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STAND GROWTH STRUCTURE AND YIELD OF PLANTATION GROWN *DRYOBALANOPS AROMATICA* IN PENINSULAR MALAYSIA: > 50 YEARS AFTER PLANTING

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AHMAD ZUHAIDI, Y. & VAN GARDINGEN, P. 1999. Stand growth structure and yield of plantation grown *Dryobalanops aromatica* in Peninsular Malaysia: > 50 years after planting. The growth structure and yield of three *Dryobalanops aromatica* stands established in the forest area of the Forest Research Institute Malaysia in the 1930s are discussed. The species when grown in plantation can grow to merchantable size in about 50 years. It exhibits rapid height and diameter growth. The study is a first assessment of the stands with regards to the growth potential of plantation grown *D. aromatica* of almost 60 years of age. The results presented in the paper have to be used with caution, since they were obtained from unreplicated small plantation plots, which were designed as probing and not as formal experimental trials.

Keywords: Growth - yield - crown projection area - plantation - *Dryobalanops aromatica*

AHMAD ZUHAIDI, Y. & VAN GARDINGEN, P. 1999. Struktur pertumbuhan dan hasil dirian ladang hutan *Dryobalanops aromatica* di Semenanjung Malaysia: > 50 tahun selepas ditanam. Struktur pertumbuhan dan hasil tiga dirian *Dryobalanops aromatica* yang ditubuhkan di kawasan Institut Penyelidikan Perhutanan Malaysia semenjak tahun 1930-an dibincangkan. Spesies ini menunjukkan pertumbuhan saiz yang boleh dituai selepas 50 tahun apabila ditanam secara perladangan. Pertumbuhan ketinggian dan perepang menunjukkan prestasi yang memberangsangkan. Kajian dirian ini adalah penilaian pertama dengan mengambil kira potensi pertumbuhan ladang hutan *D. aromatica* yang menghampiri umur 60 tahun. Penggunaan keputusan yang dibincangkan hendaklah diterima secara hemat, kerana didapati daripada petak kajian yang kecil dan tidak mempunyai ulangan serta tanpa reka bentuk dan eksperimen yang khusus.

Introduction

The establishment of *Dryobalanops aromatica* Gaertn. *f.* plantations in Peninsular Malaysia began as early as 1899 when about 130 trees were planted in a small plot near the Agriculture Department in Kuala Lumpur, Peninsular Malaysia (Vincent 1961). In the Forest Research Institute Malaysia (FRIM) (experimental plots in Bukit Lagong Forest Reserve), there are approximately 87.7 ha of *D.aromatica* stands. Extensive planting was carried out in 1932–1935 (60.7 ha) and subsequently in 1936–40 (22.1 ha). However, planting activities in FRIM discontinued during the Second World War after which another 4.9 ha of plantation were established until 1959 (Selvaraj & Muhammad 1980). The State of Negeri Sembilan, Peninsular Malaysia possesses one of the earliest plantations of *D. aromatica* which was established in 1927 at Compartment 1 of Tampin Forest Reserve. However, the present extent of the plantation is not known. Intensive planting of *D. aromatica* by the Forestry Department of Peninsular Malaysia began in 1949, when about 9 ha were established in the Kanching Forest Reserve, Selangor, Peninsular Malaysia. From 1953 to 1965 some 1200 ha were planted in Kanching, Serendah, Bukit Cherakah and Sg. Puteh Forest Reserve in the State of Selangor, Peninsular Malaysia (Afzal-Ata 1985).

This paper presents the growth data of *D. aromatica* stands in experimental plots in Bukit Lagong Forest Reserve, to provide information of its growth performance. The possibility to interpret and generalise the results is limited, since the plots are small, not replicated and not established with specific scientific focus. As probing trials, however, the results have value, for answering questions such as: (i) suitability for planting, (ii) approximate rotation length, and (iii) possible yield.

Materials and methods

Species

Dryobalanops aromatica is naturally distributed in Sumatra, Kalimantan and Peninsular Malaysia. In Peninsular Malaysia, it is confined to the east coast of the peninsula, 5° north of the equator, i.e. in the south of Terengganu to the north of Pahang and southeast and east of Johore and two small pockets at the west coast in Bukit Lagong Forest Reserve and Kanching Forest Reserve, District of Rawang, Selangor (Symington 1974). The species at the west coast was introduced, when camphor was traded between the east and the west coasts of the peninsula (Wyatt-Smith 1963). In the east coast, *D. aromatica* is found on free draining, deep sandy loams of low fertility, apparently avoiding the heavier granite derived soil. Rainfall in this zone is influenced by the northeast monsoon, and averages over 3000 mm annually, with a marked peak in November–December. The mean number of rainy days varies from 170 to 190 over the zone (Wyatt-Smith 1963). In the southeast and east of Johore, Peninsular Malaysia, this species is found on similar light soils such as terrace alluvium and less commonly on heavier granite derived Rengam series soils. The mean annual precipitation and number of rainy days are 2900 mm and 180–200 days respectively. In the District of Rawang, this species grows on heavy clay loams (Rengam series) from derived granite. Mean annual rainfall is about 2500 mm with twin peaks in April and November. Despite the species' limited distribution, Lee (1967) found that *D. aromatica* occurred on a wide range of soil types derived from different parent materials such as granite, inter-laminated shales and quarzite.

The species, belonging to the family Dipterocarpaceae, is characterised by its purple-brown shaggy bole and small ovate many veined aromatic leaves. Trees of this species sometimes exceed 60 m in height with an average diameter at breast height of 70 cm when fully mature. In the natural forest, it grows to a very large size with straight columnar trunk and has a medium-sized buttress. When mature, the crown is wide and spreading although it is conical with slender pendulous twigs when young (Wyatt-Smith 1963).

It is a shade-tolerant species and seedling survival is higher under a less dense overhead canopy. Distribution of seedlings and saplings in virgin forests is better than that of most dipterocarps (Symington 1974). The timber *D. aromatica* is a medium light hardwood with density of 755 kg m^{-3} and a light brown colour (Ser 1981).

Site location

The study site is located at an elevation of between 90 and 150 m above sea-level on the lower slopes of the Bukit Lagong Forest Reserve, Selangor, Peninsular Malaysia. Study plots of 0.96, 0.72 and 0.64 ha of *D. aromatica* at three different localities within the reserve were established in August 1997 in Block 9A, 30E and 8T. The area lies in the centre of Peninsular Malaysia at 3° 14' N and 101° 38' E. Mean daily temperatures range from 27 to 32° C. The annual rainfall is between 1900 and 2050 mm indicating that the area receives precipitation at the lower range of rainfall in the humid tropics (Wyatt-Smith 1963). The areas were formerly cultivated vegetable gardens and later overgrown with *Imperata cylindrica* (Anonymous 1935, 1939). The terrain is level to slightly undulating. The parent material is granite and the soil texture ranges from sandy loam to sandy soils. The soil is reddish loam with underlying rock and granite belonging to the Rengam series (Wyatt-Smith 1963). Generally the soil is rich in nutrients, and has good drainage with very little soil disturbances since the preparation of site before planting was manually done.

Early stand description

In 1927, the area in Field 9A was planted with *Pterocarpus peltocarpum* and *Artocarpus elasticus*. The planting of these trees was to provide shade and create an environment suitable for the establishment of *D. aromatica* seedlings. When the trees proved to be a failure, *Pterocarpus indicus* seedlings were planted to fill the blank spaces. Later in 1935, *D. aromatica* seeds were dibbled at an interval of 1.8 × 0.3 m. However, at sapling and pole stages, most of them were cut for construction of army squatter houses during the Japanese Occupation (1944–1945). Towards the end of 1947, wrenched seedlings of *D. aromatica* were replanted together with some seedlings of *Balanocarpus hemii* at a spacing of 3.3 × 1.5 m. Between 1948 and 1964, eight weeding and climber cutting treatments were carried out. The first thinning was carried out in 1960 with the removal of 451 trees. However, there was no record of the volume removed.

The *D. aromatica* stand in block 30E was established in October 1939 with seedlings from seed sown in January of the same year. The seedlings were planted at a spacing of 1.5 × 1.5 m in lines cleared at 0.5 m wide. The former vegetation consisted of vegetable gardens and secondary vegetation with a heavy infestation of ferns. Planting was done during the wet spell but this was followed by an intense drought that lasted for 20 days in December 1939.

The stand in Block 8G was established in January 1933 from seed sown in April the previous year. Parallel lines were cut throughout at 3.3 m interval, widened to a width of 1.5 m and cleared. The former vegetation was cultivated vegetable gardens. Information in Table 1 gives a summary of the age, topography, previous crop and soil of the three sites.

Table 1. Stand and site descriptions

Plot/ Block	Age (y)	Plot area (ha)	Elevation (m)	Previous crop	Topography	Soil	Trees (ha^{-1}) 1997
1/9A	52	0.96	70 - 90	Vegetable gardens	Lower slope of hill	Light reddish laterite	334
2/30E	59	0.72	80 - 90	Vegetable garden & secondary vegetation	Lower slope	Sandy granite	158
3/8G	65	0.64	150 - 180	Vegetable gardens	Gentle sloping ridge	Light reddish laterite	298

Diameter, height, basal area and volume

Until August 1997, full enumeration of *D. aromatica* trees, poles, saplings and seedlings had been carried out in all plots. Trees and poles were classed if they had a diameter at breast height of greater than 30 cm and from 10 to 30 cm respectively. Meanwhile the saplings (any individual woody species having minimum height of 150 cm height until reaching a diameter at breast height of 10 cm) were measured on five randomly selected square plots (5 × 5 m). Measurements on the number of seedlings (any woody species below than 150 cm) were made on five square randomly selected plots of 2 × 2 m.

The following parameters were measured and calculated: diameter at breast height (d_g in cm) at 100 percent enumeration, total height (h_t in m) and height to the first branch (h_b in m) for 45 sample trees per plot. For each plot individual height curves were determined using the method of least squares. The model used was

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

where

h = total height in m
d = diameter at breast height in cm
a, b = coefficients of regression function

From these height curves, dominant height (100 biggest tree ha^{-1}), average total height and average clear bole height were determined.

The basal area was calculated as

$$g = \pi * d^2 / 40000$$

where

g = basal area per tree
d^2 = squared diameter at breast height and
π = 3.142

The volume per ha was obtained as follows:

$$V = G * H_b * c$$

where

G = basal area per ha
H_b = clear bole height
c = an assumed constant factor of 0.65 for clear bole taper

The mean annual increment was based on the total production of the stand up to a certain stand age. The total production comprised the current standing stock and all the removals (thinning and mortality) of the past. When divided by stand age the mean annual increment was obtained, e.g. for stand volume:

$$\text{mai}_v = (V_t + \Sigma R_t) \,/\, t$$

where

mai_v = mean annual increment at stand age t
V_t = standing stock at age t
ΣR_t = total of removals up to stand age t
t = stand age

Crown projection area

For the estimation of final stems per ha, measurements of crown area were taken on 40 standing trees in Plot 9A. Selected trees are assumed to be representative of mature stand growing freely and not in competition. The selection criteria of the measured trees were: diameter at breast height of stand average above 30 cm and bole length of 20–25 m.

The maximum crown spread of selected trees was measured using a measuring tape as described by Suri (1975) and Kleine and Weinland (1991). The radii were measured by holding one end of the tape at the middle portion of the trunk and moving away from the base of a tree in a predetermined direction to the fringe of the crown. The reading on the measuring tape was the radius of the crown spread along this direction. Length or radius of the crown spread was measured in four directions at right angles to each other. Each radius reading was then converted into crown projection area measurement (*CPA*). These areas were added and divided by four to get the average crown projection area (*ACPA*) in square meters based on the assumption of a completely closed canopy stand:

$$ACPA = (\Sigma r_i^{\,2} * 3.142)/4 \quad \text{(Kleine \& Weinland 1991)},$$

where r = radius in m

However, in this instance, it is observed that the canopy of the stand was not completely closed and there were gaps between crowns. This means that the average crown area occupied by a tree was larger than its crown projection area and the calculation of stem number per ha would give too high a value when based on a completely closed canopy. To arrive at a more realistic figure for the average final stems per ha a distance between adjacent crowns of 1 m was assumed. The average occupied area by a tree was calculated as follows:

$$ACPA = (\Sigma\, (r_i + 0.5)^2 * 3.142) \,/\, 4$$

where:

$ACPA$ = average area occupied by a tree

The final stems ha^{-1} (N) are calculated as:

$$N = (10000 \,/ ACPA) * 3.142 \,/\, 4$$

Results and discussion

Stand growth (trees)

Stem numbers

The stand records of the three plots are given in Table 2. The plots in 9A, 30E and 8G were initially planted at a density of 2020, 4444 and 920 stems ha^{-1}. As a result of mortality mainly caused by tree competition and thinning, the density declined to 195, 124 and 184 stems ha^{-1} in 52, 59 and 65 years. It was not possible to retrieve any information on the thinning and removal in Plots 9A and 30E in 1960 and 1959 due to incomplete stand records. However, because of dead trees found standing in all plots, it is assumed that mortality was the major cause for the distinct decline in stem numbers during the 50 years period.

Table 2. Standing stock of the plots (trees of diameter at breast height ≥ 30 cm)

Parameter	Plot 9A	Plot 30E	Plot 8G
Age (years)	52	59	65
Stem number (N ha^{-1})	195	124	184
h_{dom} - mean height of 100 biggest trees ha^{-1} (m)	43.91	36.79	40.19
d_{dom} - mean diameter at breast height of 100 biggest trees ha^{-1} (cm)	62.8	59.9	64.9
h_g - mean height of the stand (m)	38.80	34.53	37.13
h_b - mean clear bole height (m)	26.2	8.1	22.8
d_g - mean diameter of the stand (cm)	45.0	50.9	48.3
G - basal area ha^{-1} ($m^2 ha^{-1}$)	30.99	25.25	33.67
V - volume ha^{-1} ($m^3 ha^{-1}$)	527.75	461.19	498.99
V_{mai} - mean annual volume increment ($m^3 ha^{-1} y^{-1}$)	10.34	7.81	7.68

Height growth

Figure 1 shows the height-diameter curves for trees and poles in each plot. The height curves cover a diameter range from 10 to 80 cm. The trees were in the height range of 10.5 to 46.60 m which corresponded to the visual impression of a distinctly two-layered canopy in all plots. Level and course of the height growth were almost congruent for all the three plots. The mean height growth increased rapidly until diameter growth of about 40 cm after which it leveled off. At this age, the trees had reached a mean height of about 38.80, 34.53 and 37.13 m with an average growth rate of 0.6–0.7 m y^{1}. Reports by Foxworthy (1932), Afzal-Ata (1985) and Rahman *et al.* (1996) show that *D. aromatica* grows at an average height of from 0.8 to 1.0 m y^{1}. The calculated mean clear bole heights were 26.2, 28.1 and 22.8 m.

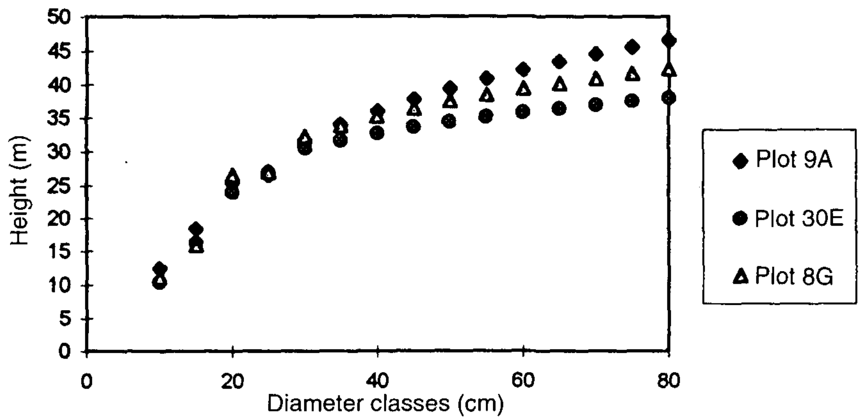

Figure 1. Height growth for the trees and poles in Plots 9A, 30E and 8G

Diameter growth

At the average age of more than 50 years, trees in the plots (9A, 30E and 8G) had an average diameter at breast height above or equal to 45 cm (i.e. 45.0, 50.9 and 48.3 cm equivalent to 0.87, 0.86 and 0.74 cm mean annual diameter growth respectively). One should expect a bigger diameter size in Plot 30E, taking advantage of the lower stem number per ha by accelerating diameter growth rates. Similar growth rates with an annual diameter increment in the range of 0.9 to 1.1 cm y^{1} were reported by Wyatt-Smith (1963), Ng and Tang (1974), Rahman *et al.* (1992) and Droste *et al.* 1994.

Observations on other plantation grown *D. aromatica* in Peninsular Malaysia, especially on their growth performance, have shown similar growth rates as given in Table 3.

Table 3 Summary of *Dryobalanops aromatica* trial results in Peninsular Malaysia

Age (y)	h_g (m)	d_g (cm)	d_{mai} (cm)	V_{mai} ($m^3ha^{-1}y^{-1}$)	Source
36	29	27.4	0.7	-	Afzal-Ata 1985[2]
38	34	39.7	1.0	7.5	Appanah & Weinland 1993[3]
38	36	37.6	1.0	6.1	Wyatt-Smith 1963[1]
40	-	-	0.9	13.8	Droste *et al.* 1994[3]
40	35	50.4	1.0 - 1.2	-	Ng & Tang 1974[3]
46	39	49.5	0.9	8.3	Rahman *et al.* 1992[3]

Remarks:
[1]Kanching Forest Reserve, Selangor, Peninsular Malaysia
[2]Sungai Puteh Forest Reserve, Selangor, Peninsular Malaysia
[3]Plantations in FRIM from different blocks
h_g - mean height
d_g - mean diameter at breast height
d_{mai} - mean diameter increment
V_{mai} - mean volume increment

Chiew and Garcia (1989) monitored the diameter growth of *Dryobalanops aromatica* in the primary and logged-over forest grown on ridgetop, middle slope and valley bottom, in Sabah, East Malaysia. The mean diameter increments for the primary forests from ridgetop to valley bottom were 0.9 (n=16), 0.6 (n=13) and 0.5 (n=5) cm; those for logged-over forests were 0.3 (n=13), 0.7 (n=38) and 0.7 (n=23) cm.

Volume growth and total yield

A determination of the total yield of the stands was not possible because thinning, mortality and other removals were not properly recorded during the early years. Since these removals are not known, the total yield is only an approximation and represents a lower level of total growth performance. The calculated standing volumes (clear bole volume) were 527.75, 461.19 and 498.99 m^3 ha^{-1} for Plots 9A, 30E and 8G, corresponding to mean annual volume increments of 10.15, 7.82 and 7.68 m^3 ha^{-1} y^{-1} respectively. These values are similar for stands of the same age on good sites of dipterocarps in Peninsular Malaysia (Ahmad Zuhaidi *et al.* 1995) and broad-leaved species in Europe (Anonymous 1990).

Tree growth (poles)

Table 4 shows the stand and stocking of poles in the Plots 9A, 30E and 8G.

Table 4. Standing stock of poles (diameter at breast height between 10 and 30 cm)

Plot	N (ha^{-1})	h_g (m)	h_b (m)	d_g (cm)	G ($m^2 ha^{-1}$)	V ($m^3 ha^{-1}$)
9A	139	28.5	19.8	19.8	4.27	54.95
30E	35	29.5	16.8	16.8	0.78	8.51
8G	123	34.5	15.4	21.4	4.43	44.34

Note:
N - number of trees per ha^{-1}
h_g - mean height of the stand
h_b - mean clear bole height
d_g - mean diameter of the stand
G - basal area ha^{-1}
V - volume ha^{-1}

The stem number ha^{-1} (N) varied from 35 to 139 poles. The mean height ranged from 28.5 to 34.5 m with the tallest in Plot 8G. The mean clear bole height ranged from 15.4 to 19.8 m, which was about 2–3 m difference between plots. Similarly, the highest average stand diameter was in Plot 8G at 21.4 cm, due probably to the older age of mother trees at the plot at 65 years.

Diameter distributions

Figure 2 shows the diameter distributions of all poles and trees of the three plots. The diameter ranges from 10 to 82.7 cm in Plot 9A, 10 to 79.6 cm in Plot 30E and 10 to 76.4 cm in Plot 8G. The wide diameter range for a whole population is not necessarily disadvantageous as long as the size of the potential final crop trees is within a relatively narrow range. Assuming the minimum diameter limit of potential final crop trees is at 45 cm, 30.1 % of the standing trees in all plots are grouped as potential final crop trees. The remaining trees and poles would be classified as intermediate size class trees as replacement for the second rotational crop.

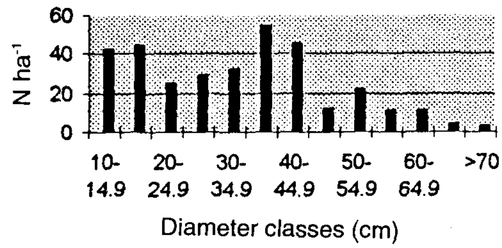

Figure 2a. Diameter distribution of trees and poles on plot 9A at 52 y

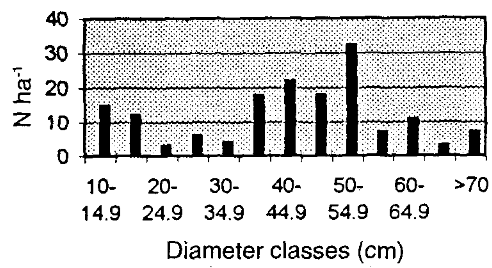

Figure 2b. Diameter distribution of trees and poles on plot 30E at 59 y

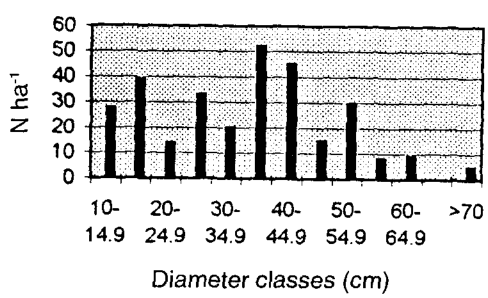

Figure 2c. Diameter distribution of trees and poles on plot 8G at 65 y

From the above figures (Figures 2a,b,c), Plot 9A had the highest number of poles (diameter at breast height between 10 and 29.9 cm) at 139 poles ha^{-1} (42%), and Plot 30E the least number at 35 poles ha^{-1} (22 %); Plot 8G was intermediate with 114 poles ha^{-1} (38%). Since no previous records of the stands are available, the occurrence of pole size trees especially of less than 20 cm diameter might be the results of previous flowering and fruiting. Burgess (1972) observed that *D. aromatica* demonstrated shorter intervals of flowering and fruiting, vigorous seedling and sapling growth even under adverse conditions , and an ability to tolerate shade compared to other dipterocarp species. Wyatt-Smith (1963) reported that the first fruiting of *D. aromatica* plantations at FRIM occurred at the stand age of 18–20 years.

Availability of saplings and seedlings

Table 5 presents the stem-height distribution of *D. aromatica* saplings for each of the plot.

Table 5. Stem-height distribution of saplings for each plot

Height-classes (m)	Plot (stems ha^{-1})		
	9A	30E	8G
1–1.9	80	400	200
2–2.9	800	60	200
3–3.9	240	400	-
4–4.9	160	-	-
5–5.9	160	-	-
6–6.9	240	-	-
7–7.9	-	-	-
8–8.9	80	-	-
9–9.9	80	-	-
Average	230	265	200

The saplings (trees of greater than 1.5 m in height to 9.9 cm diameter at breast height) of *D. aromatica* ranged in height from 1.8 to 9.4 m . The density in the height classes ranged from 80 to 800 stems ha^{-1}. All together, the average sapling population was 232 stems ha^{-1} ranging from 200 to 265 stems ha^{-1}. The diameter at breast height ranged from 0.4 to 2.9 cm indicating fast initial height growth as compared to diameter growth. The species as young plants takes advantage of gap openings by accelerating height growth to obtain a more competitive position before the gaps close again.

Figures in Table 6 show the stem-height distribution of *D. aromatica* seedlings in each plot. The height classes ranged from 0 to 1.5 m.

Table 6. Stem-height distribution of *Dryobalanops aromatica* seedlings for each plot

Height-classes (m)	Plot (stems ha^{-1})		
	9A	30E	8G
0–0.49	1500	1000	-
0.5–0.99	2000	-	1000
1.0–1.5	2000	1000	2500
Average	1833	1000	1750

Based on the assessment, the estimated number of seedlings (height of less than 1.5 m) varied from 1000 to 2500 stems ha^{-1} with the highest number in Plot 9A. Higher stem number ha^{-1} and sequence of flowerings and fruitings in Plot 9A could be the contributing factor leading to the availability of seedlings in each size-class. On the whole, the estimated average was 1528 stems ha^{-1} ranging from 1000 to 2500 stems ha^{-1}.

Crown projection area

From the calculations, the average crown area ranged from 5.137 to 73.067 m^2 and the average area occupied by a tree was 36.012 m^2. The estimated density of final stems was 218 trees ha^{-1} at an average diameter at breast height of 45.2 cm.

Conclusion

Plantation grown *Dryobalanops aromatica* can produce logs of merchantable size suitable for sawnwood in a rotation of about 50 to 60 years. The species shows rapid height and diameter growth with an average annual height increment of 0.7 m and average annual diameter increment of 0.9 cm. The average mean annual volume increment for all plots is 8.61 $m^3 ha^{-1} y^{-1}$. The results of the assessment also show that plantation grown mature dominant and co-dominant trees will attain a crown projection area of 36.01 m^2 during a growth period over 50 years. Based on the assumption of a partially closed canopy stand this would be equivalent to a possible stocking of 218 final crop trees ha^{-1}. However, the calculated number (218 trees) is not optimal since it also depends on site conditions and the targeted average diameter at the end of the rotation. It is presently not known how many trees need to be planted under regulated plantation management regimes (with thinning, etc.) in order to achieve the final stocking. The results, however, do provide some guidelines with respect to actual production target at the end of the proposed rotation age.

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