Original article

Size Distribution and Morphological Damage to 17-Year-Old *Hopea odorata* Roxb. Planted in Fast-Growing Tree Stands in Northeast Thailand

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ABSTRACT

The size distribution, morphological damage and climbing of lianas were investigated in 17-year-old *Hopea odorata* Roxb. which were planted in fast-growing tree stands at the Sakaerat Silvicultural Research Station in northeast Thailand. *Eucalyptus camaldulensis*, *Acacia auriculiformis*, and *Senna siamea* were planted as nurse trees in 1987 at spacings of 4 x 8 m, 2 x 8 m, 4 x 4 m, and 2 x 4 m. Seedlings of *H. odorata* were planted in the nurse tree stands at a uniform spacing of 4 x 4 m in 1990. In 1994, the stem numbers of nurse trees were thinned by half in the stands with spacing 2 x 8 m and 2 x 4 m. The diameter at breast height (DBH) and height of all the *H. odorata* were measured, and morphological damage to stems and climbing of lianas were checked in 2007. *H. odorata* grew well in *S. siamea* stands and the control plots (no nurse trees) showed a wide-ranging and irregular distribution of DBH, whereas the *H. odorata* remained small in the *E. camaldulensis* and the *A. auriculiformis* stands, with DBH showing a narrow bell-shaped distribution. The survival rate of *H. odorata* varied among replicates, and was high in plots near a forest road. *H. odorata* in a control plot located closest to the forest road and used for exhibition purposes suffered less damage. This implies that continuous care of a forest plantation is critical for maintaining its health. Morphological damage to *H. odorata* and climbing of lianas was high in the *E. camaldulensis* and *A. auriculiformis* stands, accounting for over 40% of all stems, whereas it was low in the control plots. The ratio of damaged *H. odorata* tended to decrease as DBH increased, suggesting that larger trees were less vulnerable to damage.

Keywords: climbing plants, forest health, nurse tree, two-storied forest management

INTRODUCTION

The shortage of natural wood resources in Indochina has led to an increased interest in the potential of indigenous trees for both timber production and rehabilitation of degraded forests. However, few silvicultural techniques for indigenous tree species have been established, due to the lack of silvicultural history and information on growth properties and/or site suitability (Montagnini and Jordan, 2005). Two-storied forest management is one option for growing indigenous tree species, since it provides suitable light conditions for seedlings during their initial stages of growth (Fujimori, 2001). Hence, this method allows diverse forest products to be harvested at different times that could provide a steady flow of profits to forest planters (Montagnini and Jordan, 2005).

Sakai *et al*. (2009) have reported on the survival and growth processes of *Hopea odorata* Roxb. planted in various fast-growing nurse tree stands over the past 17 years. According to the study, of three fast-growing tree species (*Eucalyptus camaldulensis, Acacia auriculiformis* and *Senna siamea*), *S. siamea* has proved to be the most suitable nurse tree, with both high survival and growth rates of the *H. odorata*. In addition, they concluded that *H. odorata* can be grown successfully if nurse trees (even *E. camaldulensis* and *A. auriculiformis*) are removed at the correct time (Sakai *et al*., 2009). This study evaluated the growth performance using the mean DBH, mean tree height and stand basal area. However, to produce high quality timber, the health of individual trees needs to be taken into account. In particular, the control of climbing plants (lianas) is important for forest management in tropical areas, since the climbers often infest forest plantations and cause serious damage to the trees (Richards, 1996).

The current paper aimed to study the stand structure and damage regimes of 17-year-old *H. odorata*, which were not described in the previous study (Sakai *et al*., 2009). The current study focused on the following issues: 1) to survey the DBH distribution pattern of *H. odorata* depending on the treatment (three nurse tree species and four nurse tree spacings), 2) to survey the pattern of damage to *H. odorata* and the amount of climbing by lianas in each treatment and 3) to suggest a suitable method for forest management based on an analysis of the pattern of the DBH distribution and damage to the *H. odorata* trees.

MATERIALS AND METHODS

Site descriptions

The study site was located at the Sakaerat Silvicultural Research Station (14° 29′60″N, 101°54′19″E, 420 m above sea level), Nakhon Ratchasima Province, northeast Thailand. According to meteorological data at the Station (1982-2007), the mean annual air temperature is 26.4 °C and the mean annual rainfall is 1,025 mm. The region has a monsoon climate with highly seasonal rainfall and a roughly four-month dry period from November to February. The soil is a deep loamy Acrisol formed on sandstone. The study site was previously covered with a dry evergreen forest, but by the 1960s had been converted into farmland. The farmland was abandoned later, due to low productivity and was then colonized by tall grasses (*Imperata cylindrica* and *Saccharum spontaneum*), until the 1980s. An afforestation project by JICA (Japan International Cooperation Agency) started in 1982 and the area was converted into exotic fast-growing tree plantations (Sakai *et al*., 2009). During the JICA Project, several experimental plots for indigenous tree plantation were established. The current study utilized one of these plots.

Plot design and study method

Three plots (Plot 1, Plot 2 and Plot 3), each measuring 200 x 80 m were set up as replicates (Figure 1). Each plot was divided into five equally-sized sections, each of which was planted to one of four fast-growing tree species (*Eucalyptus camaldulensis, Acacia auriculiformis, Senna siamea* and *Sesbania grandiflora*) or left bare as a control plot (no nurse trees). Because most of the *Sesbania grandiflora* died in the first four years, the plots involving this species were excluded from the analysis. Each section was divided into four blocks measuring 40 x 20 m, each of which was planted at one of four spacings: 4 x 8 m, 2 x 8 m, 4 x 4 m and 2 x 4 m. The control section was also divided into four blocks. *H. odorata* seedlings were planted in every block of every section at a uniform spacing of 4 x 4 m. Plots 2 and 3 were located in parallel, with Plot 1 at right angles to other Plots. A forest road is located near Plot 1.

Fast-growing trees were planted in 1987. *H. odorata* seedlings, raised in the nursery at the Sakaerat Station, were planted in August 1990. Weeds were cut down until the canopy had closed in all the plots. To promote the growth of *H. odorata*, in early 1994, thinning was carried out in the plots with 2 x 8 m and 2 x 4 m spacing by removing every alternate tree (Figure 1). The study plots were abandoned after terminating the JICA Project, except for the control plot in Plot 1, which was closest to the forest road and was used for exhibition purposes.

The DBH and tree height of each *H. odorata* tree were measured in 2007. Each *H. odorata* tree was checked for morphological damage to the tree stem (such as stem breakage and top dying) and the presence of climbing lianas.

To detect statistical differences due to spacing and among replicates of the nurse tree species, Tukey's honestly significant difference (HSD) test was applied to the DBH and height of *H. odorata* trees. A histogram of the DBH distribution was constructed for each treatment and Pearson's chi-square test was applied to check whether the ratio of damaged stems was affected by the DBH size class. The JMP statistical discovery software (SAS, 2000) was used to conduct Tukey's HSD test and the chi-square test.

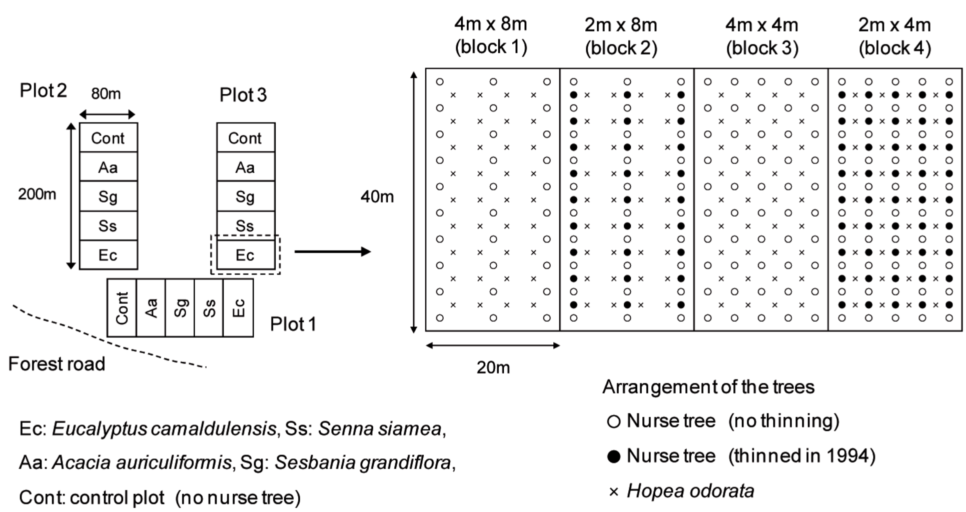

Figure 1 Layout of the study plots.

RESULTS AND DISCUSSION

Survivorship and size of *H. odorata*

The survival rate of the *H. odorata* tended to be high with the nurse tree spacing of 2 x 8 m, and low at the 2 x 4 m spacing (Table 1). Survival rates varied widely among the plots (replicates), having a tendency to be high in Plots 1 and 2 and low in Plot 3. The difference occurred due to the spacing being approximately double or greater in the 4 x 4 m and 2 x 4 m spaced-plots in the *E. camaldulensis* and *A. auriculiformis* stands. Survival rates in the control plots (no nurse trees) also varied widely, especially in Plot 1.

Table 1 Survival rate of 17-year-old *Hopea odorata* grown in fast-growing tree stands.

Nurse tree species	Spacing of nurse trees (m)	Survival rate (%)			
		Plot 1	Plot 2	Plot 3	Mean ± SD.
Eucalyptus camaldulensis	4 x 8	58.3	80.6	44.4	61.1 ± 18.2
	2 x 8 (thinning)	69.4	88.9	66.7	75.0 ± 12.1
	4 x 4	50.0	66.7	33.3	50.0 ± 16.7
	2 x 4 (thinning)	33.3	69.4	44.4	49.1 ± 18.5
Acacia auriculiformis	4 x 8	72.2	58.3	44.4	58.3 ± 13.9
	2 x 8 (thinning)	80.6	66.7	63.9	70.4 ± 8.9
	4 x 4	69.4	50.0	33.3	50.9 ± 18.1
	2 x 4 (thinning)	52.8	25.0	27.8	35.2 ± 15.3
Senna siamea	4 x 8	77.8	66.7	69.4	71.3 ± 5.8
	2 x 8 (thinning)	88.9	83.3	66.7	79.6 ± 11.6
	4 x 4	69.4	77.8	58.3	68.5 ± 9.8
	2 x 4 (thinning)	52.8	63.9	50.0	55.6 ± 7.3
No nurse trees (control)	block 1	80.6	55.6	61.1	65.7 ± 13.1
	block 2	83.3	69.4	55.6	69.4 ± 13.9
	block 3	66.7	55.6	63.9	62.0 ± 5.8
	block 4	72.2	30.6	50.0	50.9 ± 20.8

Note: SD – standard deviation.

The DBH and tree height of the *H. odorata* tended to be greater in the *S. siamea* stands and the control plots, and less in the *E. camaldulensis* and *A. auriculiformis* stands (Tables 2 and 3). The *H. odorata* tended to be larger with the nurse tree spacing of 2 x 8 m, but smaller with the 2 x 4 m spacing in the *A. auriculiformis* and the *S. siamea* stands. Among the plots, the *H. odorata* were larger in Plot 1, especially in the *A. auriculiformis* stands, and the control plots.

The stand basal area of the *H. odorata* was high in the *S. siamea* stands, as well as in the control plot (Table 4), and tended to be larger in plots with a spacing of 2 x 8 m and smaller in plots with 2 x 4 m spacing. Large variations were often observed among the replicates. The basal area of *H. odorata* trees was very large in Plot 1, except with the *E. camaldulensis* nurse trees. On the other hand, basal areas of *H. odorata* with *E. camaldulensis* nurse trees were large in Plot 2.

DBH distribution

The DBH distribution of *H. odorata* trees was bell-shaped in the *E. camaldulensis* and *A. auriculiformis* stands (Figure 2). On the other hand, there was a wide-ranging and irregular distribution in the *S. siamea* stands and the control plots. The DBH distribution pattern was similar among the different spacings in the *E. camaldulensis* stand, with the mode in the class 5-7.5 cm and few

Table 2 Stem diameter at breast height of 17-year-old *Hopea odorata* grown in fast-growing tree stands.

Plot	Spacing of nurse trees (m)	Stem diameter at breast height (cm)				
		Eucalyptus camaldulensis	*Acacia auriculiformis*	*Senna siamea*	No nurse trees (control)	
Plot 1	4 x 8	4.8 ± 2.8 a z α	6.3 ± 3.2 b z α	11.9 ± 4.5 a y -	block 1	15.6 ± 3.4 ab x α
	2 x 8 (thinning)	5.8 ± 2.5 a z α	8.2 ± 1.9 a y α	14.1 ± 4.6 a x αβ	block 2	16.2 ± 3.1 a x α
	4 x 4	5.6 ± 2.4 a z α	5.7 ± 1.5 b z α	13.3 ± 5.6 a y α	block 3	16.7 ± 5.0 a x α
	2 x 4 (thinning)	6.1 ± 1.7 a y α	5.3 ± 2.2 b y α	10.8 ± 3.2 a x α	block 4	12.5 ± 6.1 b x α
Plot 2	4 x 8	6.4 ± 2.6 a y α	7.1 ± 2.3 a y α	11.5 ± 4.8 b x -	block 1	15.2 ± 5.6 a x αβ
	2 x 8 (thinning)	6.7 ± 3.2 a z α	7.3 ± 2.7 a z β	16.2 ± 4.4 a x α	block 2	15.8 ± 4.6 a y αβ
	4 x 4	5.3 ± 3.1 a y α	3.9 ± 1.6 b y β	9.4 ± 5.8 bc x β	block 3	14.6 ± 5.2 a x β
	2 x 4 (thinning)	6.4 ± 2.8 a yz α	3.7 ± 2.2 b z β	7.3 ± 3.8 c y αβ	block 4	14.1 ± 6.0 a x α
Plot 3	4 x 8	6.4 ± 2.6 a y α	5.2 ± 2.2 ab y α	9.0 ± 4.2 b xy -	block 1	12.1 ± 6.5 a x β
	2 x 8 (thinning)	6.5 ± 2.4 a y α	6.1 ± 2.2 a y β	13.1 ± 4.0 a x β	block 2	14.9 ± 4.7 a x β
	4 x 4	6.2 ± 1.0 a y α	3.3 ± 1.1 b y β	14.3 ± 4.4 a x α	block 3	12.4 ± 3.8 a x β
	2 x 4 (thinning)	5.4 ± 2.5 a yz α	3.1 ± 2.0 b z β	8.4 ± 5.3 b y β	block 4	13.5 ± 4.9 a x α

Note: Mean ± standard deviation shown. Different letters to the right of the values indicate a significant difference at the 5% level: a, b, and c among spacings in each species, x, y, and z among nurse tree species in each spacing and α, β among replicates (Plots 1, 2 and 3).

Table 3 Tree height of 17-year-old *Hopea odorata* grown in fast-growing tree stands.

Plot	Spacing of nurse trees (m)	Tree height (m)				
		Eucalyptus camaldulensis	*Acacia auriculiformis*	*Senna siamea*	No nurse trees (control)	
Plot 1	4 x 8	4.48 ± 2.45 a z α	4.43 ± 2.03 b z α	11.18 ± 4.02 ab y α	block 1	14.43 ± 1.81 a x α
	2 x 8 (thinning)	5.11 ± 1.96 a z α	7.36 ± 2.47 a y α	13.58 ± 3.92 a x αβ	block 2	13.76 ± 3.29 a x α
	4 x 4	4.52 ± 1.75 a y α	4.07 ± 1.30 b y α	11.90 ± 4.69 a x β	block 3	14.09 ± 4.63 a x α
	2 x 4 (thinning)	4.77 ± 1.78 a y α	4.41 ± 1.85 b y α	8.29 ± 2.31 b x α	block 4	8.80 ± 4.60 b x α
Plot 2	4 x 8	5.78 ± 2.35 ab y α	5.33 ± 1.77 a y α	10.43 ± 4.39 b x α	block 1	10.37 ± 3.27 a x β
	2 x 8 (thinning)	5.86 ± 2.58 a z α	5.61 ± 2.01 a z β	15.16 ± 3.35 a x α	block 2	11.33 ± 4.18 a y β
	4 x 4	4.08 ± 1.93 b y α	3.12 ± 1.07 b y β	9.43 ± 5.14 b x β	block 3	9.78 ± 3.45 a x β
	2 x 4 (thinning)	5.31 ± 2.28 ab yz α	2.97 ± 0.81 b z α	7.43 ± 4.35 b xy α	block 4	10.50 ± 4.33 a x α
Plot 3	4 x 8	5.00 ± 1.76 a y α	5.04 ± 2.30 ab y α	7.38 ± 4.35 b y β	block 1	10.54 ± 5.09 b x β
	2 x 8 (thinning)	5.08 ± 1.83 a z α	5.69 ± 1.99 a z β	12.07 ± 3.65 a y β	block 2	14.34 ± 3.10 a x α
	4 x 4	4.45 ± 1.38 a y α	2.74 ± 0.55 c y β	13.35 ± 3.39 a x α	block 3	11.83 ± 3.19 ab x αβ
	2 x 4 (thinning)	4.62 ± 1.95 a yz α	3.03 ± 1.40 bc z α	7.00 ± 4.24 b y α	block 4	11.13 ± 4.39 ab x α

Note: Mean ± standard deviation shown. Different letters to the right of the values indicate a significant difference at the 5% level: a, b, and c among spacings in each species, x, y, and z among nurse tree species in each spacing and α, β among replicates (Plots 1, 2 and 3).

Table 4 Change in stand basal area of *Hopea odorata* planted in fast-growing tree stands.

Nurse tree species	Spacing of nurse trees (m)	Stand basal area (m^2 ha^{-1})			
		Plot 1	Plot 2	Plot 3	Mean ± SD
Eucalyptus camaldulensis	4 x 8	0.60	1.41	0.70	0.90 ± 0.44
	2 x 8 (thinning)	1.10	1.87	1.09	1.35 ± 0.44
	4 x 4	0.66	0.84	0.37	0.62 ± 0.24
	2 x 4 (thinning)	0.46	1.20	0.61	0.76 ± 0.39
Acacia auriculiformis	4 x 8	1.28	0.84	0.40	0.84 ± 0.44
	2 x 8 (thinning)	2.07	1.03	0.84	1.31 ± 0.66
	4 x 4	0.87	0.17	0.09	0.38 ± 0.43
	2 x 4 (thinning)	0.61	0.11	0.12	0.28 ± 0.29
Senna siamea	4 x 8	4.50	3.91	2.74	3.72 ± 0.90
	2 x 8 (thinning)	7.37	8.36	4.58	6.77 ± 1.96
	4 x 4	5.06	3.34	4.69	4.36 ± 0.91
	2 x 4 (thinning)	2.46	1.51	1.70	1.89 ± 0.51
No nurse trees (control)	block 1	7.90	3.58	3.87	5.12 ± 2.41
	block 2	8.12	5.12	5.03	6.09 ± 1.76
	block 3	7.52	3.66	3.96	5.05 ± 2.15
	block 4	5.23	2.13	3.94	3.77 ± 1.56

Note: SD – standard deviation.

H. odorata trees had DBH greater than 12.5 cm. The DBH distribution pattern in the *A. auriculiformis* stands was similar to that in the *E. camaldulensis* stands, except for the 2 x 4 m spacing. The DBH distribution pattern and maximum size of DBH in the *S. siamea* stands were different for the different spacings. With the 2 x 4 m spacing, no *H. odorata* trees had DBH greater than 17.5 cm. While the mode for the DBH distribution was high in the 2 x 8 m spacing, it was low in the 4 x 4 m spacing (Figure 2). The DBH distributions in the control plots were irregular and their modes were generally low, similar to those in the *S. siamea* stands.

Damage to *H. odorata*

The ratio of stem damage tended to be high in the *E. camaldulensis* and the *A. auriculiformis* stands, with values exceeding 40%, whereas it was low in the control plots (Table 5). Although the effect of the nurse tree spacing on the damage ratio was not clear, it tended to be high in the 2 × 4 m spacing. Damage to *H. odorata* trees was lowest in the control plots of Plot 1. The ratio of trees climbed by lianas showed a similar pattern to the morphological stem damage and tended to be high in the *E. camaldulensis* and the *A. auriculiformis* stands, but low in the *S. siamea* stands and the control plots. The ratio of trees climbed by lianas was high in the 2 x 4 m of Plot 1 and in the *A. auriculiformis* stand of Plot 3, while it was low in the control plots of Plot 1 and the *S. siamea* stand of Plot 2 (Table 5).

According to the chi-square test, the ratio of morphologically damaged stems was affected significantly by the DBH class in some plots, namely the 2 × 8 m spacing of the *E. camaldulensis* stands, the 2 × 4 m spacing of the *S. siamea* stands and the three blocks of the control plots (Figure 2). The ratio of damaged stems tended to decrease as the DBH size class increased in these plots, implying that lianas tended to climb smaller trees in preference to larger trees. Little damage was observed in any DBH class greater than 20 cm in any of the treatments.

It is well known that climbing plants damage trees and forest plantations

Table 5 Percentage of damage to *H. odorata* and percentage of climbing lianas.

Nurse tree species	Spacing of nurse trees (m)	Damaged *Hopea odorata* (%)							
		Plot 1		Plot 2		Plot 3		Mean ± SD	
		Damage to stem	Climbing lianas	Damage to stem	Climbing lianas	Damage to stem	Climbing lianas	Damage to stem	Climbing lianas
Eucalyptus	4 x 8	33.3	33.3	65.5	27.6	66.7	20.0	55.2 ± 18.9	27.0 ± 6.7
camaldulensis	2 x 8 (thinning)	50.0	20.8	43.8	18.8	60.9	47.8	51.6 ± 8.7	29.1 ± 16.2
	4 x 4	33.3	44.4	66.7	41.7	66.7	55.6	55.6 ± 19.3	47.2 ± 7.4
	2 x 4 (thinning)	83.3	83.3	56.0	16.0	60.0	13.3	66.4 ± 14.7	37.5 ± 39.7
Acacia	4 x 8	50.0	26.9	42.9	14.3	38.5	23.1	43.8 ± 5.8	21.4 ± 6.5
auriculiformis	2 x 8 (thinning)	44.8	17.2	45.8	37.5	30.0	50.0	40.2 ± 8.8	34.9 ± 16.6
	4 x 4	66.7	33.3	93.8	31.3	75.0	50.0	78.5 ± 13.9	38.2 ± 10.3
	2 x 4 (thinning)	68.4	73.7	75.0	0	100.0	55.6	81.1 ± 16.7	43.1 ± 38.4
Senna siamea	4 x 8	39.3	0	50.0	8.3	52.0	8.0	47.1 ± 6.8	5.4 ± 4.7
	2 x 8 (thinning)	28.1	9.4	16.7	0	41.7	12.5	28.8 ± 12.5	7.3 ± 6.5
	4 x 4	28.0	4.0	35.7	0	9.5	14.3	24.4 ± 13.5	6.1 ± 7.4
	2 x 4 (thinning)	47.4	36.8	56.5	0	64.7	5.9	56.2 ± 8.7	14.2 ± 19.8
No nurse trees	block 1	0	0	20.0	10.0	28.6	4.8	16.2 ± 14.7	4.9 ± 5.0
(control)	block 2	6.7	0	32.0	8.0	10.0	20.0	16.2 ± 13.8	9.3 ± 10.1
	block 3	20.8	0	40.0	10.0	21.7	13.0	27.5 ± 10.8	7.7 ± 6.8
	block 4	53.8	7.7	27.3	9.1	27.8	38.9	36.3 ± 15.2	18.6 ± 17.6

Note: SD – standard deviation.

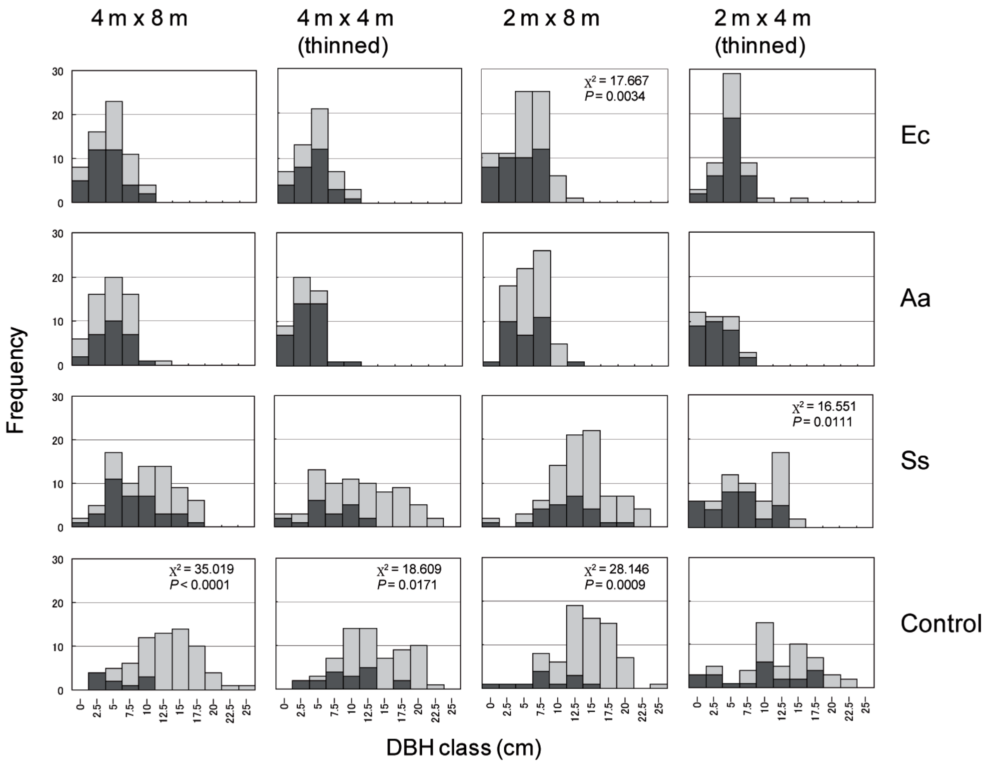

Figure 2 Distribution patterns of DBH of Hopea odorata, damaged stems shown in dark column (excluding climbing liana), Pearson's chi-square and p-values shown in the graph in which ratio of damage significantly related to DBH class. Ec: Eucalyptus camaldulensis, Aa: Acacia auriculiformis, Ss: Senna siamea.

in tropical areas (Richards, 1996). Putz (1984) found lianas on Barro Colorado Island (Panama) to be the most abundant in recent tree-fall gaps (that is, where small trees are present) and decreased in abundance with increasing time since the last disturbance. Sakai *et al*. (2002) demonstrated that lianas climbed small trees rather than large trees in a secondary deciduous forest in Central Japan. These findings are consistent with the observations in the current study that lianas seldom damaged larger *H. odorata* trees (Figure 2). Because lianas account for a large amount of the forest floor biomass in tropical areas (Putz, 1984; Kamo *et al*., 2002), continuous vine cutting is needed to manage forest plantations in these areas.

Effects of maintenance frequency on *H. odorata*

There was considerable variation among the replicates (Plots 1, 2 and 3) in the survival rate, size and damage ratio of *H. odorata* trees. It appeared that the intensity or frequency of care (weeding and vine cutting) created these variations. For example, the control plots of Plot 1, located near the forest road and maintained as an exhibition stand, showed a high survival rate, large size and less damage to the *H. odorata* trees. On the other hand, the control plots in Plots 2 and 3, which were located farther from the forest road and had not experienced any care since the termination of the JICA Project, showed poorer survival values.

Moreover, the survival rates of *H. odorata* trees tended to be high in the *A. auriculiformis* stands in Plot 1, the *E. camaldulensis* stands in Plot 2 and the *S. siamea* stands in Plots 1 and 2, which were relatively close to the forest road and could be maintained easily (Table 1, Figure 1). Although there is no official record of maintenance of the study plots, a previous chief of the Sakaerat Station commented that more intensive efforts were directed at the plots closer to the forest road (personal communication with R. Thai-ngam, Royal Forest Department). This implies that plot maintenance is important for maintaining the survival rates and the health of a forest plantation.

CONCLUSION AND RECOMMENDATION

The results showed that the size of *H. odorata* trees was too small to allow efficient timber production and close to half or more of the *H. odorata* trees were damaged by stem breakage or lianas in the *E. camaldulensis* and the *A. auriculiformis* stands, suggesting these two species are less feasible as nurse trees. However, as Sakai *et al*. (2009) pointed out, the growth of *H. odorata* trees can be improved by frequent or heavy thinning, even in the *E. camaldulensis* and the *A. auriculiformis* stands. In contrast, *H. odorata* grew strongly and damage was relatively small in the *S. siamea* stands and in the control plots. It was found that populations of small trees (in the *E. camaldulensis* and the *A. auriculiformis* stands) contained many damaged trees, while populations of large trees (in the *S. siamea* stands and the control plots) were relatively undamaged. Thus, it could be concluded that larger trees are less likely to sustain damage. Therefore, encouraging the growth of undergrowth trees will protect them effectively from lianas and morphological damage in two-story forest management systems. Such findings emphasize that continuous care, such as weeding and vine cutting, will be critical for maintaining forest health in tropical areas.

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