-treated cuttings exhibited the highest fresh root weight (0.20 g), followed by those treated with aloe vera (0.106 g) (Fig. 4). Similar increases in root biomass with IBA have been reported in *Synsepalum dulcificum* and *Hylocereus undatus* (Ahmad et al. 2016; Chen et al. 2012). The positive effect of IBA on root growth and vascular tissue differentiation aligns with well-documented findings (De Klerk et al. 1999; Hartmann et al. 2011).

3.2.5 Callus Length per Cutting

Among the treatments that resulted in callus formation only, coconut water-based treatments induced the most vigorous callus development, with significant differences observed ($p<0.05$) (Fig. 5). Coconut water is known to contain cytokinins and auxins, which promote cell division and tissue swelling (Yong et al. 2009). However, callus development without subsequent organogenesis suggests hormonal imbalance. It is well-established that a high auxin-to-cytokinin ratio promotes adventitious root formation, whereas a cytokinin-rich environment encourages callus or shoot initiation (Skoog & Miller, 1957; Motte et al. 2019).

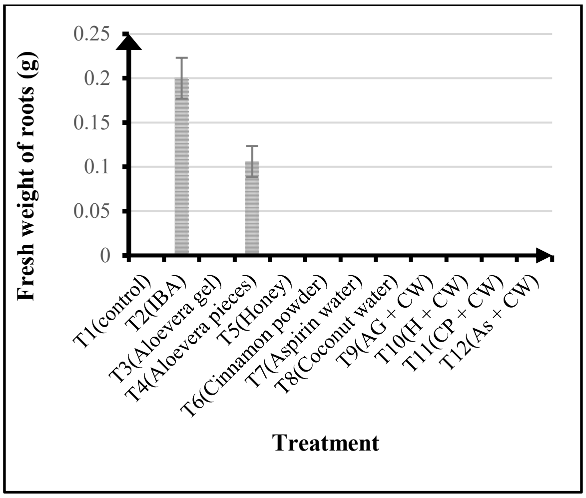

Figure 4: Root fresh weight as affected by natural and synthetic substances

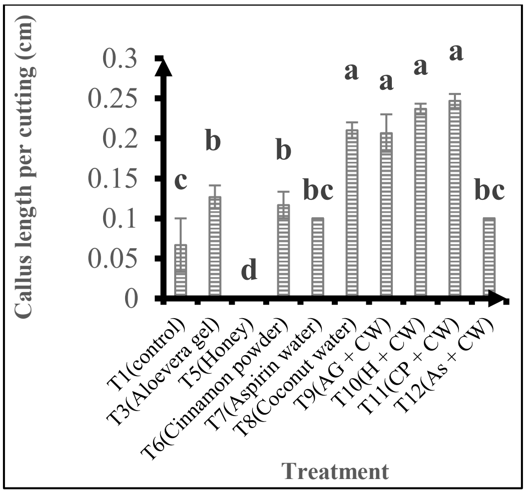

Figure 5: Callus length as affected by natural and synthetic substances

Treatment codes and descriptions: T1 – Control (well water); T2 – IBA rooting powder (synthetic auxin); T3 – Aloe vera gel; T4 – Aloe vera pieces; T5 – Bee honey (undiluted); T6 – Cinnamon powder; T7 – Aspirin solution (1000 ppm); T8 – Coconut water; T9 – Bee honey + coconut water (1:1 v/v); T10 – Aloe vera gel + coconut water (1:1 v/v); T11 – Cinnamon powder + coconut water; T12 – Aspirin + coconut water (50 mg in 50 mL). Means followed by the same letter are not significantly different at the α = 0.05 significance level, according to the LSD test.

3.3. **Cost-effectiveness**

The cost-effectiveness of each treatment was evaluated by considering the total cost of all input materials used and the number of surviving cuttings obtained. The cost included the price of all components used in each treatment during the propagation process, based on the current market prices in Kegalle in April 2021. Based on this calculation, cuttings treated with aloe vera pieces were found to be more cost-effective, with an estimated cost of LKR 6.50 per surviving cutting, compared to LKR 7.87 for IBA-treated cuttings. Although IBA treatment resulted in superior rooting performance, the aloe vera treatment required lower input costs. Therefore, aloe vera pieces may represent a more affordable and environmentally friendly alternative for small-scale nurseries or resource-limited propagation systems.

4. Conclusions

This study confirmed that indole-3-butyric acid (IBA) is the most effective rooting agent for Syzygium campanulatum softwood cuttings under controlled nursery conditions, as evidenced by significantly higher rooting percentage, root length, and root biomass. Among the natural biostimulants evaluated, aloe vera pieces demonstrated moderate efficacy and superior cost-efficiency, indicating their potential for use in resource-limited or environmentally conscious propagation systems. While the other natural treatments did not induce adventitious root formation, several promoted callus developments at the basal end of cuttings, suggesting partial cellular activity. These findings highlight the need for further research to refine the concentrations, application techniques, and combinations of natural biostimulants to enhance rooting responses in hard-to-root ornamental species.

Conflicts of interest: The authors have no conflicts of interest regarding this publication.

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