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Original Article

Growth of teak regenerated by coppice and stump planting in Mae Moh Plantation, Lampang province, Thailand

Anatta Auykim,[a] Khwanchai Duangsathaporn,[b] Patsi Prasomsin[b,*]

[a] The Graduate School, Kasetsart University, Bangkok, Thailand
[b] Department of Forest Management, Faculty of Forestry, Kasetsart University, Bangkok, Thailand

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A B S T R A C T

The current annual increment (CAI_{dbh}) and the mean annual increment (MAI_{dbh}) both for the diameter at breast height (1.3 m) were investigated to compare the differences between coppice and stump-planted teak in Mae Moh Plantation. Forty-eight sample cores were collected from a 9 yr-old teak plantation using an increment borer; annual increments were analyzed using dendrochronological techniques. The results indicated that there was no significant ($p > 0.05$) difference in the average diameter at breast height (DBH) between the coppice and stump-planted teak, whereas the total height of stump planting was significantly greater than that of coppice teak. The CAI_{dbh} of coppice teak was in the range 0.316−2.371 cm and continuously decreased throughout the 9 yr period. The CAI_{dbh} of stump planting was in the range 0.162−1.982 cm and continuously increased from the beginning of growth for 5 yr followed by a decline thereafter for 4 yr. The CAI_{dbh} of coppice showed rapid growth in the years 1−4 and was greater than for the stump-planted teak even in years 5−8 after planting; however, the growth of the stump-planted teak in the ninth year was higher than for the coppice. The MAI_{dbh} values of coppice and stump-planted teak were not significantly ($p > 0.05$) different. The results showed that CAI_{dbh} at age 5 yr can be used as a silvicultural guide to increase the yield of teak coppice.

Introduction

Teak (*Tectona grandis* Linn. f.) is one of the most widely planted hardwood timber species in the world (Ball et al., 1999). It is indigenous in Southeast Asia with a discontinuous or patchy distribution of 2.25 million ha at latitudes in the range 9°−25°30′N and longitudes in the range 73−104°30′E (Thaiutsa et al., 2001). In the deciduous forests of Thailand, teaks grow well on deep fertile soil with fine sandy loams and loams in an altitudinal range of 200−750 m above mean sea level (Thaiutsa, 1999). Bhumibhamon (1986) reported that teak was the best economic tree species and consequently was selected as one of the priority plantation species. However, the management of teak plantations is complex due to variations in environmental, social and economic conditions; therefore, government, private and state enterprises have trialed many different practices in teak plantation silviculture, including regeneration, intermediate cuttings and protection (Suwannapinant, 2001).

Planting and regeneration are important practices in teak plantation management; in Thailand, the Forest Industry Organization (FIO), which is the agency responsible for state teak plantations, improved the regeneration system of teak and reduced its rotation period, utilizing two techniques for teak planting and regeneration. The first technique was stump planting, where a stump is a seedling with all leaves and root hairs removed, leaving only the main stem and roots. Stump planting offers several benefits such as being able to be transported considerable distances while maintaining stump viability and being easy and quick to plant; consequently, this technique is used in several countries (Chaudhari, 1963; Thaiutsa, 1999; Midgley et al., 2007). The second technique was coppicing; it utilizes natural regeneration from the cut stump of a harvested tree and can contribute to rapid restoration of forest cover after clear cutting (Sukwong et al., 1976). The primary advantages of coppicing for short rotations are that it is easy, offers a low cost of establishment and accelerates early growth (Bailey and Harjanto, 2005; Chowdhury et al., 2008) and thus, is widely practiced in many countries (Smith, 1962). However the common technique in permanent sample plots for mean annual increment (MAI) analysis involves comparing the teak growth difference between coppice and stump planting by measuring tree diameter at breast height (1.3 m) either over bark or under bark, and there can be errors introduced due to bark moisture differences and bark loss between remeasurements and the delay in obtaining

* Corresponding author.
E-mail address: fforpsp@ku.ac.th (P. Prasomsin).

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timely data for teak plantation management (Prasomsin and Duangsathaporn, 2005). In addition the average growth data provide an average, static value that might overestimate or underestimate tree growth periods over the rotation and the assumed rotation age may be incorrect. If plantations are harvested before or after that assumed rotation age, mean yields will be different.

Current annual increment (CAI) is the difference between the attribute value of interest at the beginning and at the end of a year's growth. It is a useful measure of site quality and forest stand dynamics, which are important factors in sustainable plantation management that vary with age (Prasomsin and Duangsathaporn, 2005), which means the MAI will also vary with age. This study used tree-ring analysis to investigate the CAI as dendrochronology allows rapid analysis of long-term growth data and comparison of the annual increment difference between coppice and stump-planted teak has not been reported in Thailand (Sukwong et al., 1976; Thaiutsa et al., 2001; Akkhaseeworn, 2007).

The objectives of this study were: 1) to investigate teak CAI growth of the diameter at breast height (1.3 m) under bark (CAI_{dbh}) of the coppice system and of the stump-planting system using a dendrochronological technique (tree-ring analysis); and 2) to compare the difference in teak growth in terms of CAI_{dbh} and the mean annual increment growth of the diameter at breast height (1.3 m) under bark (MAI_{dbh}) between coppice teak and stump planting, in order to select suitable planting and regeneration techniques.

Materials and methods

Study site

The study site was located at the Mae Moh Plantation belonging to FIO in Mae Moh district, Lampang province, northern Thailand, at a latitude of 18°25′N and longitude of 99°44′E (Fig. 1). The elevation of the study site was in the range 300–350 m above mean sea level. Means of annual rainfall and temperature in the period 1986–2011 were 1212 mm and 25 °C, respectively. The site was located in the foothills on a flat area and the soil type was sandy clay and slightly acidic with high organic matter. The stand (70.19 ha) was planted at an initial 4 × 4 m spacing. Old records showed that the study site had been clear cut in 2002 and natural regeneration had been allowed to grow from coppice, so this site had two ages of plants—teak from coppice and teak from stump planting with no thinning (Forest Industry Organization, 2012).

Sample collection

The study used the forest inventory line plot system (Sathit, 1982) comprising 35 plots. In each plot, information collected comprised: the regeneration system, each tree total height, each tree diameter at breast height over bark (DBH_{ob}) using a diameter tape and their distribution by diameter classes, with accurate checking of borderline trees, The radius of each sample plot was 12.62 m and the target number of plots was calculated using Eq. (1):

$$n = t^2 cv^2 \Big/ AE^2 \tag{1}$$

where n is the target number of the plots, t is the confidence value at the 95% probability level, cv is the coefficient of variation for DBH_{ob} and AE is the allowable error in the DBH_{ob} which was equal to 0.01 for the current study.

The number of sample plots from a forest inventory should be higher than the target calculation (Prasomsin and Duangsathaporn, 2005). Teak diameter classes were then classified and trees in each class were core sampled (Stokes and Smiley, 1968), using 10 trees per class for the CAI and MAI studies with CAI calculated using Eq. (2):

$$CAI_{dbh} = DBH_{t+1} - DBH_t \tag{2}$$

where CAI_{dbh} is the difference between the growth value measured at the beginning (DBH_t) and end (DBH_{t+1}) of a one-year period (where DBH is the diameter at breast height over bark).

The periodic MAI was calculated by dividing the mean annual increment by the stand age (Eq. (3)):

$$MAI_t = \frac{DBH_t}{t} \tag{3}$$

where MAI_t is the mean annual increment at stand age t years and DBH_t is the diameter at breast height under bark at age t years, with both tree measurements being either over bark or under bark. For the teak trees selected for tree-ring analysis, which were dominant, healthy and far away from watercourses, wood increment cores were collected from the bark to the pith at 1.30 m above the ground using an increment borer. In each tree, two wood increment cores were collected perpendicular to each other. The direction of core collection avoided tension wood (Cook and Kairiukstis, 1990), and wood cores were kept in plastic tubes to prevent them from breaking.

Preparation and measurement of annual ring width

The wood cores were prepared in the Laboratory of Tropical Dendrochronology, Kasetsart University, Faculty of Forestry (LTD–KUFF). Wood cores were ventilated at room temperature and fixed in wooden supports following the standard methods of dendrochronology (Stokes and Smiley, 1968). The fixed core samples were polished with several grades of sandpaper until the transverse surfaces and boundaries of annual rings were clear enough for macroscopic investigation. The growth year of each annual ring was determined using a cross matching technique and ring widths were measured on a tree-ring measuring stage with an accuracy of 0.001 mm. The results of annual ring width analysis were displayed and converted to a table format showing the growth year and ring width in columns using the KU-TRA program (version 1.0.; Laboratory of Tropical Dendrochronology, Faculty of Forestry, Kasetsart University, Bangkok, Thailand) The widths of annual rings were then cross-dated to verify the year of annual ring formation using the COFECHA program (Fritts, 1976).

Data analysis

Data analysis was conducted using the following four steps:

1. The distribution of diameter classes derived from the descriptive statistics was used to describe the characteristics of the selected coppice and stump-planted teak stand.
2. Mean plantation total height and DBH_{ob} of coppice and stump-planted teak were compared using the independent two-sample t-test statistics.
3. Annual ring widths of coppice and stump-planted teak were converted to CAI_{dbh} values using a forest mensuration technique (Prasomsin and Duangsathaporn, 2005).
4. Growth patterns between CAI_{dbh} and MAI_{dbh} of coppice and stump-planted teak were compared using the independent two-sample t-test statistics.

Statistical significance was tested at the ($p < 0.05$) level.