


Research Article

Effects of Planting Season, Planting Method, and Fertilization Regime on Survival and Early Growth of *Camellia rubriflora*

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Abstract

Single petal red camellia (*Camellia rubriflora*) is a rare endemic species with high ornamental, medicinal, and conservation value in northern Vietnam. However, its large-scale cultivation remains constrained by high mortality and inconsistent early growth due to the lack of standardized agronomic practices. This study provides a systematic evaluation of key cultivation factors affecting the establishment phase of *C. rubriflora*, aiming to develop an optimized technical framework for its sustainable production. Three independent experiments were conducted using a randomized complete block design (RCBD) with three replications at Thai Nguyen University of Agriculture and Forestry from 2023 to 2024. The study investigated the effects of planting season (spring, autumn, winter), planting method (open-field monoculture vs. intercropping), and fertilization regime (varying levels of organic manure combined with NPK 16: 16: 8) on survival rate and growth performance. Plant height, basal diameter, and survival rate were monitored over 12 months and analyzed using ANOVA and LSD tests ($p < 0.05$). The results revealed that planting season significantly influenced long-term plant performance, with spring planting achieving the highest survival rate (85.55%) and superior growth. Intercropping systems markedly improved microclimatic and soil conditions, resulting in significantly higher survival (88.89%) and enhanced vegetative growth compared with monoculture systems. The optimal fertilization regime was identified as 5 kg of well-decomposed manure combined with 0.3 kg NPK per planting hole, ensuring balanced growth and maximum survival (90.89%). These findings provide novel insights into the integrated effects of ecological and nutritional factors on *C. rubriflora*, offering a robust scientific basis for developing standardized cultivation protocols and supporting sustainable expansion of this valuable species.

Keywords

Camellia rubriflora, Single Petal Red Camellia, Planting Method, Fertilization, Planting Season

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1. Introduction

Single petal red camellia (*Camellia rubriflora*) is a rare native plant species with high ornamental, medicinal, and biodiversity conservation value [1-3]. However, its cultivation and development remain largely spontaneous, lacking a comprehensive scientific basis for standardized agronomic practices. Previous studies on species within the genus *Camellia* have demonstrated that planting season, planting method, and nutrient management are key factors determining plant survival and early growth performance [4-6]. Nevertheless, these studies have primarily focused on *Camellia oleifera* or *Camellia sinensis*, while systematic research on *C. rubriflora* a species with specific ecological requirements and a narrow distribution range remains very limited.

Practical production experience indicates that high mortality rates during the first year after planting, slow growth, and uneven plant development represent major constraints to the expansion and establishment of *Camellia rubriflora* cultivation areas. Studies by Chen et al. (2018) and Wang et al. (2021) further confirmed that inappropriate planting season, unfavorable microclimatic conditions, and inadequate soil nutrition can substantially reduce the adaptive capacity of native woody species during the establishment phase. Therefore, a comprehensive and systematic investigation of the combined effects of planting season, planting method, and fertilization regime is essential to elucidate the growth response mechanisms of *Camellia rubriflora* under major cultivation factors [7, 8].

The results of this study not only contribute to strengthening the scientific foundation for the cultivation of *Camellia rubriflora* under the ecological conditions of northern mountainous Vietnam, but also provide a basis for developing cultivation, management, and sustainable development protocols for this valuable species, in line with national strategies for genetic resource conservation and ecological agriculture development.

2. Materials and Methods

2.1. Plant Materials

Research object: Single petal red camellia (*Camellia rubriflora*) plants propagated by stem cuttings from healthy, disease-free mother plants collected from the Tam Dao National Park area.

Materials:

- 1) Single petal red camellia seedlings meeting planting quality standards.
- 2) Well-decomposed farmyard manure.
- 3) NPK fertilizer (16: 16: 8).
- 4) Materials and tools for planting and maintenance (plant height measuring devices, vernier calipers for basal diameter measurement, soil preparation tools, etc.).

2.2. Time and Location of the Study

- 1) Study period: From January 2023 to December 2024.
- 2) Study site: The experiments were established and monitored at Thai Nguyen University of Agriculture and Forestry, Thai Nguyen, Vietnam.
- 3) Soil conditions: The experimental site was characterized by red basalt soil (Ferralsols), with good drainage and moderate fertility, suitable for perennial woody species.
- 4) Climate conditions: The study area has a tropical monsoon climate, characterized by high humidity, distinct wet and dry seasons, and an average annual temperature ranging from 22- 25°C.

2.3. Research Methods

2.3.1. Experimental Design

The study consisted of three independent experiments, including:

- (i) The Effect of Planting Season;
- (ii) The Effect of Planting Method;
- (iii) The Effect of Fertilization Regime.

All experiments were arranged in a randomized complete block design (RCBD) with three replications. Each experimental plot consisted of 30 plants per treatment, and uniform management practices were applied throughout the experimental period.

The planting density was maintained at a spacing of 1.0 m × 1.0 m (row-to-row and plant-to-plant distance).

2.3.2. Experiment 1: Effect of Planting Season on the Growth and Development of Single Petal Red Camellia

This experiment aimed to evaluate the effects of planting season on plant survival rate and growth parameters during the first year after planting.

The experimental treatments were as follows:

- 1) T1: Spring planting (February)
- 2) T2: Autumn planting (August)
- 3) T3: Winter planting (November)

2.3.3. Experiment 2: Effect of Planting Method on the Growth and Development of Single Petal Red Camellia

This experiment was conducted to clarify the role of planting method in regulating microclimatic conditions and soil ecological environment affecting plant growth.

The experimental treatments included:

- 1) T1: Open-field monoculture planting on bare land with nurse plants
- 2) T2: Intercropping in home gardens or forest gardens

2.3.4. Experiment 3: Effect of Fertilization Regime on the Growth and Development of Single Petal Red Camellia

This experiment was designed to determine the appropriate fertilization level to ensure balanced and stable plant growth during the first year after planting.

The experimental treatments were as follows:

- 1) T1: 3 kg of well-decomposed manure + 0.3 kg of NPK (16: 16: 8) per planting hole
- 2) T2: 5 kg of well-decomposed manure + 0.3 kg of NPK (16: 16: 8) per planting hole
- 3) T3: 7 kg of well-decomposed manure + 0.3 kg of NPK (16: 16: 8) per planting hole
- 4) T4: No fertilizer application (control)

2.4. Data Collection and Statistical Analysis

Measured parameters:

- 1) Plant survival rate (%) at 3, 6, 9, and 12 months after planting
- 2) Plant height (cm) and basal diameter (cm) at corresponding observation times
- 3) Growth of flushes (spring and autumn flushes), including shoot length (cm) and shoot diameter (cm)

All growth parameters were measured directly on plants following standard technical procedures.

Data analysis: The collected data were processed using Microsoft Excel and IRRISTAT 5.0 software. Differences among treatment means were evaluated using analysis of variance (ANOVA), and mean comparisons were performed using the least significant difference (LSD) test at the 0.05 probability level.

3. Results and Discussion

3.1. Effect of Planting Season on the Growth and Development of Single Petal *Camellia rubriflora*

3.1.1. Study on the Effect of Planting Season on the Survival Rate of Single-petal Red Camellia (*Camellia Rubriflora*)

Table 1. Effect of planting season on the survival rate of single petal *Camellia rubriflora*.

Treatment	Survival rate after (%)			
	3 months	6 months	9 months	12 months
Spring planting (February)	95.55	88.89	87.78	85.55
Autumn planting (August)	97.78	81.1	80	68.89
Winter planting (November)	98.89	86.45	85.3	81.1
LSD0.05				3.1
CV (%)				5.02

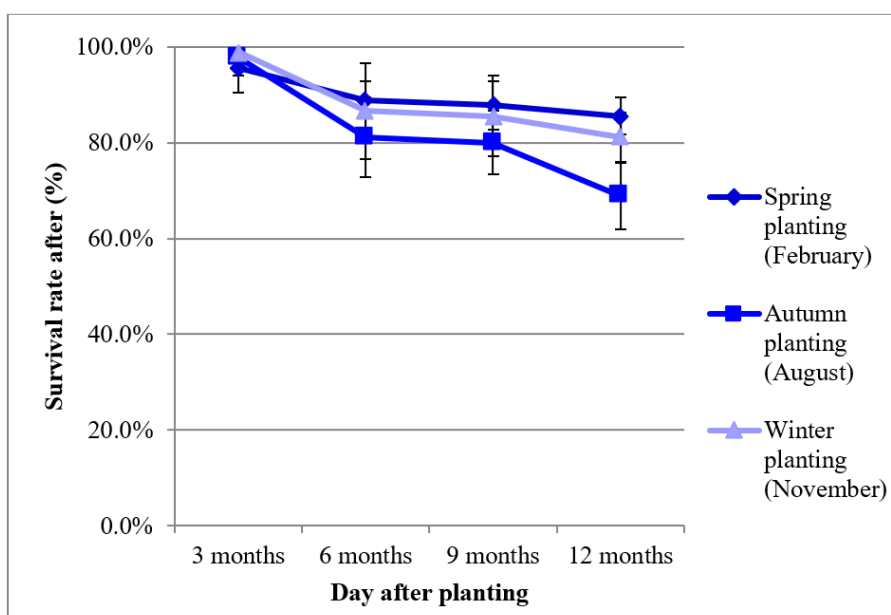


Figure 1. Effect of planting season on the survival rate of single petal *Camellia rubriflora*.

Results presented in Table 1 indicate that planting season had a significant effect on the survival rate of single petal red camellia during the first year after planting. At 3 months after planting, survival rates were very high across all planting seasons, ranging from 95.55% to 98.89%. Among them, winter planting recorded the highest survival rate (98.89%), followed by autumn planting (97.78%) and spring planting (95.55%).

After 6 months, survival rates began to diverge more clearly among planting seasons. Spring planting maintained the highest survival rate (88.89%), whereas winter planting reached 86.45%, and autumn planting declined sharply to 81.10%.

At 9 months after planting, this trend was maintained. Survival rates of spring and winter plantings reached 87.78% and 85.30%, respectively, both markedly higher than that of autumn planting (80.00%).

By 12 months, differences among planting seasons became most pronounced. Spring planting achieved the highest survival rate (85.55%), followed by winter planting (81.10%), while autumn planting recorded the lowest survival rate

(68.89%). The difference between spring and autumn plantings reached 16.66%, far exceeding the $LSD_{0.05}$ value, confirming that the effect of planting season on survival rate was statistically significant. This result reflects the superior long term adaptability of plants established in spring compared with other planting seasons [9].

Overall, spring was identified as the most suitable planting season when the objective is to maintain a stable plant survival density over the long term.

3.1.2. Effect of Planting Season on the Growth of Single Petal *Camellia rubriflora*

A high and stable survival rate is a prerequisite for plants to enter a favorable vegetative growth phase. Therefore, differences in survival rate among planting seasons were expected to be clearly reflected in subsequent growth parameters. The effects of planting season on the growth of single petal red camellia are presented in Table 2.

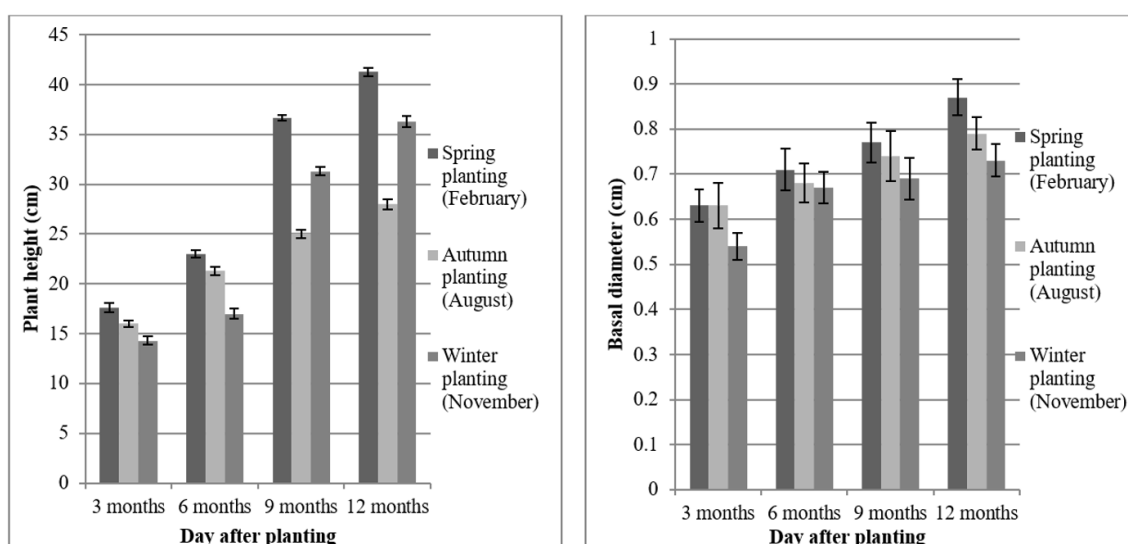


Figure 2. Effect of planting season on the growth of single petal *Camellia rubriflora*.

Table 2. Effect of planting season on the growth of single petal *Camellia rubriflora*.

Treatment	Plant height (cm)				Basal diameter (cm)			
	3 months	6 months	9 months	12 months	3 months	6 months	9 months	12 months
Spring planting (February)	17.67	23	36.67	41.3	0.63	0.71	0.77	0.87
Autumn planting (August)	16	21.3	25	28	0.63	0.68	0.74	0.79
Winter planting (November)	14.3	17	31.3	36.3	0.54	0.67	0.69	0.73
$LSD_{0.05}$				2.2				0.09
CV (%)				2.3				2.2

Table 2 shows that planting season significantly affected the growth of single petal red camellia, as reflected by plant height and basal diameter measured from 3 to 12 months after planting.

Effect of planting season on plant height

At all observation times, plants established in spring (February) consistently exhibited the greatest height, followed by winter planting (November), while autumn planting (August) resulted in the lowest plant height. After 3 months, spring-planted trees reached 17.67 cm, exceeding those planted in autumn (16.00 cm) and winter (14.30 cm). This trend persisted at 6 months, with spring planting reaching 23.00 cm compared with 21.30 cm in autumn and 17.00 cm in winter.

At 9 and 12 months, differences became more pronounced. Spring planting achieved heights of 36.67 cm and 41.30 cm, respectively; winter planting reached 31.30 cm and 36.30 cm; whereas autumn planting remained the lowest at only 25.00 cm and 28.00 cm. With an $LSD_{0,05}$ value of 2.2, differences in plant height between spring planting and the other planting seasons at 6, 9 and 12 months were statistically significant. These results confirm that spring is the most suitable planting season for promoting height growth of single petal red camellia.

Effect of planting season on basal diameter

Similar to plant height, basal diameter was also markedly influenced by planting season. After 3 months, basal diameters of spring and autumn planted trees were comparable (0.63 cm), whereas winter planting resulted in a smaller diameter (0.54 cm). From 6 to 12 months, spring planting consistently produced the largest basal diameter, reaching 0.71, 0.77, and 0.87 cm, respectively. Autumn planting showed intermediate values (0.68, 0.74, and 0.79 cm), while winter planting remained the lowest (0.67, 0.69, and 0.73 cm).

The superior growth performance of single petal red camellia planted in spring can be attributed to favorable early season temperature, humidity, and rainfall conditions, which facilitate rapid root establishment and enhance water and nutrient uptake, thereby promoting stem and basal growth from the initial growth stages.

Overall, the results demonstrate that appropriate selection of planting season plays a critical role in ensuring high survival rates and promoting early growth of single petal red camellia. However, in addition to planting time, local ecological conditions—particularly planting method—are also considered key factors capable of modifying microclimate and soil environment, thereby strongly influencing plant growth and development.

3.2. Effect of Planting Methods on the Growth and Development of Single Petal *Camellia rubriflora*

While planting season determines the initial climatic conditions to which plants must adapt, planting methods directly

regulate microclimatic factors and soil ecological conditions throughout the entire growth period.

3.2.1. Effect of Planting Methods on the Survival Rate of Single Petal *Camellia rubriflora*

Table 3. Effect of planting methods on the survival rate of single petal *Camellia rubriflora*.

Treatment	Survival rate after (%)			
	3 months	6 months	9 months	12 months
T1	90	83.3	80	73.3
T2	96.67	94.45	92.2	88.89
$LSD_{0,05}$				9.4
CV%				3.4

Notes: T1: Monoculture planting on open land with supporting plants; T2: Intercropping in home gardens or forest gardens.

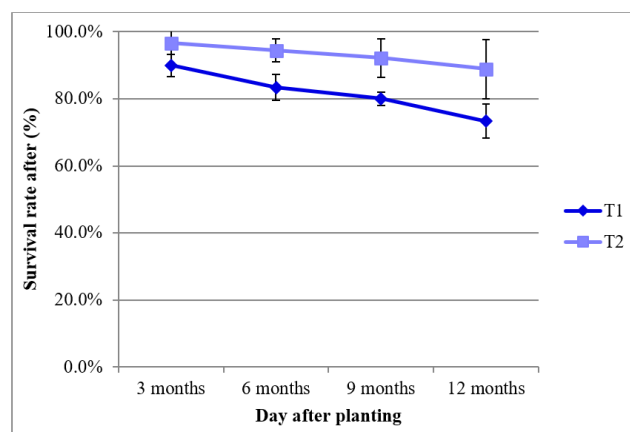


Figure 3. Effect of planting methods on the survival rate of single petal *Camellia rubriflora*.

Results in Table 3 indicate that planting method had a significant effect on the survival rate of single-petal red camellia during the first 12 months after planting. At all observation times, T2 (intercropping in home gardens or forest gardens) consistently achieved higher survival rates than T1 (monoculture planting on open land with supporting plants).

At 3 months after planting, T2 recorded a survival rate of 96.67%, higher than that of T1 (90.00%), indicating that intercropped plants adapted better during the initial establishment stage. From 6 to 9 months, survival rates under T1 declined rapidly (83.30% and 80.00%), whereas T2 maintained high survival levels (94.45% and 92.20%). This trend reflects the more stable microcli-

matic conditions provided by intercropping systems, which effectively reduced scattered plant mortality.

By 12 months, the difference between planting methods became most pronounced. T2 achieved a survival rate of 88.89%, markedly higher than T1 (73.30%). The difference of 15.59% exceeded the $LSD_{0,05}$ value (9.4), confirming that the effect of

planting method on survival rate was statistically significant. The low coefficient of variation ($CV = 3.4\%$) indicates high reliability of the results.

Conclusion: Intercropping in home gardens or forest gardens (T2) is a more suitable planting method, ensuring high and stable survival rates for single petal red camellia.

3.2.2. Effect of Planting Methods on the Growth of Single Petal Red Camellia

Table 4. Effect of planting methods on the growth of single petal *Camellia rubriflora*.

Treatment	Plant height (cm)				Basal diameter (cm)			
	3 months	6 months	9 months	12 months	3 months	6 months	9 months	12 months
T1	16.3	20.3	25	28.3	0.53	0.62	0.69	0.75
T2	18	23.67	29.67	35.67	0.6	0.71	0.81	0.88
$LSD_{0,05}$				0.8				0.06
CV%				1.4				1.0

Notes: T1: Monoculture planting on open land with supporting plants; T2: Intercropping in home gardens or forest gardens.

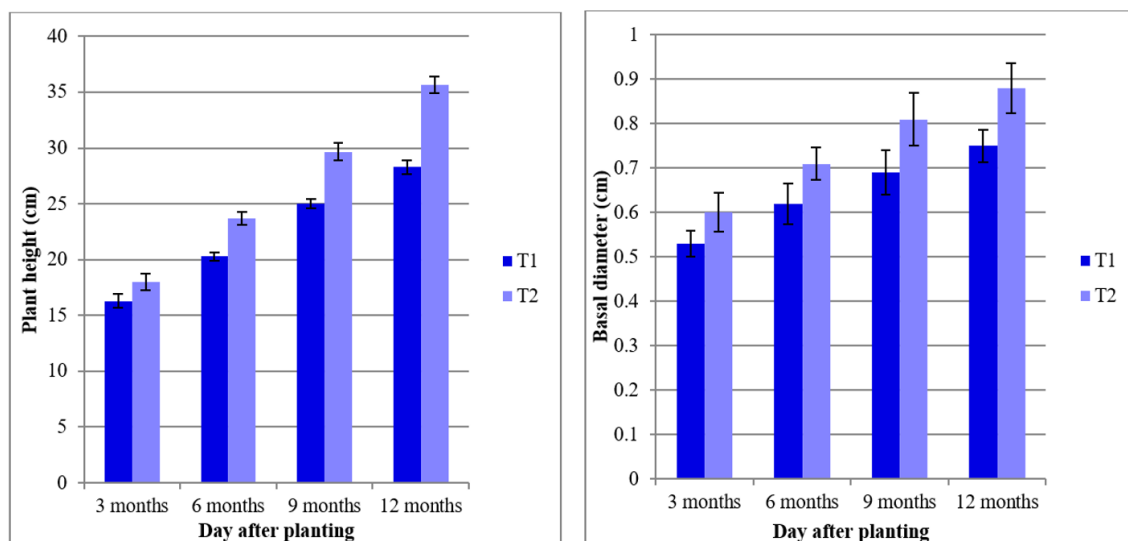


Figure 4. Effect of planting methods on the growth of single petal *Camellia rubriflora*.

Results in Table 4 show that planting method significantly influenced the growth of single petal red camellia, as reflected by both plant height and basal diameter during the 12 months after planting.

Regarding plant height, plants under T2 (intercropping) were taller than those under T1 as early as 3 months after planting (18.00 cm versus 16.30 cm). This difference continued to increase over time; by 12 months, T2 reached 35.67 cm, significantly exceeding T1 (28.30 cm). At all observation

times, the differences were greater than $LSD_{0,05} = 0.8$, indicating statistically significant effects.

For basal diameter, T2 consistently produced larger values than T1. After 12 months, basal diameter under T2 reached 0.88 cm, compared with 0.75 cm under T1. With an $LSD_{0,05}$ value of 0.06, these differences were statistically significant, particularly during the 9-12 month period. The low coefficients of variation ($CV = 1.0 - 1.4\%$) confirm the high reliability of the data.

Conclusion: Intercropping in home gardens or forest gardens (T2) significantly enhances the growth performance of single petal red camellia compared with monoculture planting on open land (T1). Therefore, this planting method should be prioritized in production to improve growth and planting efficiency.

Although appropriate planting methods substantially improved survival rates and growth of single petal red camellia, achieving stable development and optimal growth potential requires adequate and balanced nutrient supply through appropriate fertilization regimes [11].

3.3. Effect of Fertilization on the Growth and Development of Single Petal *Camellia rubriflora*

In the cultivation system of single petal red camellia, fertilization plays a decisive role in maintaining and enhancing vegetative growth, particularly after the plants have passed the post transplant recovery stage and entered a phase of vigorous development of stems, branches, and shoots.

3.3.1. Effect of Fertilization on the Survival Rate of Single Petal *Camellia rubriflora*

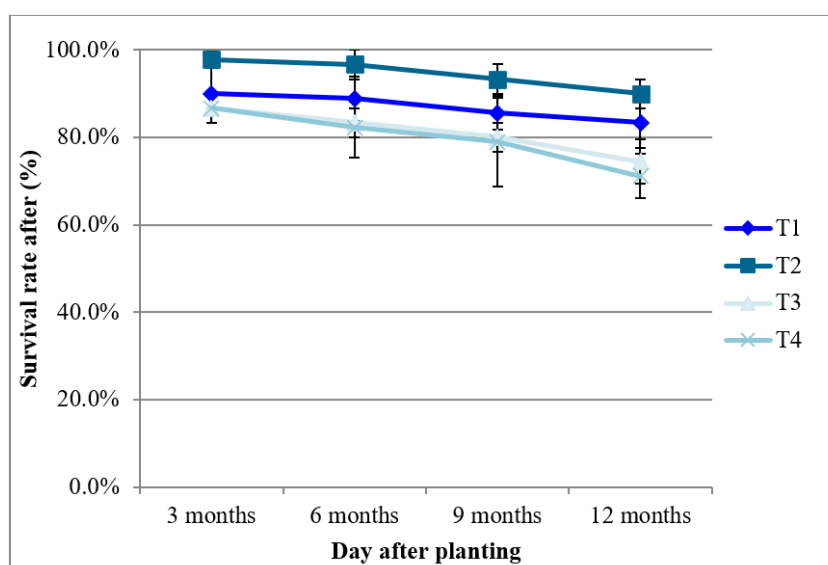


Figure 5. Effect of fertilization on the survival rate of single petal *Camellia rubriflora*.

Table 5. Effect of fertilization on the survival rate of single petal *Camellia rubriflora*.

Treatment	Survival rate after (%)			
	3 months	6 months	9 months	12 months
T1	90.4	89.3	86	83.3
T2	97.67	96.45	93.2	90.89
T3	86.9	83.3	80.2	74.3
T4	86.67	82.45	78.2	71.89
LSD _{0,05}				5.4
CV%				2.4

Notes:

T1: 3 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T2: 5 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T3: 7 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T4: No fertilizer (control)

The results presented in Table 5 clearly demonstrate that fertilization regime significantly influenced the survival rate of *Camellia rubriflora* during the first 12 months after planting. Among the tested treatments, T2 (5 kg of well-decomposed manure combined with 0.3 kg NPK 16: 16: 8 per planting hole) consistently resulted in the highest survival rates across all observation periods. At 3 months after planting, T2 achieved a survival rate of 97.67%, markedly higher than T1 (90.40%) and substantially exceeding T3 and T4 (approximately 86–87%). This indicates that a balanced nutrient supply plays a critical role in supporting early plant establishment.

This trend remained stable throughout the experimental period. At 12 months, T2 maintained the highest survival rate (90.89%), compared with T1 (83.30%), and significantly higher than T3 (74.30%) and T4 (71.89%). These findings confirm that moderate fertilization provides optimal conditions for root development and physiological adaptation during the establishment phase.

3.3.2. Effect of Fertilization on the Growth of Single Petal *Camellia rubriflora*

Table 6. Effect of fertilization on the growth of single petal *Camellia rubriflora*.

Treatment	Plant height (cm)				Basal diameter (cm)			
	3 months	6 months	9 months	12 months	3 months	6 months	9 months	12 months
T1	15.67	21.67	29.3	38	0.51	0.65	0.74	0.8
T2	17.67	27	33.3	43	0.56	0.7	0.8	0.89
T3	13.67	29.3	21.47	37.52	0.52	0.63	0.75	0.86
T4	15.3	27.3	24.3	39.3	0.49	0.59	0.67	0.7
<i>LSD</i> _{0,05}				1.2				0.02
CV%				1.1				0.7

Notes:

T1: 3 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T2: 5 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T3: 7 kg of well decomposed manure + 0.3 kg NPK (16: 16: 8) per planting hole

T4: No fertilizer (control)

Results in Table 6 demonstrate that fertilizer application significantly affected the growth of single petal red camellia, as reflected by changes in plant height and basal diameter over time [10].

During the first 3 months, differences among treatments

Notably, the lower survival rate observed in T3 (7 kg manure) suggests that excessive nutrient input may negatively affect plant performance. This could be attributed to osmotic stress, nutrient imbalance, or potential ammonia toxicity resulting from the decomposition of large amounts of organic matter, particularly during the early adaptation stage when root systems are not fully developed. Such conditions may inhibit water uptake and damage root tissues, thereby reducing plant survival.

Overall, the results indicate that an optimal fertilization regime should ensure a balance between nutrient availability and plant absorption capacity, avoiding both deficiency and excess. The application of 5 kg of well-decomposed manure combined with 0.3 kg NPK (16: 16: 8) per planting hole is therefore recommended as the most suitable fertilization level for achieving stable establishment and high survival rates of *Camellia rubriflora* under the studied conditions [13].

were relatively small, with plant height ranging from 13.67 to 17.67 cm and basal diameter from 0.49 to 0.56 cm, indicating that plants were mainly in the post transplant adaptation stage, during which the effects of fertilization had not yet become apparent.

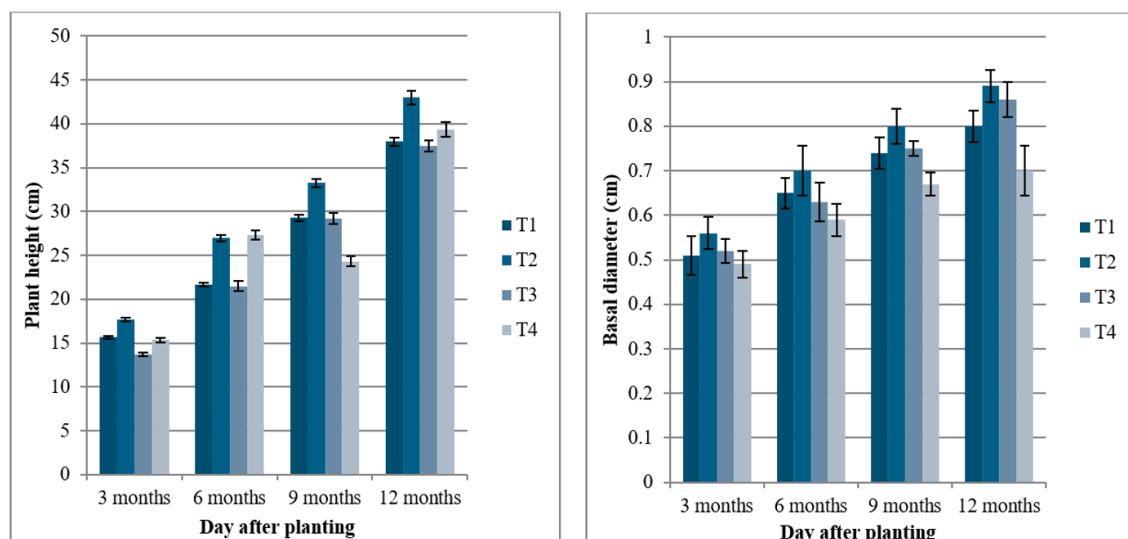


Figure 6. Effect of fertilization on the growth of single petal *Camellia rubriflora*.

From 6 months onward, differences among treatments became more pronounced. T2 (5 kg of decomposed manure combined with 0,3 kg NPK 16: 16: 8 per hole) exhibited superior growth, with plant height ranging from 27.00 to 43.00 cm and basal diameter from 0.70 to 0.89 cm, exceeding those of the other treatments. At 9 - 12 months, the observed differences were greater than the $LSD_{0.05}$ values (1.2 cm for plant height and 0.02 cm for basal diameter), confirming that fertilization application rate had a statistically significant effect.

T1 (3 kg manure + NPK) and T3 (7 kg manure + NPK) resulted in moderate growth; notably, T3 tended to improve basal diameter at later stages but showed unstable plant height development. T4 (no fertilizer) consistently exhibited the poorest growth across most parameters. The low coefficients of variation ($CV = 0,7 - 1,1\%$) further confirm the high reliability of the results.

Conclusion: Application of 5 kg of well-decomposed manure combined with 0,3 kg NPK (16: 16: 8) per planting hole represents the most suitable fertilization regime for single petal red camellia at the establishment stage. This treatment promotes balanced growth in terms of plant height and basal diameter, as well as vigorous shoot development, producing longer and thicker shoots in both spring and autumn flushes.

General synthesis

Overall, the results indicate that planting season, planting method, and fertilization regime do not act independently but are closely interconnected and complementary in determining the growth and development of single petal red camellia. An appropriate planting season facilitates successful early establishment; a suitable planting method creates favorable ecological conditions throughout the growth period; and a balanced fertilization regime plays a key role in sustaining and maximizing the plant's growth potential.

The harmonious integration of these three factors provides an important scientific basis for proposing optimized cultivation and management protocols for single petal red camellia

under the studied conditions. The findings not only clarify the individual effects of each cultivation factor but also highlight the systemic and interactive nature of growth responses of single petal red camellia to simultaneous changes in environmental and nutritional conditions [12].

4. Conclusions and Recommendations

4.1. Conclusions

The results of this study clearly demonstrate that planting season, planting method, and fertilization regime exert significant and statistically meaningful effects on the survival rate and early growth performance of single petal red camellia (*Camellia rubriflora*) during the establishment phase. Among the evaluated factors, spring planting (February) was identified as the most suitable, ensuring high survival rates and stable growth in terms of plant height, basal diameter, and shoot development. Intercropping systems in home gardens or forest gardens significantly improved microclimatic conditions and soil ecological properties, resulting in superior plant performance compared with open-field monoculture systems. In addition, the application of 5 kg of well-decomposed manure combined with 0.3 kg of NPK (16: 16: 8) per planting hole was determined to be the optimal fertilization regime, providing balanced nutrient supply and maximizing plant survival and growth.

Importantly, this study provides one of the first systematic and integrated evaluations of key cultivation factors for *Camellia rubriflora* under the ecological conditions of northern mountainous Vietnam. The findings contribute to the development of a scientifically grounded and standardized cultivation protocol, thereby offering a practical and reliable foundation for the sustainable production, conservation, and expansion of this valuable endemic species.

4.2. Recommendations

Based on these findings, it is recommended that spring planting, intercropping systems, and the optimal fertilization regime described above be applied in an integrated manner for the production and expansion of single petal red camellia cultivation areas. Furthermore, additional studies should be conducted to evaluate the long term effectiveness of these practices during the productive stage and under different ecological conditions, in order to further refine and develop a sustainable cultivation protocol for this valuable plant species.

Abbreviations

RCBD	Randomized Complete Block Design
NPK	Nitrogen – Phosphorus – Potassium Fertilizer
LSD	Least Significant Difference
CV	Coefficient of Variation
ANOVA	Analysis of Variance
IEER	Institute for Excellence in Education and Research
T	Treatment

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Author Contributions

Nguyen Thi Tinh: Conceptualization, Data curation, Investigation, Methodology

Duong Thi Thu Hoai: Investigation, Methodology, Data curation

Nguyen Thi Thu Ha: Data curation, Formal Analysis, Visualization

Ngo Xuan Binh: Resources, Supervision, Validation

Nguyen Huu Tho: Conceptualization, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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