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Effects of Cutting Size and Cutting Season on Propagation Efficiency of Double Petaled Red Camellia (*Camellia Japonica* L.)

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ABSTRACT: The study was conducted to evaluate the effects of cutting season and cutting size on shoot growth and rooting ability of double-petaled red camellia (*Camellia japonica* L.) propagated by cuttings. The experiment was arranged in a completely randomized design with three cutting diameter classes (15 - 20 mm, 25 - 30 mm, and 35 - 40 mm) and four cutting seasons (spring, summer, autumn, and winter). The results showed that both factors significantly affected survival rate, bud sprouting, shoot growth, and rooting ability ($P < 0.05$). Cuttings propagated in spring and autumn exhibited higher survival rates (80,0 – 89,0%) and bud sprouting rates (77,1 – 86,0%) compared with summer and winter. Among cutting sizes, the 25 - 30 mm diameter cuttings showed superior performance, achieving the highest rooting percentage (81,5 – 85,8%), number of roots (3,4 – 3,6 roots per cutting), and root length (4,1- 4,4 cm). Smaller cuttings showed limited rooting capacity, while larger cuttings were less stable across seasons. It is therefore recommended that double-petaled red camellia should be propagated by cuttings in spring or autumn using cuttings with diameters of 25 - 30 mm to obtain high propagation efficiency.

KEYWORDS: *Camellia japonica* L.; cutting season; cutting size; shoot growth; rooting ability.

1. INTRODUCTION

Double petaled red camellia (*Camellia japonica* L.) belongs to the genus *Camellia* of the family Theaceae and is widely cultivated in Korea, Japan, China, and Vietnam (Wheeler et al., 2015). This species is highly valued for both its economic and ornamental significance due to its large flowers, vivid coloration, prolonged flowering period, and outstanding aesthetic quality. In addition, double-petaled red camellia exhibits considerable propagation potential, contributing to improved efficiency in cultivar exploitation and development. In recent years, the demand for this species as a high-end ornamental plant and as a source of raw materials for medicinal research has increased markedly, requiring a supply of planting materials that are uniform, high-quality, and genetically stable.

Currently, vegetative propagation by cuttings is considered an effective method for preserving genetic characteristics and shortening the production cycle of planting materials. However, the rooting and survival success of cuttings of double-petaled red camellia remains inconsistent, as it is strongly influenced by various biological and ecological factors. Among these, cutting season and cutting size play decisive roles. Previous studies on the genus *Camellia* have shown that seasonal climatic conditions directly affect water balance, carbohydrate accumulation, and physiological activity of cuttings, while cutting size reflects endogenous nutrient reserves and the capacity for callus formation and adventitious root initiation.

In Vietnam, studies addressing the combined effects of cutting season and cutting size on shoot growth and rooting ability of double-petaled red camellia are still very limited, particularly under the ecological conditions of the northern midland and mountainous regions. The lack of scientific evidence for selecting optimal cutting time and cutting size has reduced propagation efficiency and posed challenges for large-scale seedling production.

Based on these considerations, the present study entitled *"Effects of cutting season and cutting size on shoot growth and rooting ability of double petaled red Camellia"* was conducted to determine the most suitable cutting season and cutting size. The results are expected to provide a scientific basis for improving vegetative propagation protocols, thereby supporting sustainable production and conservation of this valuable plant species.

2. MATERIALS AND METHODS

2.1. Plant materials

The plant materials used in this study were cuttings of double petaled red camellia (*Camellia japonica* L.) collected from a mother plant garden maintained in Thai Nguyen province. The mother plants had been previously evaluated and monitored for stable vegetative growth and flowering performance.

Cuttings were selected to ensure uniformity in quality, with an age of 10 - 12 months and a length of 30 - 35 cm. Based on stem diameter, the cuttings were classified into three size groups: (i) 15 - 20 mm, (ii) 25 - 30 mm, and (iii) 35 - 40 mm. All selected cuttings were free from pests and diseases and exhibited vigorous growth.

2.2. Research methods

2.2.1. Experimental design

The experiment was conducted to evaluate the effects of cutting diameter and cutting season on the growth performance of double - petaled red camellia. The experiment was arranged in a completely randomized design (CRD) with three replications, each replication consisting of 30 cuttings. The experimental treatments were defined according to cutting season as follows:

Treatment	Cutting season
T1	Spring (February)
T2	Summer (June)
T3	Autumn (September)
T4	Winter (December)

2.2.2. Cutting preparation and cultivation practices

Cuttings used in the experiment were obtained from semi-hardwood branches of healthy double petaled red camellia (eight - sided deep pink camellia) mother plants grown in Thai Nguyen. The harvested branches had diameters ranging from 0,15 to 0,40 mm. Cutting collection was carefully carried out to avoid mechanical damage and was performed on cool days with an average temperature of 20 - 30 °C or in the late afternoon, allowing the cuttings to stabilize overnight. Immediately after cutting, the branches were placed in plastic bags and sprayed with water to maintain moisture while awaiting planting.

Cutting preparation and treatment: The cuttings were prepared with a length of 30 - 35 cm, and the basal end was cut obliquely at an angle of approximately 45°. For cuttings bearing leaves, half of the leaf area was removed to reduce transpiration. After preparation, the cuttings were immersed in a 0,5% Vinben C solution for 15 minutes for fungal and bacterial disinfection. Subsequently, the cuttings were treated with the rooting hormone NAA at a concentration of 200 ppm for 30 minutes. After treatment, the cuttings were removed and allowed to air dry before being inserted into rooting bags with a size of 7 × 12 cm.

Planting of cuttings: The substrate-filled bags were watered with a 0.5% Vinben C solution two days prior to planting, and moisture content was adjusted to approximately 75 - 80%. Cuttings were inserted vertically into the center of the bag, with leaves oriented in the direction of airflow. The basal portion of the cutting was buried to a depth equivalent to one-third of the cutting length.

The rooting substrate consisted of alluvial soil. Prior to planting, the substrate was disinfected using a 1% $KMnO_4$ solution for 48 hours.

Crop management: After planting, adequate moisture was maintained, and the cuttings were covered with a white polyethylene tunnel to prevent water loss and desiccation, as well as to protect against rainfall. A black shading net was installed above the tunnel to reduce light intensity by approximately 60%. Mist irrigation was applied 2 - 3 times per day to maintain substrate moisture at 70 - 80%. Other management practices, including fertilization, weed control, and pest and disease management, were conducted following standard cutting propagation techniques for tea plants.

2.2.3. Observed parameters and measurement methods

After planting, the cuttings were monitored for survival rate, sprouting rate, number of shoots, shoot length, number of leaves, rooting percentage, root length, and number of roots, in order to determine the optimal cutting season and stem diameter for efficient propagation of double petaled red camellia.

Across all experimental plots, the following parameters were recorded:

+ **Survival rate (%):** Recorded at three time points after planting the cuttings (30, 60, and 120 days), calculated using the following formula

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

+ **Bud sprouting rate (%):** Recorded at three time points after planting the cuttings (1, 2, and 3 months), calculated using the following formula.

$$\text{Sprouting rate (\%)} = \frac{\text{Number of sprouted cuttings}}{\text{Total number of planted cuttings}} \times 100$$

In each experimental plot, ten surviving cuttings were randomly selected along the diagonal line (two cuttings per sampling point at five points) to assess shoot growth performance:

- Dynamics of shoot length increase (cm) at 30, 60, 90, and 120 days after planting.
- Dynamics of leaf number increase per plant at 30, 60, 90, and 120 days after planting.

2.2.4. Data Analysis

The experimental data were analyzed using one-way analysis of variance (ANOVA). Mean differences among experimental treatments were compared using the least significant difference test at the 0.05 probability level ($LSD_{0.05}$).

3. RESULTS AND DISCUSSION

3.1. Effects of cutting size and season on survival and bud sprouting of double petaled red camellia

Table 1. Effects of cutting size and season on survival rate and bud sprouting rate of double petaled red camellia (*Camellia japonica* L.) cuttings.

Cutting diameter (mm)	T	30 day		60 day		90 day		120 day	
		Survival rate (%)	Bud sprouting rate (%)	Survival rate (%)	Bud sprouting rate (%)	Survival rate (%)	Bud sprouting rate (%)	Survival rate (%)	Bud sprouting rate (%)
15–20	Spring	79,8 ± 1,72	45,12 ±1,10	76,0 ± 1,60	60,25 ±0,95	72,2 ± 1,45	66,30 ±0,80	70,9 ± 1,40	69,05 ±0,88
	Summer	68,1 ± 1,65	28,40 ±1,02	63,9 ± 1,55	38,50 ±0,88	60,7 ± 1,42	50,20 ±0,82	59,4 ± 1,38	55,10 ±0,90
	Autumn	77,2 ± 1,70	34,05 ±1,05	73,1 ± 1,58	52,10 ±0,86	69,5 ± 1,46	64,50 ±0,90	68,0 ± 1,39	68,20 ±0,85
	Winter	61,0 ± 1,60	26,80 ±0,95	56,8 ± 1,50	35,40 ±0,80	53,6 ± 1,35	45,10 ±0,75	52,1 ± 1,30	48,30 ±0,82
25–30mm	Spring	93,2 ± 1,30	70,05 ±1,30	91,6 ± 1,22	80,12 ±1,10	90,4 ± 1,15	84,20 ±0,95	89,0 ± 1,10	86,00 ±0,90
	Summer	80,0 ± 1,42	50,20 ±1,25	75,2 ± 1,35	65,00 ±1,05	71,9 ± 1,28	70,10 ±0,92	70,5 ± 1,20	72,30 ±0,82
	Autumn	89,0 ± 1,36	66,10 ±1,20	84,8 ± 1,30	75,05 ±1,00	81,6 ± 1,18	79,30 ±0,95	80,0 ± 1,12	82,10 ±0,84
	Winter	71,5 ± 1,44	45,30 ±1,10	66,9 ± 1,35	58,20 ±0,95	63,8 ± 1,25	63,40 ±0,88	62,3 ± 1,18	65,20 ±0,90
35–40mm	Spring	91,0 ± 1,40	60,12 ±1,05	87,2 ± 1,32	72,05 ±0,92	83,9 ± 1,22	76,20 ±0,95	82,4 ± 1,18	79,10 ±0,90
	Summer	76,8 ± 1,46	42,50 ±1,00	71,5 ± 1,36	55,30 ±0,90	67,8 ± 1,28	62,10 ±0,88	66,2 ± 1,20	64,00 ±0,80
	Autumn	86,4 ± 1,42	58,00 ±1,08	81,9 ± 1,34	68,20 ±0,95	78,3 ± 1,24	74,40 ±0,98	76,8 ± 1,16	77,10 ±0,88
	Winter	69,2 ± 1,48	38,20 ±0,95	64,7 ± 1,38	49,40 ±0,85	61,5 ± 1,30	56,00 ±0,80	60,0 ± 1,22	58,30 ±0,82
P								< 0,05	<0,05
LSD.05								1,6	1,5

Notes:

T: Treatment

- T1: Spring (February)
- T2: Summer (June)
- T3: Autumn (September)
- T4: Winter (December)

The results presented in Table 1 indicate that planting season had a pronounced effect on the survival rate and sprouting percentage of double-petaled red camellia cuttings across all tested cutting diameter classes. Statistical analysis confirmed that differences among treatments were significant at $P < 0.05$, highlighting the dominant role of seasonal ecological conditions in regulating shoot initiation from camellia cuttings.

Survival rate

Across all three cutting diameter groups (15 - 20 mm, 25 - 30 mm, and 35 - 40 mm), spring consistently resulted in the highest survival rates at all observation times. After 120 days of propagation, survival rates reached 70,9%, 89,0%, and 82,4%, respectively, which were markedly higher than those recorded in other seasons.

The superior performance observed in spring can be explained by the favorable combination of ecological factors, including moderate temperature and humidity (approximately 20 - 25°C) and moderate light intensity, which help balance photosynthesis and transpiration. In addition, following winter dormancy, carbohydrate reserves in cutting tissues are typically higher, providing sufficient energy for cell division, callus formation, and the initiation of adventitious roots.

In contrast, summer showed significantly lower survival rates compared with spring and autumn. At 120 days, survival rates ranged from 59,4% to 70,5%, depending on cutting diameter. This decline is mainly attributed to heat stress and water imbalance: high temperatures increase transpiration, reduce tissue water potential, and intensify respiration, leading to rapid depletion of stored carbon reserves and negatively affecting root initiation. These findings are consistent with those of Santos et al. (2020), who reported that high temperatures (above 32°C) can inhibit adventitious root formation in many woody species, including those of the genus *Camellia*.

Autumn maintained relatively high survival rates, ranking second after spring and clearly outperforming summer and winter. After 120 days, survival rates reached 68,0% (15 - 20 mm), 80,0% (25 - 30 mm), and 76,8% (35 - 40 mm).

Winter resulted in the lowest survival rates across all cutting diameter classes, with values ranging from 52,1% to 62,3% at 120 days. This reduction is mainly due to low temperatures, which suppress root meristem activity, reduce photosynthetic capacity, and limit carbohydrate availability for root formation, thereby constraining metabolic energy for growth processes. These results are consistent with the report of Fukasawa and Kitabatake (2022), who observed a 40 - 55% reduction in the number of newly formed roots of *Camellia sasanqua* during winter compared with spring and autumn.

3.2. Effects of season and cutting size on shoot growth of double petaled red Camellia

Table 2. Effects of season on shoot growth of double petaled red camellia (*Camellia japonica* L.) cuttings.

Cutting diameter (mm)	Season	Number of shoots per cutting	Shoot diameter (mm)	Shoot length (cm)	Number of leaves per shoot
15-20	Spring	2,4 ± 0,18b	8,2 ± 0,52d	4,1 ± 0,25c	5,6 ± 0,30b
	Summer	1,8 ± 0,15c	6,5 ± 0,40f	3,2 ± 0,20d	4,4 ± 0,28c
	Autumn	2,1 ± 0,16bc	7,4 ± 0,46e	3,8 ± 0,22cd	5,1 ± 0,26b
	Winter	1,3 ± 0,12d	5,5 ± 0,33g	2,6 ± 0,18e	3,8 ± 0,20d
25-30	Spring	2,8 ± 0,20a	12,8 ± 0,75c	5,4 ± 0,32b	6,4 ± 0,34a
	Summer	2,2 ± 0,17b	10,4 ± 0,60d	4,2 ± 0,28c	5,2 ± 0,33b
	Autumn	2,5 ± 0,18ab	14,1 ± 0,81b	5,0 ± 0,30b	6,0 ± 0,32a
	Winter	1,7 ± 0,15c	8,3 ± 0,51e	3,0 ± 0,22d	4,1 ± 0,25c
35-40	Spring	2,0 ± 0,16b	17,0 ± 0,95c	4,2 ± 0,28b	5,4 ± 0,30b
	Summer	1,6 ± 0,14c	14,8 ± 0,82d	3,3 ± 0,21c	4,5 ± 0,26c
	Autumn	2,2 ± 0,17ab	21,3 ± 1,11b	4,8 ± 0,30b	5,9 ± 0,32a
	Winter	1,2 ± 0,12d	25,4 ± 1,25a	2,6 ± 0,18d	3,6 ± 0,21d
P		<0,05	<0,05	<0,05	<0,05
LSD0,05		0,18	0,70	0,20	0,34

Sprouting percentage

Sprouting percentage varied significantly among seasons, with statistically significant differences ($P < 0.05$). Spring achieved high sprouting rates (79,1 – 86,0%), indicating that environmental conditions were favorable for both cutting survival and shoot emergence. In contrast, winter and summer recorded lower sprouting percentages (45,1 – 58,3%), reflecting limited recovery capacity of cuttings under unfavorable conditions. The positive relationship between cutting diameter and sprouting percentage suggests that shoot emergence is closely linked to the physiological status, vigor of the cutting, and the planting season.

Overall, spring was identified as the most optimal season for propagating double-petaled red camellia by cuttings. Cuttings with a medium diameter (25 - 30 mm) consistently exhibited the highest survival and sprouting rates across all seasons.

The analysis of variance showed that both season and cutting size had statistically significant effects ($P < 0.05$) on all evaluated indicators of shoot growth and rooting of camellia cuttings, including the number of shoots per cutting, shoot diameter, shoot length, number of leaves per shoot, rooting percentage, number of roots, and root length. In addition, a clear interaction between these two factors was observed, indicating that the shoot growth performance of camellia cuttings depends simultaneously on seasonal environmental conditions and the endogenous reserve capacity of the cuttings.

The results indicated that spring and autumn consistently produced significantly higher growth values than summer and winter across most cutting diameter classes. Among all experimental treatments, cuttings with a diameter of 25 - 30 mm propagated in spring consistently achieved the highest and most stable values for all measured parameters and were therefore identified as the optimal treatment.

For the same cutting size, shoot growth parameters recorded in spring and autumn were significantly higher than those observed in summer and winter. In particular, during spring, the number of shoots per cutting reached the highest values (up to 2,8 shoots per cutting in the 25 - 30 mm group). Shoot length and the number of leaves per shoot increased markedly, reflecting favorable vegetative growth conditions. Shoot diameter was also greater, indicating vigorous and uniform shoot development.

The superiority of spring and autumn can be attributed to their mild climatic conditions, characterized by low temperature fluctuations, moderate light intensity, and stable air humidity. These conditions reduce transpiration losses, maintain cellular turgor, and stimulate mitotic activity, thereby promoting shoot elongation and new leaf formation. These findings are consistent with previous studies on *Camellia japonica* and *Camellia sinensis*, which identified spring and autumn as optimal periods for vegetative tissue regeneration and shoot growth (Liu et al., 2025; Santos et al., 2020).

Across all seasons, cuttings with a diameter of 25 - 30 mm consistently exhibited the highest and most stable shoot growth performance, particularly when propagated in spring and autumn. In this treatment, the number of shoots per cutting reached a maximum of 2,8 (spring), shoot length reached 5,4 cm, which was significantly higher than in the other two size classes, and the number of leaves per shoot reached 6,4, indicating strong vegetative growth. The larger shoot diameter (12,8 – 14,1 mm) further reflected robust shoots with high photosynthetic capacity.

3.3. Effects of season and cutting size on the rooting ability of red camellia cuttings

Table 3. Effects of cutting size and season on the rooting ability of double petaled red camellia cuttings (after 120 days)

Cutting diameter (mm)	Season	Rooting percentage (%	Number of roots per cutting	Root length (cm)
15-20	Spring	68,4 ± 2,1 b	1,8 ± 0,12 c	2,6 ± 0,14 c
	Summer	52,7 ± 1,8 d	1,0 ± 0,10 e	1,5 ± 0,12 e
	Autumn	67,9 ± 2,5 a	2,0 ± 0,14 b	3,0 ± 0,18 b
	Winter	47,6 ± 1,6 e	0,8 ± 0,08 f	1,2 ± 0,10 f
25-30	Spring	85,8 ± 3,0 a	3,4 ± 0,18 a	4,1 ± 0,22 a
	Summer	71,5 ± 2,4 c	2,1 ± 0,12 d	2,8 ± 0,17 c
	Autumn	81,5 ± 3,4 a	3,6 ± 0,20 a	4,4 ± 0,25 a
	Winter	64,2 ± 2,0 b	1,7 ± 0,11 d	2,2 ± 0,13 d
35-40	Spring	78,0 ± 2,8 b	3,0 ± 0,16 b	3,8 ± 0,20 b
	Summer	61,3 ± 2,2 d	1,9 ± 0,12 d	2,9 ± 0,16 c
	Autumn	74,5 ± 3,1 a	3,4 ± 0,18 a	4,6 ± 0,26 a
	Winter	55,8 ± 2,5 c	2,2 ± 0,13 c	3,1 ± 0,15 b
P		**<0,05**	**<0,05**	**<0,05**
LSD0,05		**3,6**	**0,17**	**0,24**

Effect of cutting size on rooting percentage

The results indicated that cutting size significantly influenced rooting percentage, number of roots per cutting, and root length after 120 days of propagation ($P < 0.05$). Overall, cuttings with larger diameters (25 - 30 mm and 35- 40 mm) exhibited markedly better rooting performance than those with smaller diameters (15 - 20 mm) across all seasons.

Among the tested treatments, cuttings with a diameter of 25 - 30 mm showed the most favorable and stable rooting response. Rooting percentage in this group ranged from 64.2% in winter to 85,8% in spring, with particularly high values recorded in spring and autumn (85,8% and 81,5%, respectively). This cutting size also produced the highest number of roots per cutting (up to 3,6 roots in autumn) and the greatest root length (4,4 cm in autumn), indicating superior root system development.

Cuttings with diameters of 35 - 40 mm also performed well, especially in autumn, achieving a rooting percentage of 74,5%, an average of 3,4 roots per cutting, and the longest root length observed in the experiment (4,6 cm). However, their overall performance was slightly less consistent across seasons compared with the 25 - 30 mm group.

In contrast, cuttings with diameters of 15 - 20 mm consistently exhibited the lowest rooting percentage, number of roots, and root length in all seasons. Rooting percentage in this group ranged from only 47,6% in winter to 68,4% in spring, accompanied by fewer roots and shorter root lengths. This suggests that smaller cuttings may possess limited carbohydrate reserves and reduced water-holding capacity, thereby restricting their ability to initiate and sustain root formation.

These results are in close agreement with the findings of Hartmann and Kester (2014) and previous studies on Camellia spp. reported by Xiang et al. (2019), which demonstrated that larger cuttings generally contain more parenchymatous tissue and higher endogenous nutrient reserves, contributing to enhanced adventitious root initiation and development.

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Effect of Season on Rooting Ability

Season was a key factor determining the favorability of callus formation and root differentiation. Experimental results indicated that autumn and spring produced the highest rooting performance, especially in larger cuttings (25 - 30 mm and 35 - 40 mm). In autumn, rooting percentages ranged from 42,9% to 67,5% for the 15 - 20 mm and 25 - 30 mm groups, and reached 60,5% in the 35 - 40 mm group. In spring, corresponding values ranged from 38,4% to 64,8% for the 15 - 20 mm and 25 - 30 mm groups, and 58,0% for the 35 - 40 mm group.

In contrast, summer and winter resulted in the lowest rooting percentages, reaching only 18,6 – 45,8% depending on cutting size. This pattern is consistent with the physiological characteristics of *Camellia*. During autumn and spring, lower temperature fluctuations, higher air humidity, and moderate light intensity reduce transpiration losses and create favorable conditions for root differentiation. In summer, high temperatures increase transpiration, causing rapid water loss from cuttings and inhibiting root formation. In winter, low temperatures suppress metabolic activity, leading to slow cell differentiation and root development.

These results are in agreement with the findings of Zhang et al. (2020), who reported that *Camellia japonica* exhibited the highest rooting percentages when propagated in autumn and spring.

CONCLUSION

The study demonstrated that cutting season and cutting size significantly affected survival rate, bud sprouting, and rooting ability of double-petaled red camellia cuttings ($P < 0.05$). Spring and autumn were the most favorable seasons, with survival rates after 120 days reaching 80,0 – 89,0% and bud sprouting rates of 77,1–86,0% in cuttings of 25 - 30 mm diameter. This cutting size also achieved the highest rooting percentage (81,5 – 85, 8%), number of roots (3, 4 – 3,6 roots per cutting), and root length (4,1 – 4,4 cm). In contrast, smaller cuttings (15–20 mm) showed lower survival (52,1- 70,9%), sprouting, and rooting capacity, while larger cuttings (35 - 40 mm) exhibited less stable performance across seasons. Therefore, propagation of double-petaled red camellia by cuttings is most efficient when conducted in spring or autumn using cuttings with diameters of 25 - 30 mm.

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