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STUDY OF SOILS IN NON-CONVENTIONAL AREAS OF RUBBER CULTIVATION IN KERALA AND THEIR EFFECT ON GROWTH AND YIELD OF *HEVEA BRASILIENSIS*

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Rubber (*Hevea brasiliensis*) is being cultivated in non-conventional areas *viz.*, upland paddy fields, lowlands and coastal sand belts within the traditional region of Kerala, India. These areas differ in soil characteristics and production potential among themselves as well as from the traditional rubber growing slope lands. Present study examines the difference in soil characteristics and yield of rubber plantations raised in these land forms and their relationships besides leaf nutrient content. The texture of soil of upland paddy fields varied from sandy loam to clay while low land soils were sandy clay loam to clay loam. Coastal sandy soils contained higher amount of sand throughout the profile. Moisture content at field capacity (FC), permanent wilting point (PWP) and available water content showed wider variations between land forms. The silt and clay had a significant positive influence on FC and PWP. The study showed that the performance of rubber in upland paddy fields and low lying areas is appreciable with respect to growth (gestation period) and yield. With appropriate agromanagement practices, good growth of rubber was observed in sandy soils also, though conventionally sandy soils are considered unsuitable. Significant difference between group variability in mean yield was observed indicating the difference in production potentials of land forms studied.

Key words: Growth, *Hevea brasiliensis,* Non-conventional area, Soil characteristics.

INTRODUCTION

Rubber (*Hevea brasiliensis*) can grow in a vast majority of the soils of the humid tropics. However, its performance and economic viability can be severely restricted where deep, very acidic, rocky parent material is present and drainage is excessive or impeded.

In Kerala, rubber is being cultivated in different landforms *viz.*, midhill slope lands, upland paddy fields, low lands and coastal sandy soils. In upland paddy fields, rubber is usually planted in raised bunds so that rainwater is allowed to retain in the furrows for most part of the year. Low lands are mostly inundated during rainy season and therefore, sub-soils are moist throughout the year. Rubber is also being cultivated in coastal sandy soils where the soil is deep, excessively drained and less productive. Information on soil characteristics and rubber yield in these areas is lacking. The present study, therefore is an attempt to examine the difference in soil characteristics and yield of rubber plantations raised in these landforms and also to know the relationship of soil characteristics with leaf nutrient content and yield.

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MATERIALS AND METHODS

Based on survey of rubber smallholdings raised in marginal areas, suitable holdings were selected for the study. Sixteen holdings were selected representing upland paddy fields. These were traditionally paddy soils where rubber was planted after making raised bunds, resulting in inversion of soils. Water remains in the furrows during most part of the year. These locations are liable to flooding during rainy season every year and subsoils are poorly drained. Profiles 1 and 2 collected from Manarcad and Mannanam (Kottayam District, Kerala) respectively represent this type of rubber growing areas.

In the low lying areas, eleven holdings were selected. These areas are subject to inundation during rainy season for some days resulting in accumulation of alluvium in the field. The surface is well drained except during rainy season and the subsurface is mostly moist. These areas were earlier supporting coconut cultivation and now are under rubber. Profiles 3 and 4 representing this landform were excavated from Kidangara and Veliyand villages respectively of Alleppey District.

Representing the sandy tract, fifteen holdings were selected. Rubber is grown in the sandy tract also where the soil is deep and excessively drained and generally less productive with very low organic matter content. Profiles 5 and 6 were excavated in rubber growing sandy soils in Chertala (Alleppey District) and Vaikom (Kottayam District) respectively.

The rubber trees in all these holdings were of clone RRII 105, being tapped in the BO2 panel during the course of the study. Two typical soil profiles from each of the above landforms and one from midhill slope land at Research farm, Rubber Research Institute of India, Kottayam (Profile 7) representing traditional rubber growing laterite soil (for comparison) were collected and studied for their physico-chemical characteristics. All the profiles except the one representing mid-hill slope land (RRII) were excavated to the water table during summer months. Composite soil samples (0-30 and 30-60 cm depth) were also collected from all the holdings. Soil samples of each horizon of the profiles and composite soil samples were air dried, crushed using pestle and mortar and sieved through a 2 mm sieve before analysis. The soils were analysed for particle size distribution by the International Pipette method (Piper, 1950). Soil water contents at 33 kPa and 1500 kPa metric potentials were determined using pressure plate apparatus (Richards, 1949). Bulk density (BD) and particle density (PD) were determined by the methods as described by Black (1965). Standard methods were followed for determining soil pH (1:2 soil:water suspension), organic carbon (OC), cation exchange capacity (CEC) and exchangeable cations. Total nitrogen, phosphorus and potassium contents were determined as per the methods outlined by Jackson (1973). Leaf samples were collected from each holding under different landforms and analysed for N, P and K using standard methods (Karthikakuttyamma, 1989).

Dry rubber yield from all the holdings in one location in each land form was collected for nine months from September 2000 to May 2001. Statistical comparisons of means were made by Tukey's Honestly significant difference (Steel and Torie, 1980) among the landforms. Analysis of variance was performed at different significance levels to split the components depending on the landforms (Snijder's and Bosker, 1999).

RESULTS AND DISCUSSION

Soil profile studies

The details on depth, particle size fractions, texture, bulk density, particle density, soil water content at field capacity (FC) wilting point (PWP) and available water observed in the profile samples are given in Table 1. The soils in general were moderately deep to very deep. The sand distribution in general showed a decreasing trend with depth while clay content showed an increase irre-

Table 1. **Physical characteristics of the soils**

Depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Soil texture*	Bulk density (Mg/m³)	Particle density (Mg/m³)	Soil water content (%) 33kPa	1500kPa	Available
Profile 1 Upland paddy field, Manarcad									
0-42	11.1	26.4	58.8	c	1.08	2.05	32.1	20.8	11.3
42-58	14.7	20.4	59.9	c	1.15	2.11	34.9	24.0	10.9
58-100	13.2	23.0	61.9	c	1.02	2.14	35.9	24.0	11.9
Profile 2 Upland paddy field, Mannanam									
0-8	73.1	11.8	13.4	sl	1.53	2.60	9.6	6.5	3.1
8-26	66.3	14.4	16.6	l	1.59	2.65	6.9	4.7	2.2
26-56	54.0	18.9	22.6	l	1.35	2.31	15.8	10.4	5.4
56-75	58.3	17.8	20.4	l	1.53	2.54	8.2	5.5	2.7
Profile 3 Lowlands, Kidangara									
0-11	48.9	19.3	29.0	scl	1.08	2.20	24.0	12.0	12.0
11-31	45.0	22.1	29.7	cl	0.98	2.24	25.1	13.1	12.0
31-57	45.5	22.9	31.4	cl	1.01	2.25	29.1	14.1	15.0
57-78	37.4	22.3	34.9	cl	0.99	2.16	28.8	14.6	14.2
78-100	40.1	22.5	35.5	cl	0.99	2.27	27.1	14.6	12.5
Profile 4 Low lands, Veliyanad									
0-17	74.8	12.1	12.0	sl	1.12	2.51	13.4	5.9	7.5
17-37	64.2	15.4	19.3	sl	1.31	2.52	13.7	6.8	6.9
37-50	54.4	17.1	26.8	scl	1.09	2.49	14.5	7.0	7.5
50-70	50.2	18.6	29.6	scl	1.02	2.43	14.2	6.7	7.5
Profile 5 Coastal sand, Chertala									
0-12	96.8	0.1	2.1	s	2.26	2.64	3.9	1.9	2.0
12-50	95.9	0.2	3.8	s	2.25	2.63	3.8	1.7	2.1
50-92	95.5	0.2	3.9	s	2.25	2.65	3.5	1.6	1.9
92-116	91.6	2.7	5.4	s	2.24	2.66	3.6	1.5	2.1
Profile 6 Coastal sand, Vaikom									
0-20	91.0	3.4	4.5	s	1.49	2.63	5.4	1.9	3.5
20-53	91.3	2.2	5.7	s	1.22	2.63	5.0	1.7	3.3
53-73	91.7	2.0	6.1	s	1.32	2.59	5.1	1.6	3.5
73-92	91.9	1.3	6.8	s	1.61	2.67	5.2	1.7	3.5
92-114	91.6	1.0	6.9	s	1.54	2.60	6.2	1.2	5.0
114-160	91.3	0.9	7.3	s	1.55	2.64	6.3	1.0	5.3
Profile 7 Mid-hill slope land, RRII, Kottayam									
0-13	52.8	6.4	40.8	sc	1.33	2.51	28.8	17.8	11.0
13-27	36.1	6.4	57.6	c	1.31	2.48	24.1	16.3	7.8
27-60	36.1	6.4	57.6	c	1.29	2.48	23.9	16.0	7.9
60-87	42.4	6.4	51.2	c	1.27	2.47	25.3	16.8	8.5
87-120	42.4	3.2	54.4	c	1.26	2.46	25.6	17.3	8.3

* c: clay, cl: clay loam, sl: sandy loam, scl: sandy clay loam, sc: sandy clay, s: sand

spective of landforms. The increase in clay content with depth could be attributed to the clay migration by illuviation. The texture of the soil profiles from rubber plantations planted in upland paddy fields varied from sandy loam to clay while lowland soils were sandy clay loam to clay loam. Coastal sandy soils contained higher amount of sand throughout the profile. Texture of mid-hill slope land soil profile (RRII) was sandy clay in upper layer while sub-surface horizons were clay.

Table 2. **Chemical characteristics of the soils**

Depth cm	OC %	pH	CEC (cmol/kg)	Total nutrients (%)			Exchangeable nutrients (cmol(p+)/kg)			
				N	P	K	Ca	Mg	K	Na
Profile 1 Upland paddy field, Manarcad										
0-42	1.3	4.5	22.5	0.20	0.09	0.18	0.60	0.39	0.15	0.65
42-58	1.0	4.6	24.4	0.15	0.09	0.23	0.78	0.33	0.08	0.38
58-100	1.0	4.7	25.7	0.15	0.09	0.20	0.67	0.53	0.26	0.43
Profile 2 Upland paddy field, Mannanam										
0-8	0.6	4.4	12.5	0.07	0.03	0.07	0.25	0.14	0.02	0.76
8-26	0.5	4.4	10.5	0.06	0.02	0.06	0.18	0.08	0.01	0.38
26-56	1.0	4.5	12.4	0.13	0.08	0.09	0.15	0.12	0.01	0.22
56-75	0.6	4.6	11.6	0.06	0.03	0.05	0.12	0.09	0.01	0.10
Profile 3 Lowlands , Kidangara										
0-11	1.6	4.0	18.1	0.20	0.10	0.19	0.58	0.35	0.48	0.86
11-31	1.4	3.9	18.3	0.13	0.09	0.23	0.37	0.24	0.22	0.97
31-57	1.2	3.9	20.5	0.13	0.05	0.13	0.34	0.19	0.15	0.70
57-78	1.5	4.7	21.3	0.17	0.06	0.19	0.32	0.19	0.12	0.41
78-100	1.7	4.7	17.5	0.18	0.06	0.20	0.30	0.20	0.12	0.26
Profile 4 Lowlands, Veliyanad										
0-17	0.8	4.7	3.8	0.08	0.08	0.05	0.90	0.33	0.04	0.11
17-37	0.6	4.8	4.2	0.08	0.08	0.04	0.88	0.23	0.01	0.12
37-50	0.4	4.7	4.1	0.08	0.07	0.04	0.69	0.21	0.01	0.09
50-70	0.4	5.0	4.0	0.07	0.07	0.05	0.51	0.15	0.01	0.02
Profile 5 Coastal sand, Chertala										
0-12	0.4	4.9	2.5	0.05	0.02	0.03	0.29	0.30	0.03	0.16
12-50	0.3	4.8	1.3	0.03	0.02	0.03	0.28	0.20	0.02	0.22
50-92	0.3	4.4	0.9	0.02	0.02	0.02	0.11	0.12	0.01	0.16
92-116	0.2	4.6	0.4	0.02	0.02	0.02	0.01	0.02	0.01	0.27
Profile 6 Coastal sand, Vaikom										
0-20	0.5	5.1	3.0	0.06	0.05	0.05	0.34	0.22	0.37	0.11
20-53	0.2	5.1	2.5	0.04	0.04	0.05	0.27	0.13	0.04	0.10
53-73	0.3	5.1	1.2	0.03	0.05	0.03	0.11	0.05	0.02	0.16
73-92	0.2	5.4	1.4	0.03	0.04	0.04	0.20	0.18	0.01	0.54
92-114	0.2	5.1	1.7	0.02	0.05	0.08	0.07	0.06	0.01	0.22
114-160	0.1	5.2	0.8	0.02	0.04	0.10	0.03	0.10	0.01	0.05
Profile 7 Midhill slope land, RRII, Kottayam										
0-13	1.5	4.3	4.1	0.21	0.04	0.22	0.12	0.01	0.34	0.51
13-27	1.4	4.5	4.9	0.18	0.03	0.22	0.01	0.06	0.04	0.01
27-60	1.0	4.3	3.9	0.14	0.03	0.22	0.01	0.05	0.02	0.01
60-87	0.6	4.3	5.4	0.12	0.02	0.22	0.01	0.03	0.01	0.01
87-120	0.6	4.5	4.8	0.11	0.03	0.38	0.01	0.04	0.01	0.01

Bulk and particle densities varied among landforms as well as within them. Moisture content at field capacity, permanent wilting point and available water content showed wider variations among profiles within the same as well as between landforms.

Data on soil chemical characteristics including total nutrients and exchangeable elements is given in Table 2. Organic carbon and CEC were low for sandy soils. Wide variations were observed among profiles for total N, P, K and exchangeable bases.

Interrelationships among soil properties

Statistical analysis showed significant correlation between sand content and other properties, such as clay content (-0.942**), bulk density (0.706**), particle density (0.867**), moisture content at field capacity (-0.939**) and moisture content at permanent wilting point (-0.948**) (Table 3). Silt content showed a positive correlation with clay and a negative correlation with BD and PD. The role of silt in moisture retention was expressed with a positive significant relationship with FC and PWP. Clay content showed a negative relation with BD and PD. Higher content of organic matter reduced the particle density as shown by the negative correlation. In addition to silt and clay, increasing organic matter improved the moisture retention in soils as indicated by the positive significant correlation between OC and FC and PWP.

H. brasiliensis can grow in a wide range of soils but deep, well-drained soils of pH below 6.5 are well suited for its performance as a viable plantation crop (Pushpadas and Karthikakuttyamma, 1980). A minimum soil depth of 100 cm, gentle slope and loamy texture are reported to be best suited for rubber cultivation (Krishnakumar and Potty, 1992). Nevertheless, rubber grows in soils, which do not exactly possess these qualities. It was reported that *Hevea* could withstand soil physical conditions ranging from stiff clayey with impeded drainage to well drained sandy loam (Krishnakumar and Potty, 1992). *Hevea* is reported to thrive well in soils in which the clay content ranges from 14.8 to 71.7 per cent (Soong and Lau, 1977). In the present study, it was observed that rubber is grown in soils with more than 92 per cent sand content. The content of organic carbon in these soils was invariably less though rubber adds leaf litter to the soils. The retention of organic carbon is dependent on soil texture as is evident in the negative correlation observed with sand content.

The influence of landforms on leaf

Table 3. **Correlation among soil properties**

	Sand	Silt	Clay	BD	PD	FC	PWP
Silt	-0.769 **						
Clay	-0.942 **	0.514 **					
BD	0.706 **	-0.694 **	-0.592 **				
PD	0.867 **	-0.844 **	-0.716 **	0.694 **			
FC	-0.939 **	0.67 **	0.912 **	-0.704 **	-0.876 **		
PWP	-0.948 **	0.606 **	0.957 **	-0.613 **	-0.821 **	0.975 **	
OC	-0.736 **	0.658 **	0.637 **	-0.602 **	-0.771 **	0.811 **	0.749 **

Table 4. **Leaf nutrient composition of rubber**

Landform	Location	Leaf nutrient content (%)		
		N	P	K
Upland paddy field	Manarcad	3.60	0.30	1.18
	Mannanam	3.43	0.32	1.29
Low lands	Kidangara	3.83	0.38	1.40
	Veliyanad	3.35	0.32	1.32
Coastal sand	Cherthala	3.26	0.32	0.98
	Vaikom	3.67	0.31	1.28
Mid-hill slope land	RRII	3.48	0.30	1.24

nutrient composition is shown in Table 4. Since the information on mean values of individual nutrient elements did not lead to any conclusive inference, the data collected from different plantations in all the landforms were analysed using MANOVA (Tabachnick and Fidell, 2001). It was observed that the landforms varied significantly from each other (Wilk's Lambda = 0.041) in leaf nutrient composition when all the three nutrients are considered simultaneously. Among the nutrient elements, P and K contributed significantly (0.041 and 0.011 significance levels respectively) to the test of 'Between-Subjects Effects' while N did not contribute much. Multivariate analysis indicated statistically that leaf nutrient composition varied with landforms and that the contributions of the variations was not pronounced.

Gestation period

The gestation period of rubber plantations in different landforms is shown in Table 5. The shortest gestation period was observed in lowland (5 years) followed by upland paddy fields (6.5 years). Gestation period was longest in coastal sand (8 years). High water storage capacity being fully charged with moisture throughout the year coupled with high value of CEC (Table 2) might have facilitated enhanced growth and early attainment of tappable girth in lowlands. Though soils of Vaikom were sandy textured and low in fertility status (Tables 1 & 2), growth of rubber was comparable to that in traditional area, which reiterates the role of moisture availability.

Table 5. **Gestation period (Years)**

Land form	Location	Gestation period (Years)
Upland paddy field	Manarcad	6.5
	Mannanam	6.5
Low lands	Kidangara	5.0
	Veliyanad	5.0
Coastal sand	Chertala	8.0
	Vaikokm	7.0
Mid-hill slope land	RRII	7.0

Yield of rubber

The highest mean yield of rubber was observed in lowland at Kidangara and lowest was in coastal sandy field of Vaikom (Table 6). In general, there was a declining trend in yield from November to April. However, yield depression was less pronounced in lowlands and upland paddy field during this period. This seems to indicate the influence of moisture availability on rubber yield as in case of growth during immaturity period. In upland paddy fields rubber is usually planted in raised bunds and rain water is allowed to retain in the furrows for most part of the year. Therefore, the contact of plant roots with water may have helped in maintaining a higher plant water status leading to a higher latex yield.

Variability in yield among landforms was assessed by one way ANOVA (Table 7).

Table 6. **Yield (g/t/t) of clone RRII 105**

Year	Month	Upland paddy field (Mannanam)	Low lands (Kidangara)	Coastal sand (Vaikom)	Mid-hill slope land RRII
2000	September	57.50	64.02	49.86	68.69
	October	58.45	68.37	48.57	68.54
	November	61.58	69.13	54.23	72.05
	December	55.23	65.51	49.65	63.01
2001	January	52.81	58.86	40.30	36.28
	February	47.90	52.30	37.21	35.75
	March	42.03	47.86	31.17	24.15
	April	37.51	43.57	23.69	21.29
	May	43.40	46.80	23.97	31.48
	Mean	50.71	57.38	39.85	46.80

There was a significant difference between group variability, which indicates the difference in production potential of landforms studied. ANOVA of repeated measures also indicated similar trend between subject effects and it shows that there were differences among times of measurement of yield, due to seasonal variations in yield (Wilk's Lambda = 0.009; P ≤ 1%). The interaction influence of yield and landform was also significant from time to time (Wilk's Lambda = 0.002; P ≤ 1%).

Comparisons of group means were made by using Tukey's HSD among the landforms from time to time. The overall comparisons show that upland paddy field and low lying areas were similar in yield. Similarity in coastal sand and mid hill slope land was also conspicuous indicating low moisture retention capacity could be the limiting factor. The variations in yield among different landforms at different times were thus due to the factors that influence the moisture availability.

Variance observed are a measure of contribution of landforms and plantations to the yield (Table 7). There was a general decrease in the contribution from landforms from September to December followed by an increase. The increasing trend in the variance due to landforms during summer months, clearly indicated that the capacity to retain moisture may have influenced the rubber latex yield.

Table 7. **Variability of yield in landforms**

Year	Month	Between group variability-significance	Tukey's Honestly Significant Difference	Variance due to landform(%)
2000	September	0.000	1&4, 2&3 and 3&4	74
	October	0.000	1&2, 1&3, 2&3 and 3&4	80
	November	0.010	2&3 and 3&4	53
	December	0.032	2&3	39
2001	January	0.002	1&3, 2&3 and 2&4	65
	February	0.001	1&3, 2&3 and 2&4	67
	March	0.000	1&3, 1&4, 2&3 and 2&4	80
	April	0.000	1&3, 1&4, 2&3 and 2&4	83
	May	0.000	1&3, 1&4, 2&3 and 2&4	90

1: Upland paddy fields; 2: Low lands; 3: Coastal sand; 4: Mid hill slope land

CONCLUSION

The study of rubber plantations in different non-conventional areas showed that rubber is grown in some of these non-conventional areas successfully. Soil and leaf analytical data indicated that soil properties varied significantly among these areas and that it influenced the leaf nutrient composition. In upland paddy fields and low lying areas, good growth and yield of rubber was observed. With appropriate agro-management practices, rubber grows well in sandy tracts also, though conventionally, sandy soils are rated as unsuitable. The study reveals that with appropriate agromanagement, rubber plantation can be developed in a variety of soil conditions.

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