DIAMETER GROWTH OF NATURALLY REGENERATED *DRYOBALANOPS AROMATICA* IN PENINSULAR MALAYSIA

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AHMAD ZUHAIDI, Y., VAN GARDINGEN, P. R. & GRACE, J. 2004. Diameter growth of naturally regenerated *Dryobalanops aromatica* in Peninsular Malaysia. This paper discusses the overall diameter growth of naturally regenerated *Dryobalanops aromatica* trees using results obtained from measurements taken for a period of 61 years (1915 till 1976). The plot was located at Kancing Forest Reserve, Selangor, Peninsular Malaysia. After 61 years, the achieved mean DBH was 61.4 ± 2.0 cm. The periodic annual diameter increment was 0.91 ± 0.01 cm year^{-1} (ranging from 0.4 ± 0.01 to 1.3 ± 0.07 cm year^{-1}). Stands of plantation grown *D. aromatica* at Bukit Lagong Forest Reserve (5 km away) were used as comparison for growth. The growth at Kancing was significantly higher compared with that of plantation grown *D. aromatica* at Bukit Lagong. The thinning down to a low stocking at Kancing were largely responsible for the high diameter growth of the species.

Key words: Periodic annual diameter increment – thinning

AHMAD ZUHAIDI, Y., VAN GARDINGEN, P. R. & GRACE, J. 2004. Pertumbuhan diameter *Dryobalanops aromatica* yang tumbuh secara anak liar di Semenanjung Malaysia. Kajian ini adalah tentang pertumbuhan diameter dirian *Dryobalanops aromatica* yang tumbuh secara anak liar berdasarkan pemerhatian selama 61 tahun mulai 1915 hingga 1976 di Hutan Simpan Kancing, Selangor, Semenanjung Malaysia. Selepas 61 tahun, purata pencapaian diameter ialah 61.4 ± 2.0 cm. Kadar pertumbuhan diameter berkala ialah 0.91 ± 0.01 cm setahun (julat antara 0.4 ± 0.01 cm hingga 1.3 ± 0.07 cm setahun). Dirian *D. aromatica* yang serupa di Hutan Simpan Bukit Lagong (5 km jauhnya) digunakan sebagai perbandingan pertumbuhan. Pertumbuhan diameter pokok di Kancing lebih tinggi daripada pertumbuhan diameter di Bukit Lagong. Faktor penjarangan di Kancing menyebabkan pertumbuhan diameter yang tinggi dalam spesies ini.

**Key name of author: Ahmad Zuhaidi*

Introduction

The growth of forest stands is a central issue in forestry research and management. In recent years, much emphasis has been placed on the growth of mixed tropical forest (Lieberman & Lieberman 1987, Vanclay 1989, Yong 1990, Alder 1995, Ong & Kleine 1995, Silva *et al.* 1995, Kohler & Huth 1998) and sub tropical forests (Rautiainen *et al.* 2001). However, a full understanding of the growth of pure stands of indigenous tropical species such as *Drybalanops aromatica* is still lacking.

Currently in Malaysia, much of the focus in plantation forestry issues are centred on growing dipterocarps as well as exotic species. Not much is known about the early growth performance of *D. aromatica*, which was mainly restricted to mature, naturally regenerated *Dryobalanops* species of unknown age (Chiew & Garcia 1989, Primack *et al.* 1989, Abd. Rahman *et al.* 1992, Abd. Rahman *et al.* 1996). This study was, therefore, initiated after recognising the importance of growth studies of dipterocarp species for future forest management decisions, coupled with a general paucity of knowledge about the growth of this species. *Dryobalanops aromatica* is regarded as the most promising indigenous species for plantation forestry in Peninsular Malaysia (Afzal-Ata *et al.* 1985, Abd. Rahman *et al.* 1992, Appanah & Weinland 1993) and future reforestation works with this species will cover a wide variety of land areas including flat, undulating and even sloping topography. The study provides an opportunity to generate baseline information on growth of *D. aromatica* for future plantation. This paper is based on the analysis of growth and estimates of diameter growth recorded between 1915 and 1976. The data in this study were made available by the Forestry Department, Selangor, Peninsular Malaysia. Unfortunately, no more data were collected, therefore a 61-year run of data is rare and provides an opportunity for growth study.

Materials and methods

Study area

The main study area was situated in Compartment 15, Kancing Forest Reserve, Selangor in the western part of Peninsular Malaysia (latitude 3° 14' N, longitude 101° 38' E) (Amir Husni *et al.* 1997). Located just north of the equator, the area has a perhumid climate with an average daily temperature ranging from 27 to 32 °C (Ismail 1964). The annual rainfall is between 1900 and 2050 mm. The Kancing plot is located at an elevation of 150 m asl and is classified as a lowland dipterocarp forest with species of *D. aromatica* forming a large percentage of the growing stock. The terrain is undulating. The parent material is granite and the soil texture ranges from lateritic, sandy loam to sand. The soil is reddish loam with underlying rock and granite belonging to Palaeudult series, locally known as Rengam (Wyatt-Smith 1963).

The other study site, comprising six plots of mature plantation grown *D. aromatica* (Ahmad Zuhaidi *et al.* 2003) from Bukit Lagong Forest Reserve, situated 5 km south of Kancing, was used for comparison. The site is located at an elevation of between 90 and 130 m asl on the lower slopes of Lagong range. Most of the sites

were formerly cultivated as vegetable gardens and later overgrown with *Imperata cylindrica* (Landon 1948). Kancing and Bukit Lagong have similar climatic and soil conditions.

Growth data

Data on measured diameters for a plot of naturally regenerated *D. aromatica* at Kancing were used in this study. Measurements were made between 1915 and 1976. Data from Ahmad Zuhaidi *et al.* (2003) were used for comparison.

From 1910 till 1911, all trees within the Kancing plot area with crowns interfering with the *D. aromatica* seedlings (less than 1.5 m in height) were felled and ringed and palms cut and poisoned. In 1914, all mature *D. aromatica* trees were felled for making railway sleepers, leaving an almost pure stand of natural regeneration of *D. aromatica* with some scattered large trees. A single rectangular 0.4-ha plot was established in September 1915. The objective of establishing the plot was to study the diameter increment of individual *D. aromatica* selected trees. The estimated age of the seedlings was three years. These seedlings germinated from seeds from the most recent fruiting season at that time (Anonymous 1915). A total of 91 seedlings within the plot (initial stocking 227 seedlings ha^{-1}) were tagged and girth at breast height measured annually starting October 1915 until October 1976. During the measurement period, four climber cuttings (1917, 1922, 1927, 1929), four thinnings (1929, 1933, 1938, 1946) and three poison-girdlings (1929, 1933, 1938) of large trees were carried out. For the first five years, total height was measured for all trees but only six selected trees in 1922 and 1929; thus the readings for these were not included in the analysis. Thinnings were carried out at 17, 21, 26 and 34 years (Table 1) with the removal of 20, 25, 35 and 15 trees leaving a stocking of 118, 93, 58 and 43 trees ha^{-1} respectively. Table 1 summarises the thinning operations in the plot from 1915 till 1976.

Table 1 Records of thinnings in Kancing plot from 1915 till 1976

Year of thinning	Age (years)	Removal N (ha^{-1})	Mean DBH (cm)	Remaining N (ha^{-1})	V (m^3 ha^{-1})
1929	17	20	15.8 ± 1.0	118	3.2
1933	21	25	20.6 ± 1.9	93	8.3
1938	26	35	22.3 ± 1 4	58	10.1
1946	34	15	30 4 ± 1.7	43	12 7

N = number of stems, V = volume

Basal area

Basal area is defined as the cross-sectional area of the stem at breast height, i.e. 1.3 m above ground (Husch *et al.* 1982). The basal area per tree was obtained using Equation 1 (Loetsch *et al.* 1973).

$$g = \{(d^2 \pi) \div 4\} / 10000 \quad (1)$$

where

g = basal area per tree (m^2)
d = diameter at breast height (m)
π = 3.1416

The basal area (G) was calculated as the sum of individual tree basal area corrected for the size of each individual plot.

Periodic annual diameter increment

The periodic annual diameter increment was calculated using Equation 2.

$$P_{obs} = \frac{d_{t+k} - d_t}{k} \times 365 \quad (2)$$

where

P_{obs} = observed periodic annual diameter increment (cm $year^{-1}$)
d_{t+k} = diameter at end of growth period (cm)
d_t = diameter at beginning of growth period (cm)
k = length of growth period (days)

Analysis of data

The periodic annual diameter increment, mean periodic annual diameter increment between the years of measurements and mean annual increment were determined using SAS/STAT 1989 PROC Summary. Statistical analysis of differences between plots at Bukit Lagong was analysed using SAS/STAT 1989 PROC GLM (Generalised Linear Model). Duncan's multiple range test was used to determine differences between means.

Results and discussion

Table 1 shows the sequence of thinnings carried out in Kancing from 1915 till 1976. During this period, four thinnnings were carried out leaving a final stocking of 43 stems ha^{-1}. Table 2 shows of the achieved growth of *D. aromatica* from the age of 11 to 64 years old at Kancing. After 64 years, the mean DBH was 61.4 cm. The mean annual diameter increment was 1.00 ± 0.01 cm $year^{-1}$ (ranging from 0.96 ± 0.03 to 1.09 ± 0.04 cm $year^{-1}$). Table 3 shows the achieved growth of the six plots at Bukit Lagong. None of the plots from Bukit Lagong had mean DBH as large as those from Kancing plot at equivalent ages. Plot 2 from Bukit Lagong only achieved a mean DBH of 45.7 cm at a stocking of 161 stems ha^{-1} after 57 years. Plot 6, which is the oldest plot at Bukit Lagong, having trees aged 71 years, only reached a DBH of 49.3 cm at a stocking of 184 stems ha^{-1}. This value was already achieved at the Kancing plot at the age of between 44 and 50 years. The low stocking (43 stems

Table 2 Stand and stocking table of *Dryobalanops aromatica* at Kancing Forest Reserve

Age	N	Mean DBH (cm)	G (m^2 ha^{-1})	P_d (cm $year^{-1}$)	M_d (cm $year^{-1}$)
11	150	12.5	1.85	0.91 ± 0.07	1.09 ± 0.04
15	133	16.7	2.91	0.99 ± 0 05	1.09 ± 0.04
20	118	21.8	4.42	0.85 ± 0.06	1.01 ± 0.04
25	93	26.3	5.07	0.86 ± 0.07	1.01 ± 0.04
31	60	34.9	5.75	0.82 ± 0.07	0.99 ± 0.03
38	43	42.0	5.97	1.11 ± 0.11	0.98 ± 0.03
44	43	48 1	7.80	0.63 ± 0.06	0.99 ± 0.03
50	43	53.1	9.51	0.80 ± 0.08	1.06 ± 0.03
55	43	55.7	10.48	0.55 ± 0.08	1.01 ± 0.03
60	43	58.6	11.58	0.53 ± 0.08	0.97 ± 0.03
64	42	61.4	12.33	0.61 ± 0.01	0.96 ± 0.03
Mean				0.91 ± 0.01	1.00 ± 0.01

N = Number of stems ha^{-1}, G = basal area ha^{-1}, P_d = periodic mean annual increment , M_d = mean annual diameter increment. Calculation of volume ha^{-1} was not possible as the records on height measurement at 64 years were not available.

Table 3 Standing stock of plantation grown *Dryobalanops aromatica* stands at Bukit Lagong Forest Reserve

Plot / Age	N (ha^{-1})	Mean DBH (cm)	H_c (m)	M_d (cm $year^{-1}$)	G (m^2 ha^{-1})
1 / 50	321	32.6 ± 0.9	22.3 ± 0.2	0.64 ± 0.01 c	32.5
2 / 57	161	45.7 ± 1.9	20.8 ± 0.5	0.80 ± 0.01 a	30.2
3 / 64	318	36.2 ± 1.0	21.1 ± 0.4	0.57 ± 0.01 d	37.4
4 / 71	258	40.3 ± 1.5	24.7 ± 0.6	0.56 ± 0.01 d	38.7
5 / 51	557	27.8 ± 0.9	25.6 ± 0.3	0.54 ± 0.01 d	38.2
6 / 71	184	49.3 ± 1.5	28.6 ± 0.2	0.69 ± 0.02 b	36.7

N = number of stems ha^{-1}, H_c = crown-point height, G=basal area ha^{-1}, M_d = mean annual diameter increment. Values in each column with the same letter are not significantly different at the 0.05 probability level. Crown-point height is the distance along the axis of the tree stem from ground level to the first branch forming the crown

ha^{-1}) after series of thinnings at Kancing compared with that at Bukit Lagong (161 to 557 stems ha^{-1}) is largely responsible for the higher diameter growth at Kancing. Even if all trees equal to or greater than 50 cm were considered, the mean DBH at the Kancing plot still exceeded the highest achieved mean DBH from plots 2 and 6 at Bukit Lagong.

The mean DBH growth of naturally regenerated trees accelerated from the early age of three years until 64 years (Figure 1a). All trees above 23 years old had a mean DBH above 20 cm and by the age of 50 years, the DBH exceeded 50 cm, reaching 61 cm at the age of 64 years. Overall the thinnings had caused an increase in diameter. The thinning at age 26 years caused a sudden increase in the DBH (Figure 1a). In 1960, at the stand age of 48 years, the periodic annual diameter increment of the stand (0.95 cm $year^{-1}$) fell to a level below the overall mean annual diameter increment (1.00 cm $year^{-1}$) (Figure 1b and Table 2). Theoretically,

once the periodic annual diameter increment fell below the mean annual diameter increment, the mean annual increment itself would begin to fall gradually, indicating that growth of the species had passed the culmination point of mean annual increment. The point of intersection between the periodic and mean annual diameter increments was also the maximum value the mean annual diameter increment could reach. The calculated mean annual increment at age 48 years was 1.06 cm.

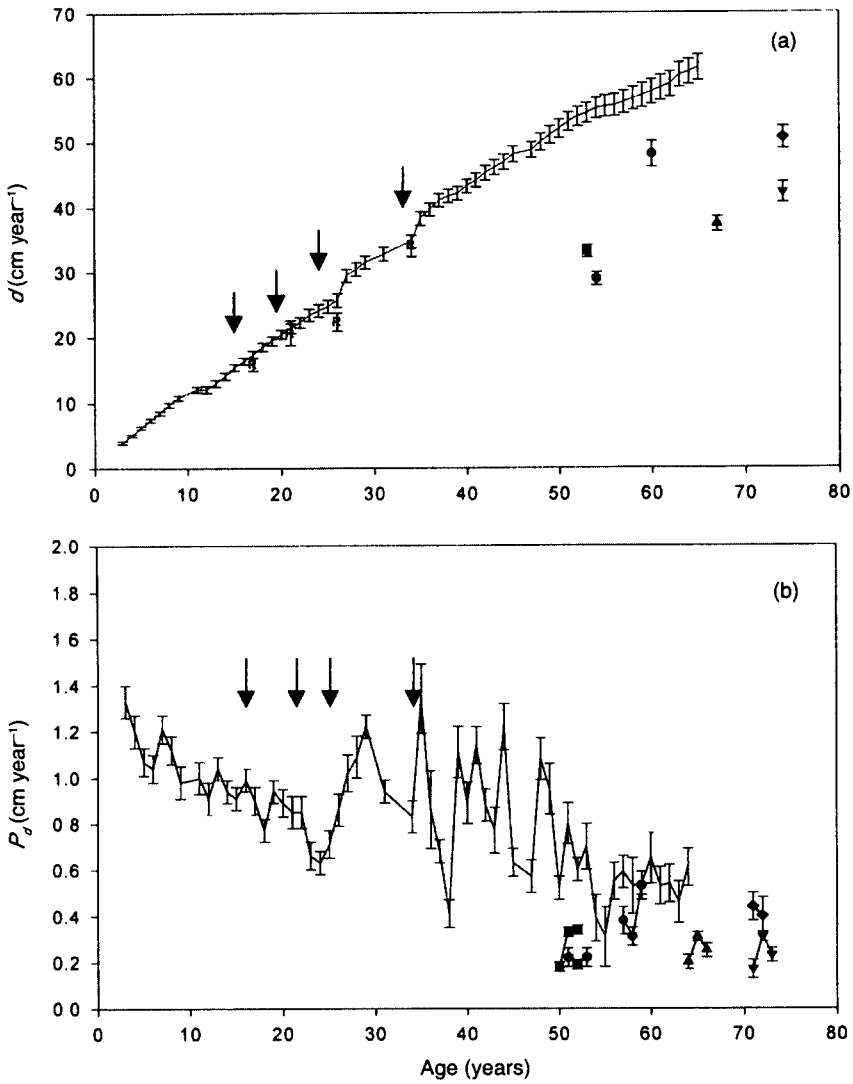

Figure 1 (a) Achieved diameter (d) growth and (b) periodic annual diameter increment (P_d) of the Kancing plot in Kancing Forest Reserve from 1915 to 1976 and plots in Bukit Lagong Forest Reserve. Plot 1 = ■, Plot 2 = ●, Plot 3 = ▲, Plot 4 - ▼, Plot 5 = ●, Plot 6 = ◆. Mean d during thinnings = R at stand age of 17, 21, 26 and 34 years. Arrows indicate time of thinnings. Means are reported ± 1 standard error

Conclusions

Dryobalanops aromatica can be categorised as a relatively fast growing dipterocarp with the ability to produce marketable size logs (greater than 60 cm diameter) in a rotation length of 60 years, if grown at the right density and heavy thinning is applied. Under this condition, the species shows relatively fast diameter growth with a mean annual diameter increment of 0.96–1.09 cm year^{-1} over the whole rotation period. At age of 64 years, the periodical annual diameter increment fell below the mean annual increment, indicating that the species had reached the culmination point of the mean annual diameter increment. The site at Kancing plot was an undisturbed forest in the lowland dipterocarp except for the manual felling operations of mature *D. aromatica* forests during establishment of the plot, compared with plots at Bukit Lagong, which were formerly cultivated vegetable farms. The Kancing plot is located at a higher altitude of 152 m asl compared with Bukit Lagong at 98 m. These factors may partially explain the more favourable growth at Kancing as low lying areas are generally flat and poorly drained.

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