GROWTH AND SURVIVAL OF *CALAMUS SUBINERMIS* IN PROVENANCE TRIALS IN SABAH, MALAYSIA

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CHIA FR, LEE YF & AMINUDDIN M. 2010 Growth and survival of *Calamus subinermis* in provenance trials in Sabah, Malaysia. A study was carried out to assess the growth and survival of 14-year-old provenance cum progeny trials of *Calamus subinermis* at three different sites and soil types in Sabah, Malaysia. These sites were Kolapis A, a logged-over forest with sandy clay loam; Segaliud Lokan, an *Acacia mangium* plantation with sandy loam to sandy clay loam and Sook, scrub dominated by *Baeckia frustescens* with gleyic podzol. High survival percentage (more than 85%) was observed in Sook while high mortality rate (more than 60%) was noticed in both Kolapis A and Segaliud Lokan. Mean annual growth rates of *C. subinermis* were 1.36, 3.34 and 3.78 m year^{-1} in Sook, Segaliud Lokan and Kolapis A respectively. The growth performance of *C. subinermis* was more affected by soil type or soil condition than by provenance.

Keywords: Rotan batu, stem length, mortality, sandy, clay, loam, gleyic podzol

CHIA FR, LEE YF & AMINUDDIN M. 2010. Pertumbuhan dan kemandirian *Calamus subinermis* dalam percubaan provenans di Sabah, Malaysia. Satu kajian dijalankan untuk menilai pertumbuhan dan kemandirian *Calamus subinermis* berusia 14 tahun di plot percubaan provenans serta progeni di Sabah, Malaysia. Spesies tersebut ditanam di tiga tapak yang mempunyai jenis tanah yang berbeza. Tapak-tapak ini ialah Kolapis A, sebuah hutan sudah kerja yang mempunyai tanah jenis lom lempung berpasir; Segaliud Lokan, sebuah ladang *Acacia mangium* dengan tanah jenis lom berpasir dan lom lempung berpasir; dan Sook, belukar yang dikuasai oleh *Baeckia frustescens* dengan tanah jenis glei podzol. Sook menunjukkan peratusan kemandirian yang tinggi (melebihi 85%) manakala Kolapis A dan Segaliud Lokan menunjukkan kadar kematian yang tinggi (melebihi 60%). Purata kadar pertumbuhan tahunan *C. subinermis* ialah 1.36 m/tahun bagi Sook, 3.34 m/tahun bagi Segaliud Lokan dan 3.78 m/tahun bagi Kolapis A. Prestasi pertumbuhan *C. subinermis* lebih dipengaruhi oleh jenis atau keadaan tanah daripada provenans.

INTRODUCTION

Rattans are climbing palms that are mainly used in South-East Asia. Interest in plantation establishment of rattan is steadily growing as the development and use of rattan are still dependent on existing natural forests which are not sustainable for the industry (Raja Barizan 2008). The identification of suitable rattan species, provenances and genotypes for plantation establishment is urgent. During the last decades, many studies on growth and other silvicultural aspects of rattan have been carried out on *Calamus manan, C. caesius* and *C. trachycoleus* (Manokaran1982, Shim 1989, Nur Supardi & Aminuddin1990). However, there is limited information on *C. subinermis,* which is the most commercially important large-diameter rattan species in Sabah, Malaysia. Only a few preliminary results on the growth of wild and planted *C. subinermis* (rotan batu) had been reported in the last decades (Chia 1995, Bacilieri *et al.* 1999, Lee 1999). Most of these results were limited to wild population of a certain site and soil type of uncertain age. As *C. subinermis* is confined naturally in coastal regions and usually on sandy and shallow soil in heath forest, it is necessary to gather detailed information on the growth performance of this species under plantation condition. This species is recommended for large-scale planting due to its favourable growth rate in the natural environment, clustering behaviour and high quality cane. It produces large-diameter cane (18–30 mm) that is comparable in

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quality to *C. manan* (Dransfield *et al.* 1989). Due to the depletion of rattan from natural forest and the increasing demand in both local and international markets for rattan product, there has been considerable interest in the cultivation of rattan such as *C. subinermis*. However, no large-scale plantation has been established for this species due to the lack of ecological information such as site, soil nutrient and optimum relative light intensity.

The main factors that affect the growth of rattan are soil nutrients, light intensity and seed source (Manokaran 1985, Raja Barizan & Aminuddin 1992, Tan 1992, Lee 1999). Plants require macro- and micronutrients for healthy growth. Macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) are important elements for plant growth (Raja Barizan & Aminuddin 1992). These elements are also widely found in commercial fertiliser.

Seed source or provenance is another important factor that affect the growth of rattan (Appanah *et al.* 1999). The large variation in growth rate may be due to genetic or environment. This makes management of rattan plantation difficult (Appanah *et al.* 1999). The unselected seed source may contribute to inconsistent growth of rattan.

The provenance cum progeny trial of *C. subinermis* was established in 1993 for the purpose of genetic conservation. There are three provenance trials in Sabah at three different localities, namely, Sook at the interior west coast, and Kolapis A and Segaliud Lokan at the east-coast. The provenance information gathered to date remains insufficient for provenance variation to be fully exploited for planting purposes. The preliminary results of the provenance cum progeny trials of *C. subinermis* at Sook, Segaliud Lokan and Kolapis A have been reported by Lee (1995). However, these results are still inconclusive because the canes have not reached biological maturity. For timber species, half the rotation age is the shortest time for reliably determining the growth characteristic of a species (Zobel & Talbert 1984). Raja Barizan and Shamsudin (2003) estimated that the rotation age for large-diameter rattan such as *C. manan* was about 20 years to produce good quality cane. Assuming that rattan is the same as timber, the performance of rattan in these trials can only be reliably assessed at 10 years after planting. Thus, the objectives of this study were to determine the growth performance and survival percentage of *C. subinermis* from different provenances of different soil types, canopy openings, plant spacing and support trees.

MATERIALS AND METHODS

Assessment was carried out at the existing provenance cum progeny trial of *C. subinermis* in Sabah that was established in 1993. There are 13, 11 and 14 provenances tested in Sook, Kolapis A and Segaliud Lokan respectively (Table 1).

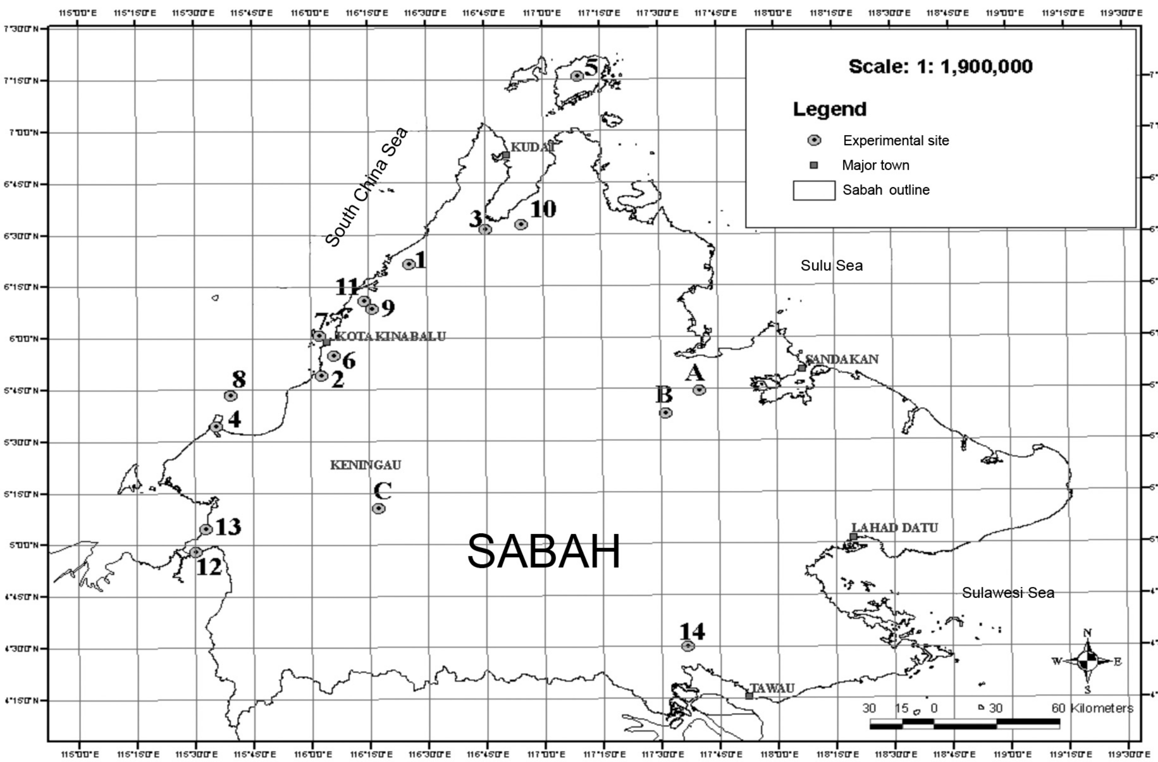
The geographical locations of these provenances and experimental sites, namely, Kolapis A (5° 44' N, 117° 40' E), Segaliud Lokan (5° 38' N, 117° 32' E) and Sook (5° 8' N 116° 17' E) are indicated in Figure 1. The soil in Kolapis A is sandy clay loam of the Tanjung Lipat Family, that in Segaliud Lokan is sandy loam to sandy clay loam of the Kapilit Family (Acres & Folland 1975) and that in Sook is gleyic podzol of the Baiayo Family (Bower *et al.* 1975). Table 2 shows the macronutrient contents and microclimatic conditions of the three sites. Kolapis A was formerly a burned logged-over forest while Segaliud Lokan, a 3-year-old *Acacia mangium* plantation planted with a spacing of 3 × 3 m. In Sook, the vegetation was scrub dominated by *Baeckia frustescens*. The planting distance for *C. subinermis* was 3 × 2 m, double row system within 7 and 6 m cleared planting path in Kolapis A and Segaliud Lokan respectively. In Sook, single-row planting with 3 m distance was implemented. The spacing was decided based on the condition of the forest that supported the rattan whereby in Segaliud Lokan, row thinning of *Acacia* stand; in Kolapis A, clearing of suitable planting paths in disturbed forest; and in Sook, planting in berungis scrub.

Measurements of total stem length, stem diameter, internode length, length of stem covered with dried sheath, length of stem covered with green sheath and number of suckers were made. For the clustering of *C. subinermis*, only the oldest (mother) aerial stem was selected from the clump for measurement. The stem diameter was measured at the middle region of the 10th internode with digital callipers. The internode length was determined based on the mean internode lengths of three internodes, i.e. 11th, 12th and 13th internodes of the stem. The data collected were analysed to describe the

Table 1 Provenances tested at the three sites

Provenance	Sook			Kolapis A			Segaliud Lokan		
	NF	TR/b	TRP	NF	TR/b	TRP	NF	TR/b	TRP
Kota Belud (KBE)	3	15	60	18	90	450	18	90	450
Kinarut (KIN)	3	15	60	6	30	150	6	30	150
Kota Marudu (KM)	1	5	20	1	5	25	2	10	50
Kuala Penyu (KP)	4	20	80	26	130	650	28	140	700
Banggi Island (PBA)	2	10	40	2	10	50	2	10	50
Penampang (PEN)	4	20	80	29	145	725	33	165	825
Gaya Island (PG)	3	15	60	20	100	500	27	135	675
Tiga Island (PT)	3	15	60	14	70	350	19	90	450
Tamparuli (TAM)	3	15	60	15	75	375	16	80	400
Tandek (TAN)	2	10	40	2	10	50	2	10	50
Tuaran (TUA)	3	15	60	8	40	200	8	40	200
Lawas (LAW)	1	5	20	–			1	5	25
Sipitang (SIP)	1	5	20	–			1	5	25
Brumas (BRU)	–	–	–	–			1	5	25
Total	33	165	660	141	705	3525	163	815	4075

NF = number of families; TR/b = total rattan planted per block; TRP = total rattan planted



Experimental sites
A Kolapis A
B Segaliud Lokan
C Sook

Provenances
1. Kota Belud (KBE)
2. Kinarut (KIN)
3. Kota Marudu (KM)
4. Kuala Penyu (KP)
5. Banggi Island (PBA)
6. Penampang (PEN)
7. Gaya Island (PG)
8. Tiga Island (PT)
9. Tamparuli (TAM)
10. Tandek (TAN)
11. Tuaran (TUA)
12. Lawas (LAW)
13. Sipitang (SIP)
14. Brumas (BRU)

Figure 1 Location of experimental sites and provenances of *Calamus subinermis* tested

Table 2 Macronutrient contents in top soil (0–30 cm) and microclimatic conditions of the three sites

Macronutrient/ microclimatic condition	Sook	Kolapis A	Segaliud Lokan
N (%)	0.05	0.14	0.09
P (ppm)	2.75	1.50	2.20
K (m.e.%)	0.05	0.23	0.33
Ca (m.e.%)	0.46	1.40	0.86
Mg (m.e.%)	0.01	0.14	0.08
Mean relative light intensity (%)	28.93	19.18	32.07
Relative humidity (%)	63–75	60–87.5	60–87.5
Temperature (°C)	23–28	25–34	26–28
Mean annual rainfall (mm)	2000	3000	3000
pH	4.38	4.98	4.64

growth performance of provenances at each site. The growth rate of rattan was calculated using mean total stem length divided by the age of the rattan. The mean annual growth rate for each site and provenance was calculated by dividing the mean total stem length with the age of the trial. The survival percentage for each block in each provenance was calculated by dividing the total number of living rattan with the total number of planted rattan and multiplying by 100. Data collected from the trial plots were analysed based on randomised complete block design. Analysis of variance in SPSS 8 was applied to determine the difference between provenances at each site. Two way analyses by using the general linear model procedure in SPSS 8 were carried out to determine the growth performance at each site. Comparison of means between provenances was carried out to determine the best growth performer at each site.

RESULTS AND DISCUSSION

Survival percentage

The survival rate was high at Sook with a mean of 88.93% (Table 3). The high survival rate of *C. subinermis* in Sook indicates that this species is well adapted to this site as it is a heath forest where this species normally thrives. This plot recorded a 100% survival for the first year after planting (Lee 1995). The high mortality rate of about 86% in Segaliud Lokan indicated that *C. subinermis* could not survive in this plot. The major cause of mortality was the disturbance of wild elephants. The survival percentage of 42% in Kolapis A indicated that *C. subinermis* could survive under sandy clay loam soil.

The survival percentages for 13 provenances at Sook ranged from 70 to 93% with PG recording the highest survival percentage (Table 3). The overall survival percentages for the 14 provenances tested in Segaliud Lokan were not encouraging, ranging from 0 to 15.56%. There was no survival for provenance SIP, LAW and BRU in Segaliud Lokan. The survival percentages for the 11 provenances tested in Kolapis A ranged from 12 to 37%.

Provenance PT recorded the highest survival percentage across the three sites (Table 3). The survival percentages of provenances PT, KP and TAM were significantly higher in Kolapis A. Provenances KIN, PT, PG, KP and PBA had higher survival percentages in Segaliud Lokan. Provenances PT and KP, which are geographically very near to each other (Figure 1), seem to be more adapted to the surrounding as compared with the others. The three main geographical isolated provenances were KBE, PT and PEN (Lee 1999).

Growth performance

The stem elongation rates for all provenances tested ranged from 0.82 to 1.69 m year^{-1}, 2.87 to 4.73 m year^{-1} and 2.37 to 3.82 m year^{-1} in Sook, Kolapis A and Segaliud Lokan respectively (Table 3). The overall performance of all provenances was totally dependent on site condition. This was indicated by the different top performers at different sites. Provenance KM outperformed other provenances in terms of stem elongation rate in Sook and Kolapis A but TAM appeared to be the top performer in Segaliud Lokan.

This result indicated that *C. subinermis* grew well under Kolapis A soil condition or sandy clay

Table 3 Survival of all the provenances tested at three sites

Provenance	Sook			Kolapis A			Segaliud Lokan		
	N	S	MAI	N	S	MAI	N	S	MAI
SIP	20	90.00	0.82	–	–	–	25	0.00	–
PEN	80	70.00	1.22	725	22.34	3.41	825	6.91	3.67
KIN	60	81.67	1.30	150	32.00	3.67	150	14.00	2.37
KBE	60	85.00	1.27	450	33.33	3.96	450	10.00	3.58
TAM	60	91.67	1.27	375	36.80	3.85	400	11.75	3.82
PG	60	93.33	1.32	500	25.20	3.67	675	13.33	3.40
PT	60	91.67	1.41	350	36.29	4.10	450	15.56	3.37
KP	80	81.25	1.39	650	37.23	3.83	700	13.28	3.53
TUA	60	88.33	1.41	200	32.50	4.21	200	11.00	3.69
PBA	40	90.00	1.49	50	24.00	3.27	50	14.00	3.22
TAN	40	82.50	1.49	50	32.00	2.87	50	12.00	2.99
LAW	20	80.00	1.63	–	–	–	25	0.00	–
KM	20	80.00	1.69	25	12.00	4.73	50	6.00	3.07
BRU	–	–	–	–	–	–	25	0.00	–
Mean	–	88.93	1.36	–	42.06	3.78	–	14.07	3.34

N = number of rattan planted in a provenance; S = survival percentage; – = not planted; MAI = stem elongation rate (m $year^{-1}$)

loam. The annual growth rate for all provenances tested was also influenced by the planting condition. All provenances seemed to grow better on fertile soil like Kolapis A and Segaliud Lokan. For example, all the provenances tested in Kolapis A had an annual growth rate of more than 3 m $year^{-1}$ except for provenance TAN. None of the provenances tested in Sook exceeded 2 m $year^{-1}$ in annual growth rate. The average growth rates for all the provenances tested were 3.78, 3.34 and 1.36 m $year^{-1}$ for Kolapis A, Segaliud Lokan and Sook respectively.

The annual growth rate of *C. subinermis* was extremely variable between sites. The results showed that 33.94, 11.20 and 10.56% of the total population in Sook, Segaliud Lokan and Kolapis A respectively had annual growth rates of ≤ 1 m (Table 4). About 43.36% of the total rattan canes assessed in Segaliud Lokan were more than 4 m in annual growth rate compared with 50.74% in Kolapis A. Only 0.55% of the total canes assessed in Sook had annual growth rates of more than 3 m. This indicated that Kolapis A produced longer canes compared with the other sites. The growth performance of *C. subinermis* was affected by the availability of macronutrients as the soil in Kolapis A had higher macronutrients compared with the other two sites (Table 2). As indicated by previous studies, the combination of N, P, K and Mg will result in better growth of plants in plantation (Raja Barizan & Aminuddin 1992). For example, the stem growth rate of *C. manan* planted under rubber plantation was enhanced by N × K and N × P fertilisations but P fertilisation elicited no direct response (Raja Barizan & Aminuddin 1992). Thus, the low availability of macronutrients except for P in Sook as indicated in Table 2 could affect the overall performance of rattan. Soils in Kolapis A and Segaliud Lokan had high percentage of clay and silt whereby nutrients could not be easily leached out from the soil stratum. The soil pH was lower in Sook (4.38), compared with Segaliud Lokan (4.64) and Kolapis A (4.98). This indicates that *C. subinermis* prefers less compacted soil that is rich in macronutrients.

The results showed the differences in growth performances of *C. subinermis* at each site. The high variation in total stem length might be affected by different vegetation cover that influenced relative light intensity (RLI). Segaliud Lokan is an *A. mangium* plantation with more uniform environment than Sook, a natural heath forest and Kolapis A, a logged-over lowland dipterocarp forest. The environment at Kolapis A was considered as not uniform due to its nature as secondary logged-over forest with different types and sizes of standing trees that created different canopy gaps. The heath forest nature at Sook was also considered not uniform as it was dominated by *B. fructescens* and other treelets below 10 m in height. These treelets did not produce big branches and crowns. The *A. mangium* plantation in Segaliud Lokan had uniform environment. The mean RLI (Table 2) was higher in Segaliud Lokan (32.07%) compared with Sook and Kolapis A (28.93 and 19.18% respectively). However, the RLIs in Segaliud Lokan and Sook were not statistically different. This result indicated that RLI did not significantly affect the overall performance of rattan as the microclimatic condition and macronutrient content were quite similar for Kolapis A and Segaliud Lokan. The optimum RLI for stem elongation was about 20% as Kolapis A produced the highest number of longer stem. Furthermore, the planting distance and width of planting path did not affect the growth and total stem length of *C. subinermis* (Chia 2009). Based on the field observation, it could be concluded that the rattan stand was not a pure stand as rattan canes were found crawling between and within the planting path.

The result presented in Table 5 shows that the three top performers for each characteristic are different according to site. For example the top performers for stem diameter in Segaliud Lokan were KIN, TAM and TUA; Kolapis A, PEN, KIN and TUA; and Sook, PG, TUA and PBA. Different rankings for each characteristic indicated the existence of provenance–site interaction. However, PT and TUA appeared simultaneously as one of the top performers across three sites for internode length and stem diameter. These two provenances are not similar and are geographically isolated from each other. Provenances TAM and TUA resemble each other most closely and these two provenances are in descending order of resemblance to KIN, PEN, PG, KBE and PT (Lee 1999). The three main geographical isolated provenances were KBE, PT and PEN (Lee 1999). This result indicated that the seed origin was not the primary factor for rattan growth.

The stem diameter in disturbed sites such as Segaliud Lokan and Kolapis A was significantly larger than that of Sook. This result may be related to the fact that the stem diameter of *Desmoncus orthacanthos* in disturbed area is larger as the plants assign their resources to increase stem diameter (Quiroz *et al.* 2008).

The rate of sucker production is an important element that ensures sustainable production of clustering species such a *C. subinermis.* Clustering species sometimes possess up to 50 stems of varying ages in each clump and produce suckers that continually replace stems lost through natural senescence or harvesting (Sunderland & Dransfield 2002). *Calamus subinemis* seemed to produce more clustering than solitary stem in Sook (Table 5). However, the total stem length was significantly lower at this site. This indicates that the capability of the sucker to elongate to a stem is questionable. Sunderland and Dransfield

Table 4 Growth variation in *Calamus subinermis* at different sites

Growth class ($m\ year^{-1}$)	Sook (n = 551) %	Segaliud Lokan (n = 420) %	Kolapis A (n = 1070) %
0.01–1.00	33.94	11.20	10.56
1.01–2.00	45.20	16.43	12.62
2.01–3.00	20.52	15.72	11.12
3.01–4.00	0.55	13.34	14.95
4.01–5.00	–	20.72	21.03
5.01–6.00	–	15.00	17.66
6.01–7.00	–	6.44	9.72
7.01–8.00	–	0.96	2.24
8.01–9.00	–	0.24	0.00
9.01–10.00	–	–	0.09

n = Number of observation; % = percentage in the population included in the growth class

Table 5 Mean internode length, stem diameter and number of suckers of *Calamus subinermis* at three different sites

Provenance	Internode length (cm)			Stem diameter (mm)			Number of suckers		
	SK	SL	KA	SK	SL	KA	SK	SL	KA
PEN	26.58	29.00	25.75	23.73	25.78	**27.36**	3.88	2.46	2.06
KIN	**28.54**	28.53	**28.66**	22.58	**26.37**	**26.81**	5.58	1.50	3.13
KBE	26.85	27.36	26.74	22.81	26.11	25.09	5.00	4.80	3.42
TAM	26.00	**31.58**	**28.43**	23.09	**26.19**	25.74	**6.38**	4.75	**4.91**
PG	24.97	**31.22**	27.47	**24.38**	24.90	25.87	3.52	**5.33**	2.67
PT	**27.92**	**31.57**	**29.63**	24.02	24.67	25.22	6.13	2.83	3.80
KP	26.07	30.35	27.18	23.99	24.29	25.23	6.06	**6.16**	**4.83**
TUA	26.87	29.48	28.28	**24.03**	**26.18**	**26.07**	**7.87**	5.00	**6.75**
SIP	24.62	–	–	24.03	–	–	5.89	–	–
TAN	26.94	26.25	26.22	23.98	25.16	22.89	5.92	**5.33**	0.00
PBA	26.72	25.9	26.66	**24.39**	25.16	21.3	6.05	0.00	0.00
LAW	25.35	–	–	23.12	–	–	**9.40**	–	–
KM	**27.68**	26.1	33.33	23.73	20.94	22.29	3.57	0.00	0.00
Mean	26.55	28.85	28.03	23.68	25.07	24.90	5.79	3.45	2.87

SK = Sook; SL = Segaliud Lokan; KA = Kolapis A; top three performers are in bold

(2002) reported that the capability of the sucker to replace senescence mother stem was highly related to light intensity. The suitable RLI for seedling establishment in *C. manan* is 20 to 60% (Aminuddin 1987) and *C. subinermis* needs 70% light (Bacilieri *et al.* 1999). The juvenile (2 years old) *C. subinermis* has a higher photosynthetic rate of 2.34 to 14.28 μmol $m^{-2} s^{-1}$ (Chia 1994) compared with *C. manan* and *C. tumidus* with less than 1 μmol $m^{-2} s^{-1}$ (Aminuddin 1987). The assimilation rate was saturated at the light intensity of 1926 μmol $m^{-2} s^{-1}$ for *C. subinermis* (Chia 1994). This figure is far higher than those of *C. manan* and *C. tumidus* with values of 60 and 40 μmol $m^{-2} s^{-1}$ respectively (Aminuddin 1987). This indicates that *C. subinermis* is a light demanding species which requires a substantial amount of sunlight for seedling establishment. This was indicated by the prominent regeneration rate in Segaliud Lokan site which had higher RLI compared with Kolapis A. It was anticipated that the RLI in Sook (28.93%) might be just suitable for producing suckers rather than aerial stem.

All parameters measured were affected by the environment at Sook due to the highly significant variations between provenance and replicate (Table 6). This was not the case with Kolapis A. The significant difference in provenance × replication for internode length and diameter indicated that the performances of these parameters were highly affected by the environment at Sook and Segaliud Lokan. This result indicated that the growth performance of *C. subinermis* was affected by soil type and site conditions.

CONCLUSIONS

The overall results showed that the growth performance of *C. subinermis* varied between sites and provenances. The fertile sandy clay loam and sandy loam sites at Kolapis A and Segaliud Lokan produced longer canes than the extremely nutrient poor podzol site at Sook. High production rate is expected from wild populations thriving in fertile soil. Site conditions such as soil and light are important factors that need to be taken into consideration for rattan plantation establishment. Seed source is also important.

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Table 6 F-values and degree of significance following two-way ANOVA for four quantitative characters in *Calamus subinermis* at three different sites

Source of variation	Df	Total stem length	Internode length	Diameter	Number of suckers
Sook					
Provenance (Prov)	12	1.98*	0.98	1.76*	1.11
Replicate (Rep)	3	44.66***	2.01	18.40***	3.28*
Prov × Rep	36	1.71**	1.84***	2.11***	1.60*
Segaliud Lokan					
Provenance (Prov)	7	0.84	0.89	2.06	1.20
Replicate (Rep)	4	19.39***	5.71***	6.35***	1.27
Prov × Rep	28	1.12	2.12***	1.99**	0.88
Kolapis A					
Provenance (Prov)	7	1.74	5.22***	4.83***	4.35***
Replicate (Rep)	4	2.10	2.26	2.43*	1.34
Prov × Rep	28	1.07	0.74	1.07	1.37

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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