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Appendix 3

SOME EXPERIENCES FOR SECONDARY FOREST ENRICHMENT THROUGH RATTAN PLANTATION IN SABAH[1]

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SUMMARY

In 1987, Innoprise Corporation Sdn Bhd (ICSB), embarked in a large scale project for the enrichment of a logged-over forest through rattan plantation. In 1989, CIRAD-Forêt joined the project to bring scientific assistance to the research on rattan silviculture and genetics. The plantation method consisted of rattan line planting under logged-over forest. This system showed however some limitations, mainly due to the lack of control on competitors (as surrounding trees, bamboo and lianas) and on the environmental variability (extremely large at the site), that resulted in rattan stands with heterogeneous growth.

Studies of the effect of environmental variability on rattan growth, and of methods to control it, started since 1994. A first study focused on the observation of correlation among rattan growth and a number of environmental variables. The study showed that competition from surrounding dipterocarp trees was the main element of the variability of rattan growth. It allowed defining which forest types are more suitable for rattan enrichment. Another study focused on the effect of light on rattan growth. Trials have been established both in the nursery and in the field. The nursery trials showed that each rattan species has special requirements in terms of light. The field trials allowed to quantify the gain in rattan growth that can be obtained through shade adjustment interventions. Both these studies gave to the ICSB's rattan project important information for an improved plantation management.

INTRODUCTION

Secondary forest rehabilitation will be one of the main concerns for tropical forestry in the near future. The common experience of Innoprise Corporation Sdn Bhd (ICSB) and CIRAD-Foret in Sabah (Malaysia), even if focusing on a non-timber forest product as rattan, may cast some light on the problems of the forest enrichment technique, and be of interest to researchers and foresters involved in this difficult task.

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ICSB is a Sabah-based company, managing a forest concession of about 900.000 hectares. In 1987, as part of its forest management effort, ICSB embarked in a large scale rattan planting project: 40.000 ha of a secondary dipterocarp forest were to be enriched with rattans. CIRAD-Forêt joined the project in 1989, bringing scientific assistance to the research on rattan silviculture and genetics. The collaboration was concretised by the creation of a research structure named Plant Improvement and Seed Production Project (PISP), based in Luasong. Nasi & Monteuuis (1992) and Nasi (1994) gave first descriptions of the work carried out by PISP.

The four large diameter species included in the research programme were: *Calamus manan, C. subinermis, C. ornatus and C. merrillii*. The system implemented for commercial plantation was to plant rattans in lines under the logged-over forest. This system seemed easier to manage than other systems of rattan plantation under fast growing tree species, for a number of large trees that could support without damage the rattans were still present in the forest, and no silviculture treatment that could disturb or be rendered difficult by the thorny rattans was planned for this forest. However, the method showed some limitations, resulting in rattan stands with heterogeneous growth.

Rattans, as other palms, have a peculiar pattern of growth: in the first stage of development, called establishment phase (or rosette stage), the stem diameter and the number of roots increase, but stem elongation is negligible; once the stem has attained a maximum, the second phase of development may start with a significant aerial growth of the stem. The establishment phase may last few months up to several years according to species and environment conditions.

Continuous checking of the rattan plantation in Luasong showed that, together with "normal" growing rattans, 5 or 6 years after the plantation there were still quite a large proportion of rattans still in the establishment phase, i.e. with almost no elongation. Even if it was common to find fast and slow growing plants just side by side, some plantation compartments were doing significantly better than others.

With the objective of understanding the reasons behind such variability, PISP started to study the effect of environment conditions on rattan growth. Preliminary observations seemed to point to canopy opening, and hence to the light reaching the planted rattans, as an important element for rattan growth. Little was known, at that time, about the optimal shade requirement for rattans. In nature, rattans are found under forests with a relative light intensity (RLI) as low as 0.5 to 5%. However, the pattern of growth of rattans in these conditions was not known. At young stages, the optimum RLI requirement seems to be higher, between 50% and 85% (Wan Razali *et al.* 1992, Budiman & Nana 1988). Finally, no information at all was available on the effect of competition from surrounding trees and of environmental variability on rattan growth.

In order to improve our knowledge on the matter, in 1995 we established, as described here, two experiments, one in the nursery and one in the field, analysing the effect of light on rattan growth. A third study reported in this paper focused on the observation of correlation among rattan growth in the commercial plantation and a number of physical environment variables as light, soil, slope, etc., and biotic variables as stand density, species composition, and competition.

MATERIAL AND METHODS

The secondary forest and the rattan planting technique

The Luasong's rattan plantation is established under a secondary forest that had been logged-over by a timber company about 20-25 years ago. The forest is composed by a variable ratio of dipterocarps and pioneer trees: some compartments, only lightly logged-over, are now largely dominated by dipterocarps, while others, where the harvesting had been more intensive, are now dominated by pioneers. The elevation is from 50 to 450 meters above sea level; the average annual rainfall is 2,500 mm (1966-1972); the topography is very irregular, often with steep slopes; soils belong to the Orthic Acrisol and Distric Nitosol families (FAO/UNESCO classification, 1974).

The nursery technique for rattans consists of: a) germination of the rattan seeds in sand beds; b) 1 to 3 months after germination, transplanting of the seedlings in plastic polybags under Sarlon nets; c) 9 to 18 months after transplanting, plantation of the seedlings in the field. For plantation, strips of 4-5 m of width were opened under the logged-over forest by cutting all the plants but the commercial trees. Two lines of rattan were then planted within the strip. The spacing along the row was of 2.5 meters, and the distance among strips 5-6 meters, giving a planting density of 800 plants/ha.

Effect of light on rattan growth in the nursery

The experiment was aimed to assess the light requirement at the nursery stage for 4 commercial large-diameter rattan species: *C. ornatus*, *C. merrillii*, *C. manan* and *C. subinermis*. Three different Sarlon nets, according to the supplier specifications with RLIs of 30%, 50% and 70% were compared. Prior to the experiment, our team re-assessed the RLI given by each of the Sarlon nets by using 10 calibrated LICOR quantum sensors combined with a data logger. Eight sensors were installed under each of the Sarlon net for a whole day. Two sensors were installed in a fully open space and used as an open-sky reference. Five-second-interval readings were then integrated over the 12 hours of measurement. This gave us a more precise estimation of the RLI given by each of the Sarlon nets, that were 22%, 42% and 61% respectively. In our experiment, the variation of RLI within each single Sarlon net was of about 5% of the total variation.

Each treatment for each species was repeated three times; the experimental unit included 33 plants. The seedlings were transplanted from the seed beds when they were about 1 cm tall. The plants were all raised in the same conditions, by using a slow release fertiliser and 6' x 9' polybags. The experiment started just after transplanting the seedlings from the seedbeds to the polybags. The first assessment occurred 8 month after transplanting and the second 1 year after transplanting. The only measured character has been the shoot length (length between the collar base and the insertion of the last leaf).

The different RLI treatments and the repetitions were compared by using a variance analysis, and their ranking tested with a Duncan test. The statistical model used for each species included 2 factors:

$$Yijk = X... + Xi.. + X.j. + Xij. + error$$

where $X...$ = general mean; $Xi..$ = RLI effect; $X.j.$ = repetition effect; $Xij.$ = interaction RLI*repetition; *error* = residual.

Effect of light on rattan growth in the field: shade adjustments

To evaluate the role of the canopy cover on the slow growth of rattans, in 1996 we carried out a canopy manipulation experiment. In a compartment planted in 1993 with *C. subinermis,* three rectangular plots (A2, A4, A6) of 60x70 meters have received the shade adjustment treatment. Twenty meters apart from each of the three plots, control plots of the same size have been established, without treatment (A1, A3, A5).

The shade treatment was carried out in Septembre 1996 as follows: i) all the non-commercial trees with a DBH less than 15 cm were cut with conventional methods (axes, chain saw); ii) the non-commercial trees with a DBH larger than 15 cm were girdled; iii) all the lianas and bamboos that could affect the rattan growth were eliminated; iv) all the small commercial trees (DBH<20 cm) with a bad form were eliminated.

In the centre of the six 60x70 plots, smaller plots of 30x30 meters have been identified for the measurements: 1) the light, with LICOR quantum sensors, 2) the rattan length, 3) the mortality of the girdled trees. The light measurements were carried out by placing eight LICOR sensors along a planting line, one every four rattans, for a 12-hours period. The subsequent RIL estimation procedure followed what has been described above. The trial has been assessed three times: i. before the shade treatment (August 1996); ii. just after the treatment (October 1996), iii. one year after the treatment (August 1997). The rattan growth and light data of the three repetitions were analysed both by a two way-ANOVA, with treatments and blocks as factors, and by three independent one-way-ANOVA, one for each repetition.

Environmental variability and rattan growth

This series of observations was carried out between 1995 and 1996 on a *C subinermis* stand planted in 1991. One hundred sampling points were established over a compartment of about 150 ha. A stratified sampling (where, in order to avoid over-representation of very shaded situations, we established two strata of canopy opening), and a random sampling within each layer were used to draw the position of each point. The centre of each plot was established on the middle line among the two rattan lines. In each sampling point we measured:

- the length [LEN] and the survival of the two nearest rattans.
- the slope [SLO]. the bearing [BEA], the aspect [ASP].
- the light, with the help of pictures taken by a Fish-eye [SH1] and read by digital scanning.
- the soil conditions (we described three horizons: Ao [SOM], A1 [SOA] and B [SOB]).
- the forest type [FOR], the percentage of dipterocarps [DIP], other timbers (OT) and pioneer trees (100-DIP-OT).
- the species, the diameter and the distance (from the centre of the sampling point) of each trees within a circle of 10 m radius.

From the point n. 6 of above, we calculated: the number of trees/ha (NT), the basal area/ha (BA) and a competition index (CI) calculated, for each plot, as:

$$CI=\sum(diam_i / dist_i),$$

where $diam_i$ and $dist_i$ were respectively the diameter and the distance from the centre of the plot of each ith tree within the sampling circle (Steneker & Jarvis 1963). This arbitrary index allows weighting the competition given by a neighbour tree according to its diameter and distance from the rattan. The nearer and larger the tree, the larger its weight on the CI, and vice versa.

The relationships among rattan growth and the environmental factors have been studied by linear regression and factorial correspondence analysis (SAS 1996).

RESULTS

Effect of light on rattan growth in the nursery

For all the species, significant different responses (at the 0.01% risk level) to light treatments in the nursery were detected. The repetition effect was in general not significant, except for *C. ornatus*. The average shoot length of each species under each RLI treatment is shown in Table 1.

Table 1. Response of rattan seedlings to different shade regimes, 8 and 12 months after transplanting. Shoot length, measured (in cm) from the base of the collar to the last leaf insertion.

8 MONTHS AFTER TRANSPLANTING	*C. ornatus*	*C. merrillii*	*C. manan*	*C. subinermis*
RLI=61%	10.9 a*	12.7 a	5.6 c	9.8 a
RLI=42%	10.0 b	11.2 b	6.5 b	9.4 a
RLI=22%	11.5 a	10.0 c	10.4 a	10.4 B
LSD	*0.6*	*0.6*	*0.7*	*0.5*

1 YEAR AFTER TRANSPLANTING	*C. ornatus*	*C. merrillii*	*C. manan*	*C. subinermis*
RLI=61%	18.1 a*	21.1 a	9.8 a	17.4 a
RLI=42%	15.9 b	15.6 b	10.2 a	14.7 b
RLI=22%	14.8 c	14.6 c	14.5 b	14.4 b
LSD	*0.8*	*1.0*	*1.2*	*0.6*

Note: * Duncan ranking (two treatments are significantly different if they have a different letter).
LSD: Least significant difference among two treatments.

It is interesting to note the differences among species and among assessments. *C. manan* clearly grew better under low light intensities, while *C. merrillii* preferred more light. The gain in growth under the best treatment was of 48% for *C. manan* and 45% for *C. merrillii*. For *C. ornatus* and *C. subinermis*, the light requirements seemed to evolve through time: at the first assessment these species did better under low light, while later they required more abundant light.

Effect of light on rattan growth in the field: shade adjustment

The girdling of all the adult non-commercial trees has been quite effective in our experiment, gradually killing about 80% of the treated trees (most of the trees died within a six months period). As it can be seen in Figure 1, the death of the girdled trees brought a major change in the light percentage reaching the soil (and hence the young rattans). By contrast, cutting the small non-commercial trees, the small commercial trees with a bad form and lianas and bamboo, did not have a very significant effect on the canopy opening.

On average, the RLI at the seedling level before the shade adjustment treatment was of only 3.0% (standard deviation, sd=3.9%); one year after the treatment, the RLI averaged 20.7% (sd=15.4%). The shade adjustment was the most effective in plot n. 2, where the RLI evolved from 2% to 31%.

Concerning rattans, it has to be noted that unfortunately, two plots, A2 and A4 (both treated by shade adjustment) were visited by elephants (November 1996), that destroyed about 10% of the plants. Because of the importance of the damages, we had to discard these plants from subsequent measurement and analysis. The damages concentrated on the tallest rattans; thus the results of these two plots were in some way biaised downward.

A two-way ANOVA on rattan length after treatment, with blocks and treatments as factors, showed that the three repetitions bore significant differences in rattan length among them even before the shade treatment, probably due to the heterogeneous environment conditions. Consequently, the three "repetitions" could not any longer be considered as such. Rather, they were analysed by three independent one-way-ANOVA. Results from this analysis are shown in Table 2. A graphic representation of the evolution of rattan growth before and after the treatment is shown in Figure 2.

Table 2. Effect of shade adjustment on rattan growth, one year after the treatment, as compared to the control. Mean height in centimeters.

	Control$^{(1)}$	Shade adjustment$^{(1)}$
Repetition 1	Plot A1: *67.2*	Plot A2: ***76.8*** $^{(ns)}$
Repetition 2	Plot A3: ***66.6***	Plot A4: ***96.8*** $^{(*)}$
Repetition 3	Plot A5: ***212.3***	Plot A6: ***231.4*** $^{(ns)}$

Note: Significance level of the difference among (1) and (2): ns = not significant; * = 0.10.

The gain in rattan growth obtained by shade adjustment as compared to control was 18% over the whole experiment. The differences among shade adjustment treatment and control were in general not significant at the statistical analysis. One of the main reasons of the lack of significance is that even within repetitions, there were still a lot of variability both in the environment and in the rattan size. However, all the three repetitions showed the same pattern, i.e. rattans respond positively, even if in a low measure, to the increased light. The exclusion of the tall plants destroyed by elephants without doubt lowered the average of the plots 2 and 4, leaving less difference among treatments. Finally it has to be noted that, at the moment of the experiment, this rattan plantation was already three years old, and many plants had been stagnating for long time at the rosette stage. Probably the rattan response would have been more important had the treatment been applied earlier.

Environmental variability and rattan growth

A standard analysis of variance revealed that the differences in rattan length among the 100 plots were significant at the 0.001 level. Multiple regression among the rattan length and the whole set of the above characters gave a correlation coefficient of 0.48, that means that by mean of the environmental description we are able to predict 23% of the variation in rattan growth. The ranking of the characters according to their correlation with the rattan length was reported in Table 3.

The characters linked to the forest density (BA, NT and DIP), and in particular the Competition Index, were well linked with the rattan growth. The light (SH1) was also related to the growth, but in a minor measure. In general, the lower the competition, the density, the shade and the percentage of dipterocarps, the better the rattan growth. The relationships among rattan growth and BA and CI were represented in Figure 3.

A second group of variables (ASP, SOA, BEA, OT, SLO, SOM and SOB) showed no significant effect on rattan growth. A factorial correspondence analysis (not shown) confirmed this pattern.

The specific contribution of dipterocarp and pioneer trees to the competition index and to the rattan growth has been explored further. Bacilieri *et al.* (in preparation), have shown that competition from dipterocarp trees have a much more important effect on rattan growth than competition from pioneers trees.

Table 3. Correlation coefficients of the measured environmental variables with the rattan growth, and their significance level.

Variables	Correlation with Rattan length	Significance level
CI	-0.45	0.0001
BA	-0.35	0.001
NT	-0.33	0.01
SH1	0.31	0.01
DIP	-0.31	0.01
FOR	0.20	ns
ASP	-0.19	ns
SOA	0.16	ns
BEA	-0.13	ns
OT	0.09	ns
SLO	-0.09	ns
SOM	0.07	ns
SOB	0.01	ns

CONCLUSION

The secondary forest enrichment practice, adding a plus value to forests that have been impoverished by logging, may be interesting both from the economic and social point of view, and for the conservation of the forest itself. However this task is made difficult by the intricate combination of biotic and abiotic factors typical of the tropical natural forest: competition from surrounding plants, close canopy covers, steep slopes, low nutrient contents and high environment variability often intrinsic to marginal lands, etc.

In this situation, our experiments allowed us to better understand the plants and plantation requirements. First, it appeared that the two major elements playing a role on rattan growth in the enrichment plantation were the light and the competition from surrounding trees, while we were not able to detect any effect by other factors as slope, topography and soil composition.

Furthermore, the study of the effect of environment variation on rattan growth showed that competition from surrounding trees (especially dipterocarps) was more important than the effect of light. One reason for this may be that light is a difficult-to-measure parameter, because of: a) its variation along the year, b) the difficulty to know which radiation length is most used by the plant, c) the difficulty to measure the diffuse radiation, etc. Another important reason may be that competition, in addition to the light effect, may summarise also other effects due to competition for nutrients, water and space availability, etc.

Figure 3 may be seen as an indication that there is a threshold in stand density (around 25 m^2 of basal area) and competition (CI=125) beyond which the rattan can not grow (we recall that the rattans were planted, in this compartment, 5 years before our observations). Below this threshold there is still much to do to improve the rattan growth; however, it is not worth to plant where the stand is denser. The gain in rattan growth that, in the Luasong's conditions, can be achieved by selecting the forest stands to be planted according to their density is given in Table 4. Another way to see these results is to consider the capital that can be saved by not planting the points were the stand is too dense and the rattan growth is expected to be poor.

Table 4. Percentage of gain in rattan growth that can be achieved, in the Luasong conditions, by selecting the points to be planted according to their density. Also given are the percent of sampling points that had a given density and their mean rattan length. Rattan should not be planted in forest compartments or sub-blocks with a basal area exceeding 25 m^2 (in our sample, 34% of the sampling points have a basal area superior to 25 m^2). A gain in the rattan growth of 32% may be predicted if these points were avoided.

Sampling Point Basal Area	Mean rattan length at that given Basal Area	% of improvement compared to the general mean of the compartment	% of sampling points falling in this category
lower than 15 m^2	518 m/ha	55	38
lower than 20 m^2	432 m/ha	39	57
lower than 25 m^2	441 m/ha	32	66
lower than 30 m^2	410 m/ha	23	75
lower than 35 m^2	394 m/ha	18	80
lower than 40 m^2	372 m/ha	11	85

Estimating the competition in the forest with a sufficient approximation seems not a very heavy task. In addition, one may consider that on small plots the competition index and basal area are tightly correlated, and that measuring the local basal area with classical methods (both in the field or by using aerial photos) can give good estimation of the local competition.

A procedure to mark, before planting, the point to be planted according to the forest density has already been tested and has shown feasible. In practice, a trained forest ranger walks along the lines and labels the points to be planted; the workers then follow with the plantation operation. On a larger scale, the aerial photo interpretation can discriminate among compartments according to their suitability for planting.

The light experiments also gave useful information. The result of the nursery experiment will allow to apply light treatments specific to each species. Furthermore, even if the light requirements may evolve during life stages, some rattan species appeared to be more shade tolerant than others. The plantation can thus tune the species distribution in the field by matching the species light requirements with the compartment characteristics.

In spite of the problems of the experimental design and of the damages in the shade adjustment experiment, it has been possible to demonstrate that rattans respond positively to canopy manipulation. A better response might be expected if the treatment was applied earlier than in our case, just after plantation. Shade adjustment may profit, by the way, to other valuable tree species in the forest. Its cost/benefit balance is now under evaluation at Luasong.

The combination of the information on competition and light effect helps to optimise the rattan plantation technique. An accurate choice of the compartments and points to be planted, together with appropriate shade adjustments, may significantly improve the rattan performances in the ICSB's commercial plantation.

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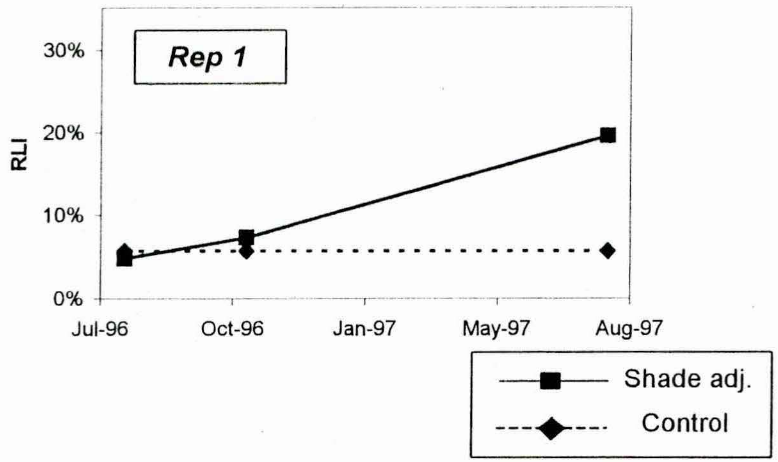
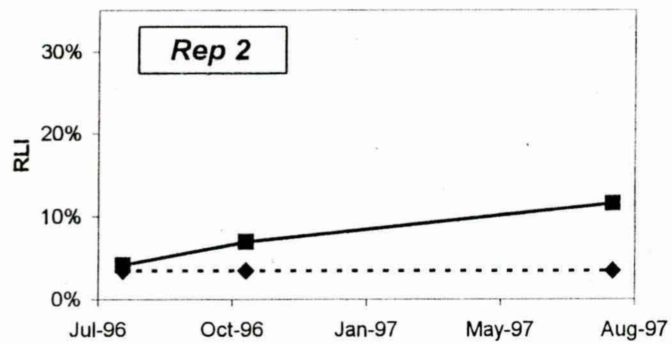




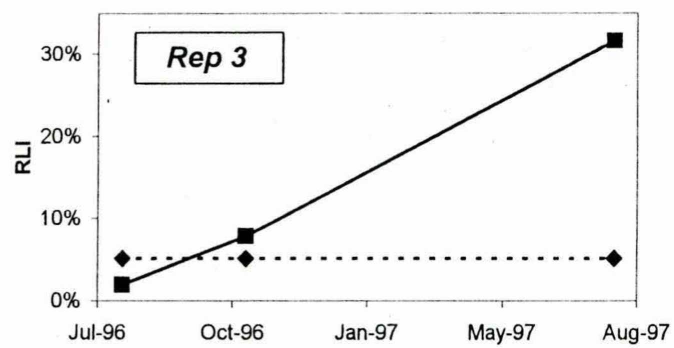
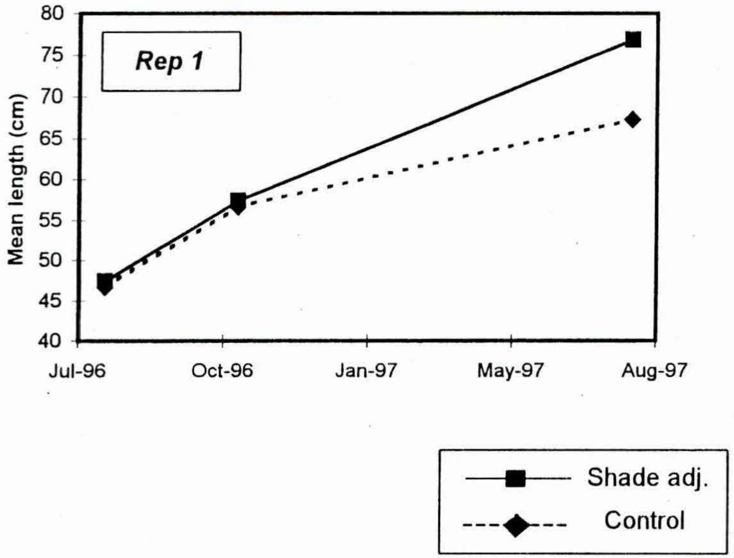


Figure 1. Effect of shade adjustment on the relative light intensity (RLI) within plots (24 sampling points and one measurement every hour over a 12-hours-period, per plot) as compared to open conditions (reference sensor on the roof of the nursery building).



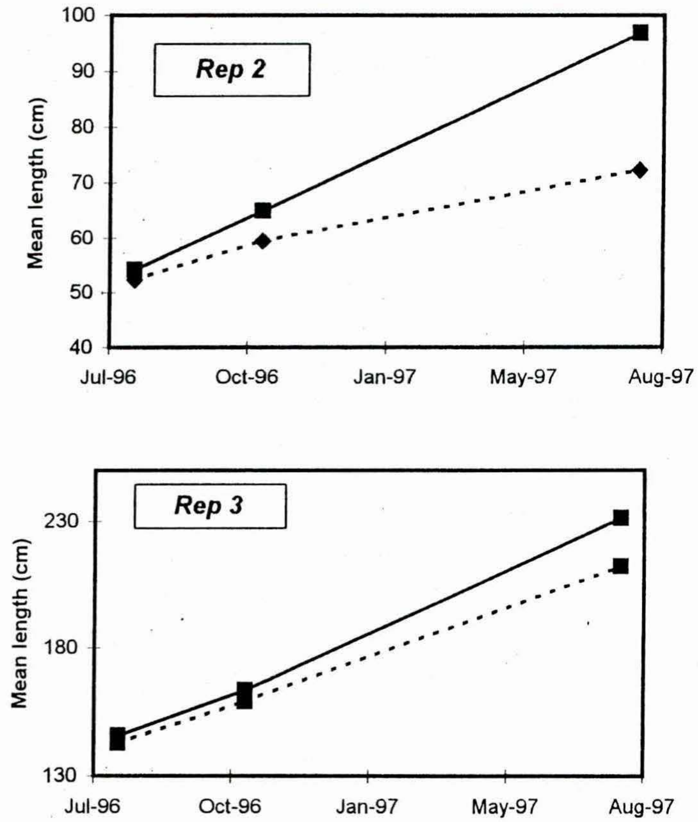


Figure 2. Effect of shade adjustment, as compared to control, on rattan growth. Means for each plot (control and treatment) within each repetition (1, 2 and 3).

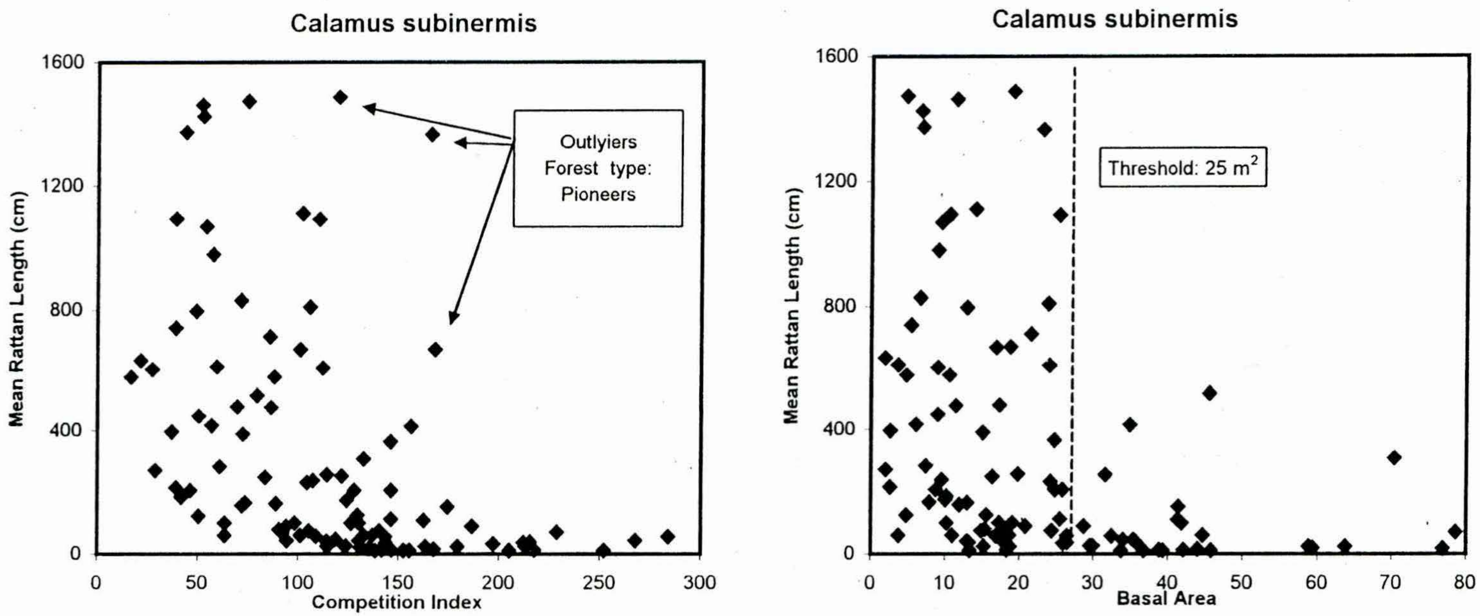


Figure 3. Relationships among rattan length growth and two forest descriptors, the basal area and the competition index. The relationship with CI is improved if only the dipterocarp trees are considered.