

Effects of cutting size and growth regulator concentration on the propagation of eight-sided deep pink camellia (*Camellia japonica* L.) Cuttings

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Abstract

The study aimed to evaluate the effects of cutting size and NAA concentration on the survival, growth, and root formation of Eight-Sided Deep Pink Camellia (*Camellia japonica* L.) under cutting propagation conditions. The experiment was carried out using a two-factorial design (3 × 4), with three cutting sizes (15-20 mm, 25-30 mm, 35-40 mm) and four NAA concentrations (0, 100, 200, 500 ppm). The cuttings were monitored over 120 days, and the survival rate, shoot sprouting rate, rooting percentage, root number, and root length of the cuttings were evaluated at regular intervals. The results indicated that both cutting size and NAA concentrations significantly affected rooting ability. Medium-sized cuttings (25-30 mm) showed the highest performance for most growth parameters. NAA at 200-500 ppm significantly improved survival rate, sprouting rate, and root formation in all cutting size groups. The optimal NAA concentration depended on cutting lignification, with 200 ppm being most suitable for small cuttings, whereas 500 ppm was more effective for medium and large cuttings. The combination of 25-30 mm cuttings and 200 ppm NAA produced the highest number of roots and the greatest root length among all treatments. These findings provide a scientific basis for developing a cutting propagation method for Eight-Sided Deep Pink Camellia, supporting conservation programs and the scaling up of plant propagation.

Keywords: *Camellia japonica* L, cutting propagation, NAA, cutting size, rooting

Introduction

The genus *Camellia* (Theaceae) consists of over 250 species widely distributed across Southeast Asia, with China and Vietnam recognized as two major centers of genetic diversity (Liu *et al.*, 2025; Quach *et al.*, 2024; Nguyen 2020) [1, 2, 1]. The double-flowered red *Camellia* group, including Eight-Sided Deep Pink Camellia, Imperial Red, and Pink Camellia *etc.* is highly valued for its landscape value and its potential for developing native cultivars suitable for urban greening. However, the scarcity of high-quality cultivars remains a major challenge due to slow growth, low germination rates, and high genetic variability when propagated by seeds (Liu *et al.*, 2025; Quach *et al.*, 2024) [1, 2].

Vegetative propagation through cuttings is currently considered an effective method to maintain stable traits and ensure a reliable supply of planting material. In *Camellia*, rooting of cuttings is strongly affected by factors such as season, substrate, cutting size, and especially auxin-type plant growth regulators. Previous studies on *Camellia japonica*, *Camellia sinensis*, *Camellia azalea*, and several Vietnamese ornamental *Camellia* cultivars have highlighted the essential role of auxins, particularly NAA and IBA, in promoting callus formation and adventitious root induction (Van *et al.*, 2024; Wang *et al.*, 2022; Kang *et al.* 2019; Dao *et al.*, 2019) [4, 5, 6, 7, 10]. However, the response to auxin is not uniform among different *Camellia* species and may even differ significantly among cuttings of different sizes within the same species. Van *et al.* (2024) [6] reported that auxin (NAA) significantly influenced the rooting ability of Ma Do tea (*Camellia sinensis* var. *madoensis*), but the response varied depending on cutting size and auxin concentration. Similarly, Dao *et al.* (2019) [7] found that the rooting efficiency of *Camellia impressinervis* was strongly affected

by cutting size and position. Moreover, Kang *et al.* (2019) [5] and Wang *et al.* (2022) [10] demonstrated that the rooting response to auxin is influenced by the physiological status of the cuttings and their endogenous hormone levels. These studies show that genetic and physiological factors, together with auxin treatment, determine the rooting success of *Camellia* cuttings. Cutting size also influences carbohydrate accumulation and endogenous growth regulation, affecting auxin efficacy during root induction.

Although many studies have examined the effects of auxins or substrates on rooting in *Camellia*, most have investigated one or two individual factors. The interaction between cutting size and NAA concentration, which is a critical determinant of rooting potential, has not been fully analyzed. To date, no studies on eight-sided deep pink *Camellia* (*Camellia japonica* L.) have simultaneously assessed the effects of cutting season, substrate, cutting size, and NAA concentration. This has resulted in a lack of comparative scientific data, leaving the propagation procedure unstandardized and difficult to implement in practical production.

This study aimed to determine the optimal season for survival and rooting of cuttings, evaluate substrate effects on shoot and root development, and investigate the interaction between cutting size and NAA concentration on rooting after 120 days. These results are expected to contribute to the development of a cutting propagation protocol for eight-sided deep pink *Camellia* (*Camellia japonica* L.), with practical applicability at a production scale. They also provide additional scientific data on the species' physiological responses and support germplasm conservation, the development of native ornamental plants, and the expansion of high-quality propagation material production.

Materials and Methods

1. Materials

Cuttings of eight-sided deep pink Camellia (*Camellia japonica* L.) were obtained from healthy, disease-free mother plants aged 7 to 10 years. Cuttings were taken from semi-hardwood branches, each bearing 2-3 fully expanded leaves and having a uniform length of approximately 10-12 cm. Three diameter categories of cuttings were established, including small (15-20 mm), medium (25-30 mm), and large (35-40 mm). After collection, the cuttings were surface-sterilized in 0.1% Benlat C solution for 10 minutes and allowed to dry before treatment with plant growth regulators.

2. Experimental design

The experiment was carried out using a two-factorial design (3 × 4), with three cutting sizes (15-20 mm, 25-30 mm, 35-40 mm) and four NAA concentrations (100, 200, 500 ppm). Each experimental treatment included 30 cuttings and was replicated three times.

The basal end of each cutting, approximately 3 cm in length, was dipped into NAA solutions at concentrations of 0, 100, 200, and 500 ppm for 30 minutes. The control treatment (0 ppm) was dipped in distilled water. After treatment, the cuttings were drained and inserted into the prepared substrate. The substrate used was fertile organic-amended topsoil, pre-treated with a 1% KMnO₄ solution for 48 hours before inserting the cuttings. After insertion, the cuttings were transferred to a shade house providing 50% light reduction. The cuttings were irrigated by misting 2-3 times per day to maintain substrate moisture at 65-75%. The environmental conditions in the shade house were maintained at 22-28°C with 80-90% relative humidity.

At 30, 60, 90, and 120 days after insertion of the cuttings, the survival rate, sprouting rate, rooting percentage, root number, and root length were evaluated. Across all cuttings in the experimental plots, the following parameters were monitored and recorded:

- **Survival rate (%)**: The survival rate (%) of the cuttings was monitored every 30 days for a period of 4 months following insertion. The survival rate was calculated using the formula:

$$\text{Survival rate (\%)} = \frac{\text{Number of surviving cuttings}}{\text{Total number of cuttings}} \times 100$$

- **Sprouting rate** was recorded at the same 30-day intervals. The sprouting rate was calculated as:

$$\text{Sprouting rate (\%)} = \frac{\text{Number of cuttings with emerging shoots}}{\text{Total number of cuttings}} \times 100$$

- **Shoot growth parameters**: After 4 months, five representative cuttings per plot were selected to evaluate shoot growth. For each sampled cutting, the number of shoots, shoot length, and number of leaves were measured.
- **Rooting percentage (%)**: Rooting ability was assessed by carefully removing the topsoil from the containers to avoid damaging the roots. The number of cuttings that developed roots was recorded, and the rooting percentage was calculated as:

$$\text{Rooting rate (\%)} = \frac{\text{Number of rooted cuttings}}{\text{Total number of cuttings}} \times 100$$

- **Root growth parameters**: For the same sample cuttings used for shoot growth assessment, the number of roots per cutting was counted, and root length (cm) was measured by recording the length of the longest root for each cutting.

3. Data analysis

The data were analyzed to one-way analysis of variance (ANOVA). Mean differences among treatments were compared using the least significant difference (LSD) test at 0.05 significance level. Experimental results are presented as mean ± standard deviation (mean ± SD).

Results and Discussion

1. Effect of NAA concentration on the survival rate of the eight-sided deep pink camellia (*Camellia japonica* L.) cuttings

The results showed that NAA concentration significantly affected the survival rate of Eighteen-Sided Deep Pink cuttings among different cutting size groups. Cuttings without NAA treatment had low survival rates, indicating the cultivar's limited natural rooting ability. Cuttings without NAA treatment showed low survival rates, whereas the use of NAA significantly increased survival, with medium and large sized cuttings exhibiting the greatest improvement. These results provide a scientific basis for selecting appropriate NAA concentrations to enhance survival and optimize the asexual propagation protocol.

Table 1: Effect of NAA concentration on the survival rate of the eight-sided deep pink camellia (*Camellia japonica* L.) cuttings Unit: (%)

Cutting size	NAA concentration (ppm)	30 days	60 days	90 days	120 days
15-20mm	0	18.9	13.3	10.0	6.7
	100	70.0	66.7	60.0	56.7
	200	85.6	80.0	72.2	68.9
	500	81.1	76.7	70.0	66.7
25-30mm	0	20.0	18.9	17.8	13.3
	100	80.0	75.6	70.0	66.7
	200	88.9	82.2	78.9	75.6
	500	89.6	87.0	86.7	83.3
35-40mm	0	15.6	14.4	12.2	10.0
	100	75.6	70.0	65.6	62.2
	200	89.1	86.7	82.2	77.9
	500	88.9	83.3	80.0	78.7

The results in Table 1 shown that NAA concentration had a significant effect on the survival rate of the eight-sided deep pink camellia cuttings among three cutting size groups: 15-20 mm, 25-30 mm, and 35-40 mm. In all groups, cuttings without NAA treatment (control) showed very low survival rates, ranging from 6.7% to 13.3% after 120 days, indicating the species' limited natural rooting ability. This is in agreement with the physiological characteristics of the genus *Camellia*, which generally shows slow adventitious root formation and limited natural regeneration (Gong *et al.*, 2025; Wang *et al.*, 2022; Wei *et al.*, 2019) [4, 9, 10, 12]. Cuttings treated with NAA showed significantly increased survival, with medium and large cuttings showing the greatest improvement, which was maintained over time in

all size groups. The higher survival rates observed in medium and large cuttings may be related to their greater nutrient reserves and degree of lignification (Chang *et al.*, 2023; Wang *et al.*, 2022, Guan *et al.*, 2019) [4, 8, 10, 11]. The cuttings of small size (15-20 mm) treated with 200 ppm NAA showed the highest survival rate (68.9%), followed by 500 ppm (66.7%) and 100 ppm (56.7%), indicating that a medium NAA concentration is optimal for this size group. For medium sized cuttings (25-30 mm), survival increased as NAA concentrations increased from 100 to 500 ppm, with 500 ppm producing the highest survival rate (83.3%), significantly higher than at 200 ppm (75.6%). Large cuttings (35-40 mm) treated with both 200 and 500 ppm NAA showed high survival rates (77.9% and 78.7%, respectively), considerably higher than the control (10.0%) and 100 ppm (62.2%). This is likely because more lignified (mature) cutting tissues form a mechanical and developmental barrier to root induction and therefore require higher auxin doses to stimulate cell division and initiate root primordia (Chang *et al.*, 2023; Xu *et al.*, 2017) [8, 13].

Medium and large cuttings showed significantly higher survival than small cuttings at the same NAA concentration. Cuttings of 25-30 mm showed the strongest response to NAA, with the highest survival rate (83.3%) at 500 ppm, suggesting that this size has accumulated sufficient nutrients while not yet being highly lignified, creating favorable conditions for root regeneration. For larger cuttings (35-40 mm), the survival rate at 500 ppm was not much higher than at 200 ppm, indicating that the cuttings' response to auxin had nearly reached its maximum, and additional increases in NAA concentration did not significantly enhance root formation.

Taken together, the results confirm that NAA is an important factor enhancing the survival and rooting rates of eight-sided deep pink camellia cuttings. The observed increase in survival rates with NAA concentration is consistent with the physiological mechanism in which auxin activates cell division and elongation in the soft tissues of the cuttings, thereby promoting adventitious root formation. The observed increase in survival rates with NAA concentration supports the physiological mechanism in which auxin activates cell division and elongation in the soft tissues of the cuttings, thereby promoting adventitious root formation (Gong *et al.*, 2025; Wang *et al.*, 2022; Guan *et al.*, 2019) [4, 9, 10, 11]. These findings are in agreement with previous studies on the genus *Camellia*, where both NAA and IBA play important roles in cutting propagation (Wang *et al.*, 2022; Guan *et al.*, 2019, Wei *et al.*, 2019) [4, 10, 11, 12].

2. Effect of NAA concentration on the sprouting rate of the eight-sided deep pink camellia (*Camellia japonica* L.) cuttings

To evaluate the effect of NAA concentrations on the sprouting ability of the eight-sided deep pink camellia cuttings, the NAA-treated groups were assessed at 30, 60, 90, and 120 days. The results showed that NAA strongly stimulated meristem differentiation and the formation of lateral shoots, while the sprouting rate depended on both cutting size and auxin concentration, reflecting the physiological characteristics of woody species that are difficult to propagate.

Table 2: Effect of NAA on the sprouting rate of the eight-sided deep pink camellia cuttings *Unit: (%)*

Cutting size	NAA (ppm)	30 days	30 days	30 days	30 days
15-20mm	0	5.6	4.7	5.1	5.4
	100	28.9	38.0	48.9	52.4
	200	45.6	63.7	65.2	67.4
	500	52.2	59.3	64.0	65.3
25-30mm	0	9.2	11.0	12.3	12.8
	100	40.0	60.0	63.9	65.2
	200	52.2	63.3	70.0	72.4
	500	68.9	80.0	82.7	81.4
35-40mm	0	6.9	8.7	9.1	10.0
	100	56.7	60.6	61.3	62.2
	200	75.6	74.7	76.3	61.2
	500	55.6	75.6	81.1	77.2

The results in Table 2 show that NAA concentration significantly affects the sprouting rate of the eight-sided deep pink camellia cuttings in all cutting sizes. In all cutting size groups and NAA concentration treatments, the sprouting rate increased gradually from 30 to 120 days, indicating the characteristically slow meristem differentiation observed in the Theaceae family. For the untreated control cuttings, the sprouting rate remained at very low levels, ranging only from 4.7 to 12.8%, showing that this species initiates shoots poorly without exogenous auxin.

Treatment with NAA significantly increased the sprouting rate in all cutting sizes, with the most pronounced improvement observed after 60 days. For 15–20 mm cuttings, both 200 and 500 ppm resulted in high sprouting rates (67.4% and 65.3%), significantly higher than the control (5.4%), with 200 ppm achieving the highest rate at 120 days. For 25-30 mm cuttings, this group showed the strongest response to NAA, with 500 ppm producing the highest sprouting rate (81.4%), followed by 200 ppm (72.4%). For 35-40 mm cuttings, 200 ppm NAA resulted in the highest sprouting rate at 90 days (76.3%); however, by 120 days, the rate for 200 ppm had decreased to 61.2%, whereas 500 ppm reached 77.2%. This suggests that larger cuttings are likely to require higher auxin levels to maintain prolonged shoot differentiation.

Overall, NAA at 200-500 ppm was most effective, with the optimal level depending on cutting size. At the same NAA concentration, the sprouting rate was highest in medium cuttings (25-30 mm), likely due to their balanced physiology and adequate nutrient reserves without excessive lignification, which allows a strong response to auxin. In contrast, small and large cuttings exhibited lower sprouting rates, especially in the absence of NAA, suggesting that cutting size plays a decisive role in shoot regeneration.

Auxins, including NAA, play an essential role in activating parenchyma cells at the cutting site, stimulating callus formation, promoting cell division for lateral shoot development, and regulating the endogenous balance between auxin and cytokinin. The increasing sprouting response to higher NAA levels observed in this study corresponds to the physiological characteristics of woody species that are difficult to propagate and agrees with previous findings. Viet *et al.* (2025) [15] and Viet *et al.* (2019) [14] reported that exogenous auxin significantly increased sprouting in *Camellia chrysantha* cuttings,

especially at 100-500 ppm. Nguyen (2011) showed that auxin enhanced new shoot formation in *Camellia japonica*, with 200-400 ppm being most effective. Similarly, Dao *et al.* (2019) [7] observed stronger sprouting at higher auxin levels in *Camellia impressinervis*, consistent with the response of medium and large cuttings in the present study. Studies on woody species such as *Camellia*, *Magnolia*, *Michelia*, and *Rhododendron* have shown that auxin is essential for overcoming lateral bud inhibition (apical dominance), which explains the very low sprouting rate observed in the control group of this study.

3. Effects of NAA concentration on shoot growth of eight-sided deep pink *Camellia* (*Camellia japonica* L.) cuttings

After determining the effects of NAA on survival and sprouting rate, the study further evaluated the impact of different NAA concentrations on shoot growth after 120 days. Analyzing parameters such as the number of shoots per cutting, shoot diameter, shoot length, and number of leaves per shoot clarifies the physiological responses of cuttings of different sizes to auxin and identifies the optimal NAA concentration to enhance the propagation efficiency of eight-sided deep pink *Camellia*.

Table 3: Effects of NAA concentration on shoot growth of eight-sided deep pink *Camellia* cuttings after 120 days

Cutting size	NAA (ppm)	Shoots per Cutting	Shoot Diameter (mm)	Shoot Length (cm)	Leaves per shoot
15-20mm	0	1.2	5.4	3.8	5.6
	100	2.6	7.6	3.3	4.8
	200	2.1	9.8	3.0	4.4
	500	1.9	10.1	1.7	2.8
25-30mm	0	1.0	7.3	3.0	5.0
	100	1.9	12.8	3.6	5.4
	200	2.4	16.3	6.4	5.1
	500	2.2	18.7	1.5	2.2
35-40mm	0	0.8	13.9	2.7	4.5
	100	1.6	21.8	3.1	4.9
	200	2.0	27.4	1.9	3.1
	500	2.3	30.2	5.2	3.0



a. Cutting diameter 15 – 20mm



b. Cutting diameter 25 – 30mm



c. Cutting diameter giống 35 – 40mm

Fig 1: Eight-sided deep pink *Camellia* plants under different NAA treatments: plants developed from cuttings of 15-20 mm diameter (a), 25-30 mm (b), and 35-40 mm (c) treated with NAA at 0, 100, 200, and 500 ppm

Table 3 shows that NAA significantly affected all shoot growth parameters (shoots per cutting, shoot length, shoot diameter, and leaves per shoot) in all cutting sizes. Increasing NAA concentration enhanced growth compared to the control, reflecting the stimulatory effect of exogenous auxin on shoot differentiation and elongation. The most significant effect was observed at 100-200 ppm NAA, whereas 500 ppm NAA was observed to decrease some growth parameters, particularly the number of leaves per shoot and shoot diameter.

- **Shoots per cutting:** The number of shoots per cutting increased significantly from 0 to 200 ppm NAA in all three size groups. At 200 ppm NAA, 2.0-2.4 shoots per cutting were observed, approximately 2-3 times higher than the control, while 500 ppm NAA was not higher than 200 ppm. The 15-20 mm cuttings showed the lowest growth shoots per cutting. These results indicate that 200 ppm NAA is the optimal concentration for shoot differentiation, whereas 500 ppm NAA begins to inhibit growth due to excessive auxin.
- **Shoot length:** Shoot length increased continuously with NAA concentration in all cutting size groups. The 35-40 mm cuttings showed the greatest shoot length, increasing from 13.9 cm at 0 ppm NAA to 21.8 cm at 100 ppm NAA, 27.4 cm at 200 ppm NAA, and reaching the maximum of 30.2 cm at 500 ppm NAA. Larger cuttings exhibited greater shoot elongation than smaller cuttings, likely because they contain higher nutrient reserves to support growth.
- **Shoot diameter:** Shoot diameter increased significantly at 100-200 ppm NAA but decreased markedly at 500 ppm in the 25-30 mm and 35-40 mm cutting groups. This indicates that high NAA concentrations promote shoot elongation but result in weaker shoots with reduced development of supporting tissues. These findings are consistent with Liu *et al.* (2020), who

reported that high auxin levels stimulate elongation without promoting woody tissue development.

- **Leaves per shoot:** The number of leaves per shoot increased as NAA concentration increased from 0 to 200 ppm. However, at 500 ppm NAA, leaf number per shoot decreased markedly, from 5.1 at 200 ppm NAA to 2.2, suggesting that high NAA concentrations disrupt the auxin/cytokinin balance, promoting shoot elongation while inhibiting leaf differentiation

These results agree with previous studies by Dao *et al.* (2019)^[7] on *Camellia impressinervis*, Phuong (2011)^[16] on *Camellia japonica*, and Viet *et al.* (2025)^[15] on *Camellia chrysantha*, which all reported that moderate auxin concentrations increase shoot number and length, whereas high concentrations result in thin shoots with fewer leaves. Consistently, in this study, 25-30 mm cuttings showed optimal growth performance across all parameters and are considered the most suitable for propagation, while large cuttings (35-40 mm) developed the longest shoots but exhibited reduced diameter and leaf number at high NAA concentrations, and small cuttings (15-20 mm) showed weaker growth due to their limited size and nutrient reserves.

4. Effect of NAA concentration on root formation of eight-sided deep pink *Camellia (Camellia japonica L.)* cuttings

To determine the responsiveness of the root system to exogenous auxin, the study further analyzed the effects of different NAA concentrations on root formation after 120 days in three cutting size groups. The parameters determined included rooting percentage, number of roots per cutting, and root length, providing a comprehensive assessment of NAA's root-inducing efficiency and identifying the optimal concentration for root regeneration in eight-sided deep pink camellia cuttings.

Table 4: Effect of NAA concentration on root formation of eight-sided deep pink camellia cuttings after 120 days

Cutting size	NAA (ppm)	Rooting percentage (%)	Number of roots per cutting (roots)	Root length (cm)
15-20mm	0	25.6	1.2	1.3
	100	60.0	2.6	3.8
	200	63.3	3.0	3.4
	500	60.0	2.7	3.1
25-30mm	0	20.0	1.0	1.7
	100	55.6	3.8	3.0
	200	68.9	4.4	4.7
	500	63.3	3.1	5.4
35-40mm	0	18.9	0.8	1.9
	100	45.6	2.2	5.7
	200	56.7	3.8	6.1
	500	70.0	3.5	7.9

NAA strongly influenced root formation in eight-sided deep pink *Camellia* cuttings. In three cutting sizes, NAA treatment enhanced rooting percentage, number of roots per cutting, and root length compared to the control, which reflects the key role of auxin in callus induction, adventitious root formation, and root elongation. Optimal NAA concentrations differed depending on cutting size, reflecting differences in lignification and nutrient reserves that influenced tissue responsiveness.

Rooting percentage increased with NAA treatment for all cutting sizes. Specifically, 15-20 mm cuttings increased from 25.6% at 0 ppm to 60.0% at 100 ppm, then slightly decreased at higher concentrations (63.3% at 200 ppm; 60.0% at 500 ppm). Rooting percentage of 25-30 mm cuttings was highest at 68.9% at 200 ppm, while 35-40 mm cuttings was highest at 70.0% at 500 ppm, indicating that larger cuttings require higher auxin concentrations for optimal rooting.

Number of roots per cutting increased with NAA treatment in all cutting sizes. Maximum root numbers were reached at 200 ppm for all sizes, with 3.0, 4.4, and 3.8 roots for 15-20 mm, 25-30 mm, and 35-40 mm cuttings, respectively, indicating that 200 ppm is the most effective concentration for stimulating root cell division.

Root length also increased with NAA treatment. Small cuttings (15-20 mm) reached 3.8 cm at 100 ppm NAA, medium cuttings (25-30 mm) reached 5.4 cm at 500 ppm NAA, and large cuttings (35-40 mm) reached 7.9 cm at 500 ppm NAA, reflecting their greater nutrient reserves and tissue capacity for elongation.

These results indicate that cutting size determines the “physiological threshold” for NAA-induced root formation with small cuttings require lower NAA, medium cuttings showing maximum rooting at intermediate concentrations, and large cuttings need higher NAA to adventitious root formation. Excessively high NAA reduced rooting percentage or root length in all sizes, consistent with known physiological mechanisms, where high auxin inhibits root elongation, increases callus at the base, and limits nutrient allocation to true roots (Morales-Orellana *et al.*, 2022; Bai *et al.*, 2020; Zheng *et al.*, 2020; Orel and Curry, 2015)^{17, 18, 19, 20}. Consequently, in this study, the highest number of roots per cutting was observed at 200 ppm NAA, while the longest roots developed at 500 ppm NAA, particularly in large cuttings.

Conclusion

This study demonstrated that NAA concentration strongly influences survival, shoot sprouting, growth, and root formation in three cutting size groups of eight-sided deep pink Camellia (*Camellia japonica* L.) cuttings after 120 days. Rooting efficiency depended on both cutting size and NAA concentration, reflecting the interaction between nutrient reserves, lignification, and auxin requirement. For 25-30 mm cuttings, 200 ppm NAA resulted in the highest survival (83%) and shoot sprouting rates (81.4%), with optimal shoot growth (length, diameter, and leaf number). At the same NAA concentration, root formation reached 68.9% with an average root length of 4.7 cm.

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