The Growth of Coppiced Teak in Northern Thailand

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Abstract

Coppicing is an alternative regeneration method to replanting that reduces reestablishment costs and time. However, whether the growth from coppicing is different from that of the original planted trees is a frequent concern. The growth of teak after coppicing was studied in teak plantations in Uttaradit Province at the Tha Pla Plantation, belonging to Forest Industry Organization (FIO), and the Den Kra Tai and Nam Ang Plantations, belonging to Tha Sao Sawmill Limited Part. The objectives were to compare the growth performance of teak after coppicing and teak from planting, including comparing the growth of teak after coppicing using different management methods.

The results revealed that mean height and diameter at breast height (DBH) of teak from coppicing were significantly higher than teak from planting grown in the same area because of the faster growth of sprouts in the first stage affected the growth of seedling. In contrast, the growth of teak had no significant difference if sprouting occurred in different areas from replanting. The sprouts from a clear cut stump showed better growth than sprouts from thinned stumps. Additionally, the stump diameter was positively correlated with the mean height and DBH of sprouts.

Keywords: Growth, Coppiced teak, Northern Thailand

Introduction

Teak (*Tectona grandis*) is an important indigenous tree species in Thailand, and it is one of the most widely cultivated hardwood timber species in tree plantations. The first teak plantation in Thailand was established in 1906 in Phrae Province, Northern Thailand, with the aim of producing teak to meet increasing demand. At present, teak is widely planted with many forms of planting by several agencies. The main agencies responsible for teak planting in Thailand are the Royal Forest Department (RFD) and the Forest Industry Organization (FIO), including the farmers who have increasingly planted teak for tree farming near their homesteads and mixed with other crops along the boundaries and other planting systems. Teak somehow still remains as a promising economic species across the country.

Teak is one of tree species that has the ability to coppice after it has been cut. Chaweepuk (1999) found that the coppicing ability of teak was 100 percent, whereas the survival rate of sprouts was about 71.40%, which suggests that the sprouting ability of teak may contribute to the rapid restoration of forest cover in gaps after timber extraction or cyclone damage (e.g. Bellingham et al. 1994; Riswan and Kartwawinata 1991). Where sprouts are able to grow into mature trees, sprouting may be a more effective means of re-establishment than slow-growing seedlings (Harcombe and Marks 1983; Ohkubo 1992). Rapid production of sprouts can benefits from the established root system and may enable the species to reestablish in gaps (Rijks et al. 1998), which is also important for wildlife habitats (Solomon and Blum 1967). However, the ability to coppice declines with age, and the ability to coppice may also vary with local environmental conditions and the felling season (Grundwald and Karchon 1974; Jacobs 1955). Vacharangkura and Viriyabuncha (2003) found that 3 years after treatment, two thinning treatments affected neither stand-level volume growth nor total yield. A study on coppicing in a teak plantation indicated that diameter at breast height (DBH) and total height of coppice sprouts in thinning with two alternate rows were higher than those in thinning with an alternate row. However, there was no significantly difference between the two treatments. The advantages of the coppicing system is not only in shortening the rotation but also in the productivity of the plantation (Himmapan and Noda 2012). Coppicing is an alternative regeneration system that has a low cost of establishment because little or no site preparation is required (Thaiutsa et al. 2001), and Akkhaseeworn (2007) recommended that the stumps left after teak had been cut could be allowed to undergo self-coppicing, which in turn would reduce the cost in both new seedlings and site preparation. The decrease in the costs with 4 × 4 m spacing in teak plantation management using coppicing was the cost of land preparation, planting, the first weeding, fertilizing, and seedlings in the first year. In the case of a coppicing rate of 50%, the first year cost of management was reduced from 3,960 Baht rai^{-1} (24,750 Baht ha^{-1}) to 2,028 Baht rai^{-1} (12,675 Baht ha^{-1}), and it reduced to 2,203 Baht rai^{-1} (13,769 Baht ha^{-1}) if the coppicing rate was high at 70% (Himmapan, 2008). Moreover, Noda and Himmapan (2012) established a discounted cash flow model for producing teak timber with a 15-year cutting cycle, and they evaluated the profitability of coppicing using afforestation with genetically improved seedlings with an incremental net present value (NPV). In the first rotation period, seedlings were planted and for reforestation in the second rotation period, separate models with coppicing and seedling reforestation were prepared. The results found that in these two rotation periods lasting 30 years, the introduction of coppicing improved the initial-year balance of payments by 50% or more.

This study was a joint research project between RFD and Japan International Research Center for Agricultural Science (JIRCAS) under the program for the development of combined management techniques for agriculture and forestry to support farmers engaged in planting beneficial indigenous tree species, by focusing on teak. This study aimed to examine the growth of coppiced teak in various patterns to identify low-cost teak plantation management methods.

Materials and methods

This study was conducted at teak plantations in Uttaradit Province, Northern Thailand, at the latitude of 17°8′–18°11′ N and longitude of 99°54–101°11′ E. The elevation was about 64 m above mean sea level. Uttaradit has a tropical savanna climate, and winter is dry and very warm. Temperature rises until April, which is very hot with an average daily maximum of 38.2 °C (100.8 °F). The monsoon season occurs from May through to October with heavy rain and somewhat cooler temperatures during the day, although nights remains warm. Most of the province was once covered with teak forests, and teak is a major product of Uttaradit. The largest teak tree in the world is to be found at the Ton Sak Yai Park in the Luang Prabang Range. This 1,500-year-old tree measures 9.87 m in circumference and 37 m in height, although it was originally 48.5 m high before being damaged in a storm (Wikipedia 2016).

There are teak plantations belonging to FIO and private plantation across Uttaradit Province. Coppice regeneration after clear cutting is used in some areas with various management systems. Three coppicing management systems were selected for examination in this study.

1. The growth of teak from coppicing and from planting within the same area at Tha Pla Plantation belonging to FIO, Uttaradit Province.

This plantation was planted in 1981 with 2 × 8 m spacing for agroforestry, and clear cutting was conducted in 2007 when the teak trees were 26 years old. After clear cutting, sprouting occurred from stumps and new seedlings were planted within the 8 m row widths and in positions where no sprouts had grown. This changed the spacing to 2 × 4 m. Thus, coppices and seedlings grew in the same area. The best sprout (healthiest, best growth rate, and occurring from the lowest position on the stump) was selected for each stump. Three experimental plots of 40 × 40 m were set when the teak trees were 4 years old in 2012 with a completely randomized design. The growth in terms of DBH and height was measured once a year from 2012 to 2016, and mean variables were compared using independent t-tests (5% significance level).

2. The growth of teak from coppicing and from planting in different areas at Den Kra Tai Plantation belonging to Tha Sao Sawmill Limited Part, Uttaradit Province.

This plantation was planted in 1996 with 2 × 4 m initial spacing, and all trees were clear cut in 2006 when the teak trees were 10 years old after being bought from farmers. Sprouts occurred from more than 85% of stumps, and then the best sprout (healthiest, best growth rate, and occurring from the lowest position on the stump) was selected for each stump. Tha Sao Sawmill Limited Part also planted the new seedling with 2 × 4 m spacing in a nearby area in the same year. The three experimental plots of 20 × 40 m were set in 2011 with a completely randomized design in each coppiced plot and planted plot for a total of 6 plots. Because the sprouts grew in different areas, some initial factors may effect to the growth in the first stage, the relative growth rate (RGR) of DBH and height were calculated and compared using independent t-tests (5% significance level).

3. The growth of sprouts coppiced from thinning stumps and clear cutting of stumps at Nam Ang Plantation belonging to Tha Sao Sawmill Limited Part, Uttaradit Province.

This plantation was planted in 1989. The plantation underwent line thinning in 2004, and all tree, including the sprouts that grew from the thinning, were clear cut in 2011. Sprouts occurred from both kinds of stump in 2012, and the most vigorous sprout was selected from each stump. Three experimental plots of 40 × 40 m were set in 2013, with a completely randomized design, when all of the sprouts were 1 year old. The growth in terms of DBH and height was measured once a year from 2012 to 2016. The growth characteristics of sprouts from the two kinds of stump were compared using independent t-tests (5% significance level). The correlation efficient between the diameter of a stump and growth characteristics was also analyzed.

Results and discussion

The growth of teak from coppicing and planting within the same area.

The growth of teak from coppicing and planting was studied in teak from 4 to 9 years old. The average numbers of trees in the study area (1 rai) were 49 coppiced and 51 planted trees. The average values of growth, including the comparison based on t-test results, are shown in Table 1. The DBH of coppiced trees was 9.10 cm when teak was 4 years old, increasing to 15.35 cm at 9 years old, whereas those of planted seedlings increased from 5.79 cm to 11.93 cm over the same time period. The increments of DBH and height of coppiced trees were 1.25 cm $year^{-1}$ and 1.17 m $year^{-1}$, respectively. The height increment of coppiced in this study was higher than the study of Chaweepuk (1999) which showed a height increment of coppiced teak at Lampang Province of 0.99 m $year^{-1}$. Comparisons based on t-test showed that the DBH and height of coppiced teak were significantly higher than planted teak ($p<0.05$). This result

Table 1. Mean values with standard deviation of growth performance and comparison between teak from coppicing and planting at Tha Pla Plantation, Uttaradit Province.

Age	Treatment	DBH (cm)			Height (m)		
		Mean	Std.	t-test	Mean	Std.	t-test
4-year	Coppicing	9.10	2.62	**	7.90	1.82	**
	Planting	5.79	2.69		5.32	2.31	
5-year	Coppicing	11.45	3.03	*	9.84	1.80	*
	Planting	7.87	3.14		7.26	2.58	
6-year	Coppicing	13.22	3.36	*	11.48	1.75	*
	Planting	9.70	3.45		8.97	2.75	
7-year	Coppicing	14.80	3.71	*	12.44	1.85	*
	Planting	11.22	3.65		10.31	2.82	
8-year	Coppicing	15.45	4.10	*	13.21	2.20	*
	Planting	12.08	3.82		11.43	2.97	
9-year	Coppicing	15.35	3.95	*	13.74	2.31	ns
	Planting	11.93	3.74		11.98	3.31	

ns – non-significant, * - significant at $p < 0.05$, ** - significant at $p < 0.01$

was similar to the study of Akkhaseeworn (2007), which found that the growth of coppiced sprouts in the plantation was higher than those in other teak plantations. Additionally, the study of Himmapan (2008) found that the growth characteristics, including DBH, height, basal area, stem volume, and biomass, of teak coppice sprouts that grew in the same area with the additional seedlings were increasing dramatically at 2–3 years old, and slightly increased in the age of 8 years. Bailey and Harjanto (2005) also reported that diameter growth as well as height of coppiced teak was higher than from teak seedlings, and this was due to stored food reserves in the mother stumps (Troup, 1921). The height at the last measurement showed no significant difference between coppiced teak and planted teak ($p = 0.08$), which was similar to the studies of Thueksathit (2006), who reported that the difference in growth between sprouts and additional seedlings became smaller as teak trees grew older.

The growth of teak from coppicing and from planting in different areas

The growth of coppiced teak and planted teak was studied when teak was 5 to 10 years old. The average number of coppiced teak and planted teak in the study area were 179 coppiced teak rai^{-1} and 190 planted teak rai^{-1}. The DBH of 5 years old coppiced and planted teak were 9.61 cm and 9.19 cm, respectively, and increased to 12.00 cm and 11.13 cm at 10 years old. The growth of both coppiced teak and planted teak in this area was poorer than teak of the same age at the Tha Pla Plantation.

The coppiced teak grew in different areas to a planted teak, and RGR in term of DBH and height were calculated for the comparison of growth between teak from coppicing and planting. The average values of growth including the comparison based on t-test are shown in Table 2. The result showed that the RGR of DBH of teak from coppicing and from planting was not significantly different in every measurement during the study, whereas the RGR of height of planted teak was significant higher than that of coppiced teak. As a result, the growth of teak from planting was not less than from coppicing if they were grown together because the planted teak did not suffer any negative effects from the faster growth of coppices in the initial stage and small difference in growth performances when teak became older.

The growth of sprouts coppiced from thinning stumps and clear cutting stumps

Planted teak and coppice sprouts after thinning in 2004 were clear cut in 2011. Not all stumps produced coppices. The rate of sprouts that occurred from stumps after thinning and from clear cutting were 45.24% and 54.76%, respectively. The DBH and the height of coppiced sprouts from thinning stumps were 2.75±1.10 cm and 0.96±0.93 m, respectively, whereas the DBH and the height of coppiced sprout from clear cutting stumps were 4.08±0.91 cm and 3.42±1.27 m, respectively. Fig. 1 shows the growth of coppiced sprouts from clear cutting stumps, which was significantly different from coppiced sprouts from thinning stumps ($p<0.01$). The results were in agreement with an earlier study by Thaiutsa et al. (2001), which found that teak coppiced well after clear cutting. Additionally, Himmapan and Noda (2012) found that the growth ability

Table 2. Mean values with standard deviation of the relative growth rate of DBH and height, and comparison between teak from coppicing and planting at Den Kra Tai Plantation, Uttaradit Province.

Age	Treatment	RGR DBH ($cm\ cm^{-1} year^{-1}$)			RGR Height ($m\ m^{-1} year^{-1}$)		
		Mean	Std.	t-test	Mean	Std.	t-test
6-year	Coppicing	0.118	0.019	ns	0.087	0.022	*
	Planting	0.114	0.016		0.127	0.017	
7-year	Coppicing	0.082	0.005	ns	0.058	0.015	*
	Planting	0.093	0.010		0.092	0.007	
8-year	Coppicing	0.069	0.001	ns	0.053	0.008	*
	Planting	0.072	0.009		0.075	0.011	
9-year	Coppicing	0.058	0.006	ns	0.047	0.008	*
	Planting	0.053	0.007		0.064	0.010	
10-year	Coppicing	0.044	0.012	ns	0.042	0.005	*
	Planting	0.038	0.011		0.060	0.010	

ns – non-significant, * - significant at $p < 0.05$

of coppiced sprouts of teak was affected by the origin of teak with coppiced sprouts from stumps after final cutting being better than from stumps after thinning or additional seedlings, whereas coppiced sprouts from stumps after a second thinning were better than from stumps after the first thinning. The study of Thaiutsa et al. (2001) also found that thinning methods did not affect shoot density, but they affected shoot growth. Modified mechanical thinning such as 2:2 mechanical thinning could be the recommended thinning method for faster growth of new shoots if clear cutting could not be applied.

Correlation of diameter of stump and growth of coppiced teak

Stumps after thinning and clear cutting had different diameters. The study showed that the diameter of thinned stumps was 5.0–34.4 cm, whereas the diameter of clear cut stumps was 7.3–38.8 cm. The average diameter was significantly different between these two stump origins (Table 3). The results also indicated that DBH of sprouts from clear cut stumps was 4.11 cm (1.60–6.10 cm) and height was 3.56 m (0.12–6.29 m). The growth of sprouts from thinned stumps was smaller than that from clear cut stumps; DBH was 2.99 cm (0.93–5.80 cm) and height 1.04 m was (0.10–5.10 m). Furthermore, both DBH and height of sprouts of clear cut stumps were positively correlated with stump diameter (r = 0.4393, $p < 0.0001$ and r = 0.5848, $p < 0.0001$, respectively) (Fig. 2). In cases of thinned stumps, it was only the height of sprouts from thinned stumps that was positively correlated with stump diameter (r = 0.2144, $p = 0.0024$) (Fig. 3). This result was similar to the study of Kwame et al. (2014), who found that stump diameter was positively correlated with leader height as well as the number of sprouts, but conversely the study of Akkhaseeworn (2007) showed that the size of the stump did not affect shoot growth.

Conclusion

In the earlier stages, the growth of teak from coppicing regeneration was faster than when it was raised from seedlings, especially when coppicing occurred in the same area with planting. The difference was decreased as teak trees grew older. The growth ability of coppice sprouts of teaks was affected by the source of the teak stump;

Table 3. Comparison of diameter of stump after thinning and clear cutting at Nam Ang Plantation, Uttaradit Province.

	Clear cutting	Thinning	t value	*p* (>t)
Average	22.26	15.36	13.893	<0.0001
S.D.	5.90	4.35		
Max.	7.30	5.00		
Min.	38.80	34.40		

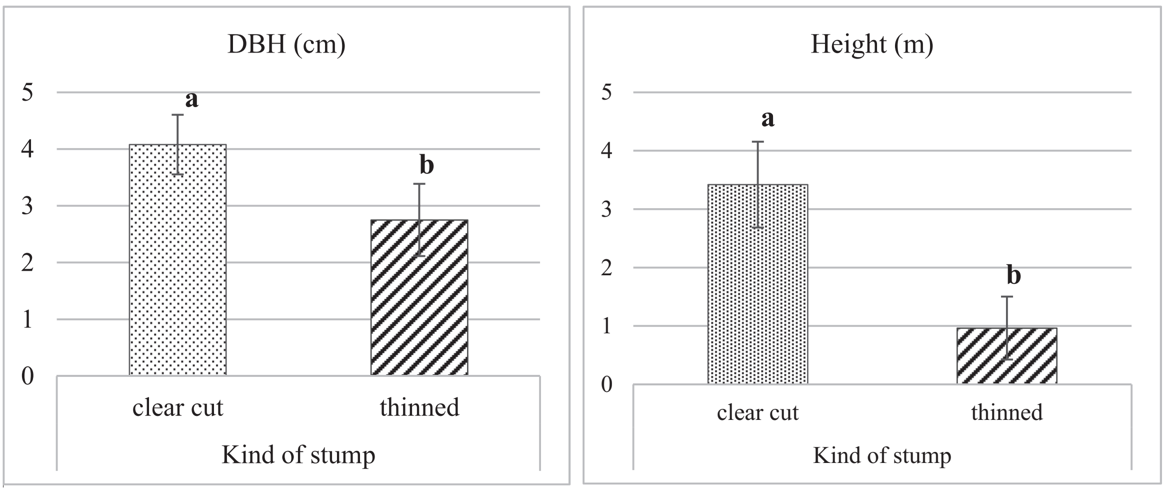

Fig. 1. Average DBH and height of coppiced teak from thinned stumps and clear cut stumps at Nam Ang Plantation, Uttaradit Province; different letters denote significant differences at $p<0.05$; vertical bars indicated standard error.

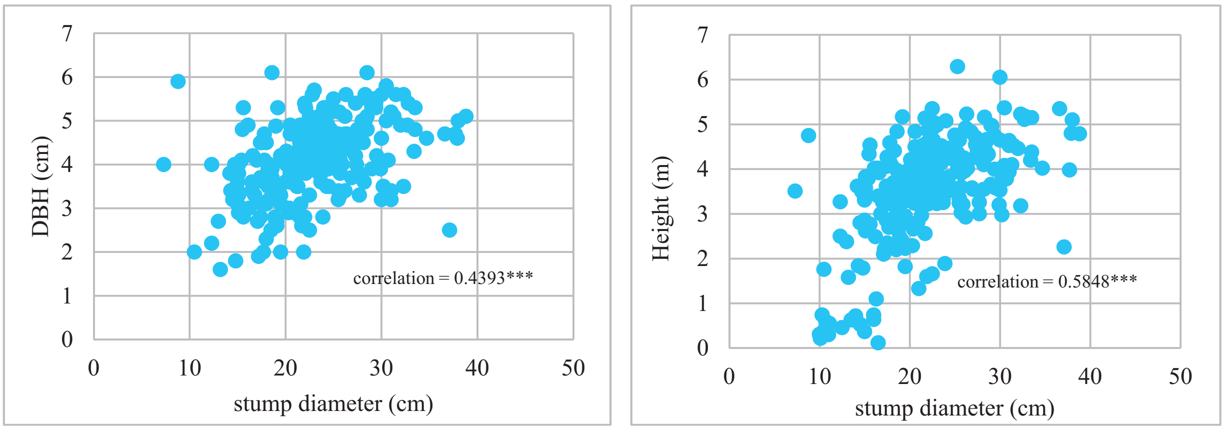

Fig. 2. Relationship between the diameter of clear cut stumps and DBH and height of sprout at Nam Ang Plantation, Uttaradit Province. Correlations with *** are significant at $p<0.001$

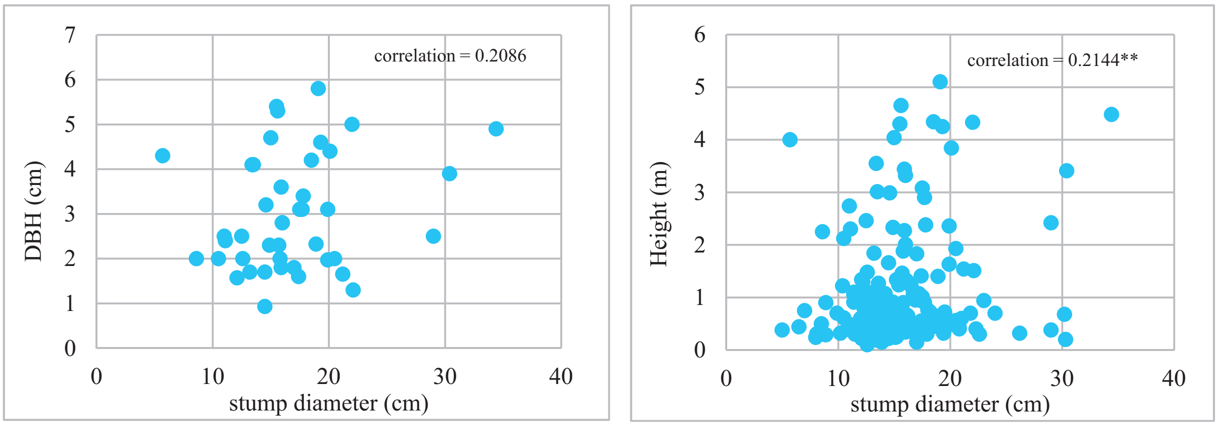

Fig. 3. Relationship between diameter of thinned stumps and DBH and height of sprouts at Nam Ang Plantation, Uttaradit Province. Correlations with ** are significant at $p<0.01$ and *** are significant at $p<0.001$

coppice sprouts from stumps after clear cutting were better than from stumps after thinning. The interaction of stump diameter had a positive impact on the size of coppicing in teak. Coppicing is one of the alternative regeneration systems and has advantages for coppice silviculture, which is very simple in its application, and reproduction from coppicing was usually more reliable and cheaper than reproduction from planting. Furthermore, there were some benefits from minimal soil damage during harvesting, a reduced need for weed management, physical protection of the site, and negligible risk of wind throw. However, management decision are still an important factor.

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