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EFFECT OF THINNING ON GROWTH OF DIFFERENT AGES OF *Eucalyptus camaldulensis* Dehnh. PLANTATION

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ผลของการตัดสางขยายระยะต่อการเจริญเติบโตของสวนป่ายูคาลิปตัส อายุ ๔ ปี และ ๗ ปี ได้ทำการศึกษาที่สวนป่าสมเด็จ จังหวัดกาฬสินธุ์ โดยทำการตัดสางขยายระยะจากระยะปลูกเดิม ๒×๘ เมตร (S_0) ไปเป็น ๔×๘ เมตร (S_1), ๒×๑๖ เมตร (S_2) และ ๘×๘ เมตร (S_3)

จากการศึกษา โดยอาศัยค่าที่ใช้ประเมินการเจริญเติบโตต่าง ๆ ได้แก่ relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI) และ crop growth rate (CGR) พบว่าการตัดสางขยายระยะมีผลต่อการเจริญเติบโตของต้นไม้ ทั้งที่มีอายุ ๔ ปี และ ๗ ปี กล่าวคือ แปลงที่มีการตัดสางขยายระยะเจริญเติบโตได้ดีกว่า

อย่างไรก็ดี สวนป่ายูคาลิปตัสอายุ ๗ ปี แสดงการตอบสนองต่อการตัดสางขยายระยะได้ดีกว่า สวนป่าอายุ ๔ ปี ในสวนป่าอายุ ๔ ปี ความแตกต่างของการเจริญเติบโตมีนัยสำคัญเฉพาะเมื่อตัดสางขยายถึง ๘×๘ เมตร (S_3) แต่สำหรับสวนป่าอายุ ๗ ปี ไม่ว่าจะตัดสางออกเพียง ๔×๘ เมตร (S_1) หรือ ๒×๑๖ เมตร (S_2) หรือ ๘×๘ เมตร (S_3) ก็จะมีความแตกต่างจากแปลงควบคุมอย่างมีนัยสำคัญ

จากผลการศึกษา แสดงให้เห็นว่าในสวนป่ายูคาลิปตัสซึ่งปลูกด้วยระยะปลูก ๒×๘ เมตรนั้น เมื่อมีอายุมากขึ้นถึง ๗ ปี จำเป็นที่จะต้องมีการตัดสางขยายระยะเพื่อปรับปรุงการเจริญเติบโตของต้นไม้แล้ว แต่สำหรับเมื่อมีอายุ ๔ ปี ยังไม่มีความจำเป็นที่จะต้องกระทำ เนื่องจากการเจริญเติบโตของต้นไม้ที่ไม่มีการตัดสางขยายระยะยังดีอยู่

ABSTRACT

The role of thinning in Thailand's forest village plantations, Somdet, Kalasin province, was assessed. Specifically, the study sought to investigate the post-thinning situation in 4-year-old and 7-year-old *Eucalyptus camaldulensis* plantations, particularly the response of the tree stands. In this case, tree stands with an initial spacing of 2 m × 8 m were thinned to three spacing levels: 4 m × 8 m, 2 m × 16 m, and 8 m × 8 m.

Application of thinning affected tree growth. Based on the growth parameters: relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI), and crop growth rate (CGR), thinning of stands with an original spacing of 2 m × 8 m (S_0) to 4 m × 8 m (S_1), 2 m × 16 m (S_2) and 8 m × 8 m (S_3) showed better growth in both the 4-year-old and the 7-year-old plantation. However, trees in the 7-year-old plantation were found to be more sensitive to thinning than those in the 4-year-old plantation. The trees in the 4-year-old plantation showed significant difference only between the highly thinned stand (S_3) and the unthinned stand (S_0), but trees in the 7-year-old plantation showed significant differences between the thinned group (S_1, S_2, S_3) and the unthinned stand (S_0).

The study recommends that thinning should not be applied in 4-year-old plantation if the purpose is just to enhance growth of tree stands, but it was shown to be essential in 7-year-old plantation.

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INTRODUCTION

Presently, *Eucalyptus camaldulensis* is most popular species for north-east reforestations both under the government agencies and private sectors. This is because of its superior characteristics such as fast growth, high coppicing power, ability to tolerate water logging, salt tolerance and high calorific value (FAO, 1979). In addition, it has shown high market demand.

In forest village plantations, trees are commonly intercropped with food crops, the spacing of *E. camaldulensis* is therefore somewhat wider than that of traditional planting, namely : 2m. × 8m. However, this spacing could sufficiently provide space for intercropping within only three years after planting, since the tree canopies become closed after the third years. Therefore, if the reforestation area can not be further extended and the intercropped situation is essential, thinning may be the appropriate alternatives. Nevertheless, thinning at the appropriate time would improve the quality and growth of the residual stands.

This study has purpose to compare growth of young (4 years) and old (7 years) *E. camaldulensis* after thinning. It intends to suggest about thinning in the plantations as well.

MATERIALS AND METHODS

1. Study Area

The Somdet plantation, Kalasin province, was the study area. It is about 513 km. from Bangkok. The rainfall was annually about 1,380.6 mm. with the highest of 281.7 mm. in September. Soil is a fine sandy-loam with some increase in clay content with depth. (Jamroen prucksa, 1988).

2. Experimental Design

The same design, randomized complete block design (RCBD) with four treatments and three replications, and layout was implemented in two different ages of the plantations, namely, the 4-year-old plantation and 7-year-old plantation.

The four treatments were coded as follows :

S_0 = stand with no thinning (original spacing of 2m. × 8m.)

S_1 = stand subjected to thinning (the spacing became 4m. × 8m.)

S_2 = stand subjected to thinning (the spacing became 2m. × 16m.)

S_3 = stand subjected to thinning (the spacing became 8m. × 8m.)

2.1 Block layout. Experimental plots were selected from plantations representing two ages : 4-year-old plantation and 7-year-old plantation. Each of three blocks then was laid out over the rows of trees as shown in Figure 1.

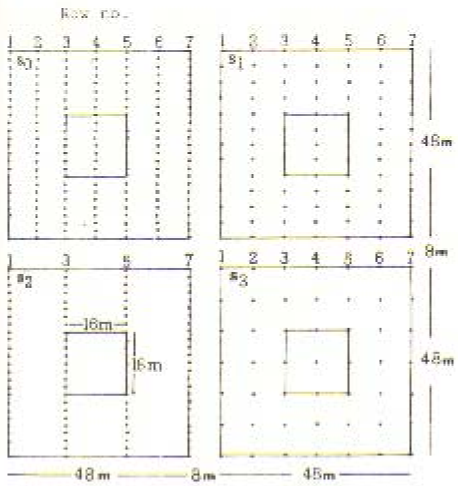

Figure 1 Diagram of the characteristics of the experimental blocks.

Each block consisted of four plots (representing the four spacing or thinning treatments) lying side by side as seen in the figure. Each plot, 48m. × 48m., covered 7 tree rows that were spaced 8m. from each other. At the center of each plot, a smaller subplot of 16m. × 16m. (called "data plot") was established and fenced in order to keep it as the representative plot for each treatment. The area outside the data plot was considered as the buffer according to the traditional design.

2.2 Assignment of thinning. When the block was established, as described above, each of the main plots was given a 3-digit number. The first digit refers to the age of the plantation (4 or 7 only), the middle one refers to the replication (1 up to 3), and the last one refers to the number of the data plot (1 up to 4). Thus, Plot No. 712 signifies that it is a 7-year-old plantation, replication No. 1, and data Plot No. 2. The assignment of treatments (last digit) was done randomly.

3. Data collection and Computation

The data collection was done twice : at the beginning (May 25, 1987) and at the end of the study (February 5, 1988), or interval of 256 days. Tree growth was based on the diameter increment in the said interval. Tree biomass and tree volume were estimated using allometric equations, while leaf area was determined in the laboratory from leaf samples collected.

3.1 Tree growth. At the beginning of the experiment, before thinning was applied, the diameter at breast height (D) and height (H) of all the trees in the experimental plots were measured using a diameter tape and a Haga altimeter. At the end of the study, only the diameters at breast height of all the trees were measured, since their heights were estimated by the allometric equations.

3.2 Stand production. Stand biomass or biomass of standing trees is the summation of the individual tree's biomass within a certain plot. For individual tree, the biomass can be computed through the following equations,

$$H = 2.63148\,(D)^{0.6507} \quad (1)$$
$$(r^2 = 0.578^{**})$$
$$V_S = 0.00009\,(D^2H)^{0.9983} \quad (2)$$
$$(r^2 = 0.998^{**})$$
$$W_S = 0.03614\,(D^2H)^{0.9246} \quad (3)$$
$$(r^2 = 0.993^{**})$$
$$W_B = 0.00205\,(D^2H)^{1.0542} \quad (4)$$
$$(r^2 = 0.820^{**})$$
$$W_L = 0.00222\,(D^2H)^{0.9681} \quad (5)$$
$$(r^2 = 0.833^{**})$$

where D and H represent diamerer at breast height (cm.) and height (m.); W_S, W_B, and W_L represent stem, branch, and leaf biomass (kg.), and V_S represents stem volume ($m.^3$). Equation (1) is the allometry of H and D constructed from a large number of observations, i.e., 647 standing trees from all 24 data plots measured carefully at the onset of the study.

Through equation (1), the standing trees' individual heights can be obtained. Similarly, equations (2), (3), (4), and (5) can be used to obtain stem volume, stem biomass, branch biomass, and leaf biomass, respectively.

3.3 Growth quantities. Based on the data available, relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI) and crop growth rate (CGR) were computed using the method described by Hunt (1982).

RESULTS AND DISCUSSION

1. Diameter Increment

During the 256-day interval, tree growth based on diameter increment had observed twice. There was a marked difference between the 4-year-old and 7-year-old plantations, and also between the thinned spacing within the same plantation ages. From the allometric point of view, diameter is the vital parameter for this study. All production of trees estimated by allometric equation in the study stemmed from it. Specifically, all of the productions were estimated by D^2H as independent variable and H was derived from the allometric equation having D as independent variable. Changes of diameter will, therefore, definitely affect the production of individual trees and the whole stand.

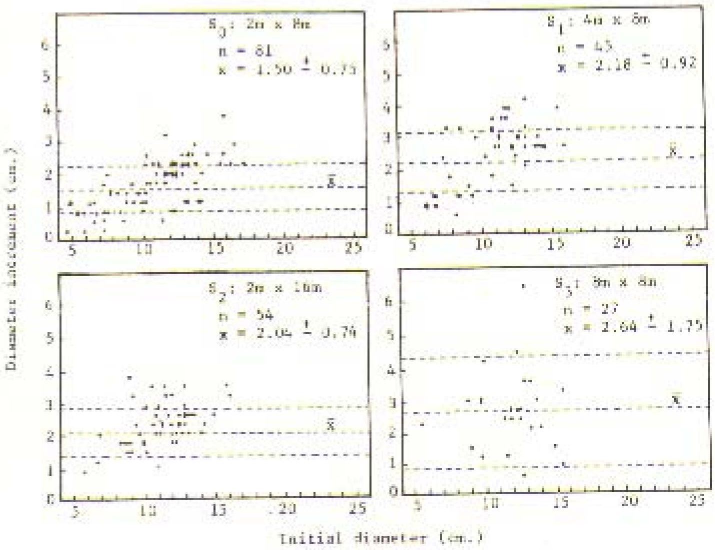

Figure 2 Diameter increment of the 4 – year – old *E. camaldulensis*, stand subjected to different degrees of thinning, During the 256 – day period of study.

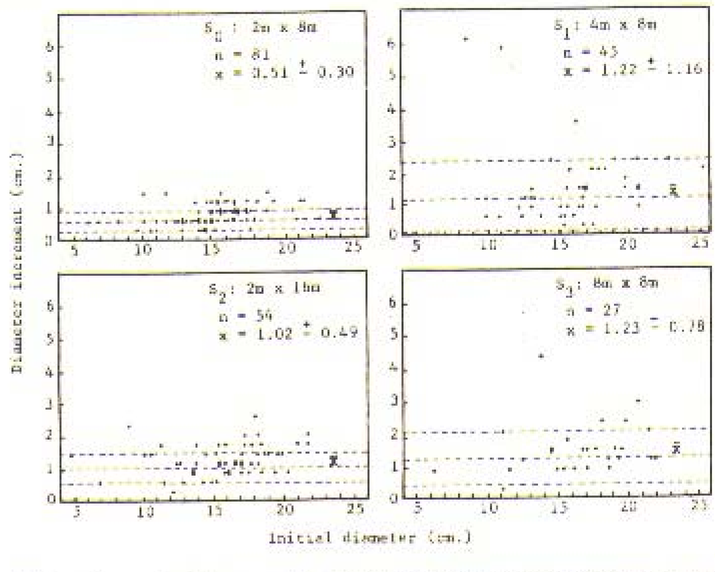

Figure 3 Diumeter increment of 7 – year – old *E. camaldulensis*, subjected to different degrees of thinning, in the 265 – day period of sutdy.

Figures 2 and 3 illustrate the relationship of the tree size (diameter) and its increment for the 4-year-old and 7-year-old plantations, respectively. Each of the figures consists of four scattering diagrams belonging to the stands subjected to different thinnings, i.e., S_0 (2m. × 8m.), S_1 (4m. × 8m.), S_2 (2m. × 16m.), and S_3 (8m. × 8m.). Each scatter diagram is the plot of tree diameter at the first observation and the increment of the stands for the three respective replications. The common difference among the scatter diagrams is in the number of plots which correspond to the number of trees in the data plot. In a replication, number of trees in the data plot belonging to S_0, S_1, S_2 and S_3 stand are 27, 15, 18, and 9 trees in that order. They, therefore, become 81, 45, 54 and 27 trees for the total three replications.

1.1 In the 4-year-old plantation. The average in diameter increment ranged from 1.50 cm. in S_0 to 2.64 cm. in S_3. Most of the trees got diameters greater than 10 cm., but not more than 18 cm. It was observed that the trees with larger diameter are most likely to get larger increment in all stands (see Figure 2). The control stand (S_0) got a low average increment compared to the thinned stands (S_1, S_2, S_3) which got higher average increments. This should be attributed to the thinning application that helped provide the factors enhancing growth of the stands and at the same time significantly reduce the competition among trees in the stand.

In the control stands where no thinning was applied, the 4-year-old plantation showed evidently some sort of competition among trees within the stand. Larger trees (more than 10 cm. in DBH) grew in diameter about two times higher than the smaller trees. Thus, on graph this situation is likely to exhibit a linear relationship between the initial diameter and its increment in the S_0 stand. This shows that the larger trees would be able to take advantage of the site at the expense of the smaller ones. From the silvicultural point of view, the age of 4 years is not the right time to conduct thinning in *E. camaldulensis* plantations since trees in this plantation age are still growing relatively well in their diameter. However, exceptions to the rule are such other reasons for thinning as the demand of small trees, need of the land for agriculture, and so on.

With regards to the diameter growth among the stands subjected to thinning, stand S_3 (thinned to 8m. × 8m.) had a diameter increment greater than the others. Nevertheless, there seems to be no relationship here between tree diameter and its increment since no matter how big or small, diameter would not be significantly different unlike those of stands S_1 and S_2. This may be attributed to the wider spacing which enables the trees in the stand to receive more sunlight.

On the other hand, stand S_3's spacing of 8m. × 8m. provides sufficient space to the stand and enables all trees within the stand to have the same chances of being affected by the growth factors especially light intensity. In this case, therefore, smaller trees which usually bear relatively large amounts of leaves are able to function efficiently.

1.2 In the 7-year-old plantation (see Figure 3). The trees are bigger in diameter compared to those in the 4-year-old plantation and distributed over a wider range of about 5 to 25 cm. The average diameter increment of trees in stands S_1, S_2 and S_3 were 0.51, 1.22, 1.03 and 1.23 cm. in that order. Similarly, the trees in the 4-year-old plantation that have been subjected to thinning increased in diameter greater than those in the control stand. In addition, in the control stand S_0, trees with bigger diameter increased in diameter almost 2 times more than the smaller trees. Most of the increment above the average are likely to have diameters of more than 15 cm. This also showed some linear relationship between the diameter and the increment. The attribute of larger trees having greater increment is similar to that for stand S_3 in the 4-year-old plantation. That is to say that the larger trees are capable of competing for growth factors better than the smaller trees.

Comparatively, thinning has more influence on the growth of the 7-year-old plantation than that of the 4-year-old plantation, although all stands in the 4-year-old plantation have higher increment. In Table 1, diameter increments of the two plantations are shown comparatively.

Table 1. Average diameter increment and relative increment of thinned (Si) and unthinned (So) 4-year-old and 7-year-old *E. camaldulensis* plantations.

SPACING (m × m)	4-YEAR		7-YEAR	
	Increment (cm)	Si/So ratio	Increment (cm)	Si/So ratio
S_0 – 2 × 8	1.50	1.0	0.51	1.0
S_1 – 4 × 8	2.18	1.45	1.22	2.39
S_2 – 2 × 16	2.04	1.36	1.03	2.02
S_3 – 8 × 8	2.64	1.76	1.23	2.41

As far as the effect of thinning is concerned, growth of the stand before and after the operation should be compared in order to understand the dynamics of the stand subjected to different degrees of thinning. In terms of absolute increment, which is the net increment at a time interval disregarding age and size of trees in a stand, the 4-year-old plantation showed evidently higher increment over those of the 7-year-old plantation. Even the largest increment of the 7-year-old plantation in stand S_3 is still smaller than the lowest increment of the 4-year-old plantation in S_0. This does not mean that the stands of the 7-year-old plantation are less sensitive to thinning than those of the 4-year-old plantation. On the contrary, considering the Si/So ratio or the corresponding increment of each stand divided by that of stand S_0, the ratio of each stand is the 7-year-old plantation (except) for S_3) is greater than those of the 4-year-old plantation. The ratio are 1.0, 2.39, 2.02 and 2.41 for the S_0, S_1, S_2, and S_3 stands for the 7-year-old plantation, and respectively 1.0, 1.45, 1.36 and 1.76 for those of the 4-year-old plantation. This should imply that the 7-year-old plantation is likely to respond very well to thinning and is more sensitive than the 4-year-old plantation. It coincides with the finding that the diameter increments of the trees in the 7-year-old stand subjected to thinning were more than 2 times greater than the control stand, while those of the 4-year-old plantation were only about 1.76 or less.

These results should account for the effect of thinning on the growth of stands especially the old-age stands where crown competition predominates. Thinning in 7-year-old plantation stands would dramatically enhance growth of the trees, although done in a small degree such as in the S_1 and S_2 stands. This is probably because prior to thinning, the 7-year-old plantation had trees with dense crown or with leaves so close together causing mutual shading such that sunlight can hardly get through and thus result in inefficient photosynthesis. Thus, when the crowns were thinned sufficiently to provide enough light distribution over the leaves, a dramatic change occurred in the trees, resulting in a high relative increment among the stands. For the 4-year-old plantation, thinning also enhanced growth of the stands although to a lesser degree. This may be because the trees in the 4-year-old stand have leaves relatively exposed to sunlight in their crown. Although the light distribution over the leaves was increasing due to thinning, it was relatively smaller in degree thus bringing about the relatively lesser increment among the stands as compared to the 7-year-old plantation.

2. Leaf Area Index, Crop Growth Rate and Net Assimilation Rate

Leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) are well-known growth quantities used to determine the significance of any differences between treatment on a 'per crop' basis. Nevertheless, in the study of per crop basis, net assimilation rate provides exactly the same information as it does in the study of the growth of individuals (Hunt, 1978).

LAI, CGR and NAR of the 4-year-old and 7-year-old stands subjected to different thinning are summarized in Table 2. RGR is also presented for comparative purposes.

Table 2. Leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR) of 4-year-old and 7-year-old plantations subjected to different thinnings.

ATTRIBUTES	YEAR	S_0 2m × 8m	S_1 4m × 8m	S_2 2m × 16m	S_3 8m × 8m
LAI	4	1.1964^{a}	0.6992^{b}	0.6373^{b}	0.3951^{b}
	7	2.1908^{a}	1.3706^{b}	1.2636^{b}	0.7320^{c}
NAR	4	1.3820^{a}	1.6510^{a}	1.6200^{a}	1.820^{a}
	7	0.4111^{a}	0.7314^{a}	0.6362^{a}	0.7066^{a}
CGR	4	1.5040^{a}	1.1280^{a}	1.0013^{a}	0.7022^{a}
	7	0.7205^{a}	0.9664^{a}	0.7777^{a}	0.6844^{b}
RGR	4	0.5186^{a}	0.6723^{ab}	0.6570^{ab}	0.7410^{a}
	7	0.1267^{a}	0.2802^{a}	0.2434^{a}	0.2718^{a}

Note : Comparison by column ; DMRT 5%

Unit : LAI = $m^2 \cdot m^{-2}$, NAR = $kg \cdot m^{-2} \cdot yr^{-1}$, CGR = $kg \cdot m^{-2} \cdot yr^{-1}$, RGR = $kg \cdot kg^{-1} \cdot yr^{-1}$

From Table 2, it is obvious that the LAI of the 4-year-old plantation were lower than those of the 7-year-old plantation, but reversely the NAR and CGR of the 4-year-old plantation were higher than those of the 7-year-old plantation.

This phenomenon shows evidently that 7-year-old plantations have a relatively slower growth, as indicated by lower NAR, or even in terms of productivity which is indicated by the less value of CGR. This may be attributed to the high competition among the bigger trees within the stand coupled with the ontogeny of trees. Specifically, the trees' growth mostly follows the sigmoid curve; while trees are young they grow at a fast rate up to a certain period, then their growth gradually declines. Thus, silvicultural management should be done in some way to improve and earn more benefit from the stands through time.

Comparing the stands subjected to different thinning, LAI of both the 4-year-old plantation and 7 year-old plantation decreased as the spacing become wider. LAI was highest in the S_0 stand and lowest in the S_3 stand. This is logical, since by definition, LAI is the total leaf area of the crops divided by the ground area they occupy. As the number of trees or leaf biomass decreases through thinning but the ground area is fixed, the LAI similarly decreases.

If the attributes LAI, NAR and CGR of stands subjected to different thinning are rearranged in descending order, a less complicated interpretation would come out (see Table 3).

In Table 3, the stands belonging to the same line have statistically non-significant differences. On the other hand, those that are not on the same line have statistically significant differences. The stands appearing on the left hand side have higher attributes than those on the right hand side.

From Table 3, it is clear that thinning affects the performance of 4-year-old stands and 7-year-old stands in different ways. In terms of crop growth or productivity, the 7-year-old stands are likely to be very sensitive to thinning.

Table 3. Leaf area index (LAI), net assimailation ratio (NAR) and crop growth rate (CGR)

ATTRIBUTES	HIGHER	TO	LOWER	
		For 4-year-old stands		
LAI	S_0	S_1	S_2	S_3
NAR	S_3	S_1	S_2	S_0
CGR	S_0	S_1	S_2	S_3
		For 7-year-old stands		
LAI	S_0	S_1	S_2	S_3
NAR	S_1	S_3	S_2	S_0
CGR	S_1	S_3	S_2	S_0

2.1 In 4-year-old plantation. LAI or leaf area index of stand S_3 was logically the lowest but it was not significantly different from the other thinned stands. This was because the density of S_3 was 50% lower than that of S_1 or S_2. The relative growth rate (RGR) and net assimilation rate (NAR) may have to be taken into account. LAI in this respect is the mean leaf area index which is the average of the leaf area at the beginning and at the end divided by the plot area. Because stand S_3 was subjected to the highest degree of thinning and because its trees were still young, it was able to produce leaves more rapidly than the other stands. This attribute was confirmed by stand S_3's highest RGR and NAR (See Table 2). The highest leaf growth rate of S_3 came out to be equal to the others, particularly stands S_2 and S_1. Hence, the LAI of the thinned stands were not statistically significant difference.

Considering net assimilation rate (NAR), it can be seen that such thinning operation did not affect much the net assimilation rate of 4-year-old stands. NAR is defined as the net gain in weight per unit of leaf area. It is a measure of the average photosynthetic efficiency of leaves in a crop community. It is hightest when the plants are small and most of the leaves are exposed to direct sunlight (Gardner, 1985). As observed in Table 3, there are no significant differences of NAR among the different stands of the 4-year-old plantation. This shows that thinning in this plantation did not enhance much the efficiency of the crowns to produce more dry matter. On this contrary, the existing space is still sufficient for trees to receive sunlight in order to continue their rapid growth. However, more thinning would likely result in higher NAR as in stand S_3.

Crop growth rate (CGR) of the 4-year-old stands is positively correlated with LAI. This means that stands with high LAI will give high values of CGR. In this situation LAI is negatively associated with NAR, and so since CGR is approximately equal to NAR × LAI, therefore CGR of the stands is not significantly different.

Is it all right or suitable then that thinning be done in the 4-year-old plantation? The answer to this depends on the objectives of the manager. If the value of CGR determines what degree of thinning should be done if needed, it can be seen that any type of thinning can be applied. After all, thinning will not lower the value of CGR in any way.

2.2 In 7-year-old plantation. The order of LAI in this plantation is the same as that of the 4-year-old plantation. The largest LAI belongs to stand S_c and the smallest belongs to S_3. Unlike the 4-year-old plantation, the LAI of S_c was significantly larger than those of S_2 and S_3. Those of S_2 and S_1 were also significantly larger than that of S_3 in the statistical point of view. This phenomenon conforms with the assumption that the LAI decreases as the spacing increases especially at the early application of thinning.

Considering the NAR of the 7-year-old plantation, thinning affected much the efficiency of the tree crowns to produce dry matter. Thus, the NAR of thinned stands was significantly higher than that of the control stand S_c. Nevertheless, those of thinned stands were not significantly different. It is evident that the 6-year-old plantation established with the initial spacing 2m. × 8m. needs some thinning to provide the trees's crowns wider space for receiving more sunlight.

In terms of productivity or crop growth rate (CGR), there were two significantly different groups. First group were stands S_1 and S_2 and the second group were stands S_3 and S_0. The first group has higher CGR than the second group. Although stand S_3 had higher NAR than S_c, The LAI of S_3 was much less than that of S_0. There is thus no significant difference between the CGR of S_3 and S_c, even if the CGR of the former stand was proven to be lower.

Based on the results, it is recommended that the application of thinning in the 7-year-old plantation should be a necessity to obtain more productivity. Thinning from 2m. × 8m. to either 4m. × 8m. or 2m. × 16m. would result in a crop growth rate that is 50% higher than those of the unthinned stands. Otherwise, if wood production is extremely demanded, thinning to 8m. × 8m. is feasible since the crop growth rate of the stand to be thinned will be any way not be less than that of the unthinned stand. In contrast, if the stand will remain unthinned, the growth of the stand will not improve and many of the trees will not reach the desired economic sizes. In addition, in terms of agrisilvicultural management, the thinning should be applied considerably to lessen the pressure on the land and to enhance intercropping activities in productive areas where fallowing and agroforestry can be practiced.

CONCLUSION

The diameters of the trees in the 4-year-old and the 7-year-old plantation were about 10.7 ± 2.8 and 15.3 ± 3.4 cm., respectively. The periodical annual increment (PAI) would be 1.5 cm. per year. The small-size trees (diameter less than 4 to 6 cm.) were observed in both plantations, which may be attributed to the intraspecific competition and replanting due to the mortality.

Trees with larger diameter are most likely to get larger increment in all stands. Those in the 4-year-old plantation increased their diameter by approximately 1.50 ± 0.75 cm., while those in 7-year-old plantation by approximately 0.51 ± 0.30 cm. However, the 7-year-old plantation was relatively more sensitive to thinning than the 4-year-old plantation. This is confirmed by the relative growth rate (RGR). Specifically, in the 4-year-old plantation, there is a transition of relative growth rate at the S_1 and S_2 stands, but in the 7-year-old plantation, there is a distinction between the RGR of the control stand (S_0) and the thinned stands (S_1, S_2, S_3).

Based on net assimilation rate (NAR), the stands of the 4-year-old plantation showed evidently much more efficiently in producing dry matter than those of the 7-year-old plantation. However after thinning, the NAR of the 7-year-old stand increased markedly. This, therefore, suggests that thinning should be done in 7-year-old plantations to enhance tree growth and get more benefit, while in 4-year-old plantations thinning depends on the manager's decision.

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