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EARLY GROWTH PERFORMANCE OF FIVE HALF-SIB FAMILIES OF *HOPEA ODORATA* ROXB. (DIPTEROCARPACEAE) AND THEIR MULTIPLE SEEDLINGS PLANTED IN BUKIT HARI FOREST RESERVE

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In Malaysia, *Hopea odorata* (locally known as merawan siput jantan) occurs mainly in the states of Perlis, Kedah, Perak, Kelantan and Terengganu. In its natural habitat, it is normally found growing near riverbanks (Symington 1943). *Hopea odorata* is a promising indigenous species with good wood qualities and pliable to management under plantation conditions. However, no tree improvement work has yet been carried out for the species. The timber is moderately durable under exposed conditions (Ho 1981) and is generally used for light to medium construction work such as flooring for pedestrian traffic, light industrial floors and joinery purposes. No extensive study on reproductive biology has yet been carried out for the species. Kaur *et al.* (1978) reported that 90% of the seeds produced by the species have multiple seedlings and the phenomenon of multiple seedlings is generally associated with apomixis.

A study on the early growth (2 y after planting) of *H. odorata* by Wan Razali and Ang (1991) on the degraded sites of logged-over forest such as decking sites, skid trails and road shoulders showed that the mean annual increments of height and diameter 30 cm above the ground were 1.15 m y^{-1} and 2.4 cm y^{-1} respectively. They also found that the species grows better at decking site, which has compacted soil and open environment compared to the trees planted on skid trails and road shoulders, which are partially shaded by the remaining trees. Here we report on the early growth performance of five half-sib families of *H. odorata* planted under open environment in Bukit Hari Forest Reserve. The specific objectives of this study were: (1) to test the significant difference in terms of growth performance among the five half-sib families, and (2) to test the hypothesis that multiple seedlings from the same seed have similar growth performance because they are derived from apomixis.

Seeds of five half-sib families were collected in 1994 and the details of the collected families are given in Table 1. Collected seeds were sown in medium consisting of forest topsoil and sand in the ratio of 3:1. The germinated seedlings were potted in black perforated polythene bags when they reached a height of about 10 cm. Multiple seedlings from the same seed were separated before potting in different bags. Planting sites are located in Bukit Hari (3° 14'N, 101° 38'E). The area is characterised by a uniformly high temperature and rainfall throughout the year. The mean annual rainfall is 2173 mm while the mean temperature is 27 °C.

The seedlings were planted at a spacing of 3 × 3 m in two nearby plots (designated as plot 1 and plot 2). Each of the plots consisted of all the five studied families (Table 1). Plot 1 was at an altitude of 100–150 m above sea-level (asl) whereas plot 2 was 200–220 m asl. The soil in both plots is a heavy clay loam of granitic origin and drainage is free. The plots were maintained as follows: weeding and climber cutting every four months; fertilising every six months; and pruning was carried once after 16 months of planting. To test the hypothesis that multiple seedlings from the same seed have similar growth performance because they are derived from apomixis, seedlings of five half-sib families which seed produced five to six multiple embryos were planted next to one another in

plot 1. The total height and collar diameter (at 5 cm above the ground) of the seedlings were measured at four-month intervals after planting. Analysis of variance was conducted to assess the significant difference among families and between plots.

Table 1. Seed sources of the five half-sib families and number of seedlings planted in the plots

Family	Source	No. of seedlings planted	
		Plot 1	Plot 2
HTR	Terengganu (Bukit Ajil)	85	67
H01	FRIM (Club ID=01)	45	42
H03	FRIM (School ID=03)	40	40
H10	FRIM (Club ID=10)	30	33
HAB	FRIM (Aboretum)	50	51

ID = field identification number.

Table 2. The growth performance of the five half-sib families of *Hopea odorata* in two replicate plots after 20 months of planting. Values in parentheses are standard deviations.

Family	Plot 1						Plot 2					
	h20	d20	$h20^{5\%}$	$d20^{5\%}$	hCAI	dCAI	h20	d20	$h20^{5\%}$	$d20^{5\%}$	hCAI	dCAI
HTR	156 (32)	26.55 (5.16)	222 (20)	36.69 (0.86)	94	15.93	176 (50)	31.79 (7.23)	265 (7)	45.75 (2.23)	106	19.07
H01	165 (32)	27.00 (5.35)	243 (11)	39.16 (0.93)	99	16.20	222 (42)	36.17 (6.63)	310 (0)	49.45 (3.34)	133	21.70
H03	134 (26)	19.52 (4.12)	167 (12)	28.50 (0.38)	80	11.71	171 (38)	26.50 (5.29)	238 (4)	36.96 (0.87)	103	15.90
H10	151 (29)	22.22 (4.59)	195 (1)	30.62 (1.81)	91	13.33	163 (49)	25.31 (7.35)	250 (28)	39.07 (3.81)	98	15.19
HAB	124 (19)	18.22 (3.55)	157 (2)	25.30 (2.16)	74	10.93	188 (38)	30.07 (6.28)	257 (8)	43.69 (2.84)	113	18.04

h20 = mean height at 20 months (cm)
d20 = mean diameter at 20 months (mm)
$h20^{5\%}$ = mean height of 5% most vigorous seedlings at 20 months (cm)
$d20^{5\%}$ = mean diameter of 5% most vigorous seedlings at 20 months (mm)
hCAI = current annual increment of height (cm y^{-1})
dCAI = current annual increment of diameter (mm y^{-1})

The growth performance of family H01 was generally better than that of the other four families in both plots (Table 2, plot 1: mean at 20 months for height [h20] and diameter [d20] = 165 cm and 27.00 mm, mean of 5% most vigorous seedlings at 20 months for height [$h20^{5\%}$] and diameter [$d20^{5\%}$] = 243 cm and 39.16 mm, current annual increment of height [hCAI] and diameter [dCAI] = 99 cm y^{-1} and 16.20 mm y^{-1} respectively; plot 2: h20 = 222 cm,

d20 = 36.17 mm, $h20^{5\%}$ = 310 cm, $d20^{5\%}$ = 49.45 mm, hCAI = 133 cm y^{-1} and dCAI = 21.7 mm y^{-1}). This was followed by HTR. HAB performed well in plot 2 but not in plot 1. However, analysis of variance among families for mean height at 20 months showed no significant difference and small significance (p = 0.074) for mean diameter at 20 months (Table 3). As expected, significant differences were observed between plots for height (p = 0.020) as well as diameter (p = 0.009) (Table 3). The two plots were maintained in similar manner. However, weeds growing in plot 1 were combative and after each weeding and climber cutting cycle, within a month, seedlings were covered again by *Mikania micrantha* (selaput tunggul) and the area was overgrown with *Themeda villosa* (riong), *Scleria sumatrensis* (sendayan), *Ottochloa nodosa* (rumput pait), *Musa malaccensis* (pisang hutan) and *Mimosa pudica* (malu-malu). Thus, the significant differences between plots appear to be related to the overgrowth of weeds, especially *M. micrantha.*

Table 3. Analysis of variance to test the significant difference of growth performance among the five half-sib families of *H. odorata* and between plots

Sources of variation	df	Height				Diameter			
		SS	MS	F	P	SS	MS	F	P
Family	4	2229	557	2.19	0.234	116.11	29.03	5.02	0.074
Plot	1	3610	3610	14.17	0.020*	131.99	131.99	22.84	0.009**
Error	4	1019	255			23.13	5.78		

* significant at 5% level.
** significant at 1% level.

Table 4. The growth performance (height and diameter) of multiple seedlings from the same seed after 20 months of planting. H = height (cm) and D = diameter (mm).

Multiple seedlings	Seed A		Seed B		Seed C		Seed D		Seed E	
	H	D	H	D	H	D	H	D	H	D
1	121^{ns}	21.45^{ns}	140^{ns}	$23.32^{<1}$	$185^{\geq1}$	$33.68^{\geq2}$	$140^{<2}$	$24.70^{<2}$	$140^{<2}$	$26.12^{<2}$
2	125^{ns}	$23.03^{\geq1}$	$123^{<2}$	$23.23^{<1}$	$\underline{167}^{ns}$	$\underline{26.45}^{ns}$	$170^{\geq1}$	25.91^{ns}	$250^{\geq3}$	$36.50^{\geq3}$
3	123^{ns}	$24.26^{\geq2}$	$\underline{174}^{\geq2}$	$\underline{32.35}^{\geq2}$	$\underline{160}^{ns}$	$\underline{26.23}^{ns}$	$180^{\geq3}$	$30.66^{\geq3}$	205^{ns}	$28.18^{<1}$
4	$151^{\geq3}$	$18.97^{<1}$	$\underline{160}^{\geq2}$	$\underline{31.47}^{\geq2}$	$185^{\geq1}$	25.66^{ns}	160^{ns}	26.07^{ns}	180^{ns}	31.01^{ns}
5	$93^{<3}$	$15.37^{<3}$	$125^{<1}$	$19.55^{<3}$	$105^{<3}$	$15.82^{<3}$	$145^{<2}$	27.02^{ns}	$158^{<1}$	30.65^{ns}
6	$141^{\geq2}$	$24.23^{\geq2}$	-	-	-	-	-	-	-	-
Mean	126	21.22	144	25.98	160	25.57	159	26.89	187	30.49
S. error	8	1.42	10	2.52	15	2.85	7	1.01	19	1.74

^{ns} no significant difference from general mean.
$^{\geq1}$ higher or equal than general mean plus one standard error.
$^{<1}$ lower than general mean minus one standard error.
$^{\geq2}$ higher or equal than general mean plus two standard errors.
$^{<2}$ lower than general mean minus two standard errors.
$^{\geq3}$ higher or equal than general mean plus three or more standard errors.
$^{<3}$ lower than general mean minus three or more standard errors.

The growth performance of multiple seedlings from the same seed after 20 months of planting is shown in Table 4. Most of the multiple seedlings from the same seed exhibited different patterns of growth performance. Only two out of the five multiple seedlings of seed B (multiple seedlings 3 and 4) and seed C (multiple seedlings 2 and 3) showed similar growth of height and diameter. This suggests that they might not necessarily involve apomixis and agrees with the report of Wickneswari *et al.* (1995), who detected two to three randomly amplified polymorphic DNA (RAPD) profiles among some multiple seedlings from the same seed, indicating a possible combination of sexual and asexual reproduction. The ovary in Dipterocarpaceae is usually three locular with two ovules in each loculus. Generally, only one ovule develops into a seed. Thus multiple seedlings could result from occasional development of seeds from more than one ovule and the presence of such seedlings does not always imply apomixis.

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