AJAB

Asian J Agri & Biol. 2018;6(3):300-307.

Original Research Article

Promoting reforestation through supplementing native forest tree species in northwestern Vietnam

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Received:
February 01, 2018
Accepted:
July 31, 2018
Published:
September 30, 2018

Abstract

Forest enrichment and/or supplement planting is a silvicultural technique to improve number of valuable trees in natural poor forests. In this study, two native species including *Canarium album* (Lour.) Raeusch and *Cinnamomum obtusifolium* (Roxb.) Nees were planted in fallow stands by two experiments as planting in clear band of 6 m wide (band planting) and in canopy gaps of >200 m^2 (cluster planting). The results indicated that planted trees of both species in both planting experiments had high survival rates (>89%) after planting three years, and more than 75% survival trees had good quality as straight boles without diseases. The difference of stump diameter and stem height between experiments and species was statistically significant. *C. obtusifolium* in band planting had biggest stump diameter (2.86 cm), while *C. album* in band planting had tallest stem height (2.69 m) after planting three years. *C. obtusifolium* had significantly larger crown diameter in band planting (1.09 m) than that in cluster planting (0.92 m). While it was conversely found in *C. album* as significantly larger crown diameter was found in cluster planting (1.12 m) compared to smaller one in band planting (0.96 m). It is concluded that silvicultural techniques are required to promote growth of planted trees after planting three years, especially for *C. album* as it requires more sunlight at this age. The techniques must focus on opening forest canopy for sunlight reaching crown of planted trees and on removing bad-growth trees surrounding planted trees to minimize competitions.

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Keywords: Fallow land, Forest gap, Growing space, Sustainable management, Timber species

Introduction

Fallow land is a result of abandoning the land from slash and burn agriculture, which is known as one of the major indigenous agricultural techniques in tropics (Ekwall, 1955) and sustains 300–500 million people worldwide (Brady, 1996). In Vietnam, 50 of 54 ethnic minorities have practiced slash and burn agriculture in an area of 3.5 million ha (Do et al., 2010). After abandoning the land, native forest trees naturally regenerate. Natural regeneration in fallow land depends on soil seed bank, vegetative resprouting, and seed dispersals from nearby forests (Guariguata and Ostertag, 2001; Gehring et al., 2005; Fukushima et al., 2007, 2008; Do et al., 2010, 2011). Because of using repeated burnings in slash and burn agriculture for land preparation, soil seed bank and vegetative resprouting are much reduced (Fukushima et al., 2007). While, seed morphology, distribution of forest patches, and dispersers affect seed dispersal (Do et al., 2005). The number of naturally regenerated forest tree species increases gradually with ages of fallow stand (Do et al. 2010). However, it is far to reach species number the same that before slash and burn agriculture and most species are pioneers and less economical value than late succession species (Do et al., 2010, 2011; Fukushima et al., 2007, 2008). Therefore, supplementing native trees of highly economical value is an alternative to promote restoration process (Singh and Singh, 2006) and improve economical value of fallow stand.

To reforest fallow land, native forest trees are preferred (Sovu et al., 2010; FAO, 2014), although planting native trees is not easy because of lack of silvicultural knowledge and regeneration ecology (Bautista, 1990). Planting native trees could be beneficial because the species may be well known and high value for local communities (Peters et al., 1989; Lacuna-Richman, 2002; Mangaoang and Pasa, 2003; McElwee, 2008). Community forestry with native species has shown some successes. The models combine native species for reforestation with some fruit trees to support local livelihoods (Vilei, 2009; Schneider et al., 2014). Similar initiatives are sponsored throughout the world by regional governments and international agencies to combat deforestation, foster sustainable forest management, and fight rural poverty (Agrawal and Angelsen, 2009).

The aim of the present study was to evaluate the growth of two native species (*Canarium album* (Lour.) Raeusch and *Cinnamomum obtusifolium* (Roxb.) Nees supplemented in fallow stands in Northwestern Vietnam.

Material and Methods

Study site

The study was conducted in Binh Thanh commune, Cao Phong district, Hoa Binh province, Northwestern Vietnam at 20º45’40’’N and 105º16’37’’E. The original forest in Binh Thanh commune is characterized as tropical evergreen broadleaf forests (Thai, 1978), distributing on elevation of 130–200 m above sea level. The climate is warm and moist. The mean annual rainfall is 1500–2500 mm, in which 80% falls in April–September. The annual relative humidity is 80–85%, mean monthly temperature ranges from 21 to 24ºC in summer and 15 to 16ºC in winter. The dominant soil types are acrisols, acidic soils with low base saturation. The soil in fallow stands was generally acidic with a low pH of 3.5–3.7, and had humus of 4.4–6.3% and nitrogen of 0.23–0.36%.

The area was subjected to slash and burn agriculture for a long history. The naturally regenerated forest species are mainly *Wendlandia paniculata*, *Schima wallichii*, *Camellia tsaii*, and *Lithocarpus ducampii*. The average height of canopy layer was 10–12 m. In old fallow stands, soil moisture and fertility were gradually improved, and other species were recruited such as *Litsea cubeba*, *Camellia* sp, *Quercus* sp, and *Castanopsis* sp.

Description of study species

Two species including *Canarium album* and *Cinnamomum obtusifolium* (MARD, 2000) were selected in this study by the following reasons: (1) they are high economic valuable species, which local people prefer to grow, (2) planting guidelines are available (MARD, 1994), (3) seed sources are available, and (4) they are native forest tree species of Vietnam (Chan and Huyen, 2000; Sam and Nghia, 2002).

C. album (Vietnamese name; Trám Trắng) belongs to Burseraceae family and distributes under 600 m above sea level. Annual precipitation of 1500–2000 mm, annual air humidity of 80–85%, and annual temperature of 22–27ºC are suitable conditions for growing *C. album*. At maturity, trees may grow up to 30 m tall and 80 cm diameter at breast height. This is a shade-intolerant species. Seedlings require shading to grow, while shading requirement decreases gradually with ages (VAFS, 2014).

C. obtusifolium (Vietnamese name; Re Gừng) belongs to Lauraceae family and distributes from 50 to 1500 m above sea level. Annual precipitation of 800–2500 mm, annual air humidity of 75–85%, and annual temperature of 20–25ºC are suitable conditions for growing *C. obtusifolium*. At maturity, trees may grow up to 30 m tall and 50 cm diameter at breast height. This is a shade-intolerant species. Seedlings require shading to grow, while shading requirement decreases gradually with ages (Nguyen, 2009)

In this research, seedlings of *C. album* and *C. obtusifolium* were purchased from Vietnamese Academy of Forest Sciences, which was 0.4–0.6 cm stump diameter and 0.4–0.6 m tall.

Experiment design

There were two experiments as planting in band of 6 m wide (band planting) and planting in forest gap of

>200m^2 (cluster planting). The experiments were designed in a completed random block with four replicates. Each replicate covers an area of 0.1 ha.

For experiment of planting in band, clear bands had width of 6 m and remained bands had width of 8 m. The bands are parallel with contours. Lower vegetation including grasses, herbs, bushes, and shrubs in clear bands were cleared and vegetation was loaded to minimize effects on planted trees. In clear bands, planting holes of 40 cm × 40 cm × 40 cm were made in space of 3 m intervals in the middle of the clear band.

For experiment of planting in cluster, forest gaps of >200 m^2 were selected. In the gaps, vegetation was cleared the same as mentioned above. In clear gaps, planting holes of 40 cm × 40 cm × 40 cm were made in spacing of 3 m × 3 m.

After planting, tending activities were conducted in three consecutive years. It included weeding, earthing and removing tree climbers.

Data collection and analysis

Growth data including diameter at stump (D_o in cm) and stem height (H in m) were measured at 1-, 2-, and 3-years after planting. In addition, stem crown diameter (D_c in m) was measured at 3-years after planting. All planted trees were measured and evaluated for its quality; straight and no disease trees were classified as good, disease trees were classified as medium, disease and top-truncated trees were classified as bad. The death trees were recorded for estimating survival rate.

Pair-comparisons of mean of growth parameters (D_o, H, and D_c) between two species in each experiment and between two experiments for each species were conducted by *t*-test with two-tailed distribution at p =0.05. Statistical analysis was conducted using SAS 9.2.

Results

After planting three years, the survival rate was high, regardless of species and experiments (Table 1). *C. obtusifolium* had higher survival rate than *C. album* regardless of experiments. While, the difference between band planting and cluster planting in each species was not significant. *C. album* had significant lower rate of good trees than *C. obtusifolium*. While, band planting seemed to have higher rate of good trees than cluster planting. All planted trees of *C. obtusifolium* belonged to good and medium quality regardless of experiments. While, bad quality trees were found in *C. album* (Table 1).

After planting two years, trees in band planting had significant bigger stump diameter (1.99 cm for *C. album* and 2.12 cm for *C. obtusifolium*) than that in cluster planting (1.57 cm for *C. album* and 1.43 cm for *C. obtusifolium*; Fig. 1). While, there was no difference between two species in each experiment (band planting or cluster planting). At three years after planting, the biggest stump diameter (2.86 cm) was found in band planting for *C. obtusifolium* and it was significant bigger than others (Fig. 1). Meanwhile, the difference of others was not significant (2.65 cm for *C. album* in cluster planting, 2.71 cm for *C. album* in band planting, and 2.79 cm for *C. obtusifolium* in cluster planting).

In term of height growth after planting two years, *C. obtusifolium* in band planting was highest (2.09 m) and was significant higher than others (Fig. 2). The difference among *C. obtusifolium* in cluster planting (1.52 m), *C. album* in cluster planting (1.59 m), and *C. album* in band planting (1.62 m) was not significant. After planting three years, height growth changed considerably (Fig. 2). The tallest height was found in band planting for *C. album* (2.69 m), which was significant higher than others. While, the difference of stem height among *C. album* in cluster planting (2.41 m), *C. obtusifolium* in cluster planting (2.47 m), and *C. obtusifolium* in band planting (2.51 m) was not significant (Fig. 2).

After planting three years, crown diameter of *C. album* (0.92 m) was significant smaller than that of *C. obtusifolium* (1.09 m) in band planting. While, conversely it was found in cluster planting, where crown diameter of *C. obtusifolium* (0.96 m) was significant smaller than that of *C. album* (1.12 m). Comparing between band planting and cluster planting in each species, *C. obtusifolium* had larger crown diameter in band planting compared to that in cluster planting, while *C. album* had larger crown diameter in cluster planting compared to that in band planting (Fig. 3).

Discussion

Both *C. album* and *C. obtusifolium* are shade-intolerant species, which require shading at some levels in seedling stage and full sunlight in latter stages (Chan and Huyen, 2000; Sam and Nghia, 2002; Nguyen, 2009; VAFS, 2014). Selecting those species for supplementing under forest canopy of fallow stands seems to be a good choice. There was high survival rate of >89% in all experiments for both species indicating initial success of the experiments. Meanwhile, higher stem ratio (Table 1) in good quality and no stems in bad quality of *C. obtusifolium* indicate the more suitability of this species for supplement planting in poor natural forests. *C. album* has soft top in the growing season, which is easily broken by wind and is easily attacked by insects, leading to some rates of bad trees (Table 1). Maintaining light conditions in supplement planting to a multistory mixed forests has been a challenge (Ådjers et al., 1995; Abebe, 2003). As vegetation in tropics grows fast, while light requirement of planted trees increases with ages. Therefore, regular tending and canopy opening are very important to support high survival rates and growth of planted trees.

The survival rate in this study is comparably higher than other enrichment planting studies in the tropics (Marod et al., 2004; Romell et al., 2008; Sovu et al., 2010). The survival of planted seedlings depends on ecological characteristics of species, seedling quality, and environments, which support planted trees (Folk and Grossnickle, 1996). Study species in the present study are shade intolerants and seedlings were >0.4 m tall, which were healthy enough for initial growth. In addition, natural conditions in the study site are not harsh as high annual rainfall (1500–2500 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.

After planting three years, stump diameter of *C. obtusifolium* was bigger than that of *C. album* (Fig. 1), while stem high was inverted; height of *C. album* was taller than that of *C. obtusifolium* (Fig. 2). This may indicate that *C. obtusifolium* requires less sunlight at three years old. Even at this age, *C. obtusifolium* still invests much energy on diameter growth other than on height growth for getting more sunlight. While, less sunlight in under canopy may limit growth of *C. album*. Therefore, it invests much energy to height growth for reaching more sunlight, only that can support better growth of *C. album* in the following ages. As only in one-year duration from two to three years old, height increment of *C. album* was 1.07 m compared to 0.42 m of *C. obtusifolium* in band planting (Fig. 2).

There was no effect of experiments as band and cluster plantings after planting three years on height growth of *C. obtusifolium* (Fig. 2), while it was recorded in *C. album*. Open band had width of 6 m, while cluster was from open gaps of >200 m^2. Those indicated more sunlight reaching forest floor in clusters than that in bands from larger open spaces, leading to shorter height of *C. album* in cluster as in band planted trees invested more energy to height growth for reaching sunlight enough for its growth. Therefore, at three years after planting thinning or crown opening in experiment of band planting for *C. album* is required for larger growing space and sunlight, otherwise trees may die from competitions with surrounding trees. Meanwhile, silvicultural application to *C. obtusifolium* is not required at this moment. Again, those notations are confirmed by smaller crown diameter of *C. album* in band planting compared to that in cluster planting (Fig. 3). When trees invest much energy for height growth, it then will have smaller crown. Other studies indicated that planted seedlings grow faster under more open canopies than closed ones (Bebber et al., 2002; Marod et al., 2004; Romell et al., 2008; Sovu et al. 2010).

Leaf-eating insects were found to attack both species in the first two years in the present study. However, in the third year the attack reduced. Meanwhile, *C. album* was also affected by fungi on stem and young braches causing death to some trees. Fungus attack was also reduced in the third year. Applying pesticide and fungicide is not an environmental approach and seems impractical in forest conditions. Therefore, the best way to reduce impacts of insect and fungus attacks is to select best seedlings at planting. In addition, insects can be manually killed when tending planted trees. Opening forest canopy appropriately is also an alternative as insects and fungi prefer to grow in low sunlight conditions. At tending, removing disease trees of undesired species should be also conducted to minimize competitions against planted trees.

The same two species were experimented in other locations in Vietnam as North Central Coast and North Central Region (Table 2). Growth of planted trees in the present study seemed worse than that in other regions. Even these species have natural distributions in all experimented areas (Chan and Huyen, 2000; Sam and Nghia, 2002; Nguyen, 2009; VAFS, 2014). Growth of any tree species is affected by biotic as vegetation, and abiotic as climate and soil conditions and human interferences. Therefore, it is not easy to figure out the reasons for such growth differences among locations (Table 2). However, even in fallow lands the edaphic conditions are not so bad which still can support enough nutrients for planted trees (Do et al. 2011, 2018). Therefore, the main reason for different growth among experimented regions may come from canopy closure of forests. Forest canopy in the present study may be too dense to allow enough sunlight reaching to planted trees or the experiments in the present study may not be tended enough to support growth of planted trees.

Table 1: Survival rate and quality of planted trees after planting three years

Species	Band planting				Cluster planting			
	Quality (%)			Survival (%)	Quality (%)			Survival (%)
	Good	Medium	Bad		Good	Medium	Bad	
Canarium album	80.2	18.6	1.2	90.5	75.4	20.1	4.5	89.0
Cinnamomum obtusifolium	86.5	13.5	0	96.7	80.0	20.0	0	96.2

Table 2: **Comparison of growths of two study species in different regions after planting three years**

Species	Parameters	Planting locations in Vietnam		
		This research	North Central Coast*	North Central Region*
Canarium album	D_o (cm)	2.8	4.6	4.4
	H (m)	2.7	2.5	3.6
	D_c (m)	0.9	1.2	1.2
Cinnamomum obtusifolium	D_o (cm)	2.7	3.4	3.3
	H (m)	2.4	2.3	3.4
	D_c (m)	1.1	1.8	2.2

*Data were cited from Hoang et al. (2007). D_o is stump diameter, H is stem height, and D_c is stem crown diameter.

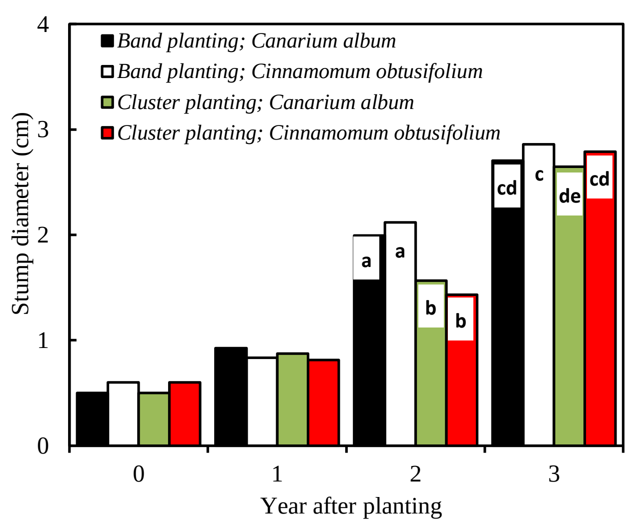

Fig. 1: **Stump diameter of two species in different experiments. Different letters [a, b, c, d, e] in bars indicate significant difference of means between experiments and species at *p* =0.05.**

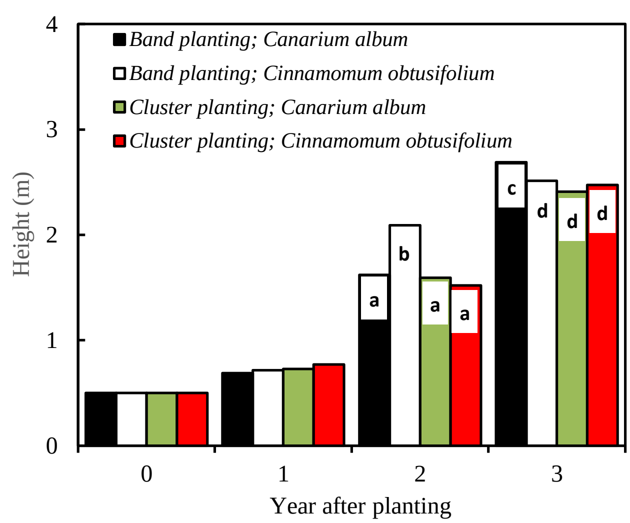

Fig. 2: Height of two species in different experiments. Different letters [a, b, c, d] in bars indicate significant difference of means between experiments and species at *p* =0.05.

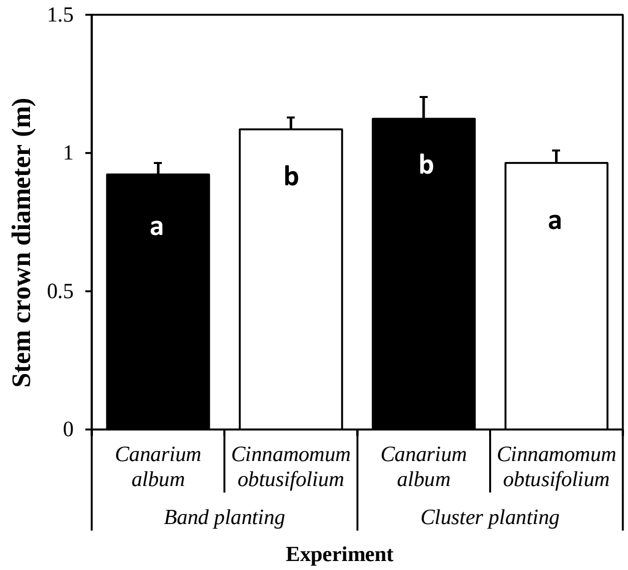

Fig. 3. Stem crown diameter of two species (error bars indicate +SE) in different experiments. Different letters [a, b] in bars indicate significant difference of means between experiments and species at *p* =0.05.

Conclusion

Supplementing native trees of commercially valuable species to poor natural forests is an effective silviculture technique, contributing to sustainable forest management. Trees can be supplemented in bands or in clusters, depending on canopy status of forests. Cluster planting should be applied to forest gaps of >200 m^2, while band planting should be applied to non-gap forests.

Tending after planting is important for the success of supplementing. It includes weeding, earthing, and gap opening. Gap opening should be conducted gradually with the size of planted trees as the older trees are, the higher sunlight they require. However, how much canopy should be open is depending on ecological characteristics of planted trees. Forest canopy should be open larger for *C. album* after planting three years. However, it is not a case for *C. obtusifolium*.

Acknowledgment

This research is funded by JICA organization through the project for Rehabilitation of natural forest in degraded watershed area in the North of Vietnam (RENFODA project). We would like to thank JICA Vietnam, Hoa Binh Forest Department, Hoa Binh Forestry Research Station, and experts from JICA, researchers of VAFS for coordinating and supporting. Comments from anonymous reviewers are highly appreciated.

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