

## Growth of Three Species of Golden Camellia Grown under Natural Forest Canopy in Northern, Vietnam

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### Abstract

The cultivation of non-timber forest products such as golden camellias under natural forest canopies is a promising model for integrating biodiversity conservation with sustainable forestry practices. This study was conducted in Dong Khe Commune, Cao Bang Province, Northern Vietnam, to evaluate the growth performance of three golden camellia species, *Camellia impressinervis*, *C. hamyensis*, and *C. tienii*, planted under natural forest canopies. Over a five-year period, survival rates and growth parameters (stump diameter, height, and crown diameter) were assessed. *C. tienii* exhibited the highest survival rate (73.7%) and good stem proportion (74.2%), indicating superior adaptability. However, *C. hamyensis* demonstrated significantly better stump diameter growth (1.57 cm) compared to *C. tienii* (0.80 cm) and *C. impressinervis* (0.26 cm). Height and crown diameter were comparable across species, with crown diameters ranging from 0.30 to 0.33 m. Regression analyses revealed weak correlations between stump diameter and other growth parameters in *C. impressinervis* and *C. tienii*, suggesting the influence of additional ecological factors. These results highlight the potential of cultivating golden camellias under natural forest canopies as a sustainable approach to forest management, biodiversity enhancement, and rural development. Future research should focus on optimizing site-specific practices and scaling this model to similar ecological contexts.

**Keywords:** Biodiversity Conservation, Forest Canopy Cultivation, Golden Camellias, Non-timber Forest Products, Sustainable Forestry.

### 1. INTRODUCTION

Non-timber forest products (NTFPs) play an essential role in sustaining rural livelihoods and conserving biodiversity, particularly in tropical and subtropical regions (Derebe and Alemu, 2023). The cultivation of NTFPs under natural forest canopies has gained attention as a viable strategy to enhance forest productivity while maintaining ecosystem services (Murali et al., 1996). This approach integrates economic development with ecological conservation, allowing farmers to derive sustainable income without over-exploiting forest resources (Do et al., 2020). In Northern Vietnam, where forests provide critical ecological and economic functions, planting high-value species such as golden camellias (*Camellia* spp.) under forest canopies offers an innovative model for both conservation and development (Takahashi et al., 2023).

Golden camellias are valued for their ornamental and medicinal properties, yet many species face significant threats from habitat destruction and overharvesting (Takahashi et al., 2023; Tran et al., 2020). Classified as critically endangered, species such as *Camellia impressinervis* are restricted to narrow ecological niches (Wheeler and Rivers, 2015). Cultivation under forest canopies not only helps to mitigate these threats but also contributes to the regeneration of degraded forests, providing critical habitat for other native flora and fauna (Cunningham et al., 2015). Moreover, such practices align with global biodiversity conservation goals by promoting the sustainable use of genetic resources and reducing pressures on wild populations (Tran et al., 2019).

The economic contributions of NTFP cultivation, particularly golden camellias, to poverty alleviation are significant (Marshall et al., 2006). Communities engaged in growing and harvesting these species can diversify their income sources, reducing reliance on timber and other unsustainable forest products (Do et al., 2020; Tran et al., 2019). By fostering local economic development, these initiatives also enhance community resilience, particularly in marginalized rural areas with limited access to alternative livelihoods.

From a forest management perspective, integrating NTFP cultivation with natural forest conservation offers a pathway toward sustainable forestry (Mello et al., 2020). This model exemplifies the principles of multi-functional forestry, where economic, ecological, and social objectives converge. In Vietnam, where forest degradation and land-use conflicts pose ongoing challenges, such integrative approaches can support national goals for forest restoration and climate change mitigation (Do et al., 2020; Tran et al., 2020). The cultivation of golden camellias under natural canopies demonstrates the feasibility of balancing productivity with conservation, contributing to the long-term sustainability of forest ecosystems (Anthony, 2022).

This study examines the growth performance of three species of golden camellia - *C. impressinervis*, *C. hamyensis*, and *C. tienii*-planted under the natural forest canopy in Northern Vietnam. By analyzing their survival rates, growth parameters, and relationships between morphological traits, we aim to provide insights into the potential of golden camellia cultivation as a sustainable forestry practice. These findings are expected to inform strategies for forest management, biodiversity conservation, and rural development in similar ecological contexts.

## 2. MATERIAL AND METHOD

### 2.1. Study Site

This study was conducted in Dong Khe Commune, Cao Bang Province, Northern Vietnam, located at 22°23'58''N and 106°24'28''E. Vegetation in the sites is classified as evergreen broadleaved forest with some dominant species as *Schima superba*, *Albizia julibrissin*, *Litsea cubeba*, *Ilex ep.*, *Liquidambar formosana*, *Diospyros decandra*. The canopy height is 10-12 m with one canopy layer and canopy cover is 0.3-0.4. The loamy soil has a thin layer, and is compacted with. It is known as poor soil with low organic content and no humus layer on forest floor.

Dong Khe Commune, situated in Cao Bang Province in Northeastern Vietnam, experiences a humid subtropical climate with distinct seasonal variations (Climate-Data, 2023). The region's average annual temperature ranges from approximately 15°C to 28°C. During the summer months, particularly from May to August, temperatures can rise to average highs of 28°C to 30°C, contributing to warm and humid conditions. In contrast, the winter months from December to February bring cooler temperatures, with averages dropping to around 10°C to 15°C, occasionally accompanied by light frost in the highest elevations. Precipitation in Dong Khe Commune is significantly influenced by the Southeast Asian monsoon system. The area receives substantial rainfall during the wet season, which extends from May to October. Annual precipitation averages between 1,500 mm and 2,000 mm, with the heaviest rainfall occurring in July and August. The dry season, from November to April, sees a marked reduction in rainfall, leading to drier conditions and lower humidity. This seasonal distribution of temperature and precipitation plays a crucial role in shaping the local ecosystem.

### 2.2. Plantation of Three Camellia Species

*Camellia impressinervis*, commonly known as the golden camellia, is an evergreen shrub or small tree naturally distributed in southern China and northern Vietnam (Tran et al., 2019; Hung and Le, 1979). This species is classified as critically endangered due to its limited range and habitat threats (Wheeler and Rivers, 2015). It typically inhabits elevations of 250 to 500 meters above sea level, thriving in regions with temperatures ranging from 13°C to 30°C and annual precipitation between 1,500 and 1,700 mm. *C. impressinervis* is predominantly found in secondary tropical evergreen broadleaved forests that have regenerated after selective logging, where forest cover ranges from 50% to 80% (Do et al., 2020; Tran et al., 2020). This species has natural distributions in Dong Khe Commune, situated in Cao Bang Province.

*Camellia hamyensis* is a small tree reaching up to 4 meters in height at maturity (Do et al., 2020; Tran et al., 2020). It flowers from October to February, producing blossoms up to 10 cm in diameter. This species is distributed at elevations between 130 and 250 meters in regions with a mean annual temperature of 22.8°C, minimum and maximum temperatures of 12.9°C and 28.6°C respectively, and annual precipitation ranging from 1,500 to 1,800 mm. *C. hamyensis* typically grows at the foothills

of mountains where high humidity prevails, and soil depths exceed 50 cm. It is found under the canopy of secondary evergreen broadleaved forests with canopy heights of 8 to 10 meters and a canopy cover of less than 30%. Although numerous flowering trees have been observed in natural habitats, the absence of fruiting individuals suggests a lack of seedling and sapling recruitment. This species does not have natural distributions in Cao Bang Province.

*Camellia tienii* is a small tree that can attain a height of up to 8 meters at maturity. Its flowering season extends from November to January (Do et al., 2020; Tran et al., 2020). This species is found at elevations between 250 and 420 meters in areas with a mean annual temperature of 22°C, minimum temperature of 13°C, maximum temperature of 25.7°C, and annual precipitation between 1,600 and 2,600 mm. *C. tienii* typically inhabits regions near streams and valleys characterized by high humidity and soil depths greater than 60 cm. It grows under the canopy of old-growth or minimally disturbed evergreen broadleaved forests with canopy heights ranging from 13 to 18 meters and a canopy cover exceeding 60%. Natural seedlings are rarely encountered, and flowering individuals are predominantly found in areas with low shading (canopy cover less than 30%). This species does not have natural distributions in Cao Bang Province.

In 2019, the three species were planted under the canopy of natural forest in Dong Khe Commune, situated in Cao Bang Province. The planting was conducted in vegetation-cleared lines measuring 1 m in width, with a distance of 4 m between lines. The planting spacing was 1 m × 5 m, and planting holes were prepared with dimensions of 40 cm × 40 cm × 40 cm. Prior to planting, compost was applied at a rate of 500 g per hole. In 2020 and 2021, tending and fertilization were carried out twice annually, before and after the rainy season. During each tending period, 100 g of NPK fertilizer (16:16:8) was applied per tree, and maintenance activities such as weeding, soil mounding, and vine cutting were performed. Since 2022, no further management practices have been applied.

### 2.3. Data Collection

Data were collected in November 2024, five years after planting (Fig. 1). For survival rate estimation, ten planting lines were randomly selected for three species, and the numbers of surviving and dead trees were recorded separately. For other parameters, random samples were collected comprising 31 individual stems of each of *C. hamyensis* and *C. tienii*, and 42 individual stems of *C. impressinervis*. Measurements taken for each stem included stump diameter, stem height, and crown diameter. Additionally, each stem was assessed for quality and classified as good, medium, or poor. Good stems were characterized by straight growth, symmetrical crowns, and absence of disease. Poor stems exhibited curved trunks, asymmetrical crowns, and signs of disease. Medium stems displayed characteristics intermediate between the good and poor categories.



**Figure 1.** Canopy of a natural forest (left), a tree of *C. impressinervis* (middle), and a flower-bearing golden camellia tree

### 2.4. Data Analysis

Mean values and standard errors were calculated for survival rate, good stem ratio, and all growth parameters. Comparative analyses were conducted to identify differences among the three species for each parameter. Regression analysis was employed to examine the relationships between growth parameters within each species. All statistical analyses were performed using SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA), with the significance level set at  $p = 0.05$ .

## 3. RESULTS

The data presented in Figure 2 compare the survival rates and good stem percentages of three species of golden camellia: *C. impressinervis*, *C. hamyensis*, and *C. tienii*. In terms of survival rates, *C. tienii*

exhibits the highest value at 73.7%, followed by *C. hamyensis* at 73.0% and *C. impressinervis* at 72.3%. For the percentage of good stems, *C. tienii* again demonstrates the highest performance with 74.2%, while *C. impressinervis* and *C. hamyensis* follow with 69.0% and 67.7%, respectively. Standard error bars are provided to indicate the variability of the data. These results suggest that *C. tienii* consistently outperforms the other two species across both metrics. However, the differences among three species are not significant.

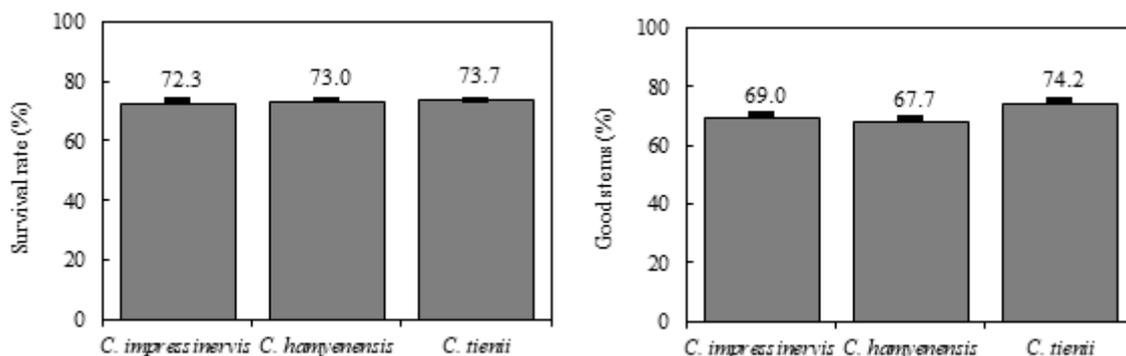


Figure 2. Survival rates and good stems of three species of golden camellia. Bars indicate +SE (standard error)

The growth parameters of three Camellia species were assessed after a 5-year planting period, comparing stump diameter, height, and crown diameter. The results revealed marked differences in stump diameter among species, with *C. hamyensis* demonstrating significantly superior growth (1.57 cm), compared to *C. tienii* (0.80 cm) and *C. impressinervis* (0.26 cm). However, height measurements showed less variation among species, with values ranging from 0.43 m for *C. impressinervis* to 0.54 m for *C. hamyensis*, and 0.50 m for *C. tienii*. Crown diameter measurements were notably consistent across all three species, with *C. impressinervis* and *C. tienii* both achieving 0.33 m, while *C. hamyensis* reached 0.30 m. Standard errors (SE) indicated by bars above each measurement suggest high data reliability, particularly for height and crown diameter measurements. These findings indicate that while *C. hamyensis* exhibited superior stump diameter growth, all three species showed comparable performance in terms of height and crown development over the 5-year period.

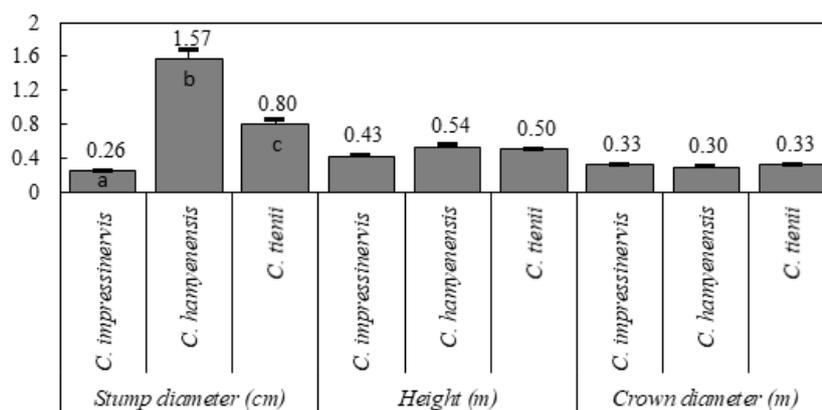


Figure 3. Growth parameter of three Camellia species after planting 5 years. Bars indicate +SE (standard error)

Figure 4 illustrates the relationships between growth parameters of *C. impressinervis* after a 5-year planting period, specifically examining correlations between stump diameter and both height and crown diameter. It shows a weak positive correlation between stump diameter and height, with a linear regression equation of  $y = 0.46x + 0.31$  and a low coefficient of determination ( $R^2 = 0.09$ ). This relationship was not statistically significant ( $p = 0.06$ ). In contrast, it demonstrates a stronger positive correlation between stump diameter and crown diameter, represented by the equation  $y = 0.57x + 0.18$ , with a moderate coefficient of determination ( $R^2 = 0.44$ ). This relationship was statistically significant ( $p = 0.00$ ). The scatter plots in both panels show considerable data dispersion, particularly in the height relationship, though the crown diameter relationship exhibits a more defined linear trend. Stump diameter measurements ranged approximately from 0.1 to 0.4 cm, while height values varied between 0.2 and 0.8 m, and crown diameter measurements fell between 0.2 and 0.5 m.

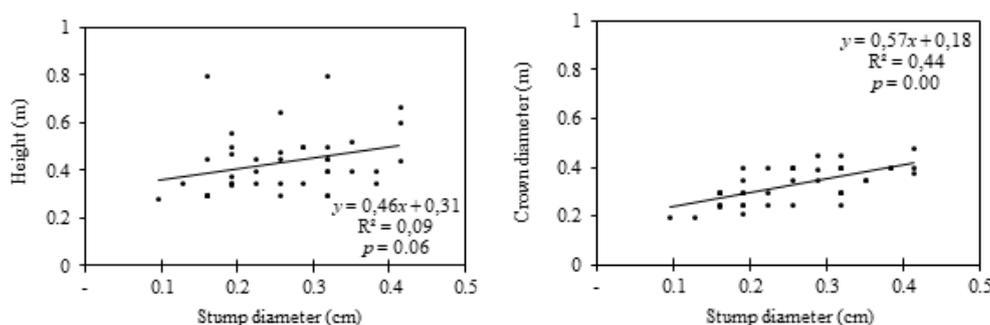


Figure 4. Relationships between growth parameters of *C. impressinervis* after planting 5 years

Figure 5 depicts the relationships between growth parameters of *C. hamyensis* after 5 years of planting, examining the correlations between stump diameter and both height and crown diameter. It shows a very weak positive correlation between stump diameter and height, represented by the linear regression equation  $y = 0.07x + 0.43$ , with a notably low coefficient of determination ( $R^2 = 0.05$ ). This relationship was not statistically significant ( $p = 0.25$ ). It demonstrates an even weaker correlation between stump diameter and crown diameter, with an almost horizontal regression line ( $y = 0.01x + 0.29$ ) and a negligible coefficient of determination ( $R^2 = 0.00$ ), also lacking statistical significance ( $p = 0.23$ ). The scatter plots reveal considerable data dispersion in both relationships, with stump diameter measurements ranging from approximately 1.0 to 2.5 cm. Height values varied between 0.2 and 1.0 m, while crown diameter measurements were distributed between 0.1 and 0.5 m. These results suggest that stump diameter is not a reliable predictor of either height or crown diameter in *C. hamyensis* at this growth stage.

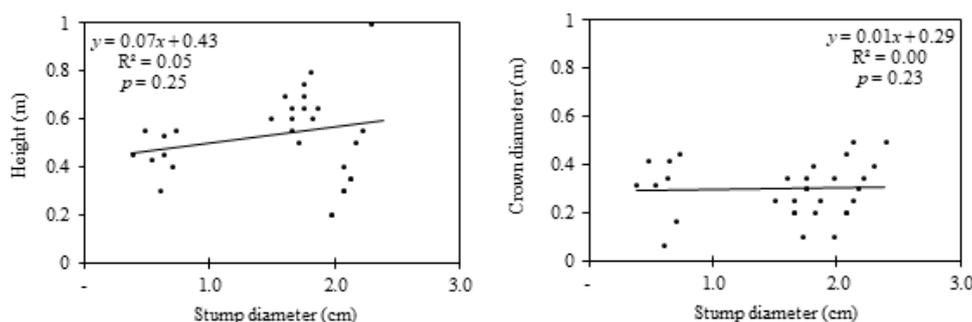


Figure 5. Relationships between growth parameters of *C. hamyensis* after planting 5 years

Figure 6 presents the relationships between growth parameters of *C. tienii* after 5 years, focusing on correlations between stump diameter and both height and crown diameter. It indicates a slight negative correlation between stump diameter and height, with a regression equation of  $y = -0.06x + 0.55$  and a low coefficient of determination ( $R^2 = 0.04$ ), which is not statistically significant ( $p = 0.29$ ). Similarly, it shows a weak negative correlation between stump diameter and crown diameter, described by the equation  $y = -0.03x + 0.36$ , with an even lower  $R^2$  value of 0.02 and no statistical significance ( $p = 0.44$ ). The scatter plots reveal substantial variability in the data, with stump diameters ranging from approximately 0.3 to 1.5 cm. Height values span from 0.2 to 0.8 m, while crown diameters range from 0.1 to 0.5 m. These findings suggest that stump diameter is not a reliable predictor of height or crown diameter in *C. tienii*, indicating that other factors may play a more significant role in influencing these growth parameters.

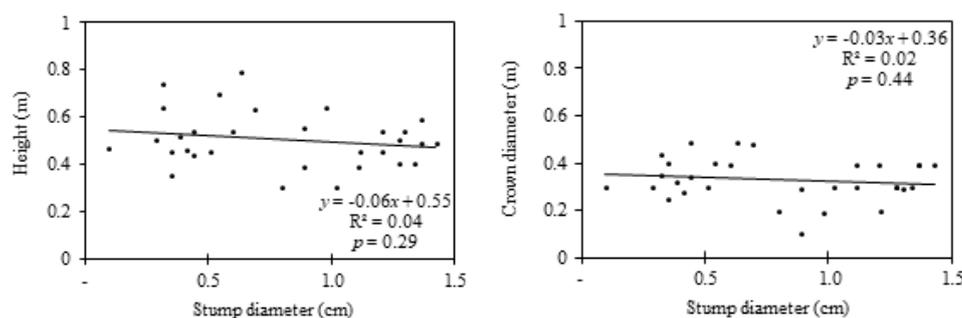


Figure 6. Relationships between growth parameters of *C. tienii* after planting 5 years

#### 4. DISCUSSION

The cultivation of golden camellias under the forest canopy offers an innovative approach to integrating biodiversity conservation with sustainable forestry practices (Takahashi et al., 2023). The results of this study highlight the ecological and economic potential of this model, contributing to the growing body of literature on non-timber forest products (NTFPs) and their role in forest management. The survival and growth performance of *Camellia tienii*, *C. hamyensis*, and *C. impressinervis* illustrate their adaptability to the forest canopy environment in Northern Vietnam. *C. tienii* exhibited a slightly higher survival rate and good stem ratio, aligning with its ecological niche preferences for high humidity and minimal disturbance (Wheeler and Rivers, 2015). Interestingly, *C. hamyensis* demonstrated superior stump diameter growth, possibly due to its tolerance of lower canopy cover and shallower soil layers (Do et al., 2020; Tran et al., 2020). These findings emphasize the species-specific responses to micro-environmental conditions and the importance of site selection in optimizing growth performance (Chelsea et al., 2024; Faeqa et al., 2021). Similar observations have been made in studies of NTFPs in other regions, where species exhibit varied growth responses based on canopy density and soil properties (Babs et al., 2016; Murali et al., 1996).

The cultivation of endangered species like golden camellias under forest canopies aligns with global biodiversity conservation goals by reducing pressure on wild populations and supporting habitat restoration (Cunningham et al., 2015). The integration of golden camellias into forest ecosystems may enhance biodiversity by providing additional canopy layers and supporting associated flora and fauna. For example, the presence of flowering camellias can attract pollinators, promoting ecosystem stability. This approach also addresses the critical need for in-situ conservation of threatened species, as highlighted in previous research on sustainable forestry models (Takahashi et al., 2023). By maintaining genetic diversity and promoting natural regeneration, such initiatives can play a pivotal role in long-term biodiversity conservation (Thomas et al., 2014). The economic viability of cultivating golden camellias under natural forest canopies contributes to poverty alleviation in rural areas (Tran et al., 2019). As high-value ornamental and medicinal plants, golden camellias provide a sustainable source of income for local communities, reducing dependency on unsustainable logging practices (Marshall et al., 2006). The findings of this study align with earlier research that highlights the economic benefits of NTFPs in enhancing rural livelihoods and community resilience (Derebe and Alemu, 2023). By fostering local entrepreneurship and engaging smallholder farmers, golden camellia cultivation supports equitable economic development, which is essential for the success of conservation initiatives (Steffen et al., 2021).

Integrating golden camellias into natural forest management offers a promising pathway toward multi-functional forestry (Miina et al., 2020). This model demonstrates the feasibility of combining economic productivity with ecological conservation, addressing key challenges in forest restoration and land-use planning in Vietnam (Mello et al., 2020). The adaptability of golden camellias to varied microclimatic conditions and their compatibility with natural forest canopies make them ideal candidates for sustainable forest management practices (Zhu et al., 2022). These findings are consistent with studies on value-chain forestry models, which emphasize the role of high-value NTFPs in promoting sustainable land-use practices (Takahashi et al., 2023). Future initiatives should focus on scaling up this model and integrating it into national forestry policies.

Despite the promising results, the study reveals some challenges in cultivating golden camellias, including the low correlation between stump diameter and other growth parameters for *C. impressinervis* and *C. tienii* (Takahashi et al., 2023; Do et al., 2020). This suggests that factors beyond stump diameter, such as soil fertility and microclimatic conditions, may play a more significant role in influencing growth outcomes. Additionally, the lack of natural seedling recruitment in *C. hamyensis* and *C. tienii* highlights the need for targeted interventions to improve reproductive success and ensure population sustainability (Tran et al., 2020; Hung and Ye, 1979). Addressing these challenges will require further research on species-specific ecological requirements and adaptive management strategies. This study underscores the need for long-term monitoring to better understand the ecological dynamics of golden camellia cultivation under forest canopies. Future research should explore the interactions between golden camellias and associated biodiversity, focusing on their role in ecosystem services such as carbon sequestration and soil stabilization (Cunningham et al., 2015). Additionally, socio-economic studies evaluating the impacts of golden camellia cultivation on local livelihoods can provide valuable insights for scaling up this model in other regions. Collaborative efforts involving researchers, policymakers, and local communities will be essential to realizing the full potential of this approach.

## 5. CONCLUSION

This study provides valuable insights into the growth performance of three golden camellia species, *Camellia impressinervis*, *Camellia hamyensis*, and *Camellia tienii*, under the natural forest canopy in Northern Vietnam. The findings revealed that *C. tienii* exhibited the highest survival rate (73.7%) and the greatest proportion of good-quality stems (74.2%), making it the most adaptable species in the study area. In terms of growth, *C. hamyensis* showed significantly superior stump diameter (1.57 cm). Despite the variations in growth parameters, all three species demonstrated comparable crown diameters, indicating their suitability for biodiversity enhancement. Weak correlations between stump diameter and other growth metrics in *C. impressinervis* and *C. tienii* highlight the need for further studies on growth dynamics. These results underscore the role of golden camellias in integrating biodiversity conservation and rural development. Cultivating high-value NTFPs such as golden camellias provides a sustainable pathway for forest management by reducing pressures on natural forests and supporting local livelihoods. Future efforts should focus on optimizing management practices and scaling up successful models to similar ecological contexts. Long-term monitoring and interdisciplinary collaboration will be crucial for maximizing the ecological, economic, and social benefits of golden camellia cultivation.

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