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INFLUENCE OF PLANTATION CROPS ON SOIL PROPERTIES IN TRIPURA

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Impact of different plantation crops on soil properties in Tripura was studied in comparison with barren land. Multivariate analysis of variance indicated that there were significant differences among tree crop plantations. The analysis of variance of repeated measures showed that Ca, Mg, K. P, OC and pH varied significantly in different years while P and K did not show significant difference among plantation systems. The highest quantum of leaf litter was added by sal followed by teak, rubber, acacia and cashew. The nutrient contents in the litter did not follow any general trend. The variability in the soil properties was due to different types of plantations while the location did not contribute much. The leaf litter addition and consequent Mg content of soil was influenced by the location. Cluster analysis showed that rubber and sal formed the initial cluster with lowest distance between them while teak alone formed the second cluster. Acacia and barren land formed another cluster, which was distant from all the others. The present study indicated that rubber plantations in Tripura are comparable to forest tree plantations particularly sal and teak for the parameters observed.

Key words: Eco-system, *Hevea brasiliensis*, Rubber growing soil, Soil property, Tripura.

INTRODUCTION

The comparison of plantations with natural forest ecosystem has attracted several scientific investigations (Evans, 1982). Besides ensuring a stable ecosystem the plantations also aim at an economic return to the planter (Bruning *et al.*, 1978; Akrcoll, 1979). The different types of canopy covers are known to influence the water movement in the soil and consequently the nutrient content (Megahan *et al.*, 1962; Nazaror, 1969). The litter added by different crops also cause differences in soil organic matter and nutrient content (Jha *et al.*, 2000). The tillage and other crop management practices along with other biotic and abiotic factors influence the soil properties (Holland, 1969; Norris, 1970).

The replacement of natural forest with crop plants usually reduces the biomass and nutrient potential of the ecosystem. However, in Tripura the tropical rain forests are largely denuded due to shifting cultivation and rubber (*Hevea brasiliensis*) cultivation on such land would lead to eco-restoration and improvement in soil physical properties (Krishnakumar *et al.*, 1990). Rubber plantations are considered as a self-sustaining eco-system, closely resembling natural forest (Samarappuli and Yogarathnam, 1995; 1997). Karthikakutyamma (1997) observed that there is no significant difference between the soil physical properties of rubber plantations and adjacent forests.

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The soil properties and biomass cycling in rubber plantations in Tripura was compared to that of teak (*Tectona grandis*) plantation and natural forest and no significant differences were observed (Krishnakumar *et al.*, 1991). In another study, jarul (*Legerstromia reginae*), teak and natural forest were compared with rubber in its effect on physical, chemical and biological properties of soil to observe that rubber plantations are similar to the others in these properties (Jacob *et al.*, 2000). However, these studies involved a maximum of three different eco-systems and were based on single observation and could not bring out the correlation between the various ecological parameters by simultaneously assessing their effects. In the present study, multivariate analysis is employed to study the joint relationship of the variables to arrive at stronger conclusion, which are not possible through univariate analysis (James and McCulloh, 1990). A set of temporal observations were analysed to compare the impact of different plantation tree crop systems that are normally seen in Tripura, on soil properties.

MATERIALS AND METHODS

A study was conducted in five different plantations planted with sal, acacia, teak, cashew and rubber and was compared with barren land. The study area covers parts of West Tripura and lies between 23° 53'N latitude and 91° 15' E longitude. The area has warm humid sub-tropical climate and total annual precipitation is 2024 mm, of which 83 per cent is received from June to August. The mean annual maximum and minimum temperatures are 30.3°C and 17.7°C respectively. Twelve trees from each plantation were randomly selected for measuring girth at breast height.

Three composite soil samples were collected from each plantation from the depths 0-15, 15-30 and 30-60 cm during August, for three years. The soil samples were air dried and sieved through 2 mm sieve and stored for analysis. Undisturbed core samples were collected for determination of field bulk density. The mechanical analysis was done by international pipette method (Piper, 1950). The moisture retention at field capacity was determined by pressure plate method (Richards, 1949).

Organic carbon, pH and available P, K, Ca and Mg were determined by the standard methods after Jackson (1958). Available DTPA, extractable micronutrient cations *viz.*, Zn, Cu, Mn and Fe were estimated using Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978).

Fallen leaf litter was collected during April every year from 1 m^2 quadrants in four spots that were randomly selected from each plantation for studying nutrient addition through biomass. The litter collected was washed with water to remove the soil particles and dried at 60°C in an oven to constant weight for assessing the biomass input. The samples were powdered and analysed for N, P, K, Ca and Mg (Jackson, 1958).

The data on the soils collected from the plantations during the second year was subjected to MANOVA (using SPSS version 10.0) in order to understand the role of selected characteristics in explaining the variance. The first and second year data did not contain all parameters. Three years' data were subjected to ANOVA of repeated measures to know the significance of the differences in the characteristics from time to time.

Regression analysis was done to relate the field capacity of the soils to clay and silt contents, organic carbon and bulk density. Variance components were calculated to split the variance due to plantation systems and due to locations.

RESULTS AND DISCUSSION

The details of the plantations selected for the present study are given in Table 1. Among the plantations studied, sal was the oldest (40 years), followed by rubber (17 years) and acacia, cashew and teak (12 years). The density varied between 225 to 500 trees per ha, the lowest being for cashew and highest for acacia and teak. The average girth was highest for sal (110 cm) and the lowest 85 cm for acacia and teak. Except cashew (9 m), all the plantation trees had a height of 25-35 m.

The physical properties of the soils are given in Table 2. The soil pH varied from 4.5 to 4.9. Organic carbon content was lowest for sal plantation (0.53%) and highest for teak (1.02%). The contents of sand ranged from 38.13 to 67.13 per cent, silt from 12.38 to 30.63 per cent and clay from 20.49 to 38.12 per cent. Bulk density ranged from 1.47 for rubber to 1.79 for sal plantations. The order of weighted mean field capacity was acacia > rubber > teak > barren land > cashew > sal. As the field capacity is the resultant of several soil factors, a regression of field capacity on organic carbon, silt, clay and bulk density was made as shown in Table 3. As observed by Krishnakumar *et al.* (1990), the field capacity was significantly influenced by the organic carbon and clay contents. This is evident from the following regression equation.

$$FC = 0.815\ OC^{**} - 0.04\ silt + 0.759\ clay^{**} - 0.113\ BD$$

The statistical parameters of soil chemical properties measured in different plantation systems are given in Table 4. It was seen that the mean pH ranged from 4.40 to 4.91 in various plantations. Organic carbon content ranged from 0.57 to 0.87 per

Table 1. **Details of plantations**

Sl.No.	Species	Average girth (cm)	Age (years)	Density (trees/ha)
1	Sal (*Shorea robusta*)	110	40	300
2	Acacia (*Acacia auriculiformis*)	85	12	500
3	Cashew (*Anacardium occidentale*)	90	12	225
4	Teak (*Tectona grandis*)	85	12	500
5	Rubber (*Hevea brasiliensis*)	88	17	400

Table 2. **Physical properties of the soil**

System	pH	Organic Carbon (%)	Sand (%)	Silt (%)	Clay (%)	Field capacity (%)	Bulk density(g/cc)
Acacia	4.5	1.01	38.13	23.75	38.12	22.41	1.70
Barren	4.7	0.62	40.63	30.63	28.74	14.48	1.55
Cashew	4.8	0.64	48.75	22.50	28.75	13.20	1.74
Rubber	4.5	0.76	43.63	23.75	32.62	17.66	1.47
Sal	4.7	0.53	43.75	23.75	32.50	13.00	1.79
Teak	4.9	1.02	67.13	12.38	20.49	16.76	1.57

Table 3. **Regression of field capacity on BD, OC, silt and clay**

	SS	df	MS	F	Significance
Regression	13.712	4	3.428	13.552	0
Residual	3.288	13	0.253		
Total	17.000	17			

	Unstandard coefficient		Standard coefficient (β)	t	Significance
	B	Standard error			
Constant	5.90E-16	0.119		0	1
OC	0.815	0.139	0.815	5.867	0
Silt	-4.83E-02	0.138	-0.048	-0.350	0.732
Clay	0.759	0.137	0.759	5.558	0
BD	-0.113	0.125	-0.113	-0.904	0.382

$R^2 = 0.807$

Table 4. **Soil properties of different plantation systems**

Crop	Statistic	pH	OC	Ca	Mg	K	P
Acacia	Mean	4.50	0.85	7.10	4.14	3.67	0.17
	Standard error	0.02	0.04	1.30	0.49	0.29	0.02
	Standard deviation	0.08	0.13	4.51	1.69	0.99	0.06
	Minimum	4.37	0.66	3.40	2.65	2.80	0.10
	Maximum	4.61	1.04	15.40	6.80	5.80	0.32
Barren land	Mean	4.63	0.70	12.39	4.30	4.40	0.20
	Standard error	0.02	0.02	2.66	0.63	0.33	0.01
	Standard deviation	0.05	0.07	7.52	1.78	0.94	0.04
	Minimum	4.56	0.65	3.55	2.15	3.10	0.16
	Maximum	4.68	0.85	20.2	6.05	5.40	0.29
Cashew	Mean	4.79	0.72	2.17	0.93	4.14	0.16
	Standard error	0.02	0.03	0.14	0.06	0.18	0.01
	Standard deviation	0.06	0.09	0.47	0.20	0.61	0.02
	Minimum	4.72	0.60	1.70	0.65	3.10	0.12
	Maximum	4.86	0.87	3.00	1.50	5.60	0.20
Sal	Mean	4.66	0.57	2.49	1.19	5.75	0.23
	Standard error	0.04	0.04	0.24	0.06	0.12	0.02
	Standard deviation	0.14	0.15	0.84	0.21	0.42	0.06
	Minimum	4.46	0.41	1.30	0.85	5.00	0.17
	Maximum	4.88	0.82	4.15	1.65	6.30	0.40
Rubber	Mean	4.40	0.87	6.18	1.34	4.10	0.29
	Standard error	0.16	0.06	0.98	0.12	1.17	0.08
	Standard deviation	0.49	0.18	2.93	0.36	3.51	0.24
	Minimum	3.7	0.66	3.05	0.85	1.90	0.11
	Maximum	5.08	1.26	10.95	2.05	10.80	0.87
Teak	Mean	4.91	0.81	26.6	5.77	2.43	0.42
	Standard error	0.06	0.02	2.18	0.35	0.21	0.16
	Standard deviation	0.13	0.04	4.37	0.69	0.41	0.32
	Minimum	4.72	0.76	21.3	5.00	1.90	0.11
	Maximum	5.00	0.85	31.9	6.68	2.90	0.74

cent, available Ca content from 2.17 mg to 26.6 mg per 100 g and Mg content from 0.93 mg to 5.77 mg per 100 g. Available potassium content was low for teak plantation (2.43 mg/100 g) while it was high for sal (5.75 mg/100 g). Available phosphorus tested was high for teak plantation (0.42 mg/ 100 g) and low for cashew plantation (0.16 mg/100 g).

The multivariate analysis of variance of data (Table 5) pertaining to soil samples collected from the depth of 0-15 cm during the second year indicated that there were significant differences among tree crop plantations as indicated by Wilk's lambda ($P \leq 1\%$). MANOVA was performed using soil chemical properties with the assumption that these might be unique to different plantation systems as a result of the different cultural practices adopted. All the variables except Zn significantly described the variance in the data collected from different plantation systems.

The ANOVA of repeated measures was performed on each element measured in all the surface soils under different tree crop systems to check for significant differences among the three years. It was seen that there were significant differences in Ca, Mg, K, P, organic carbon and pH from time

Table 5. **MANOVA of data pertaining to soil samples (0-15 cm) depth collected during the second year**

Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Intercept	Wilk's Lambda	0	2229.350	10	10.000	0
System	Wilk's Lambda	0	5.641	50	48.971	0

Tests of between-subjects effects

Source	Dep. Var.	Type III SS	df	Mean square	F	Significance
Corrected model	C	2019.850	5	403.969	18.845	0
	Mg	49.768	5	9.954	16.024	0
	K	23.722	5	4.744	3.904	0.013
	P	0.496	5	9.91E-02	3.742	0.016
	OC	0.981	5	0.196	6.063	0.002
	pH	1.585	5	0.317	14.048	0
	Cu	4.015	5	0.803	6.009	0.002
	Fe	9174.920	5	1834.990	5.035	0.004
	Mn	6319.420	5	1263.880	30.778	0
	Zn	0.636	5	0.127	1.891	0.143
Intercept	C	4842.180	1	4842.180	225.891	0
	Mg	183.680	1	183.680	295.710	0
	K	261.191	1	261.191	214.910	0
	P	6.215	1	6.215	234.633	0
	OC	21.805	1	21.805	673.995	0
	pH	546.515	1	546.515	24219.900	0
	Cu	48.662	1	48.662	364.105	0.002
	Fe	290129	1	290129	796.031	0
	Mn	27066	1	27066	659.116	0
	Zn	13.515	1	13.515	200.854	0

Adjusted R^2 for A = 0.788; B = 0.758; C = 0.377; D = 0.364; E = 0.513; F = 0.731; G = 0.511; H = 0.457; I = 0.861; J = 0.157.

Table 6. **ANOVA of repeated measures**

Calcium
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Calcium	Wilk's Lambda	0.495	5.619	2	11	0.021
Calcium* Systems	Wilk's Lambda	0.059	6.877	10	22	0.000

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	10613.701	1	10613.701	295.673	0.000
Systems	7306.134	5	1461.227	40.719	0.000
Error	430.630	12	35.886		

Magnesium
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Magnesium	Wilk's Lambda	0.087	57.506	2	11	0.000
Magnesium* Systems	Wilk's Lambda	0.024	11.946	10	22	0.000

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	481.570	1	481.570	999.131	0.000
Systems	182.642	5	36.528	75.787	0.000
Error	5.784	12	0.482		

Potassium
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Potassium	Wilk's Lambda	0.512	5.25	2	11	0.025
Potassium* Systems	Wilk's Lambda	0.353	1.505	10	22	0.203

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	868.005	1	868.005	121.418	0.000
Systems	43.292	5	8.658	1.211	0.361
Error	85.787	12	7.149		

Phosphorus
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Phosphorus	Wilk's Lambda	0.181	24.954	2	11	0.000
Phosphorus* Systems	Wilk's Lambda	0.122	4.102	10	22	0.012

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	7.989	1	7.989	149.085	0.000
Systems	0.630	5	0.126	2.352	0.104
Error	0.643	12	5.36E-02		

Organic carbon
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
Org. carbon	Wilk's Lambda	0.826	1.156	2	11	0.350
Org. carbon* Systems	Wilk's Lambda	0.228	2.407	10	22	0.041

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	56.713	1	56.713	1831.977	0.000
Systems	0.593	5	0.119	3.828	0.026
Error	0.371	12	0.031		

pH
Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Significance
pH	Wilk's Lambda	0.54	4.686	2	11	0.034
pH* Systems	Wilk's Lambda	0.051	7.504	10	22	0.012

Tests of between subjects effects

Source	Type III SS	df	Mean square	F	Significance
Intercept	1211.450	1	1211.450	48465.175	0.000
Systems	1.641	5	0.328	13.128	0.000
Error	0.300	12	2.50E-02		

to time (Table 6). However, P and K did not show significant differences among plantation systems as indicated by between-subjects effects. Seasonal differences in elemental contents in rubber plantations was reported by Rao (2000) in which the properties measured included OC, pH, Ca, Mg, K, Na, Mn, Al, Fe and Zn in different young rubber plantations.

The differences among various plantations, temporal variations and depth-wise changes in nutrients and pH of soils are shown in Figs. 1 - 5. Soils under teak plantations had higher calcium contents in all the three depths (Fig. 1) and there was a gradual decrease with depth. In general, the order of Ca content in all the depths was teak > barren land > rubber > acacia > cashew > sal during the different years. Teak maintained its lead in Mg content during all the three times of measurement. However, the order of content of magnesium among the plantations did not follow any regular trend. Depth-wise decrease in Mg content was observed.

In the case of potassium, during the first year, topsoil under rubber recorded higher content followed by sal, barren land,

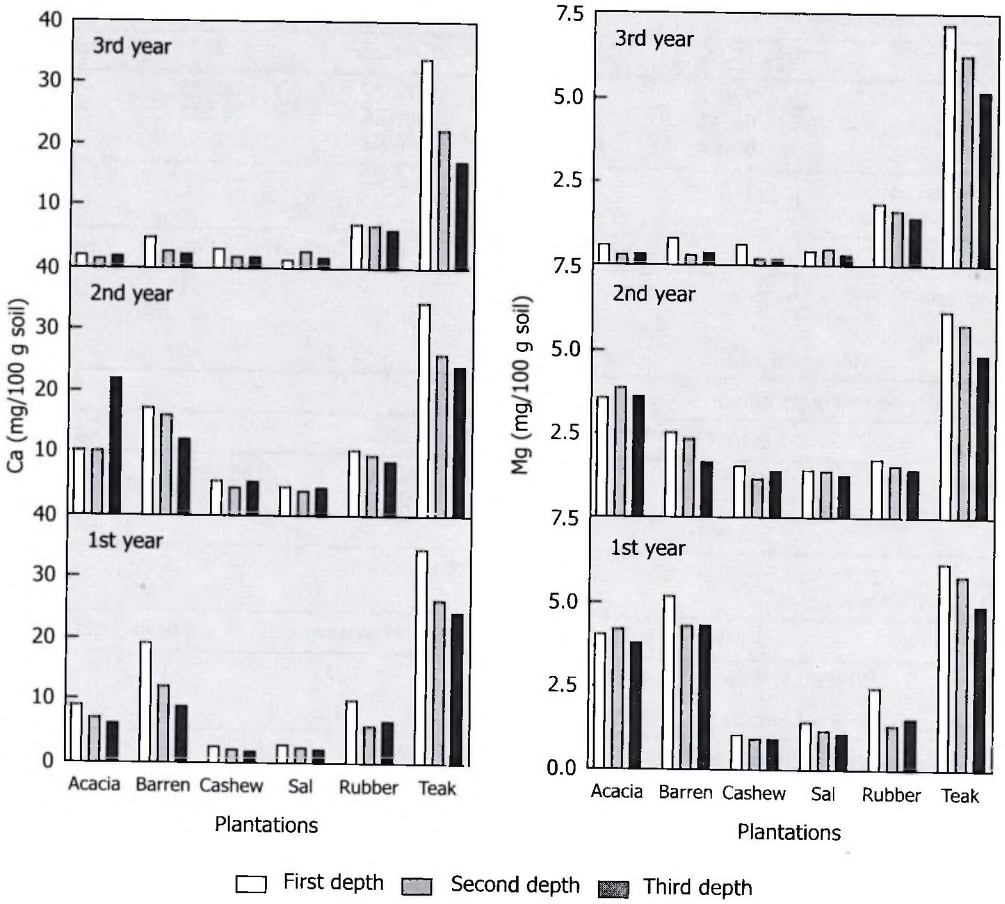

Fig. 1. Temporal changes in Ca and Mg contents at different soil depths

acacia, cashew and teak (Fig. 2). During second and third year, soil under sal had higher K content and barren soil recorded the least. In general, K content decreased depth-wise in all the plantations. There was no definite trend for P content among the different plantations during the different years (Fig. 2). However, the depth-wise variation followed a decreasing order from surface downwards. The availability of soil P is essentially influenced by soil moisture content since its mobility is by diffusion. Rao (2000) observed that soil moisture deficit periods were characterised by reduced availability of P in rubber plantations. Gutierrez-Boem and Thomas (1999) made similar observations for soybean.

The variations in soil pH as well as OC are presented in Fig. 3. It was seen in MANOVA and ANOVA of repeated measures that there were significant variations in pH among plantations as well as in different years. Organic carbon varied depth-wise and among plantations. The distribution of micronutrients of Fe and Zn (Fig. 4) and Cu and Mn (Fig. 5) also showed the

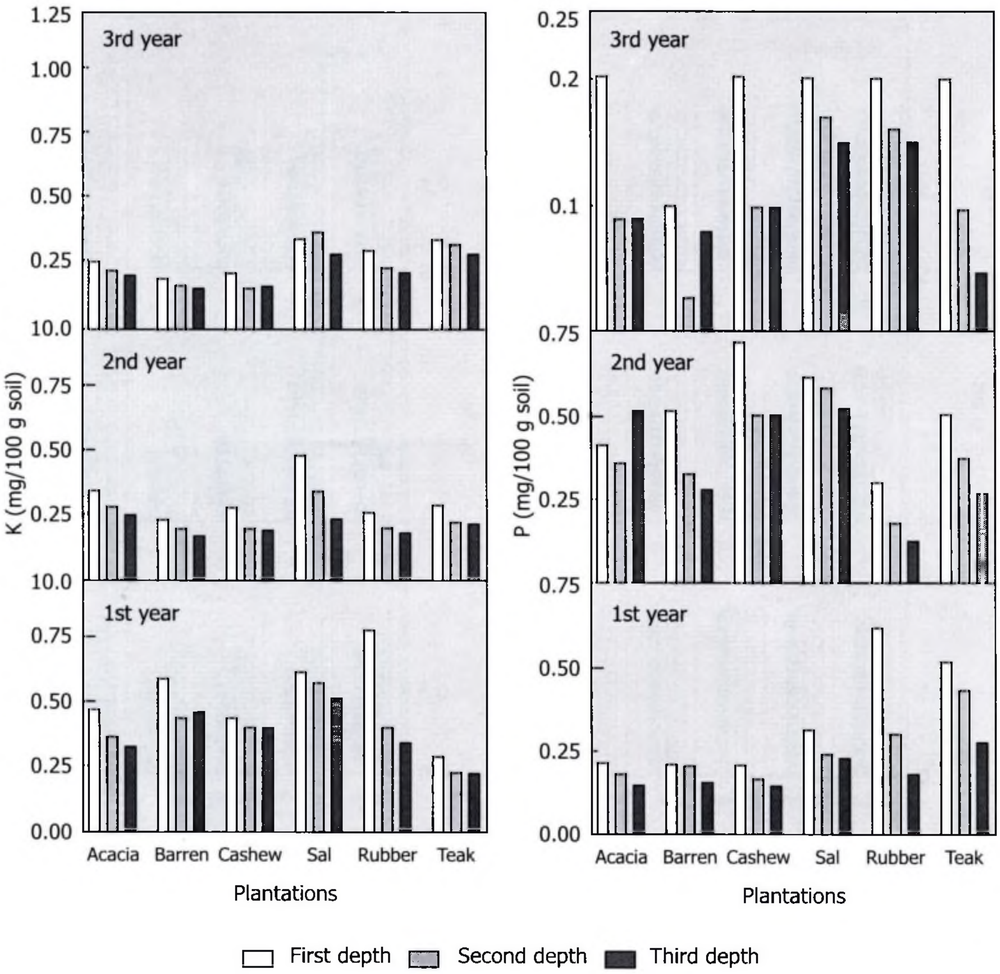

Fig. 2. Temporal changes in K and P contents at different soil depths

differences among plantation systems. In general, the surface soils had higher content compared to lower depths. Among all the micronutrients measured, the content of DTPA-Mn was less in soils under rubber plantations.

Litter studies

The analysis of leaf litter collected from different plantations contained nutrient elements in varying quantities as shown in Table 7. The leaf litter added to the soil was measured in all these plantation systems. The litter content was in the order of sal > teak > rubber > acacia > cashew. The quantity of different elements added to the soil through leaf litter was calculated. Nitrogen content was found to vary from 19.9 (cashew) to 90.46 kg per ha (teak). P content varied from 0.62 kg per ha for cashew to 26.82 kg per ha for rubber. The Ca content was minimum for cashew with 23.32 kg per ha and maximum for teak with 129.95 kg per ha. Mg content was 3.69 kg

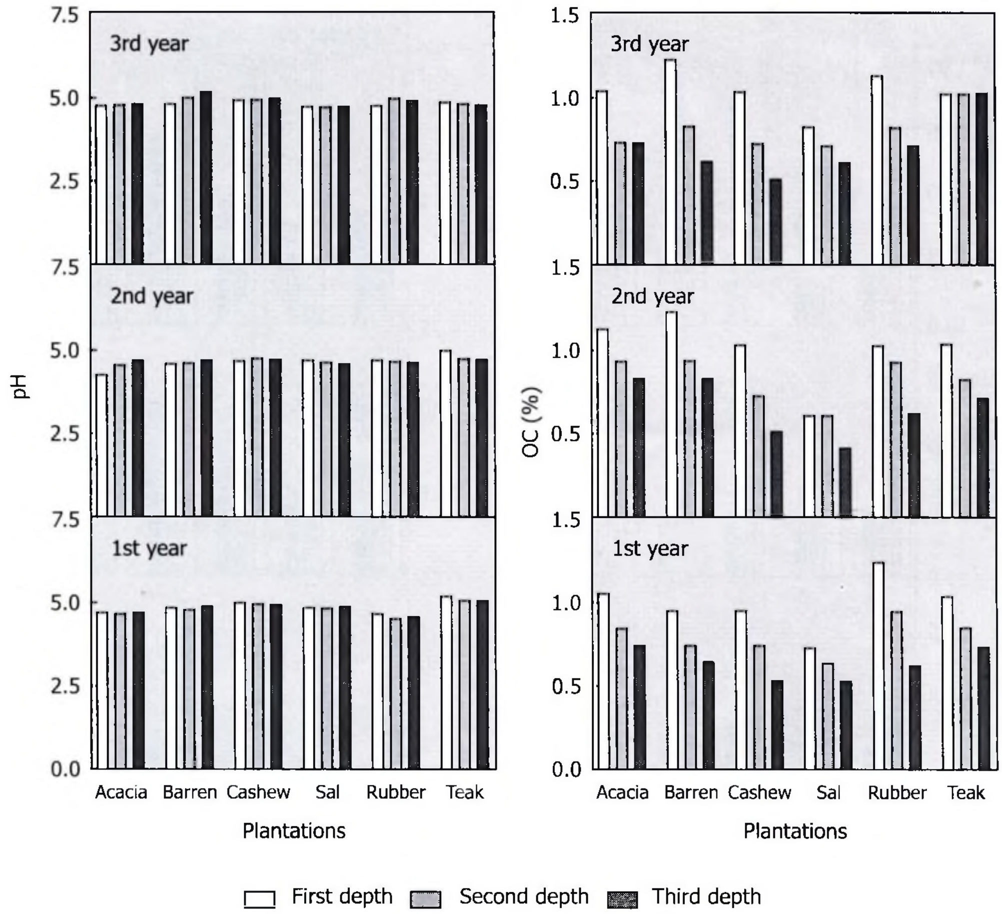

Fig. 3. Temporal changes in pH and OC contents at different soil depths

Table 7. **Leaf litter and nutrient addition to the soil**

Plantation	Litter tonnes/ha	N	P	K	Ca	Mg
		kg/ha/yr				
Acacia	4.44	51.94	0.93	12.52	105.67	7.37
Cashew	3.45	19.90	0.62	9.28	23.32	3.69
Sal	7.89	81.26	3.55	23.19	82.05	17.83
Teak	7.18	90.46	6.10	25.05	129.95	14.71
Rubber	6.85	84.52	5.83	26.82	95.20	19.72
CD (5%)	0.39	5.31	0.88	2.31	10.36	4.34

per ha for cashew and 19.72 kg per ha for rubber plantations.

Based on the critical difference value it was found that there was significant difference between the plantations for leaf litter addition. Nitrogen content in sal and rubber leaf litter was comparable whereas that of other plantation systems differed sig-

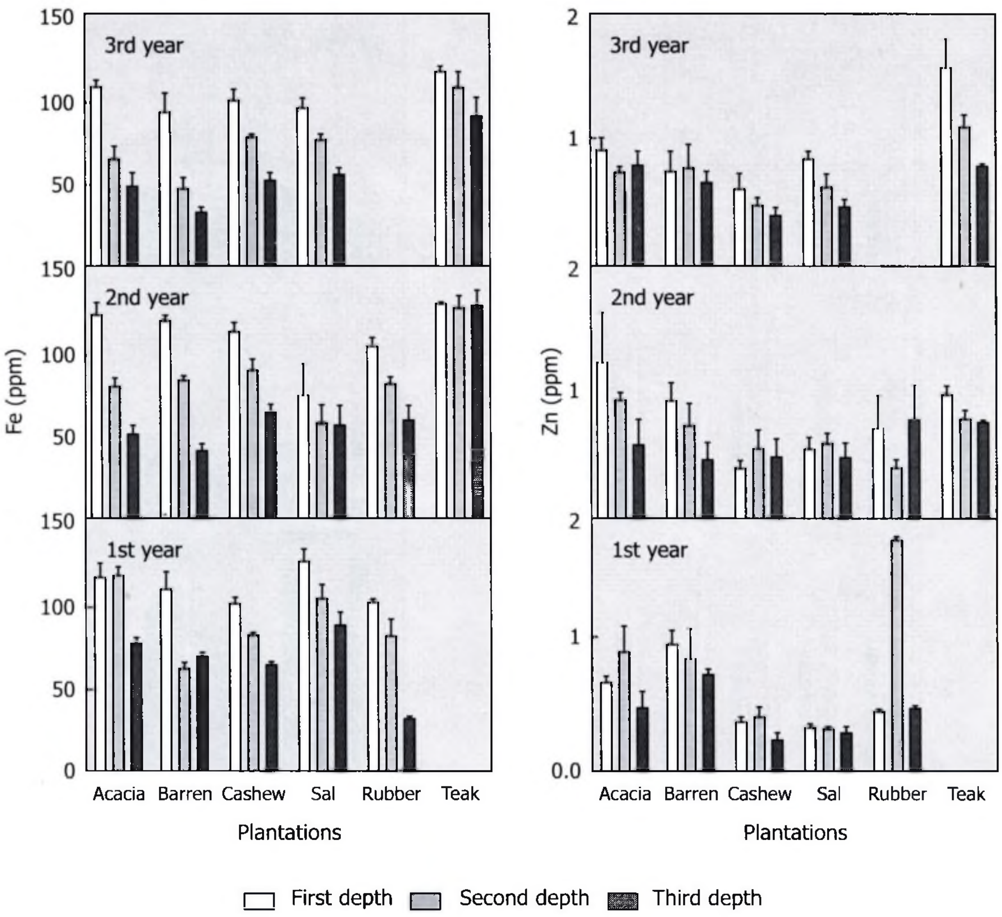

Fig. 4. Temporal changes in Fe and Zn contents at different soil depths

nificantly. In the case of P, it was found that acacia and cashew added similar quantities to the soil while teak and rubber added significantly higher quantity. Sal, teak and rubber added high quantities of K through litter. However, significant difference was observed between sal and rubber. Highly significant difference between different tree plantation systems was also noted for Ca addition through leaf litter. Rubber, sal and teak added significantly higher quantity of Mg through litter than the other two tree plantations.

The components of variation were split to those due to plantation and location and presented in Table 8. N, P, K and Ca added through litter exhibited highest percentage of variance due to plantations. It was obvious that the variability seen in the data on nutrient addition was due to the different types of plantations while the sites (used as replications) did not contribute much except for leaf litter and Mg added through it.

The Euclidean distance between different plantations was calculated using

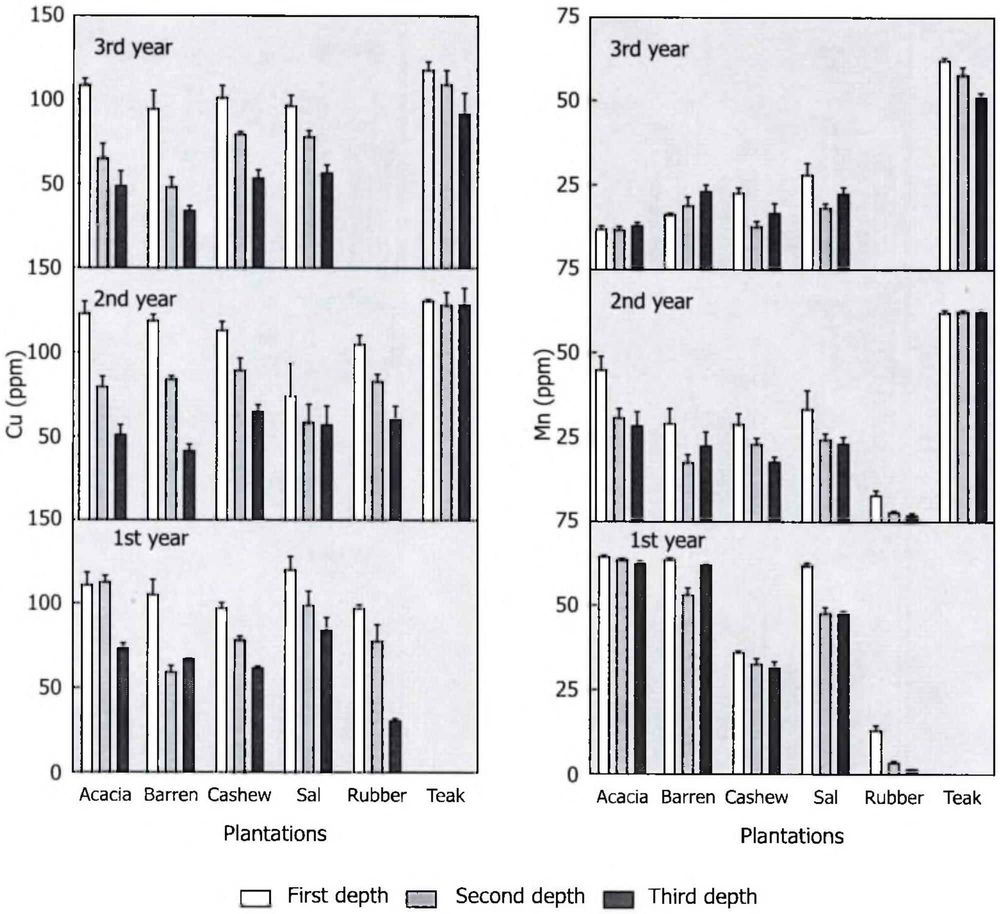

Fig. 5. Temporal changes in Cu and Mn contents at different soil depths

UPGMA of the data on soil properties *viz.*, pH, organic carbon, P, Ca, Mg, K, Cu, Mn, Fe, Zn, BD, silt, clay, FC and litter added to soil (Fig. 6). It could be seen that rubber and sal plantations formed an initial cluster with least distance between them. Cashew formed a separate cluster. Next cluster was

Table 8. **Variance components**

Characteristic	Variance %	
	Plantations	Plots
Litter	82	18
Nitrogen	98	2
Phosphorus	94	6
Potassium	94	6
Calcium	96	4
Magnesium	75	25

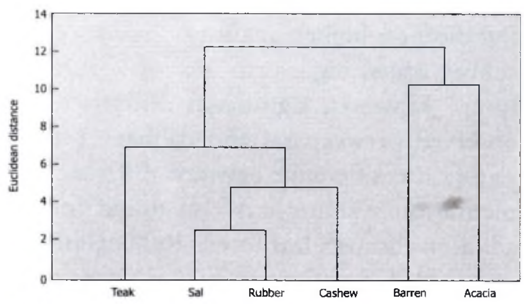

Fig. 6. Clustering pattern of soil properties of different plantation land systems and barren land

that of teak alone. In the entire hierarchy these four plantation systems formed a group. Acacia and barren land formed another cluster, which was distant from the others.

The present investigations revealed the similarity of rubber with the forest species sal in its influence on the soil properties and litter addition in Tripura.

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