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Growth performance of rattan species under plantations

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Project proposal

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Contents

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ABSTRACT

The increase in demand on rattan products has led to substantial over exploitation of the natural rattan resources in Kerala. In order to overcome the shortage, the Kerala Forest Department has started rattan plantations inside the forest areas. However, the growth performance of the plants has been poor in many locations. In order to find out the reason, a study was conducted on the growth of two species of rattans with reference to location, soil conditions, light and rainfall. The plantations of *Calamus thwaitesii* and *C. delessertianus* raised in 1998 were selected for the study.

Results revealed that, in general, growth of both the species have strong correlation with pH, organic carbon and extractable Phosphorous content of soil and hence, depletion of, soil quality especially pH, organic carbon and associated nutrients was found to be the major constraint in achieving maximum growth in these species. *C. delessertianus* is found more adaptable to soils with depleted soil fertility than *C. thwaitesii.* Intensity of light was also found to have a significant role with the growth of *Calamus.* Correlation between growth parameters and rainfall were found to be non significant in both the species. This might not be due to the lack of influence of rainfall on *Calamus*, but it could be due to the low variation in the quantity of rainfall received at all the sites studied. Thus, the study indicates that growth of *C. thwaitesii* and *C. delessertianus* under plantations is significantly influenced by soil and light conditions of the locality. High production rate is expected from plantations thriving in fertile soil under moderate light conditions (about 75%). Canopy manipulation to increase the light availability may be adopted as a silvicultural intervention should be applied to promote the stem growth.

INTRODUCTION

Rattan resources are dwindling rapidly due to the over exploitation of wild rattans and the loss of tropical forest cover, which threaten the sustainable utilization of rattan resources and the long-term survival of the rattan industry. One of the effective measures to stabilize the supply of rattan resources is to expand rattan plantations and to improve their management.

Rattan industries are still dependent on existing natural forests for sustainable supply to the industry. Hence rattan plantation development is urgently needed to relieve the pressure on rattan resources in the wild and to guarantee the supply of raw material for the industry. On the other hand, the level of plantation management should be improved to maximise growth and yield.

In India, at present, rattans are gaining importance as a plantation crop. Even though, Kerala Forest Department has initiated raising plantations 1993 onwards, the growth of plants in majority of these plantations is very poor and many of the plants have not attained harvestable length even after 12-13 years. Majority of the plantations in the South and South –East Asian countries are also facing the same problem (Manokaran, 1977, 1982, 1983; Renuka and Rugmini, 1996; Baciliery *et al.*, 1999; Renuka *et al.*, 2004 and Yin *et al.*, 2008). This signifies the importance of effective management of the plantations for better productivity. For an effective management, the basic requirement is knowledge about the relation between the growth of plants and environmental conditions. In the case of rattans, such studies are very few, that too, only from South East Asian countries (Bogh, 1996; Baciliery *et al.*, 1999; Yin *et al.*, 2008; Xu *et al.*, 1994). In India, similar studies are not reported yet. Hence a project was initiated to evaluate the effect of environmental conditions such as soil, rainfall and light on the growth of two species of rattans, viz., *C. thwaitesii* Becc. and *C. delessertianus* Becc., commonly raised in plantations by the Kerala Forest Department.

REVIEW OF LITERATURE

Studies on rattan cultivation and management did not begin in earnest until the mid 1970's. Since then a wide range of studies have been conducted on various aspects of growing rattan; however, compared with other plantation species, the attention paid to management of rattan plantation was inadequate. This is mainly due to the fact that large scale plantations have only been established in the past decades. In addition, plantations of the same species of same age in different localities also were not available.

There are only few studies on the growth of rattans in relation to environmental conditions. Manokaran (1977, 1982, 1983) reported that survival of three Malaysian species *Calamus scipionum, C. manan* and *C. caesius*, after 5-7 years, was only about 20 per cent. After seven years of growth, no stem was ready for harvest and none had flowered. Renuka and Rugmini (1996) and Renuka *et al.*, (2004) studied the growth performance of different commercially important species in plantations. They reported that after eight years, at 1000 m elevation, the survival percentage varied from 10-60 depending on the species and at 300 m elevation it varied from 0-35. Species less than 1 cm diameter attained 3-4 m height at the end of six years. Yin *et al.* (2008) reported that there is a positive correlation between monthly increment of shoot growth and rain fall and the coefficient was above 0.7.

Sujatha (1998) studied the characteristics of soil in the natural habitats of *C. thwaitesii* and *C. pseudotenuis*. Jayasree *et al.* (2004, 2005) reported that root growth of *C. thwaitesii* and *C. rotang* in degraded lateritic soils of Kerala was inversely related to the depth of soil significantly and positively related to sand, organic carbon, available Nitrogen and extractable Phosphorous.

Baciliery *et al.* (1999) reported that each rattan species has special requirements in terms of light. According to the study, two key factors having a major impact on rattan growth are light and competition from surrounding trees and soil has not much effect. The effect of light on rattan growth was

stressed by several authors (Bogh, 1996; Siebert, 1993; Yin *et al.*, 1998; Powling, 2004; van Valkenburg, 2002).

The important role of light for establishment and growth of rattan plants was observed in planting trials of rattan species in Malaysia and Indonesia (Wan Rhazali Wan Mohd. *et.al.,* 1992). The effect of logging, resulting in an increase of light, however appeared to have negative effects on the rattan resource (Abdillah Rosian and Philips, 1989; Kew and Hood, 1991; van Valkenburg, 2002).

Renuka (2004) reported that light intensity definitely has an effect on the survival percentage, growth and on the number of shoots produced. Under full sunlight all species registered low survival percentage and low rate of growth. Maximum survival was registered under 75 per cent light in *C. hookerianus* and under 50 percent light in *C. thwaitesii* and *C. rivalis.* With regard to growth in height, *C. thwaitesii* and *C. rivalis* performed well under 75 percent light whereas in *C. hookerianus* the growth rate was maximum under 50 percent light. The number of shoots produced was greater under 50 percent light in all the species.

Raja Barizan *et al.* (2005) reported that canopy manipulation is necessary to introduce more light to accelerate growth, since under forest condition, light usually falls only within 0.1% - 5.0% RLI. The success in rattan planting also depends on good field preparation. Most of the Indonesian species require soil with good moisture and relatively bright light but certain species can grow well in low light intensities and on rocky soil also (Powling, 2005).

MATERIALS AND METHODS

STUDY AREA

Even though, the Forest Department has started raising rattan plantations 1993 onwards, plantations of the same species established at the same period throughout Kerala are very rare. In 1998, *Calamus thwaitesii* (Fig. 1) was planted at three locations, Kottiyoor Range (Kannur Forest Division), Pattikkad Range (Thrissur Forest Division), and Thodupuzha Range (Kothamangalam Forest Division) and *Calamus delessertianus* (Fig. 2) was planted at two locations, Kottiyoor and Kannavam Ranges of Kannur Forest Division. These plantations were selected for the study.

MATERIALS

Calamus thwaitesii Becc.

This is a very robust high climbing rattan, stem to 20 m or more in length; with sheaths to 6 cm in diameter, without sheaths, to 3.5 cm; internode to 45 cm long, sometimes with brown spots. Sheath yellow, densly armed with black flattened spines, with yellow base, spines of varying length arising from a raised rim-like surface, the longest to 3 x 0.7 cm. Knee absent. Leaf to 3 m long, ecirrate, rachis and petiole yellowish, armed with flat black spines arranged in oblique rows; leaflets grouped, longest to 80 x 45 cm, sharply spinulose. Inflorescence long flagellate; male flowers distichous in arrangement. Fruits 2 x 1.3 cm, ovoid, covered with 12 vertical rows of yellow scales with deep brown margins, scales with median grooves. This is the thickest cane available along the Western Ghats and is widely used in furniture industry.

Calamus delessertianus Becc.

This is a single stemmed, moderate - sized rattan, stem to 20 m or more long; with sheaths to 3 cm in diameter at base, 5-6 cm at the apex, without sheaths, to 2.5 cm in diameter. Sheath green with bulbous based spines. Leaves to 2 m long; rachis armed with numerous solitary spines; leaflets 35 x 2.2 cm; regular in arrangement, veins ciliated on the upper surface; cilia to 1.5 cm long, leaf

margin closely spinulose, spinules closer and stronger towards the base. Female inflorescence rather large, partial inflorescence 30 cm long, attached inside the sheath, arising erect at first and then spreading. Fruit globose, 1.5 cm in diameter, distinctly stalked, scales straw yellow, in 28 rows, spirally arranged, deeply channeled in the middle. This is used as round or split canes in furniture industry.

METHODS

Three plots of 50 m x 50 m size were demarcated within each plantation at the selected sites. All the sites were situated within 100-200 m elevation. At Kottiyoor, Kannavam and Thodupuzha, plots were inside evergreen forests while at Pattikkad, they were inside moist deciduous forests.

Growth measurements were taken at four months interval from 25 plants in each plot. The observations were taken on plant height, number of leaves, number of new leaves, number of suckers, sucker height, and inter nodal length. The data were subjected to analysis of variance after applying appropriate transformations.

The intensity of light was categorised as 25%, 40%, 50%, 60% and 75% based on the percentage of light reaching the plant. Monthly rain fall data was collected from the Stations of the Meteorological Department, Government of India, situated near the experimental plots at Thodupuzha and Kottiyoor and from KFRI, situated near the plot at Pattikkad.

In order to study the soil characteristics, at each site, the plots were divided into different groups based on the dendrograms drawn with various growth parameters. At Thodupuzha there were 19 groups, at Kottiyur 26 groups and at Pattikad 23 groups. Soil samples were collected (0-20 cm depth) from each group and these samples were analysed for pH, organic carbon, extractable phosphorus, exchangeable K, Ca, Mg, Al, exchange acidity etc., using standard procedures.

Fig. 1. *Calamus thwaitesii* Becc.

Fig. 2. *Calamus delessertianus Becc*

RESULTS

The growth parameters of two species of rattan were evaluated in relation to the location, availability of rain and light, and soil characteristics.

Location

C. thwaitesii

The results of analyses of variance on plant height, number of leaves, number of new leaves, number of suckers and inter nodal length, for comparing locations *viz.*, Kottiyoor, Pattikkad and Thodupuzha are given in Table 1. The effects due to location and period turned out significant for number of leaves, number of new leaves and number of suckers. The effect due to interaction between period and location turned out significant for plant height, number of leaves, number of new leaves and number of suckers. This indicates that the effect of locations varies with the change in periods. There was no significant difference between locations with respect to plant height and inter nodal length. Mean values of plant height, number of leaves, number of new leaves, number of suckers and internodal length for three locations are shown in Tables 2.

C. delessertianus

The results of analyses of variance on different growth characteristics for comparing locations *viz.*, Kottiyoor and Kannavam are given in Table 3. The effects due to location, period and interaction between period and location turned out significant for number of leaves and number of new leaves. This indicates that the effect of locations varies with the change in periods. However, all the effects were found to be non significant for internodal length. With regard to plant height the effect due to period alone turned out to be significant. Mean values of plant height, number of leaves, number of new leaves and inter nodal length for two locations are reported in Table 4.

Table 1. Analyses of variance on different growth characteristics of *C. thwaitesii* for comparing locations

Sources	Degrees of freedom	Plant height		Number of leaves		Number of new leaves		Number of suckers		Inter nodal length	
		Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values
Location	2	51.80	2.54^{ns}	365.78	20.78**	7.83	113.64**	39.46	9.98**	1579.41	3.60^{ns}
Error (1)	7	20.42		17.60		0.07		3.95		438.82	
Period	7	3.58	4.25**	59.23	276.60**	4.15	69.25**	2.62	25.20**	1.75	0.67^{ns}
Location x period	14	3.34	3.97**	4.36	20.37**	0.83	13.82**	0.67	6.42**	3.66	1.40^{ns}
Error (2)	45	0.84		0.41		0.06		0.10		2.62	

** Significant at 1% level; ns- non significant

Table 2. Growth measurements of *C. thwaitesii* in three different locations

Month after planting	Plant height			Number of leaves			Number of new leaves			Number of suckers			Inter nodal length		
	Th	Pa	Ko	Th	Pa	Ko	Th	Pa	Ko	Th	Pa	Ko	Th	Pa	Ko
90	0.00	322.85	56.25	8.33	11.89	5.75	0.00	0.00	0.00	0.23	4.11	0.94	0.00	29.85	6.88
101	0.00	368.00	28.75	9.90	14.97	6.88	1.35	3.83	1.16	0.39	4.91	0.89	0.00	29.10	5.00
106	0.00	386.04	32.50	10.14	15.92	7.30	0.50	3.04	0.42	0.41	5.01	0.89	0.00	28.71	5.00
109	0.00	546.04	32.00	11.23	18.42	7.88	1.03	2.56	0.53	0.39	5.24	0.87	0.00	29.17	5.00
113	50.00	609.11	33.75	12.10	20.28	8.32	0.83	1.84	0.56	0.43	5.37	0.85	0.00	29.17	5.00
117	50.00	635.77	41.25	12.99	20.28	8.53	0.89	1.78	0.20	0.46	5.40	0.85	0.00	29.17	5.00
121	137.50	594.33	34.38	13.91	21.02	9.27	1.18	2.38	0.65	1.08	6.35	1.04	0.00	27.31	7.25
125	108.25	631.78	56.00	15.77	23.32	11.76	1.96	2.61	1.76	1.95	8.29	1.46	0.00	25.29	8.33

Th = Thodupuzha; Pa = Pattikkad; Ko = Kottiyur

Table 3. Analyses of variance on different growth characteristics of *C. delessertianus* for comparing locations

Sources	Degrees of freedom	Plant height		Number of leaves		Number of new leaves		Inter nodal length	
		Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values
Location	1	169.67	6.95^{ns}	637.76	67.58**	15.26	99.24**	2526.85	4.29^{ns}
Error(1)	4	24.43		9.44		0.15		588.68	
Period	7	0.26	3.92**	45.94	60.48**	4.10	29.23**	0.32	0.06^{ns}
Location x period	7	0.07	1.04^{ns}	3.10	4.08**	0.83	5.96**	1.12	0.20^{ns}
Error(2)	24	0.07		0.76		0.14		5.62	

** Significant at 1% level; ns- non significant

Table 4. Growth measurements of *C. delessertianus* in Kottiyur and Kannavam

Month after planting	Plant height		Number of leaves		Number of new leaves		Inter nodal length	
	Kottiyur	Kannavam	Kottiyur	Kannavam	Kottiyur	Kannavam	Kottiyur	Kannavam
90	17.5	234.4	6.0	11.4	0.0	0.0	6.7	23.1
101	17.5	302.4	7.7	14.2	1.5	2.8	6.7	23.1
106	17.5	367.7	7.9	16.1	0.3	2.0	6.7	23.1
109	28.7	362.1	8.1	17.0	0.7	1.9	6.7	23.1
113	61.3	362.1	8.5	17.0	0.4	1.9	10.0	23.1
117	77.5	366.5	8.8	17.2	0.3	1.8	9.0	23.5
121	102.5	404.5	12.4	21.4	1.6	4.2	11.5	22.8
125	135.0		8.3		1.8		10.8	

Species comparison

The results of analysis of variance on different growth characteristics for comparing *C. thwaitesii* and *C. delessertianus* are shown in Table 5. The effect due to species was found to be non significant with respect to all the growth variables. The effect due to period and interaction between period and species turned out significant for number of leaves and number of new leaves. The effect due to turned out the significant in the case of number of leaves and number of new leaves. This indicates that the effect of species varies with the change in periods with respect to number of leaves and number of new leaves. Mean values of plant height, number of leaves, number of new leaves and inter nodal length of two species are given in Table 6.

Light

The plots at Pattikkad received more light (75%) when compared to those at Thodupuzha (60%) and Kottiyur (40%). The growth characters were significantly influenced by light conditions in *C. thwaitesii* (Table 7).

Table 7. Correlation between growth parameters and light intensity

Species	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
C. thwaitesii	0.385**	0.390**	0.310**	0.335**	0.380**
C. delessertianus	0.226^{ns}	0.192 ^{ns}	0.274 ^{ns}	-	0.096 ^{ns}
Combining two species together	0.423**	0.437**	0.342**	0.410**	0.357**

*Note: **significant at 1% level*

Rainfall

All the study areas in general enjoyed similar rainfall pattern and there was no significant variation between sites (Table 8).

Table 5. The analyses of variance on different growth characteristics for comparing species

Sources	Degrees of freedom	Plant height		Number of leaves		Number of new leaves		Inter nodal length	
		Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values	Mean sum of squares	F-values
Species	1	9.04	0.20^{ns}	4.16	2.50^{ns}	0.04	1.50^{ns}	89.00	0.09^{ns}
Error(1)	5	46.03		1.66		0.03		990.76	
Period	7	0.19	0.37^{ns}	22.03	46.92**	2.05	29.23**	3.46	1.22 ^{ns}
Species x period	7	0.38	0.74^{ns}	1.41	3.01*	0.18	2.61*	0.76	0.27 ^{ns}
Error(2)	30	0.52		0.47		0.07		2.84	

** Significant at 1% level; ns- non significant

Table 6. Mean values of growth characteristics of *C. thwaitesii* and *C. delessertianus*

Month after planting	Plant height		Number of leaves		Number of new leaves		Inter nodal length	
	C. thwaitesii	*C. delessertianus*	*C. thwaitesii*	*C. delessertianus*	*C. thwaitesii*	*C. delessertianus*	*C. thwaitesii*	*C. delessertianus*
90	56.3	17.5	5.7	6.9	0.0	0.0	6.9	6.7
101	28.8	17.5	6.9	5.0	1.5	1.5	5.0	6.7
106	32.5	17.5	7.3	5.0	1.0	0.3	5.0	6.7
109	32.0	28.7	7.9	5.0	0.5	0.7	5.0	6.7
113	33.8	61.3	8.3	5.0	1.5	0.4	5.0	10.0
117	41.3	77.5	8.5	5.0	1.0	0.3	5.0	9.0
121	34.4	102.5	9.3	7.3	1.7	1.6	7.3	11.5
125	56.0	135.0	11.8	8.3	1.8	1.8	8.3	10.8

Table 8. Correlation between growth parameters and total rainfall

Growth parameters	*C. thwaitesii*	*C. delessertianus*	All
Plant height	-0.079	0.045	-0.041
Number of leaves	0.008	0.115	0.047
Number of new leaves	-0.009	0.232	0.088
Number of suckers	-0.112	-0.162	-0.066
Inter nodal length	-0.125	-0.011	-0.091

Note: all correlations are non significant at 5 % level

Soil characters

Data on surface and sub surface soil properties (Tables 9 and 10) revealed that among the different sites situated in different agro climatic conditions, soils at Pattikkad was unique with its higher soil quality as evidenced by significantly higher pH, organic carbon, extractable phosphorus, exchangeable K, Ca and Mg. Data also indicated that soils at Thodupuzha was comparatively the poorest in soil fertility with its low content of organic carbon and nutrients. The status of exchange acidity was significantly low at Pattikkad and higher at Thodupuzha and Kannavam. The content of exchangeable Al was very low and on par in all the sites indicating no signs of soil degradation.

Table 9. Soil properties of rattan plantations at 0-10 cm depth

Location	pH	OC (%)	Extr. P (ppm)	Exch. K (meq/100g)	Exch. acidity (meq/100g)	Exch. Al (meq/100g)	Exch. Ca (meq/100g)	Exch. Mg (meq/100g)
Thodupuzha	5.41^{b}	2.02^{c}	0.29^{d}	1.15^{a}	0.27^{a}	0.01	1.73^{b}	0.98^{b}
Pattikkad	6.18^{a}	3.59^{a}	1.74^{a}	1.51^{a}	0.13^{c}	0.00	3.85^{a}	2.15^{ab}
Kottiyur	5.61^{b}	1.71^{c}	1.22^{b}	1.08^{b}	0.17^{b}	0.01	3.03^{a}	2.40^{a}
Kannavam	5.34^{b}	2.84^{b}	0.69^{c}	0.80^{b}	0.26^{a}	0.00	2.99^{ab}	1.84^{ab}

Note: Means with same superscripts are homogeneous within a column

Table 10. Soil properties of rattan plantations at 10-20 cm depth

Location	pH	OC [%]	Extr. P[ppm]	Exch. K [meq/ 100g]	Exch. Acidity [meq/1 00g]	Exch. Al [meq/ 100g]	Exch. Ca [meq/1 00g]	Exch. Mg [meq/1 00g]
Thodupuzha	5.35^{bc}	1.09^{c}	0.61^{c}	1.02^{b}	0.32	0.04	1.78^{b}	0.95
Pattikkad	6.02^{a}	2.79^{a}	1.81^{a}	1.85^{a}	0.17	0.00	2.74^{a}	1.57
Kottiyur	5.50^{b}	1.21^{c}	1.17^{b}	1.16^{b}	0.28	0.02	1.85^{b}	1.33
Kannavam	5.23^{c}	2.23^{b}	0.63^{c}	0.83^{b}	0.32	0.02	2.37^{ab}	1.38

Note: Means with same superscripts are homogeneous within a column

Relation between growth of rattan and soil characteristics

In *C. thwaitesii,* there was a strong positive correlation of all the growth parameters such as plant height, number of leaves, number of new leaves, number of suckers and internodal length with soil properties such as pH and organic carbon at the two depths studied. Except in the case of number of leaves, phosphorus content also showed significant positive correlation upto a depth of 20 cm with the growth of this species (Tables 11 & 12).

Table 11. Correlation between growth parameters of *C. thwaitesii* and soil properties at 0-10 cm depth

Soil Parameters	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
pH	0.840**	0.752**	0.760**	0.748**	0.764**
OC	0.904**	0.902**	0.900**	0.869**	0.815**
P	0.755*	0.438	0.595	0.714*	0.753*
K	0.623*	0.762**	0.600	0.559	0.480
Ea	-0.548	-0.270	-0.487	-0.564	-0.519
Al	-0.366	-0.321	-0.317	-0.339	-0.395
Ca	0.630	0.298	0.374	0.632	0.474
Mg	0.266	-0.030	0.125	0.274	0.261

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

Table 12. Correlation between growth parameters of *C. thwaitesii* and soil properties at 10-20 cm depth

Soil parameters	Growth parameters			
	Plant height	No. of leaves	No. of new leaves	Inter nodal length
pH	-0.581	-0.600	-0.347	-0.143
OC	0.909*	0.873*	0.725	0.864*
P	-0.988**	-0.959**	-0.670	-0.831*
K	-0.511	-0.474	-0.638	-
Ea	0.653	0.586	0.262	0.351
Al	-0.496	-0.394	-0.445	-0.589
Ca	0.332	0.250	-0.026	0.762
Mg	-0.223	-0.315	-0.451	0.406

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

Table 13. Correlation between growth parameters of *C. delessertianus* and soil properties at 0-10 cm depth

Soil properties	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
pH	0.860**	0.798**	0.810**	0.784**	0.815**
OC	0.872**	0.837**	0.906**	0.824**	0.815**
P	0.755*	0.626	0.635*	0.694*	0.739*
K	0.665*	0.656*	0.495	0.59	0.618
Ea	-0.731*	-0.460	-0.535	-0.647*	-0.597
Al	-0.386	-0.180	-0.243	-0.365	-0.414
Ca	0.758*	0.769**	0.670*	0.655*	0.651*
Mg	0.362	-0.021	0.368	0.550	0.432

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

In *C. delessertianus*, only organic carbon and P content in the soil showed significant relation with various growth parameters at surface soil. But in the sub surface layer pH, organic carbon and P showed significant relation with the growth of rattan, but restricted to few parameters such as plant height, number of leaves and number of new leaves (only with organic carbon) (Tables 13 & 14). When the growth of two species together was considered, organic carbon was the only key variable showing significant correlation with growth at both soil depths (Tables 15 & 16).

Table 14. Correlation between growth parameters of *C. delessertianus* and soil properties at 10-20 cm depth

Soil Parameters	Growth parameters			
	Plant height	No. of leaves	No. of new leaves	Inter nodal length
pH	-0.827*	-0.818*	-0.550	-0.415
O.C[%]	0.993**	0.979**	0.816*	0.730
P [ppm]	-0.959**	-0.959**	-0.784	-0.582
K [M.eq/100g]	-0.900*	-0.932**	-0.680	-0.587
EA	0.074	-0.085	-0.596	0.297
AL	-0.110	-0.092	-0.433	-0.118
Ca [M.eq/100g]	0.563	0.601	0.459	0.778
Mg [M.eq/100g]	-0.182	-0.358	-0.526	0.272

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 %*

Relation between plant growth and soil properties at two depths combined (0-20 cm) was also worked out for each species (Tables 17 & 18). Results showed that growth of *C. thwaitesii* was strongly influenced by pH, organic carbon and extractable P while in *C. delessertianus* growth was influenced mainly by organic carbon and available P content in the soil.

Table 15. Correlation between growth parameters of two species of rattan and soil parameters at 0-10 cm depth

Soil Parameters	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
pH	0.461	0.387	0.507	0.777**	0.456
OC	0.887**	0.875**	0.848**	0.677**	0.805**
P	0.383	0.131	0.379	0.648**	0.413
K	0.263	0.356	0.289	0.573*	0.211
Ea	-0.200	-0.011	-0.303	-0.528*	-0.252
Al	-0.409	-0.347	-0.349	-0.222	-0.456
Ca	0.549	0.270	0.315	0.523	0.488
Mg	0.116	-0.118	-0.025	0.151	0.315

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

Table 16. Correlation between growth parameters of two species of rattan and soil parameters at 10-20 cm depth

Soil Parameters	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
pH	0.860**	0.798**	0.810**	0.784**	0.815**
OC	0.872**	0.837**	0.906**	0.824**	0.815**
P	0.755*	0.626	0.635*	0.694*	0.739*
K	0.665*	0.656*	0.495	0.59	0.618
Ea	-0.731*	-0.460	-0.535	-0.647*	-0.597
Al	-0.386	-0.180	-0.243	-0.365	-0.414
Ca	0.758*	0.769**	0.670*	0.655*	0.651*
Mg	0.362	-0.021	0.368	0.550	0.432

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

Table 17. Correlation between growth parameters of *C. thwaitesii* and soil properties at 0-20 cm depth

Soil Parameters	Growth parameters				
	Plant height	No. of leaves	No. of new leaves	No. of suckers	Inter nodal length
pH	0.857**	0.781**	0.792**	0.772**	0.794**
OC	0.912**	0.893**	0.926**	0.868**	0.838**
P	0.775**	0.542	0.632*	0.724*	0.767**
K	0.749*	0.847**	0.656*	0.667*	0.626*
Ea	-0.738*	-0.436	-0.591	-0.695*	-0.643*
Al	-0.437	-0.254	-0.289	-0.403	-0.467
Ca	0.742*	0.495	0.518	0.708*	0.587
Mg	0.378	-0.030	0.281	0.481	0.411

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

Table 18. Correlation between growth parameters of *C. delessertianus* and soil properties at 0-20 cm depth

Soil Parameters	Growth parameters			
	Plant height	No. of leaves	No. of new leaves	Inter nodal length
pH	-0.714	-0.722	-0.458	-0.283
OC[	0.968**	0.942**	0.785	0.816*
P	-0.991**	-0.979**	-0.745	-0.717
K	-0.659	-0.729	-0.736	
Ea	0.456	0.347	-0.114	0.343
Al	-0.278	-0.240	-0.506	-0.306
Ca	0.555	0.538	0.299	0.925**
Mg	-0.223	-0.350	-0.506	0.382

*** Significant at 1 % level; * significant at 5 % level; correlations with no superscripts are non significant at 5 % level*

DISCUSSION

In rattans, in the first stage of development, called the establishment or rosette stage, the stem diameter and the number of roots increase, but stem elongation is negligible. Once the stem has attained the maximum diameter, second phase of development starts with a significant aerial growth of the stem. Usually the rosette stage may last for two to five years according to species and environmental conditions and total stem growth increased with the increase in age.

In the present study, the species *C. thwaitesii* was in the rosette stage up to nine years at Thodupuzha. Once the stem formation started, the growth was faster and within an year i.e., at the end of 10th year the stem attained 1 m height. At Pattikkad even in the 7th year the mean height was 3.2 m and it increased to 6.3 m at the end of 10th year. But at Kottiyur, no increase in height was recorded even at 10th year. In the case of mean number of suckers, there was an increase from 0.23 to 1.95 at Thodupuzha, 4.1 to 8.29 at Pattikkad and 0.9 to 1.5 at Kottiyur within three years. Mean values of plant height and number of suckers differed significantly between locations and at various growth stages.

In *C. delessertianus*, the height increased from 17.5 cm to 102.5 cm at Kottiyur and from 234.4 cm to 404.5 cm at Kannavam. Number of leaves and number of new leaves also increased. The increase in all these growth characters is more at Kannavam. Internodal length increases at Kottiyur while it slightly decreased at Kannavam.

When the two species are compared, the increase in height and internodal length is more in *C. delessertianus*. Increase in number of leaves and number of new leaves are similar in both species. Analysis of variance revealed a significant and positive correlation of location and period with all growth parameters except in internodal length in *C. thwaitesii* whereas in *C.*

delessertianus, a significant correlation was obtained only for number of leaves and number of new leaves.

Relation between growth of *Calamus* and environmental conditions

In order to find out the relation between the growth of *C. thwaitesii* and environmental conditions, correlation coefficients of various growth parameters with soil parameters, light intensity and rainfall were worked out. Results revealed a significant and positive correlation of pH (r=0.840**, 0.752**, 0.760**, 0.748**, 0.764**) and organic carbon (r=0.904**, 0.902**, 0.900**, 0.869**, 0.815**) with all the growth parameters studied and extractable phosphorus (r=0.755*, 0.714*, 0.753*) with plant height, number of suckers and internodal length respectively. Significant relation of potassium was observed (r=0.623*) only with plant height. The results revealed a wide variation in the soil properties such as pH, organic carbon and available P between the sites at Pattikkad and Thodupuzha, where *C. thwaitesii* was growing. But the variation in the soil properties between Kannavam and Kottiyur was not that wide as in the above case. The wider the variation, the higher will be the correlation coefficient. Thus the strong correlation between the soil properties and growth parameters in *C. thwaitesii* could be attributed to the wider range in the soil properties.

Thus the above observations support the fact that depletion of soil quality especially pH, organic carbon and associated nutrients is found to be a major constraint in achieving maximum growth in *Calamus*.

It is also noted that among the two species growing at one site in Kottiyur, *C. delessertianus* attained significantly more height and girth than *C. thwaitesii* within the same period of growth. This indicates that *C. delessertianus* is more adaptable to soils with depleted soil fertility than *C. thwaitesii*.

Correlation between growth parameters and rainfall was found to be non significant in to both species. Xu *et al.* (1994) report that overshading reduced the number of suckers produced and growth in height while full illumination

promoted stem growth and nodal elongation. According to them a strong correlation exists between growth, temperature and rainfall. Yin *et al.* (2008) reported that there is a positive correlation between monthly increment of shoot growth and rain fall and the coefficient was above 0.7. The non significant correlation between growth parameters and rainfall in the present study might not be due to the lack of influence of rainfall on *Calamus*, but it could be due to the low variation in the quantity of rainfall received at all the sites studied.

Light intensity was found to be significantly correlated (r= 0.385**; 0.335**) with plant height and number of suckers respectively. Significantly higher growth recorded at Pattikkad might be due to the higher soil fertility and availability of more sunlight compared to other sites. Thus the study in general revealed that growth of *Calamus thwaitesii* is influenced by soil and light conditions of the locality. Owing to the higher soil fertility and sunlight penetration, the site at Pattikkad recorded higher growth compared to other sites. The effect of light on rattan growth was stressed by several authors (Bogh, 1996; Siebert, 1993; Yin *et al.*, 1998; Powling, 2004; van Valkenburg, 2002).The important role of light for establishment and growth of rattan plants was observed in planting trials of rattan species in Malaysia, Indonesia and China (Wan Rhazali Wan Mohd. *et al.*, 1992; Manokaran, 1985). Baciliery *et al.* (1999) report that each rattan species has special requirements in terms of light. Bogh (1996) also reported that growth rates were highly variable depending on the light conditions available. Marry (1994) emphasises the importance of maintaining an optimal light regime within the plantations to give maximum growth rates. Raja Barizan *et al.*, (2005) reports that canopy manipulation is necessary to introduce more light to accelerate growth since under forest condition, light usually falls only within 0.1% - 5.0% RLI.

Baciliery *et al.* (1999) report that each rattan species has special requirements in terms of light. According to them, two key factors having a major impact on rattan growth are light and competition from surrounding trees and soil has not much effect. But the present study reveals the effect of soil. Powling (2005) also reported that most of the Indonesian species require soil with good moisture

and relatively bright light but certain species can grow well in low light intensities and on rocky soil. The success in rattan planting also depends on good field preparation. Chia *et al.* (2010) also report that site conditions such as soil and light are important factors that need to be taken into consideration for rattan plantation establishment.

CONCLUSION AND RECOMMENDATIONS

Based on the above study it is concluded that growth of *C. thwaitesii* and *C. delessertianus* under plantations is significantly influenced by soil and light conditions of the locality.

Site conditions such as soil and light are important factors that need to be taken into consideration for rattan plantation establishment. High production rate is expected from plantations thriving in fertile soil and moderate light (about 75%). Canopy manipulation to increase the light availability should be applied to promote the stem growth.

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