INFLUENCE OF SOME *IN SITU* ENVIRONMENTAL FACTORS ON GROWTH PERFORMANCES OF *CALAMUS CAESIUS*

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BONAL, D. 1997. Influence of some *in situ* environmental factors on growth performances of *Calamus caesius*. Growth performances of 480 *Calamus caesius* seedlings distributed in 16 experimental plots in Luasong Forestry Centre, Sabah, Malaysia, were assessed yearly since establishment. At three years after planting, noticeable differences of mean annual increment of the length per stem and the number of stems per plant were found and a factor analysis was conducted to study the effect of five *in situ* environmental factors (canopy conditions, percentage of opened canopy, support tree density, topography, slope) on the growth parameters. An increase in the amount of light reaching the plants resulting from openings in the canopy strongly favoured the development of new stems but not the stem length increment. The latter parameter appeared to be positively correlated to the age of seedlings at planting.

Key words: *Calamus caesius* - growth performances - canopy cover - topography - age at planting

BONAL, D. 1997. Pengaruh beberapa faktor persekitaran *in situ* ke atas prestasi pertumbuhan *Calamus caesius*. Prestasi pertumbuhan 480 anak benih *Calamus caesius* yang diagihkan di 16 plot percubaan di Pusat Perhutanan Luasong, Sabah, Malaysia, ditaksirkan setiap tahun sejak penubuhannya. Tiga tahun selepas penanaman, terdapat perbezaan pertambahan purata tahunan bagi panjang setiap batang dan bilangan batang setiap tanaman. Satu analisis faktor dijalankan untuk mengkaji kesan lima faktor persekitaran *in situ* (keadaan kanopi, peratus pembukaan kanopi, sokongan kepadatan pokok, topografi, cerun) ke atas parameter pertumbuhan. Pertambahan jumlah cahaya yang kena pada tanaman akibat pembukaan kanopi menyokong perkembangan batang baru, tetapi tidak pertambahan panjang batang. Parameter yang kemudian menunjukkan kaitan positif dengan umur anak benih pada masa penanaman.

Introduction

Rattans are spiny climbing plants belonging to the Palmae family. Among the commercial species found in Sabah, Malaysia, *Calamus caesius*, a clustering species, is one of the most valuable small-sized cane. According to Dransfield (1979), it naturally grows on a wide variety of sites, from peat-swamp forests to lowland or hill dipterocarps forests, but growth performances can vary a lot from one site to another. It is widely recognised that the main factor affecting rattan growth is the equilibrium between the light required for photosynthesis and the protective shade

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(Nasi & Monteuuis 1992). Manokaran (1981, 1982) found that *C. caesius* growth was superior when thinnings had been conducted before planting and with poorly drained habitat. *Calamus caesius* growth performances seems to be influenced mainly by optimum light and soil moisture regimes and it appears interesting to describe more precisely these effects.

Materials and methods

Location

Observations herein presented were conducted in the plantation area of Luasong Forestry Centre, south of Sabah, Malaysia. The general aspect of the plantation was hilly and well drained and might not offer the best suitable growing conditions for *C. caesius* although Dransfield (1979) reported that this species is naturally found in hill dipterocarp forests. Logging activities in this area ceased around 1972 and the forest remained intact until rattan plantation started in 1988.

Plot characteristics

Experimental plots were set up in 1991 inside a planted area characterised by heterogeneous forest conditions. Before planting 5 m-wide strips oriented east-west were opened, all climbers, shrubs, and herbs were removed and some saplings and trees of no commercial value were poison-girdled to provide about 50% shade. Since then, strip weeding leaving intact the midstorey and overstorey vegetation was conducted once a year. As most of the plantation was following a double-line planting design, it was decided that each plot would include a total number of 30 plants distributed along two contiguous lines in the same opened strip. Spacing between the lines was 5 m and 3 m between the plants.

Plots were selected in order to have the smallest intra-plot variability for environmental conditions and to cover the widest range of forest types. Sixteen plots were included in this study for an initial number of 480 plants.

Environmental factors

Five environmental factors were studied, viz. canopy conditions, percentage of canopy opening, support tree density, longitudinal slope and topography. Canopy conditions in each plot were described by a visual note and a measurement of the percentage of opened canopy (Table 1). This latter parameter was obtained by counting the number of squares of defined size overlapping the opened area appearing on pictures taken with a "fish-eye" Nikkor lens in the centre of the plot.

A visual note was given to each plot regarding the presence of understorey, midstorey, or overstorey trees in the vicinity of the plants that could support the climbing stems.

The general aspect of the topography in the plots was also noted (Table 1) and completed by a measurement of the slope along the planting lines obtained by averaging the absolute values of measurements taken with a clinometer at one end and in the centre of the plot.

Estimations and measurements of the different environmental parameters were done during the last assessment in June 1995 by the same observer in order to minimise errors due to variability of judgements between observers.

Table 1. Summary of visual assessments and measurements

Factor	Visual assessment	Measurement
Topography	1. Level 2. Rolling 3. Hilly 4. Steep 5. Very steep	Clinometer
Canopy conditions	1. Very open 2. Open 3. Medium 4. Close 5. Very close	Pictures
Support tree density	1. Very dense 2. Dense 3. Medium 4. Few support 5. Very few support	None

Origin and age of seedlings

Seeds of the same origin in Sabah were germinated in the commercial nursery of the Luasong Forestry Centre, Sabah. Since the plots were selected in different compartments of the plantation area, age of seedlings at planting differed from one plot to another (Table 2).

Assessment

Since the planting, the number of stems per plant and the length of each stem were assessed yearly. Stems were measured from the ground to the base of the upper fully developed leaf with a ruler as high as possible. When the whole cane could not be measured, the length of the part out of reach was estimated by counting the number of internodes and assigning an average length for each internode (Lee 1994).

From these data the following parameters were computed:

- Survival rate, representing the percentage of living plants in a plot;
- Mean annual increment (MAI) of number of stems per plant, corresponding to the increase of number of stems per plant calculated per year from planting to the last assessment;
- MAI of length per stem, corresponding to the length increment per stem calculated per year from planting to the last assessment.

Additionally, the current annual increment (CAI) of length per stem, i.e. the length increment per stem between the last two assessments, was computed and compared to the MAI of the length per stem. This comparison is normally used in silviculture to characterise the stage of development of the plants.

Table 2. Age of rattan seedlings at planting

Plot	Age of seedlings (y)	Plot	Age of seedlings (y)	Plot	Age of seedlings (y)
1	2.25	7	1.08	13	0.75
2	2.25	8	1.08	14	0.75
3	2.25	9	1.08	15	0.75
4	2.00	10	0.83	16	0.75
5	2.00	11	0.75		
6	0.83	12	0.75		

Statistical analysis

Data were analysed using SPSS statistical package (SPSS 1988). The MAI of the number of stems per plant and the length per stem were compared using an analysis of variance to detect any differences among the plots. A principal component analysis was run to detect any correlation between the environmental factors and create new combined environmental factors. Multiple regression analyses were later performed to evaluate the effect of these new combined factors on the different growth parameters (Snedecor & Cochran 1957).

Results

General outlines

The mean age of the plants from the plantation was 3.1 y with only a slight variation among the plots (ranging from 2.83 to 3.83 y) (Table 3).

Table 3. Mean values of the different assessed parameters

Plot	Age (y)	Survival rate (%) mean	MAI no. stems[1] Mean	MAI no. stems[1] s[4]	CAI length per stem[2] (m) mean	MAI length per stem[3] (m) Mean	MAI length per stem[3] (m) s[4]
1	3.75	93.3	0.91	0.67	1.30	0.83	0.43
2	3.83	90.0	0.78	0.56	2.92	1.67	0.72
3	3.25	76.6	0.90	0.63	2.25	1.14	0.76
4	3.25	90.0	2.52	1.45	2.21	1.31	0.41
5	3.17	73.3	2.76	1.76	1.75	0.99	0.42
6	3.08	80.0	1.39	1.10	1.50	1.60	1.18
7	2.83	96.6	1.26	0.52	2.03	0.90	0.45
8	2.83	96.6	1.21	0.51	2.38	1.32	0.62
9	2.83	93.3	1.72	0.92	2.07	0.82	0.45
10	3.08	84.6	0.99	0.30	2.13	1.03	0.48
11	2.92	90.0	0.78	0.46	1.08	0.50	0.31
12	2.92	83.3	1.42	0.87	1.29	0.70	0.48
13	2.92	76.6	0.64	0.47	0.87	0.43	0.39
14	2.92	90.0	1.83	1.12	1.57	0.62	0.21
15	2.92	76.6	1.28	0.69	2.56	1.33	0.57
16	2.83	73.3	0.48	0.17	0.44	0.17	0.17
Overall	3.08	85.3	1.31	1.04	1.77	0.97	0.67

1 = mean annual increment of number of stems per plant
2 = current annual increment. Annual increment of length per stem between the last two assessments
3 = mean annual increment of length per stem
4 = standard deviation of the mean

At this age, survival ranged from 73.3 to 96.6%, with an overall mean of 85.3% (Table 3).

The MAI of number of stems per plant showed an overall mean of 1.3 stems per plant per year (Table 3). The analysis of variance detected a significant difference among the plots for the MAI of the number of stems per plant (probability value $p<0.001$) (Table 4). For instance, the mean of the MAI of number of stems per plant was nearly four times higher in plots 4 and 5 as compared to plots 13 or 16.

Table 4. Analyses of variance for the mean annual increment of number of stems per plant and length per stem for the 16 plots

	MAI[1] number of stems				MAI length per stem (m)			
Source	Df[2]	MS[3]	F[4]	p[5]	Df	MS	F	p
Between groups	15	10.05	13.5	0.000	15	4.42	14.3	0.000
Within groups	390	0.74			390	0.31		
Total	405				405			

1 = mean annual increment
2 = degrees of freedom
3 = mean square
4 = value of Fisher's statistical test (Snedecor & Cochran 1957)
5 = probability value

The MAI of length per stem ranged from 0.17 to 1.67 m per stem per year, with an overall mean of 0.97 m per stem per year (s = 0.42). A statistically significant variation among the plots for the MAI of the length per stem also occurred ($p<0.001$) (Table 4).

Table 5 summarises the characteristics of the different plots. As expected, the selected plots covered a wide range of site conditions. Some plots were almost flat while others were very steep ; a dense understorey and midstorey covered some of them while others were very open.

Table 5. Values of the five environmental factors

Plot number	Canopy conditions	Percentage of opened canopy (%)	Support tree density	Topography	Slope
1	4	11.7	4	3	14.5
2	4	13.1	2	4	21.0
3	2	26.4	2	3	10.0
4	1	63.1	5	4	18.5
5	1	31.8	5	2	9.0
6	2	44.9	4	4	13.5
7	1	15.5	4	5	24.0
8	3	11.6	3	2	4.0
9	1	46.5	4	2	17.0
10	4	7.5	3	5	23.0
11	2	15.8	4	2	6.5
12	3	18.1	2	1	1.5
13	5	5.5	1	5	24.0
14	1	29.2	5	4	17.0
15	2	15.8	4	5	22.0
16	5	11.4	1	3	2.0
Mean	2.6	23.0	3.3	3.4	14.2
CV[1]	53.8	70.8	39.3	35.2	54.9

1 = coefficient of variation (%) (Snedecor & Cochran 1957).

Factor analysis

The principal component analysis detected a positive correlation between the topography and the longitudinal slope, and between the support tree density and the percentage of opened canopy. A negative correlation was found between the support tree density and the light, and between the percentage of opened canopy and the light (Table 6), the latter correlation being strongly expected.

Table 6. Correlation matrix between the five environmental factors

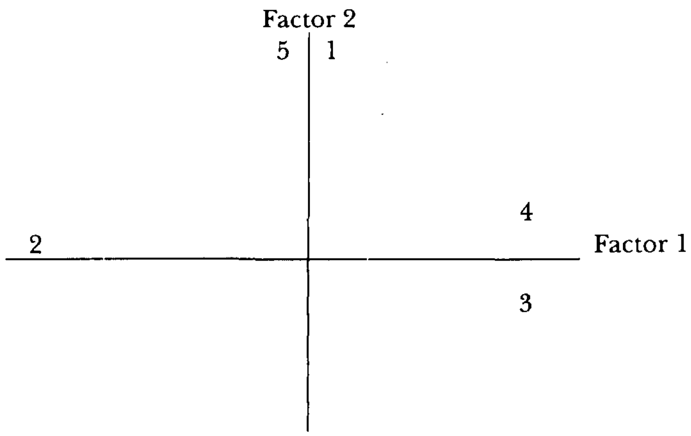
Factors	Canopy conditions (light)	Percentage of opened canopy	Support tree density	Topography	Slope
Canopy conditions (light)	1.00				
Percentage of opened canopy	- 0.69*	1.00			
Support tree density	- 0.80*	0.58*	1.00		
Topography	0.15	- 0.15	- 0.04	1.00	
Slope	- 0.07	0.02	0.19	0.83*	1.00

*Significant at 5% level.

The factor analysis retained two components with calculated Eigenvalues higher than one, accounting together for 85.3% of the variance (Table 7), and extracted two main factors, Factor 1 and Factor 2. After appropriate rotation the five environmental factors can be represented in a new axis system, Factor 1 being linked with the light, the percentage of opened canopy and the support tree density, and Factor 2 with the longitudinal slope and the topography (Figure 1).

Table 7. Descriptive statistics of the new axis system where only two factors with Eigenvalues higher than one are retained after principal component analysis

Axis	Factor	Eigenvalue	Percentage of variance	Cumulated percentage
X	1	2.43	48.5	48.5
Y	2	1.84	36.9	85.3
-	3	0.42	8.5	93.8
-	4	0.17	3.4	97.3
-	5	0.13	2.7	100.0



Symbol	Factor	Co-ordinates X	Co-ordinates Y
1	Slope	0.122	0.958
2	Canopy conditions	- 0.938	0.033
3	% opened canopy	0.840	- 0.082
4	Support tree density	0.896	0.101
5	Topography	- 0.137	0.953

Figure 1. Schematic representation of the five environmental factors in the new axis system after principal component analysis and appropriate rotation (Factor 1 is represented by the horizontal line and Factor 2 by the vertical line)

Multiple regression

The multiple regression analysis performed with the two extracted factors established that differences of survival rate between the plots could not be explained by variations of environmental factors (p= 0.60). Factor 1 appeared to have a significant effect on the MAI of number of stems per plant (p<0.001). An estimation of this relationship was given by the following equation :

$$NSTPMAI = 1.30 + 0.53 * Factor\ 1\ ,\ R^2 = 0.70$$

where NSTPMAI was the MAI of number of stems per plant and Factor 1, the first factor extracted in the factor analysis. When Factor 1 was increasing, i.e. the canopy was more opened and there were less support trees, plants received more light and developed more new stems.

No relationship was found between Factor 2 and the MAI of number of stems per plant (p=0.61) and neither Factor 1 nor Factor 2 had an influence on the MAI of length per stem (p=0.25 and p=0.44 respectively).

However, the age of seedlings at planting seemed to be slightly correlated with the MAI of length per stem (p=0.04) and the following equation described the relationship :

$$LGSTMAI = 0.56 + 0.30 * AGESD, \quad R^2 = 0.25$$

where LGSTMAI was the MAI of length per stem and AGESD, the age of the seedlings at planting. Plots planted with older seedlings had a better length increment. No relationship was found between the age of the seedlings at planting and the MAI of number of stems per plant (p=0.33) or the survival rate (p=0.66).

Discussion

Three years after planting, survival rate appeared to be good and even better than the 78.3% found two years after planting by Manokaran (1981). The environmental factors studied did not seem to have an effect on the mortality rate and observations showed that mortality of the plants was mainly caused by insects or mammals feeding on the succulent tips of the shoots. This phenomenon probably covered up any influence of light or topography conditions on the mortality.

In a well-drained site like the plantation area of the Luasong Forestry Centre differences of type of topography did not seem to influence growth performances of *C. caesius.* Steep hills as well as flat terrains were suitable for plantation.

The MAI of number of stems per plant was much smaller than the one found by Shim and Muhammad (1985) who recorded at age 3.5 y for 35 plants planted on the low hills in SAFODA'S Kinabatangan Rattan Project area near Batu Puteh, Sabah, an average of 11 stems per plant, i.e. a MAI of 3.1 stems per plant per year, with a potential of 8.3 stems per plant per year. Highly favourable environmental conditions might have been encountered. Manokaran (1982) found at 5.5 y after planting in poorly drained plots a total number of 292 stems for 115 plants, which resulted in a MAI of 0.46 stems per plant per year. Present data are therefore within the range of existing results.

Increasing percentage of light reaching the plants had a positive effect on the development of new axillary buds at the base of the plant during the first three or four years. These results are consistent with conclusions found by Manokaran (1981, 1982). Intense thinnings in the understorey and midstorey before planting leaving 50 to 60% of opened canopy seem to provide the best conditions for the plants to develop many stems.

Differences of MAI of length per stem between the plots could not be explained by environmental factors. It was actually found that the current annual increment of the length per stem was greater than the MAI of the length per stem in all plots except one. This phenomenon suggested that plants had not yet reached their optimum growth and the effect of a higher amount of light on the length increment might appear only later on in their development.

The MAI of the length per stem, however, was slightly correlated to the age of the seedlings at planting. Rattan seedlings, like most of the palms, undergo a slow juvenile growth phase for one or two years during which no external length increment occurs. Therefore, when planting occurred, the oldest seedlings had probably already entered into the adult growth phase and soon started to grow in length, which the younger seedlings did only a few months later. This suggests that rattan seedlings planted under similar environmental conditions should be selected among the ones in the nursery whose stems start to show signs of increment.

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