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Influence of edaphic and environmental factors on the growth of rattan plantations in Kerala, India

M. P. Sujatha*, C. Renuka, C. Kavitha and E. L. Linto
Kerala Forest Research Institute, Peechi, Thrissur, 680653

Abstract: The present study evaluates the influence of edaphic and environmental factors on the growth and development of rattan, especially when they are grown on plantation scale. Plantations of *Calamus thwaitesii* at three locations and *C. delessertianus* at two locations were selected for the study. Soil samples were analysed for pH, organic carbon, extractable phosphorus, exchangeable K, Ca, Mg, exchange acidity, exchangeable Al etc., using standard procedures. In general, the results revealed that growth of both species showed strong relation with pH, organic carbon and extractable P content of soil and depletion of soil quality especially pH, organic carbon and associated nutrients was found to be a major constraint in achieving maximum growth in rattans. *C. delessertianus* was found more adaptable to soils with depleted soil fertility than *C. thwaitesii.* Intensity of light was found to have a significant influence on growth of *C. thwaitesii*. The study concluded that growth of *C. thwaitesii* and *C. delessertianus* under plantations were significantly influenced by soil conditions of the locality. High production rate is expected from plantations thriving in fertile soil and moderate light condition.

*Keywords***:** Rattan, *Calamus*, soil, environment, light

INTRODUCTION

Rapid dwindling of natural rattan resources caused by alarming rate of their over exploitation threaten the sustainable utilization of rattan as well as the long-term survival of the rattan industry in the state of Kerala, India. One of the effective measures to stabilize the supply of rattan resources, which are gaining importance as a plantation crop is to expand the cultivation to large scale plantations by adopting improved management techniques. Even though Kerala Forest Department has initiated rattan plantations since 1993, growth of plants in most of these plantations are very poor and many of the plants have not attained harvestable length even after 12-13 years. Literature on cultivation of rattans revealed that majority of the plantations in the South and South –East Asian countries are also facing similar problems (Manokaran, 1977, 1982, 1983; Renuka and Rugmini, 1996; Renuka *et al*., 2004 and Yin *et al*., 2008). This signifies the importance of effective management of the plantations for

* To whom correspondence should be addressed; E mail: sujatha@kfri.org

better productivity. To achieve this, the basic requirement is the information about the relation between the growth of plants and environmental conditions. In the case of rattans, very few studies have been reported from South-East Asian countries (Bogh, 1996; Yin *et al.,* 2008; Xu *et al*., 1994). Studies on 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: Manokaran, 1985). The effect of light on rattan growth was also reported by several other authors (Bogh, 1996; Siebert, 1993; Yin *et al*., 1998; Bogh, 1996; van Valkenburg, 2002, Powling, 2004; Raja Barizan *et al.,* 2005). According to Baciliery *et al.* (1999), two key factors having a major impact on rattan growth in Malaysia were light and competition from surrounding trees and soil had very little effect. In Indonesia, most of the species require soil with good moisture and relatively bright light but, certain species could grow well in low light intensities and on rocky soils (Powling, 2005). Yin *et al.* (2008) also reported a positive correlation between monthly increment of shoot growth and rainfall and the coefficient was above 0.7.

Studies on rattans in relation to edaphic and environmental conditions have not been attempted in Kerala, India. Limited studies are available on soils of natural habitats of *Calamus* (Sujatha, 1998) and its root growth in degraded lateritic soils (Jayasree *et al.,* 2004, 2005). The present study was initiated to evaluate the effect of soil, rainfall and light on the growth of two species of rattans, *viz.*, *C. thwaitesii* Becc. and *C. delessertianus* Becc., which were raised in plantation scale by the Kerala Forest Department.

STUDY AREA AND METHODS

In 1998, *C. thwaitesii* was planted at three locations in Kerala *viz.*, Kottiyoor Range (Kannur Forest Division), Pattikkad Range (Thrissur Forest Division), and Thodupuzha Range (Kothamangalam Forest Division) and *C. delessertianus* at two locations viz., Kottiyoor and Kannavam ranges of Kannur Forest Division. These plantations were selected for the study.

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

Growth measurements of 25 plants in each plot were taken at four month intervals. Plant height, number of leaves, number of new leaves, number of suckers, sucker height, and inter nodal length were recorded.

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, 26 groups in Kottiyoor and at Pattikkad, 23 groups.

Soil samples were collected at 0-10 cm and 10-20 cm depths from each group and these samples were analysed for pH, organic carbon, extractable phosphorus, exchangeable K, Ca, Mg, exchange acidity, exchangeable Al etc. using standard procedures (Black *et al.,* 1965).

The canopy cover of the forest floor was categorised as undisturbed, partially disturbed and fully disturbed based on the amount of light penetrating through the canopy. Monthly rainfall data for the experimental plots at Thodupuzha and Kottiyoor was collected from the nearby stations of the Meteorological Department, Government of India, and rainfall data from Kerala Forest Research Institute, Peechi, was used for the nearby plot at Pattikkad, The data were subjected to analysis of variance after applying appropriate transformations. Correlation coefficients between growth parameters and soil properties were calculated using SPSS package.

RESULTS

Soil characteristics

Data on surface and sub surface soil properties (Tables 1 and 2) revealed that soils of Pattikkad was unique with its higher soil quality as evidenced by significantly higher pH, organic carbon, extractable phosphorus and exchangeable K than the other sites. Soils of Kerala in general are lateritic in nature. Hence, significantly low acidity and absence of exchangeable Al at Pattikkad are considered desirable qualities for better growth of *Calamus*. Soils of other sites were comparatively poor in soil fertility due to its low content of organic carbon and nutrients coupled with high

Table 1. Soil properties of rattan plantations at 0-10 cm depth

Location	pH	Organic Carbon (%)	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^{a}	1.73^{b}	0.98^{b}
Pattikkad	6.18^{a}	3.59^{a}	1.74^{a}	1.51^{a}	0.13^{c}	0.00^{a}	3.85^{a}	2.15^{ab}
Kottiyur	5.61^{b}	1.71^{c}	1.22^{b}	1.08^{b}	0.17^{b}	0.01^{a}	3.03^{a}	2.40^{a}
Kannavam	5.34^{b}	2.84^{b}	0.69^{c}	0.80^{b}	0.26^{a}	0.00^{a}	2.99^{ab}	1.84^{ab}

Note: Means with same superscripts are homogeneous within a column

Table 2. Soil properties of rattan plantations at 10-20 cm depth

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

Note: Means with same superscripts are homogeneous within a column

exchange acidity and exchangeable Al. In general, no significant variation among the sites could be noted with respect to the content of exchangeable Ca and Mg.

Relation between growth of rattan and soil characteristics

Correlation studies between growth and soil parameters (Tables 3 and 4) showed that in *C. thwaitesii,* there was a significant and positive correlation of all growth parameters (plant height, number of leaves, number of new leaves, number of suckers, sucker height, and inter nodal length) with pH (r=0.840**, 0.752**, 0.760**, 0.748** and 0.764** respectively) and organic carbon (r=0.904**, 0.902**, 0.900**, 0.869** and 0.815** respectively). But extractable phosphorus was significantly and positively correlated only with plant height, number of suckers and internodal length (r=0.755*, 0.714* and 0.753* respectively). Significant correlation of potassium was observed (r=0.623*) only with plant height.

In the case of *C. delessertianus*, organic carbon and P content in the soil showed significant relation with various growth parameters at surface soil (Table 5). But in

Table 3. 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	Girth	Leaf length
pH	0.840**	0.752**	0.760**	0.748**	0.764**	0.704**	0.199
Organic carbon (%)	0.904**	0.902**	0.900**	0.869**	0.815**	0.727**	0.459
Extr.P	0.755*	0.438	0.595	0.714*	0.753*	0.745**	0.069
Exch.K	0.623*	0.762**	0.600	0.559	0.480	0.389	0.550
Exch.acidity	-0.548	-0.270	-0.487	-0.564	-0.519	-0.493	0.260
Exch.Al	-0.366	-0.321	-0.317	-0.339	-0.395	-0.403	0.170
Exch.Ca	0.630	0.298	0.374	0.632	0.474	0.448	-0.213
Exch.Mg	0.266	-0.030	0.125	0.274	0.261	0.272	-0.492

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

Table 4. 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	Girth	Leaf length
pH	-0.581	-0.600	-0.347	-0.143	-0.172	-0.591
Organic carbon (%)	0.909*	0.873*	0.725	0.864*	0.912*	0.484
Extr.P	-0.988**	-0.959**	-0.670	-0.831*	-0.874*	-0.725
Exch.K	-0.511	-0.474	-0.638		-0.285	-0.25
Exch.acidity	0.653	0.586	0.262	0.351	0.289	0.384
Exch.Al	-0.496	-0.394	-0.445	-0.589	-0.624	0.074
Exch.Ca	0.332	0.250	-0.026	0.762	0.794	0.498
Exch.Mg	-0.223	-0.315	-0.451	0.406	0.283	-0.184

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

Table 5. 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	Girth	Leaf length
pH	0.860**	0.798**	0.810**	0.784**	0.815**	0.755*	0.352
Organic carbon (%)	0.872**	0.837**	0.906**	0.824**	0.815**	0.732*	0.384
Extr.P	0.755*	0.626	0.635*	0.694*	0.739*	0.712*	0.318
Exch.K	0.665*	0.656*	0.495	0.59	0.618	0.615	0.184
Exch.acidity	-0.731*	-0.460	-0.535	-0.647*	-0.597	-0.558	0.046
Exch.Al	-0.386	-0.180	-0.243	-0.365	-0.414	-0.429	0.025
Exch.Ca	0.758*	0.769**	0.670*	0.655*	0.651*	0.585	0.330
Exch.Mg	0.362	-0.021	0.368	0.550	0.432	0.420	-0.026

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

the sub surface layer (Table 6) even though pH, organic carbon and P showed significant relation with the growth of rattan, it was restricted to few parameters such as plant height, no. of leaves and no. of new leaves (only with organic carbon). When the growth of two species together was considered, organic carbon was the only key variable showing significant correlation with most of the growth parameters at both soil depths (Tables 7 and 8).

Table 6. 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	Girth	Leaf length
pH	-0.827*	-0.818*	-0.550	-0.415	-0.457	-0.654
Organic carbon (%)	0.993**	0.979**	0.816*	0.730	0.796	0.581
Extr.P	-0.959**	-0.959**	-0.784	-0.582	-0.634	-0.577
Exch.K	-0.369	-0.518	-0.328	.	-0.210	-0.175
Exch.acidity	0.074	-0.085	-0.596	0.297	0.222	0.415
Exch.Al	-0.110	-0.092	-0.433	-0.118	-0.228	0.330
Exch.Ca	0.563	0.601	0.459	0.778	0.683	0.268
Exch.Mg	-0.182	-0.358	-0.526	0.272	0.259	-0.074

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

Table 7. Correlation between growth parameters of *C. thwaitesii* and *C. delessertianus* 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	Girth	Leaf length
pH	0.461	0.387	0.507	0.777**	0.456	0.328	0.055
Organic carbon (%)	0.887**	0.875**	0.848**	0.677**	0.805**	0.733**	0.462
Extr.P	0.383	0.131	0.379	0.648**	0.413	0.332	-0.100
Exch.K	0.263	0.356	0.289	0.573*	0.211	0.098	0.456
Exch.acidity	-0.200	-0.011	-0.303	-0.528*	-0.252	-0.198	0.271
Exch.Al	-0.409	-0.347	-0.349	-0.222	-0.456	-0.473	0.130
Exch.Ca	0.549	0.270	0.315	0.523	0.488	0.457	-0.067
Exch.Mg	0.116	-0.118	-0.025	0.151	0.315	0.287	-0.374

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

Table 8. Correlation between growth parameters of *C. thwaitesii* and *C. delessertianus* 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	Girth	Leaf length
pH	0.860**	0.798**	0.810**	0.784**	0.815**	0.755*	0.352
Organic carbon (%)	0.872**	0.837**	0.906**	0.824**	0.815**	0.732*	0.384
Extr.P	0.755*	0.626	0.635*	0.694*	0.739*	0.712*	0.318
Exch.K	0.665*	0.656*	0.495	0.59	0.618	0.615	0.184
Exch.acidity	-0.731*	-0.460	-0.535	-0.647*	-0.597	-0.558	0.046
Exch.Al	-0.386	-0.180	-0.243	-0.365	-0.414	-0.429	0.025
Exch.Ca	0.758*	0.769**	0.670*	0.655*	0.651*	0.585	0.330
Exch.Mg	0.362	-0.021	0.368	0.550	0.432	0.420	-0.026

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

Table 9. 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	Girth	Leaf length
pH	0.857**	0.781**	0.792**	0.772**	0.794**	0.732*	0.273
Organic carbon (%)	0.912**	0.893**	0.926**	0.868**	0.838**	0.750*	0.437
Extr.P	0.775**	0.542	0.632*	0.724*	0.767**	0.749*	0.195
Exch.K	0.749*	0.847**	0.656*	0.667*	0.626*	0.559	0.48
Exch.acidity	-0.738*	-0.436	-0.591	-0.695*	-0.643*	-0.605	0.166
Exch.Al	-0.437	-0.254	-0.289	-0.403	-0.467	-0.487	0.086
Exch.Ca	0.742*	0.495	0.518	0.708*	0.587	0.544	-0.045
Exch.Mg	0.378	-0.030	0.281	0.481	0.411	0.412	-0.362

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

Table 10. 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	Girth	Leaf length
pH	-0.714	-0.722	-0.458	-0.283	-0.319	-0.634
Organic carbon (%)	0.968**	0.942**	0.785	0.816*	0.872*	0.535
Extr.P	-0.991**	-0.979**	-0.745	-0.717	-0.765	-0.660
Exch.K	-0.659	-0.729	-0.736		-0.372	-0.319
Exch.acidity	0.456	0.347	-0.114	0.343	0.257	0.453
Exch.Al	-0.278	-0.240	-0.506	-0.306	-0.381	0.275
Exch.Ca	0.555	0.538	0.299	0.925**	0.876*	0.440
Exch.Mg	-0.223	-0.350	-0.506	0.382	0.291	-0.154

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

Relation between plant growth and soil properties at two depths combined (0-20 cm) were also worked out in each species. Results showed that growth of *C. thwaitesii* was strongly influenced by pH, organic carbon and extractable P (Table 9) while in *C. delessertianus* growth was influenced mainly by organic carbon and available P content in the soil (Table 10).

Relation with environmental conditions

Correlation between light intensity and growth parameters were found significant in *C. thwaitesii* while the relation was not significant with any of the growth parameters in *C. delessertianus* (Table 11). No significant correlation between growth parameters and rainfall could be observed in either of the species.

Table 11. 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	Girth	Leaf length
C. thwaitesii	0.385**	0.390**	0.310**	0.335**	0.380**	0.315**	0.478**
C. delessertianus	0.226	0.192	0.274	0.269	0.096	0.102	0.226

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

DISCUSSION

The soil properties *viz.,* pH, organic carbon and extractable P varied widely between the sites at Pattikkad and Thodupuzha, where *C. thwaitesii* was growing. But the variation in soil properties between the sites of Kannavam and Kottiyur was not significant. It is a fact that wider the variations, 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 properties of soils.

C. thwaitesii was in the rosette stage up to nine years at Thodupuzha and the stem attained only 1 m height even after 10 years growth. But the same species attained 6.3 m height at the end of 10th year at Pattikkad where the soil was very fertile. At Kottiyoor, where the soil was relatively low in fertility, no increase in height was recorded even at 10th year. Similarly, increase in mean no. of suckers were observed from 0.23 -1.95 at Thodupuzha, 4.1 - 8.29 at Pattikkad and 0.9 - 1.5 at Kottiyoor within three years. The observations indicated the fact that low pH, low content of organic carbon and associated nutrients were some of the major constrains in achieving maximum growth in *Calamus.*

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. *C. delessertianus* was therefore more adaptable to soils with depleted soil fertility than *C. thwaitesii.*

Growth of *C. thwaitesii* was significantly influenced by the light intensity of the locality as revealed by the correlation of growth parameters such as plant height and number of suckers with forest types with differences in canopy cover (Table 11). Xu *et al*. (1994) reported that over-shading reduced the number of suckers produced and growth in height while intense light promoted stem growth and nodal elongation.

According to them, a strong correlation existed between growth, temperature and rainfall. Yin *et al.* (2008) reported that there was a positive correlation between monthly increment of shoot growth and rainfall and the coefficient was above 0.7. Since rainfall did not vary much between the sites this study, this could explain the absence of correlation between growth parameters and rainfall, rather than conclude that rainfall had no influence on *Calamus*. Significantly higher growth recorded for *C. thwaitesii* at Pattikkad might be due to the higher soil fertility and availability of more sunlight compared to other sites. This corroborates the finding of Chia *et al.* (2010) that site conditions such as soil and light are important factors that need to be taken into consideration for the establishment of rattan plantation establishment.

CONCLUSION

The present study concluded that growth of *C. thwaitesii* and *C. delessertianus* in plantations was significantly influenced by soil conditions of the locality. High production rate is expected from plantations thriving in fertile soil and the moderate light conditions existing under partially disturbed forest canopy. Results also revealed that *C. delessertianus* was more adaptable to soils with depleted soil fertility than *C. thwaitesii*

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