MARKING TRIAL FOR THINNING OF *ARAUCARIA HUNSTEINII* PLANTATION IN PENINSULAR MALAYSIA

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AHMAD ZUHAIDI, Y., AFZAL-ATA, M. & WEINLAND, G. 1996. Marking trial for thinning of *Araucaria hunsteinii* plantation in Peninsular Malaysia. The current stocking before and after proposed first thinning intervention of 17-y-old *Araucaria hunsteinii* stand in compartment 1C1, Kemasul Forest Reserve, Pahang was investigated. The dominant height and diameter of the stand were 23.9 m and 27.8 cm respectively, and the average height and diameter 20.3 m and 19.8 cm respectively. The stand volume was 279.75 m^3 ha^{-1}. Two hundred and seven trees were selected as potential final crop trees (PCT) and 187 trees were to be removed in the first thinning. The average height and diameter of PCT were slightly above the average values of the total stand. The mean live crown (ratio of green crown length and total tree length in percent) was 32.5 %.

Keywords: Thinning - live-crown - PCT - *Araucaria hunsteinii*

AHMAD ZUHAIDI, Y., AFZAL-ATA, M. & WEINLAND, G. 1996. Kajian percubaan penjarangan dirian *Araucaria hunsteinii* di Semenanjung Malaysia. Percubaan penjarangan ini mengkaji dan menilai prestasi stok semasa dirian *Araucaria hunsteinii* yang berumur 17 tahun di kompatmen 1C1, Hutan Simpan Kemasul, Pahang sebelum dan selepas cadangan penjarangan pertama. Ketinggian dominan dan perepang dirian ialah 23.9 m and 27.8 cm masing-masing manakala purata ketinggian dan perepang dirian ialah 23.3 m dan 19.8 cm. Isipadu dirian ialah 279.75 m^3 ha^{-1}. Dua ratus tujuh pokok telah dipilih sebagai pokok pilihan sehingga akhir pusingan hidup (PCT) dan 187 akan ditebang dalam penjarangan pertama. Purata ketinggian dan perepang dirian PCT adalah lebih tinggi daripada nilai purata dirian keseluruhan. Purata nisbah silara hidup (nisbah ketinggian silara hijau dan ketinggian keseluruhan pokok dalam peratus) ialah 32.5.

Introduction

In the mid 1970s, the Forestry Department of Peninsular Malaysia embarked on pilot scale planting of various exotic species which include *Pinus caribaea, Pinus merkusii, Araucaria hunsteinii* and *Araucaria cunninghamii.* The objective was the production of utility timber including sawlog and pulpwood. To date little information is available, particularly on the survival and growth productivity of the planted species and aspects of silviculture treatment such as thinning. In this trial, only the growth performance and procedures of marking for thinning including selection of trees to be removed and selection of potential final crop trees (PCT) and remaining trees after the proposed thinning were considered. The aim of this investigation was to determine the possibility of carrying out another commercial thinning as selective thinning. The procedure emphasised the availability of PCT and intermediate revenue from thinning materials. Thinning of the stand, however, had been carried out in 1987 but only as low thinning.

Material and methods

Site location

A hectare (100 × 100 m) *Araucaria hunsteinii* thinning plot was established in 1993 in Compartment 1C1, Kemasul Forest Reserve, Pahang, Peninsular Malaysia. The area lies at 102° 14' E and 3° 25' N. Mean daily temperatures range from 27 to 32 °C. The annual rainfall is between 1800 and 2030 mm indicating that the area receives precipitation at the lower range of rainfall in the humid tropics.

The plot has an elevation of about 60 m above sea level. The terrain is level to slightly undulating. The soil belongs to Durian series and is local alluvium. The soil parent material is sedimentary and metamorphic rocks formed during the Jurassic and Triassic period. The texture is sandy clay loam. Soil nutrient status is poor with low cation exchange capacity. The soil pH is low. Prior to planting the logged natural forests were clearfelled and sites semi-mechanically prepared.

Stand description

The stand in Kemasul was planted in October 1976 at an initial spacing of 2.1 × 2.7 m (1700 stems ha^{-1}). Upon commencement of this study in 1993 trees had reached large pole/small timber size (mean diameter 19.8 cm). The stand was distinctly mono-layered with canopy closed. The mean crown ratio was 32.5 %. Generally, foliage was dense. The stand contained a high proportion of straight trees with scattered diseased and forked stems. Self-pruning was very good. Some sapling size coppiced trees were also found.

Establishment and stand treatment

The schedule of operations and treatments of the stand are as follows:

Table 1. Stand treatment of an *Araucaria hunsteinii* stand in compartment 1C1 Kemasul Forest Reserve, Pahang

Year	Operations
1976	Planting 2.1 × 2.7 m
1977	Weeding and chemical treatment
1978	Weeding
1979	Weeding
1980	Weeding
1981	Weeding and chemical treatment
1982	Chemical treatment
1983	Chemical treatment
1984	Weeding
1987	Thinning (removal of stunted trees and diseased trees; low thinning)
1990	Survival enumeration (49% survival) for the whole compartment

Remarks: Weeding operation was done manually as circle weeding. Chemical treatment in Kemasul Forest Reserve was with heptachlor.
Source: Anonymous 1993.

Enumeration and mean diameter

All trees in the thinning plot were numbered, except for small size trees developed from coppices of uprooted and felled trees.

The following tree parameters were measured: diameter at breast height (cm), total tree height (m), crown length (m).

Heights were measured by distance-free method using a Suunto clinometer and a 6 m pole. From these measurement data individual height curves (total height and crown height) were calculated using the method of least squares.

The model is

$$h = a + b^{*}\log\ d \text{ (Curtis 1967)}$$

where a is the intercept and b is the regression coefficient.

From the height curves the following mean heights were calculated: average top height (h_{dom}), average stand height (h_g) and average height of selected PCT (h_s).

Diameter (d_g) according to the mean basal area was calculated as

$$d_g = (\sqrt{\sum d_i^2 / n})$$

where,

d_g = diameter at breast height,
d_i = sum of square diameter at breast height, and
n = number of trees measured.

The live crown ratio is defined as the ratio between the crown length and tree height expressed in percentage:

Crown ratio = (crown length/tree height) * 100

Basal area was calculated for each tree (g_i); the basal area ha^{-1} (G) was obtained by totaling the individual values and converting the result into ha^{-1} value:

$$G = \sum g_i$$

No correction for the area was required since the plot area was 1 ha.

The volume was measured on 298 sample trees from the thinning material in compartment 1A4 of the same age class in Kemasul Forest Reserve using the Hohenadl method as described in Loetsch *et al.* (1973). The single tree volume function was developed based on Meyer's comprehensive model (Meyer, in Loetsch *et al.* 1973) with diameter at breast height and total height as variables. The model is

$$v = b_o + b_1 d + b_2 d^2 + b_3 dh + b_4 d^2 h + b_5 h \text{ (Meyer's comprehensive model)}$$

where,

d = the diameter at breast height,
h = the total tree height, and
v = the stem volume from base to the tip (total stem).

The volume function was calculated using multiple linear regression with v (volume) as the dependent variable. The statistical results are shown in Tables 2 and 3.

Table 2. Intercept and regression coefficients of a volume function for a *Araucaria hunsteinii* stand in compartment 1A4 Kemasul Forest Reserve

Independent variable	Coefficient	Std. error	*t*-value	Significant level
b_0 constant	0.654932	0.394687	1.6594	0.0981
b_1	- 0.075398	0.035668	- 2.1139	0.0354
b_2	0.001782	0.000764	2.3317	0.0204
b_3	0.004610	0.001598	2.8840	0.0042
b_4	- 0.000081	0.000033	- 2.4962	0.0131
b_5	- 0.038037	0.019271	- 1.9738	0.0494

Table 3. Analysis of variance for full regression

Source	Sum of squares	DF	Mean square	*F*-ratio	*P*-value
Model	14.9339	5	2.98679	150.288	.0000
Error	5.8031	292	0.01987		
Total	20.7370	297			
R-squared	0.7201		Std. error of est. = 0.14097		

The average volume per tree (v) was calculated by using the diameter and height of the mean stem, and the volume per ha (V) is given by

$$V = v * N$$

where,

V = volume per ha,
v = average tree volume, and
N = number of stems.

Potential final crop trees (PCT)

Selection of the PCT was the most important part of the proposed thinning regime, and was chosen from the dominant class trees since this species have all the prescribed characteristics of the PCT especially self-pruning ability and acceptable clear bole height. In contrast with other broad-leaved species such as *Acacia mangium*, most of the biggest or dominant class trees suffer from deep forks and low branch shedding capacity. Selection of the potential final crop trees in *Araucaria hunsteinii* stand was based on the following criteria (in order of priority):-

a. stem form
b. no defect on the lower bole
c. high vigour
d. no visible defect on the upper stem and crown
e. diameter size above stand average
f. no epicormic branching

Results

Stem number

The stand in the Kemasul Forest Reserve was initially planted at a density of 1700 stems per ha. As a result of tree competition, mortality and a low thinning intervention in 1987, the number of stems ha^{-1} was reduced to the present number of 947 (56% of the initial stem number).

Growth in total

Table 4 shows the stand record in 1993 for the stand in Kemasul Forest Reserve. At the age of 17 years, the average height (h_g) was 20.3 m. The dominant height (h_{dom}) at 23.9 m was significantly higher than the average, indicating a distinct differentiation in dominance.

The diameter of the whole population ranged from 6.2 to 33.9 cm with an average of 19.8 cm. The average top diameter (d_{dom}) at 27.8 cm was significantly higher than the average of the whole stand, which indicates a distinct differentiation in size and probably in dominance too.

Table 4. Stand record of the 17-y-old *Araucaria hunsteinii*, in compartment 1C1, Kemasul Forest Reserve

Age y	N* stems ha^{-1}	h_{dom} m	d_{dom} cm	h_g m	d_g cm	G* m^2	V* m^3	v m^3
17	947	23.9	27.8	20.3	19.8	29.27	279.75	0.2954

Remarks:

N = number of stems per ha
h_{dom} = average dominant height
d_{dom} = average diameter of dominant trees
h_g = average stand height
d_g = average stand diameter
G = basal area per ha
V = volume per ha
v = average volume per tree

Potential final crop trees (PCT) of the stand

Out of 947 trees, 207 trees were selected as the PCT from the stand in Kemasul Forest Reserve. The parameters of the subpopulation of PCT are shown in Table 5.

Table 5. Parameters of the potential final crop trees (PCT) in 1993 for the *Araucaria hunsteinii* in compartment 1C1 in Kemasul Forest Reserve, Pahang

Age y	N stems ha^{-1}	h_g m	d_g cm	G m^2	V m^3	v m^3
17	207	22.7	24.8	9.99	98.04	0.4736

With 21.8 % of the total stems of the stand as PCT, the basal area of the PCT represented 34.1 % of the total basal area and the volume 35.0 % of the total stand volume. The selected individuals were 5 cm bigger than the average tree size and about 2 m taller.

Thinning

Marking of trees for removal was done together with the selection of PCT. The results are shown in table 6. Out of 947 trees ha^{-1}, 187 trees were marked for removal in the first thinning.

Table 6. Removal in 1993 of the *Araucaria hunsteinii* stand in compartment 1C1, Kemasul Forest Reserve

Age y	N stems ha^{-1}	h_g m	d_g cm	G m^2	V m^3	v m^3
17	187	19.6	18.6	5.10	47.78	0.2555

About 17 % of basal area and volume would be removed during the thinning. The mean size of the removed trees was distinctly smaller than that of the crop trees. The reason is that in general the biggest trees were selected as potential final crop trees owing to their good stem form, in contrast to most stands of broad-leaved species such as *Acacia mangium* where the biggest trees often are of bad form.

Figures in Table 7 show the parameters of the remaining trees after the removal based on the marking in Table 6.

Table 7. Parameters of the remaining stand of *Araucaria hunsteinii* in compartment 1C1, Kemasul Forest Reserve

Age y	N stems ha^{-1}	h_g m	d_g cm	G m^2	V m^3	v m^3
17	760	20.4	20.1	24.17	231.97	0.3052

The average tree size of the remaining stand was slightly bigger than the average tree size of the stand with the removal included.

Discussion

Availability of PCT and timing

Out of 947 trees, 207 were selected as potential final crop trees. Although it is not yet known how many excess trees of good quality are to be retained to compensate for losses in the course of the rotation, it is assumed that at least 200-250 trees ha^{-1} can be retained as final crop. The crowns are columnar with relatively small spread. The thinning procedure applied is a selective procedure where a number of crop trees are selected and harmful trees are removed. Owing to the generally good stem form the biggest trees could be selected as potential final crop trees. Consequently, trees marked to be thinned were usually smaller than the crop trees which resulted in a low thinning intervention. This can be seen from the ratio "average volume of removal/average volume of remaining trees",

$$0.2555/0.3025 = 0.84$$

If the ratio was distinctly below 1.0, a low thinning was carried out; if it was distinctly above 1.0, a crown thinning was carried out. However, it has to be considered that the intervention was not planned to be a low thinning, but it was the result of a selective thinning procedure where mainly co-dominant trees were removed. With higher stand densities respacing may very well be necessary whereby mainly dominant trees will be removed. Such an intervention will result in a crown thinning.

Timing of the first thinning influences growth of the selected crop trees. Evans (1992) mentions that the decision to commence thinning is usually judged from the crown closure or crown competition, and if maximum diameter growth is aimed at, thinning consequently would have to start later with the onset of between-tree competition. If the live crown ratio is reduced too much, the capacity of the trees to expand crowns quickly after the thinning intervention can be expected to be poor. If, however, the stand is opened too early self-pruning is very much reduced. For comparison, the first thinning in *Araucaria cunninghamii* in Queensland is carried out at the age of 17 years (Evans 1992), which would also be the suitable age for the stand in the Kemasul Forest Reserve. The thinning regime is shown inTable 8.

The rotation age is 60 years and seven interventions are proposed until the end of the rotation. The final crop is about 200 stems ha^{-1}. For the trial stand the number of final crop trees has still to be determined as well as the minimum rotation length. The achieved diameter size of the stand in Kemasul, Pahang, was 19.8 cm after 17 years. We may assume that most probably a rotation of about 35-40 years is required to grow a final crop with an mean diameter of 40 cm. It seems probable that even up to 300 stems ha^{-1} can be retained as the final crop.

Table 8. Thinning prescription for *Araucaria cunninghamii* grown for sawlogs in Queensland, Australia

Thinning	Age (years)	Number of trees after thinning	Thinning method
1	17	865	crown
2	22	642	crown
3	27	494	crown
4	32	395	crown
5	37	296	low
6	42	247	low
7	50	198	low
	60	clearfell	

Source: Evans 1992.

Based on this trial, the following preliminary stand density regime is proposed:

- planting density between 1000 and 1500 stems ha^{-1}
- at top height of about 10-12 m thinning to a density of about 900 stems ha^{-1}
- at top height of about 20 m thinning (crown thinning) down to 650 stems ha^{-1}
- at top height of about 25-30 m thinning down to 200-250 stems ha^{-1} (final crop)

The above stand density regime assumes thinnings to be carried out in well managed stand based on achieved average top height. The first thinning down to 900 stems ha^{-1} is carried out in the stand when the average top height reaches 10-12 m.

Conclusion

Araucaria hunsteinii has generally a desirable stem form; thus the biggest trees can usually be selected as crop trees. Differentiation into dominance classes is distinct so that thinning can be delayed for some time. During the first thinning trees of the co-dominant class which compete with crowns of the crop trees are removed. Crown spread is small and probably up to 300 stems ha^{-1} can be retained as final crop trees. The marking trial, however, indicated that it might be difficult to find such a high number of crop trees, which fulfill the requirements of a final crop tree, e.g. above the average tree size.

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