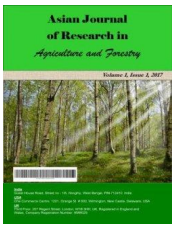

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Effect of Planting Method and Density on Initial Growth of *Carya tonkinensis* – a Multipurpose Tree

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Authors' contributions

This work was carried out in collaboration among all authors. Authors VVT, BKH, CDS, TAT, NVD, LTHX and TVD designed experiments and collected data. Author TVD wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Carya tonkinensis Lecomte is a multipurpose tree species, naturally distributing in India, China, and Vietnam. Extract from leaves of *C. tonkinensis* contains pinostrobin acting as anti-bacteria and anti-infection. It is used as traditional medicine. Seeds are edible and contain oil. In addition, seed cover can be used to produce activated charcoal. Therefore, growing *C. tonkinensis* may contribute to poverty reduction in mountainous areas. This study aims to analyze suitable planting method and density for growing *C. tonkinensis* in Son La province, Northwestern Vietnam. Three treatments in planting method were considered: mixed planting of *C. tonkinensis* and *Chukrasia tabularis*, pure planting and scattered planting. Four treatments in planting density were considered: 625 plants/ha, 830 plants/ha, 1,000 plants/ha and 1,100 plants/ha. Stem height and stump diameter (D_o) were

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measured at one year after planting, and death trees were counted for survival rate. The results indicated that scattered planting is the most suitable for *C. tonkinensis* and pure planting could also be applied. Meanwhile, planting density of 625 plants/ha (spacing of 4 × 4 m) and 830 plants/ha (spacing of 3 × 4 m) achieved the best performance. In both planting densities, the survival rate of the plants achieved >90%, their growths were >80 cm in height and >0.8 cm in D_o after planting one year. It is recommended that site preparation should be conducted by cutting bands of 2 m width and un-cutting bands of 2 m. In addition, seedlings of >1-year old, which are taller than 0.6 m, should be used to ensure higher survival and growths of plants.

Keywords: Multipurpose forest species; non-timber forest products; poverty reduction; traditional medicine; plant growth.

1. INTRODUCTION

Carya tonkinensis Lecomte is a tree species belonging to family Juglandaceae. The species has natural distribution in India, China, and Vietnam [1]. In Vietnam, this species only distributes in narrow areas of Son La province in the northwest part of the country [2].

Extract from leaves of *C. tonkinensis* contains pinostrobin, which functions as anti-bacteria and anti-infection [3]. Therefore, *C. tonkinensis* is used as traditional medicine. Wood of *C. tonkinensis* is widely used by local people for housing and furniture making. Seeds are edible and contain high oil ratio. Oil is extracted from seeds for daily life use. Seed cover can be used for activated charcoal [4]. Therefore it is known as a multipurpose and as a non-timber forest product tree species.

Due to high values, the species has been widely harvested in nature and it is listed in Redbook of Vietnam, which needs to be preserved [2]. Initial researches on ecological characteristics [5] and seedling production [6-7] have been recently conducted for *C. tonkinensis*. However, techniques for planting this species is still a gap for development and preservation [5,7]. Through reviewed articles both national and international, effects of planting density and method on growths of tree species have been widely documented [8,9]. While, mixed planting [10] or under crown planting [15] was required for shade-intolerant species in their seedling and sapling stages. These are important notes for silvicultural treatments in growing *C. tonkinensis*.

The objective of this study was to analyze suitable techniques to grow *Carya tonkinensis* Lecomte in Vietnam.

2. MATERIALS AND METHODS

2.1 Study Species

This study was conducted for *C. tonkinensis* (Mạy Châu is the Vietnamese name of this tree), a native tree species of Vietnam. This is a big-sized tree, which may reach up 30 m tall and 70 cm diameter at maturity. *C. tonkinensis* is a deciduous tree, which sheds all leaves in winter (December-January). New leaves appear in spring with the same time of blooming. Fruits are ripen in July-August [4-5,11]. Fruits have sizes of 2-3 cm in diameter, which change from green to brown/dark when ripen.

2.2 Study Site

C. tonkinensis was found to have natural distribution only in Son La province, Northwestern Vietnam. The species distributes in elevation zone of 600-1,000 m above sea level. Therefore, this study was conducted in Muổi Nọi commune, Thuận Châu district, Son La province with the suitable conditions for the development of *C. tonkinensis*. The vegetation in this area is classified as evergreen broad-leaved forest [12]. There are four distinct seasons including spring (February-April), summer (May-August), autumn (September-November), and winter (December-January). The annual temperature is 25^{o}C and the annual precipitation is 1,760 mm. The site is fertile-forested soil with high organic matter and loam texture from natural secondary forest following shifting cultivation. Soil depth is 70-80 cm, and pH is 4.5-5. The site in on elevation of 680-720 m above sea level.

2.3 Experiment Design

Two experiments were conducted: (1) planting method and (2) planting density, which were designed in a total area of 3.25ha. The

experiments were designed following Naji et al. [8] and Dutta and Hosain [9].

In the planting method, three treatments were considered: (a) mixed planting of *Chukrasia tabularis* and *C. tonkinensis*; planting density of 830 plants/ha (spacing of 3 × 4 m) with species rate of 1:1 (415 plants of *C. tabularis* and 415 plants of *C. tonkinensis*) named as MP, (b) pure planting of *C. tonkinensis*; planting density of 830 plants/ha (spacing of 3 × 4 m) named as PP, and (c) scattered planting, applied where land was available on home gardens, named as SP. There were three plots (replicates) in MP, each plot contained 120 plants (60 plants of *C. tonkinensis*). The plot size was 40 × 45 m, containing 10 lines with 12 plants/line. The similar plot size was designed in PP. While in SP, there were three areas selected representing three plots. In each area, 60 plants of *C. tonkinensis* were planted. Total area for this experiment was 1.25 ha.

In the planting density, four treatments were considered: (a) 625 plants/ha at spacing of 4 × 4 m, (b) 830 plants/ha at spacing of 3 × 4 m, (c) 1,000 plants/ha at spacing of 2.5 × 4 m, and(d) 1,100 plants/ha at spacing of 3 × 3 m. Three replicates were applied leading to a total of 12 plots. The plot size was 40 × 40 m. There were 81 (9 lines with 9 plants/line), 108 (9 lines with 12 plants/line), 135 (9 lines with 15 plants/line), and 144 plants/plot (12 lines with 12 plants/line) in planting density of 625, 830, 1,000, and 1,100 plants/ha, respectively. Total area for this experiment was 2 ha.

In both experiments, all applied techniques were the same: fully clear vegetation, planting hole of 40 × 40 × 40 cm, and applying 0.5 kg NPK/plant at planting (NPK=16:16:8). In 2016, tending was applied one in September-October. In 2017, tending was applied twice in April-May and September-October. Tending technique included weeding, tree climber cutting, and earthing.

For *C. tonkinensis,* 9 month-old seedlings were used, which had stump diameter (D_o) of 0.5 cm and height of 45 cm. For *C. tabularis*, 8 month-old seedlings were used, which had D_o of 0.45 cm and height of 40 cm. All plants were planted in June, 2016.

2.4 Data Collection and Analysis

D_o and stem height were measured at one year after planting for all plants in both experiments. In addition, death trees were counted for survival rate definition.

ANOVA one-factor and post-hoc test were applied to evaluate effect of treatments on survival and growths of *C. tonkinensis* plantation. All analyses were conducted by using SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

3. RESULTS

3.1 Planting Methods

In the MP treatment, the difference of survival rate of the two species used was not significant. The rate was 87.3% for *C. tabularis* and 87.9% for *C. tonkinensis* (Fig. 1). Meanwhile, the differences of mean stem height and mean stump diameter were significantly different between two species (Fig. 1). Mean stem height was 73.2 cm for *C. tabularis* and 83.6 cm for *C. tonkinensis.* While, mean D_o was 0.76 and 0.81 cm for *C. tabularis* and *C. tonkinensis*, respectively. The growth of *C. tonkinensis* was better than that of *C. tabularis.*

ANOVA one-factor analysis indicated that planting methods significantly effect on survival rate, mean stem height and mean D_o (Table 1). SP treatment had the highest survival rate (93.3%), mean stem height (89.5 cm), and mean D_o (0.93 cm). The values reduced in PP treatment, as survival rate was of 90.5%, mean stem height was of 85.4cm, and mean D_o was of 0.85 cm. The lowest values were showed in MP treatment as survival rate was of 87.9%, mean stem height was of 83.6 cm, and mean D_o was of 0.81 cm (Table 1).

3.2 Planting Density

Planting densities had significant effect on survival rate of *C. tonkinensis* at one year after planting (Fig. 2). The highest survival rate of 91.7% was observed in planting density of 625 plants/ha, reducing to 90.4% in planting density of 830 plants/ha, to 89.4% in planting density of 1,100 plants/ha, and to 87.0% in planting density of 1,000 plants/ha (Fig. 2). The difference of survival rate between planting densities of 625 and 830 plants/ha was not significant. However, this rate was significantly different from the ones of the other two treatments.

Planting densities significantly affected the stem height and stump diameter of *C. tonkinensis*

(Table 2) after one year of the plantation. The difference between planting densities of 625 and 830 plants/ha was not significant for both stem height and D_o, and it was not different between planting densities of 1,000 and 1,100 plants/ha for D_o (Table 2). At planting density of 625 plants/ha, plantation was the tallest, with the mean stem height of 84.6 cm, and showed the largest mean D_o (0.89 cm) among all treatments. Growth reduced in planting density of 830 plants/ha (83.2 cm of mean stem height and 0.85 cm of mean D_o), followed by plantation of 1,000 plants/ha (80.8 cm of mean stem height and 0.78 cm of mean D_o), and plantation of 1,100 plants/ha (79.2 cm of mean stem height and 0.76 cm of mean D_o).

4. DISCUSSION

Planting native forest tree species takes decades to have final products such as fruit, timber. In this study, only initial growth results were shown. However, such results are valuable for planting *C. tonkinensis* in Vietnam so far. Mixed species (MS) plantation in this study was composed by the combination of *C. tonkinensis* with *C. tabularis*, which is known as a slow-growing tree species in Vietnam [13]. After one year of MS plantation, *C. tonkinensis* showed better growth performance than *C. tabularis* (Fig. 1). However, the surplus is small. Therefore, *C. tonkinensis* could also be considered as a slow-growing tree species. At the moment of the planting phase, *C. tonkinensis* had D_o of 0.5 cm and height of 45 cm. One-year growth increment ranged from 35-48 cm for stem height and 0.26-0.43 cm for D_o, regardless of experiment and treatment. These results indicate slow growing of *C. tonkinensis*, despite fertilization applied at the planting with 0.5 kg NPK/plant. Therefore, a long duration of tending should be adopted to ensure good survival rate and growth performance. There have been no records on effect of fertilization on growth of *C. tonkinensis* in the scientific literature. Efficiency of fertilizing 0.5 kg NPK/plant applied in the present study was not clear. The fertilizer may not support growth and survival of *C. tonkinensis* as soil in the present study site is deep and quite fertile. In practical application, such high amount of fertilizer may be costly and inapplicable to poor condition of local traditional communities. Further studies on fertilization should be conducted before practical application. Before planting, details of edaphic conditions of the site such as pH, organic carbon, and nutrients should be analyzed. Such information is important to identify fertilization. Generally, slow-growing tree species requires less fertility and therefore fertilization is not necessary at planting. However, in latter stages when planted trees grow larger, fertilization may become necessary.

The survival of planted trees depends on ecological characteristics of species, seedling quality, and environments [14]. Seedlings of *C. tonkinensis* were >0.4 m tall at planting, which were healthy enough for initial growth. In addition, natural conditions in the study site are not harsh as high annual rainfall (>1,700 mm), high relative humidity (80–85%) and not too high and/or too low temperatures, those supported growth of planted trees leading to high survival rate. Survival rate of >90% is considered good enough for forest plantation activity [13]. It was recorded that dead plants were from seedlings with not so good quality at planting, even though the best seedlings were selected for experiments. This may suggest that seedlings of *C. tonkinensis* for planting should be older than one year and they should be taller than 0.6 m in height at planting to ensure higher survival rates. Forest establishment should be conducted in early rainy season and only after the first heavy rain. Only that soil fertility becomes suitable condition for planted trees to survive and grow. There is a winter in the present study site, when air temperature may drop to 7-8^{o}C. It is not recommended to grow *C. tonkinensis* in spring as temperature is still low to support growth and high survival of planted trees. In this study, clear cutting vegetation was applied for planting *C. tonkinensis*. Probably, it seems not suitable as *C. tonkinensis* requires shading at some levels for seedlings and saplings. Therefore, site preparation should not be conducted by clear cutting. Band cutting could be tested. For example, cutting bands of 2 m and un-cutting bands of 2 m could be used. Then, shading from vegetation in remained bands would support better growth and survival of *C. tonkinensis* as applied in other forest tree species such as *Canarium album*, *Cinnamomum obtusifolium* [15]. In addition, this procedure would be an environmentally-friendly approach to reduce CO_2 emission to the atmosphere, mitigating climate change, and soil erosion. Generally, in band planting remained vegetation acts as shading however it competes with planted trees. Therefore, tending should be much taken care and the remained band must be removed to release growing space for planted trees by time.

After one year of the planting, trees are still small and there was no crossing of tree's crown and also root system. Therefore, competition among planted trees for growing space seems to be negligible. However, observed differences on survival rate, mean stem height, and mean stump diameter were significant in both experiments. This may be explained by different completion between planted trees and surrounding vegetation and environment. The main purpose in mixed planting is to shade planted trees. Therefore, supplemented trees must be faster-growing tree species to have enough large and tall crown for shading. However, in this study supplemented tree was *C. tabularis* that grew slower than *C. tonkinensis* (Fig. 1), indicating that it was not a suitable species to be planted to favor *C. tonkinensis* growth. Therefore, other supplemented tree species should be tested other than *C. tabularis* in further studies. Acacias have been widely used in Vietnam for mixed plantations, which are fast-growing species to shade native slow-growing species [10]. In addition, after planting 5-6 years when native trees requires full sunlight. Acacias can be harvested to generate income for growers. Which is known as a sustainable management for planting native and multipurpose tree species.

Table 1. Survival rate, mean stem height, and mean stump diameter (D_o) of *C. tonkinensis* in different planting methods at one year after planting

Planting method	Survival rate (%)	Height (cm)	D_o (cm)
Mixed planting (MP)	87.9 ±0.7^{a}	83.6 ±0.06^{a}	0.81 ±0.00^{a}
Pure planting (PP)	90.5 ±1.3^{ab}	85.4 ±0.09^{b}	0.85 ±0.00^{b}
Scattered planting(SP)	93.3 ±1.0^{b}	89.5 ±0.09^{c}	0.93 ±0.00^{c}

Different letters$^{a, b, c}$ in a column indicate significant difference of means at p =0.05

Table 2. Mean stem height and mean stump diameter (D_o) of *C. tonkinensis* in different planting densities at one year after planting

Planting density (plants/ha)	Height (cm)	D_o (cm)
625	84.6 ±0.46^{a}	0.89 ±0.02^{a}
830	83.2 ±0.23^{a}	0.85 ±0.01^{a}
1,000	80.8 ±0.24^{b}	0.78 ±0.00^{b}
1,100	79.2 ±0.49^{c}	0.76 ±0.00^{b}

Different letters$^{a, b, c}$ in a column indicate significant difference of means at p =0.05

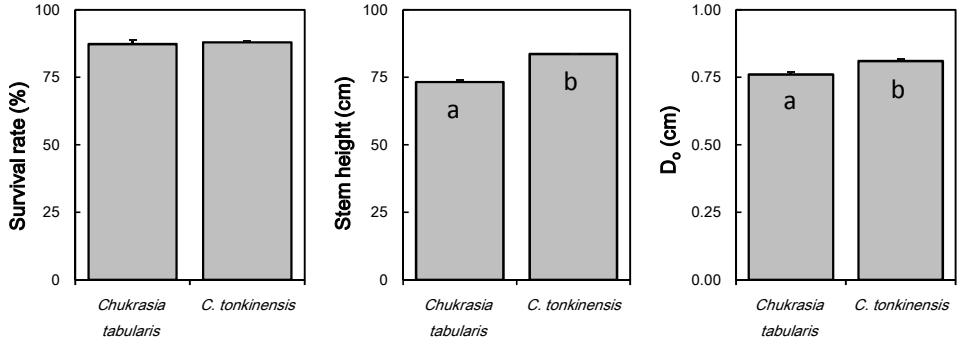

Fig. 1. Survival rate, mean stem height, and mean stump diameter (D_o) in treatment of mixed planting at one year after planting. Bars indicate ±SE. Different letters$^{a, b}$ indicate significant difference of means at p =0.05

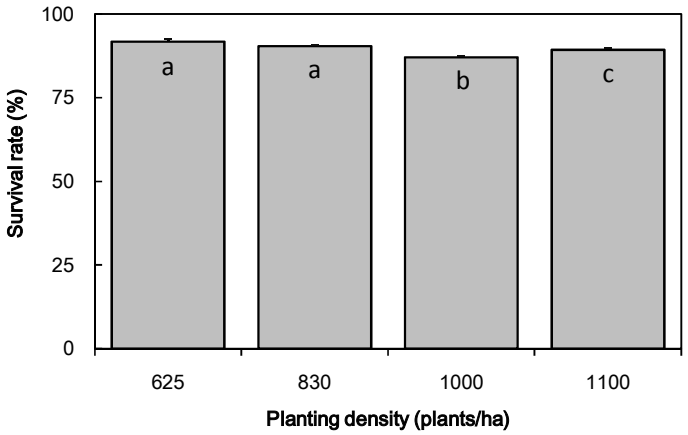

Fig. 2. Effects of planting densities on survival rate of *C. tonkinensis* at one year after planting. Bars indicate ±SE. Different letters[a, b] indicate significant difference of means at p =0.05

5. CONCLUSION AND RECOMMENDATION

Carya tonkinensis Lecomte is a multipurpose tree species, which can be used for poverty reduction in Northwestern Vietnam. Pure planting with density of 625 or 830 plants/ha should be used in forested fertile soil. It can also be planted scattered in the gardens or on the fragmented land areas. Healthy seedlings of >1-year old and taller than 0.6 m should be used for best initial growth and survival.

Further studies on planting method such as planting on bands, and on fertilization should be conducted. In addition, the results in the present study were initial. Therefore, further data collection and growth observation should be conducted to the established models for better conclusion about planting method and density for *C. tonkinensis* and to have guideline for practical application.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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