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TEMPORAL VARIABILITY IN SOIL NUTRIENT STATUS IN A RUBBER PLANTATION AND AN ADJACENT FOREST

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Tree-based land use systems have more closed nutrient cycling within the system. Quantification of seasonal variation in nutrient flows and stocks is important in development of sustainable land use systems, especially in low-fertility soils of the humid tropics. The present investigation was aimed at analysing the temporal variations in soil nutrient availability in a rubber plantation *vis-a-vis* a nearby forest ecosystem in eastern high range part of Kerala. Soil samples were collected from the rubber plantation and the adjacent forest at bimonthly intervals and analysed for soil nutrient availability. High sand, less clay and silt and low CEC were observed in rubber plantation compared to forest. Soil pH, organic carbon and available K were high in the forest soil compared to rubber soil. However, soil available P status was higher in rubber soil. Temporal variations in soil pH, organic carbon and available K contents were observed both in rubber and forest soils. Significant seasonal variation in P availability was observed only in the surface soil of forest. The variation pattern of soil pH, organic carbon and available K contents differed in rubber and forest soils.

Keywords: Forest, Nutrient availability, Rubber, Seasonal variation, Soil properties.

INTRODUCTION

Agricultural systems with perennial crops especially tree plantations are more sustainable than systems with annual crops. Tree-based land use systems are known to maintain soil organic matter and nutrient cycling through the addition of litter and root residues into the soil. Rubber plantations have a closed nutrient cycling and inorganic fertilizers are applied routinely so that soil fertility decline is less likely to occur. Nonetheless, quantification of seasonal variation in soil nutrient availability is an important step in maintaining soil productivity and development of sustainable land use system, especially in low fertility slope - land soils of Kerala. Seasonal differences in nutrient availability are important for different species which differ in their growth habit and their seasonal nutrient requirements (Gupta and Rorison, 1975). The present investigation was aimed at quantifying the seasonal variations in soil nutrient availability in rubber relative to forest ecosystem in eastern high range part of Kerala.

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MATERIALS AND METHODS

Study site was located in the eastern high range part of Kerala. The rubber plantation selected was at the TR&T Estate at Mundakayam in Idukki district and the adjacent forest for comparison. Rubber plantation and forest were of relatively similar physiography. Rubber plantation was at the age of 20 years and was located at 76^0 55' 0" E and 9^{0}33' 47" N and the forest was located at 76^0 55' 19" E and 9^0 3'4 18" N and both were at 300 m above MSL. The mean temperature of the study area was 26-27 ^{0}C and annual average rainfall was 3000 - 3500 mm. Soils of the rubber plantation were classified as clayey - skeletal *Ustic Kandihumults* with limitation of reserve potassium and coming under the Kanjirapally soil series (NBSS & LUP, 1999). Standard manuring and other soil management practices were followed in the rubber plantation.

Soil samples were collected at bimonthly intervals from August 2003 to June 2004, *i.e.* August, October, December, February, April and June from 12 different points at two depths (0-30 & 30-60 cm) in rubber as well as in forest to study the seasonal variation in soil nutrient availability. The samples were air- dried, sieved through 2 mm mesh and analysed for physico-chemical properties. Gravel content was determined by difference in weight of the gravel and soil after passing through 2 mm sieve. Particle size distribution was estimated by mechanical analysis following International Pipette Method and cation exchange capacity (CEC) was determined by the 1.0 N NH_4OAc buffered to pH 7.0. Soil pH (1: 2.5 soil: water suspension), organic carbon (Walkley-Black Method), available phosphorus (Bray-II) and available potassium (NH_4OAc) were determined as per the method outlined by Jackson (1958).

The data were subjected to statistical analysis using ANOVA by considering different months as treatments and 12 sampling points as replications to compare the variation within the systems and t-test was used to compare the variation between the two systems.

RESULTS AND DISCUSSION

The physical properties of the soil are given in Table 1. In the upper 0-30 cm depth, the gravel content was 47 and 42 per cent respectively, in rubber and forest. In the bottom layer of 30-60 cm depth, 51 per cent gravel in rubber and 63 per cent in forest were recorded. In both the systems, with increasing depth, a corresponding increase in gravel content was noticed. Soil mechanical separates showed 48, 11 and 31 per cent sand, silt and clay in rubber and 33, 12 and 42 per cent sand, silt and clay in forest at 0-30 cm depth. The corresponding values in 30-60 cm layer were 50, 10 and 32 and 31, 11 and 48 per cent respectively. Among the soil mechanical separates, the high sand and less clay content were recorded in rubber

Table 1. **Physical properties of the soils under rubber and forest**

Property	0-30 cm		30-60 cm	
	Rubber	Forest	Rubber	Forest
Gravel (%)	47	42	51	63
Sand (%)	48	33	50	31
Silt (%)	11	12	10	11
Clay (%)	31	42	32	48
Soil texture	Sandy clay	Clay	Sandy clay	Clay
CEC (cmol (p^+)/kg)	7.1	13.8	6.6	9.6

whereas low sand and high clay contents were found in forest at two depths. Koyamu and Nambiar (1978) reported that when rainfall was 3000- 4000 mm the clay content was reduced to low and consequently the proportion of coarser fraction increased and sand content increased to high level. Marginally higher clay content was observed in lower depth in both systems and this may be attributed to the high intensity rainfall causing the disturbance of the surface soil resulting in the reduction of clay and increase in sand content. Because of the high rainfall, the clay particles move towards down the profile through the voids created by plant roots and decomposing organic matter. Chavan *et al.* (1995) reported similar increase in clay content downward in lateritic soils of Konkan region under forest tree species. Singh *et al.* (2000) also reported similar observation for soils under teak (*Tectona grandis*), sal (*Shorea robusta*), chir (*Pinus roxburghi*), bamboo (*Bambusa vulgaris*), Australian babul (*Acacia auriculiformis*) and eucalyptus (*Eucalyptus grandis*) plantations. Cation exchange capacity was 7.1 cmol (p+) kg in rubber and 13.8 in forest at 0-30 cm depth and 6.6 cmol (p+)/kg in rubber and 9.6 in forest at 30-60 cm depth. Rubber recorded very low CEC as compared to forest at both the depths. As soil depth increased, the CEC was found to decrease. High sand, low clay and silt contents and low CEC in rubber than adjacent forest indicated that the fertility was less in rubber soils than the undisturbed forest soils.

Soil pH

In rubber, significant temporal variation in soil pH was observed (Table 2; Fig. 1A). Among all months, significantly higher pH during October and lower pH during April were recorded in the surface soil. Soil pH during October was significantly higher than all other months except June in the surface soil in rubber. In lower depth, the highest pH was recorded in December and it was comparable with that of October in rubber. In forest, the highest pH was observed during December (5.42) and it was comparable with that of October at 0-30 cm. When both systems were compared, the lowest pH was recorded during April at 0-30 cm in rubber (4.52) and forest (4.65). Both systems had a similar trend (Table 2&3; Fig. 1A&B) in the variation pattern except in December when a decrease of pH (4.84) was observed in rubber and significant increase in pH (5.42) in forest ecosystem at 0-30 cm. In the bottom layer also, similar trend was observed from August to February in both systems. In April, soil pH increased in rubber followed by a decrease in June, whereas it showed a decreasing trend in forest in April followed by an increase in June. Because of the diverse nature of vegetation, a uniform

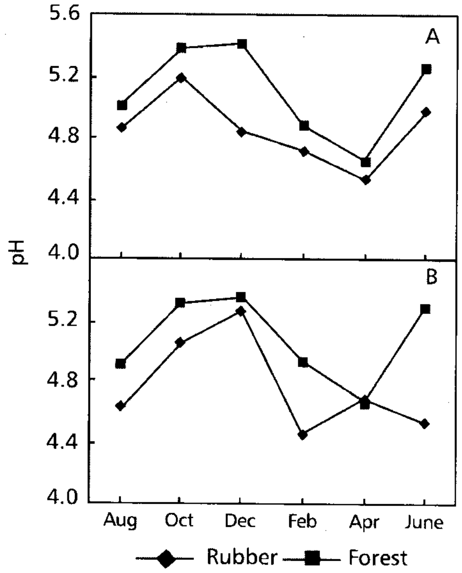

Fig. 1. Variation pattern in soil pH
A - 0-30 cm; B - 30-60 cm

Table 2. **Variations in soil fertility parameters in rubber and forest (0-30 cm)**

Month	pH		OC (%)		Av. P (mg/100 g soil)		Av. K (mg/100 g soil)	
	Rubber	Forest	Rubber	Forest	Rubber	Forest	Rubber	Forest
August	4.87	5.02	1.71	2.18	1.54	0.24	7.37	13.47**
October	5.19	5.39	2.18	2.73 *	1.08	0.12*	9.08	20.81 *
December	4.84	5.42 **	2.32	2.90 **	0.52	0.16	9.19	27.88**
February	4.78	4.88	1.87	2.03	0.05	0.08	10.11	20.46**
April	4.52	4.65	1.46	2.85 *	1.20	0.07*	15.83	16.67
June	4.97	5.23	1.82	2.16	0.54	0.14	10.32	15.55
G. Mean	4.84	5.10	1.91	2.48	0.88	0.13	10.32	19.14
CD (P = 0.01)	0.24	0.16	0.39	0.43	NS	0.11	2.83	5.76

* Significant at P = 0.05 ** Significant at P = 0.01

Table 3. **Variations in soil fertility parameters in rubber and forest (30-60 cm)**

Month	pH		OC (%)		Av. P (mg/100 g soil)		Av. K (mg/100 g soil)	
	Rubber	Forest	Rubber	Forest	Rubber	Forest	Rubber	Forest
August	4.60	4.87	1.37	1.65	0.33	0.24	6.76	10.58*
October	5.01	5.27	1.92	1.47 *	0.46	0.08*	5.98	14.08**
December	5.22	5.31	1.31	2.34 **	0.42	0.10*	7.23	28.58*
February	4.42	4.89	1.14	1.32	0.14	0.09	6.78	15.57**
April	4.65	4.63	1.02	1.70 *	0.25	0.06*	13.84	9.75
June	4.50	5.23	1.02	1.38	0.12	0.04	10.32	16.50
G. Mean	4.86	5.03	1.35	1.63	0.32	0.10	8.72	15.73
CD (P = 0.01)	0.23	0.18	0.28	0.34	NS	NS	3.65	5.36

* Significant at P = 0.05 ** Significant at P = 0.01

pattern of decomposition cannot be expected in forest. The pH change may be due to the activity of microorganisms associated with decomposition of leaf litter. Rubber shed leaves during December and January which start decomposing with pre-monsoon showers in March-April. The decrease in pH might be due to the formation of CO_2 and organic acids. Chavan *et al.* (1995) reported a slight decrease in pH due to the addition of leaf litter of four tree species *viz.* shivan (*Gamelina arborea*), ain (*Terminalia tomentosa*), Australian babul (*A. auriculiformis*) and Karanj (*Pongamia pinnata*) in the lateritic soils.

Soil organic carbon

In rubber, soil organic carbon was the highest in December and it was comparable with that of October (Table 2) and significantly higher than that of other sampling periods in the 0-30 cm soil layer. Soil OC was the lowest in April and it was comparable with that of June and August. In the 30-60 cm soil layer, the highest OC content was recorded in October and it was significantly higher than that of all other sampling months (Table 3). In forest, in the surface soil layer, OC content was the highest in December and it was on par with that of

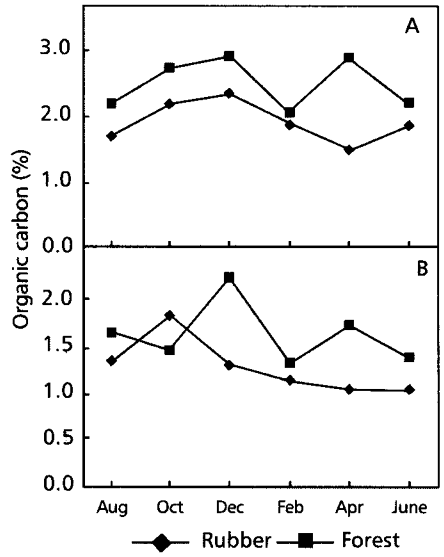

Fig. 2. Variation pattern in soil OC
A - 0-30 cm; B - 30-60 cm

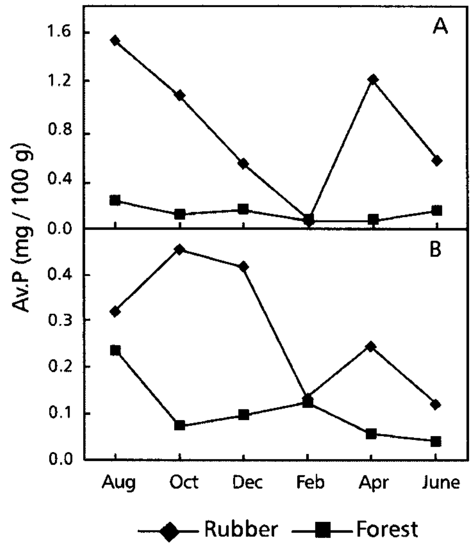

Fig. 3. Variation pattern in soil av.P
A - 0-30 cm; B - 30-60 cm

October and April (Table 2). In the bottom layer, OC content during December was significantly higher than that of other sampling months (Table 3). The variation pattern in rubber and forest soils in the surface layer followed similar trend from August to February and then varied. In the bottom soil layer, no definite trend was observed. Comparing between both systems, OC content was significantly higher in forest than in rubber during three sampling periods at both depths. Depthwise difference in both the ecosystem may be due to variation in the relative decomposition rates between the above and below ground parts which differ with plant species and root litter. Translocation of particulate organic matter and dissolved organic matter may also affect the components of the subsoil carbon. Humic and fulvic acids are translocated to deeper soil horizons and the levels increased with depth (Lorenz and Lal, 2005). When rubber ecosystem recorded a lower organic carbon content during April, a higher content was observed in forest (Table 2&3; Fig. 2A&B). This may be attributed to the increased sun light and soil temperature which favours OM decomposition in rubber than forest. Hains and Cleveland (1981) reported similar observation under clear cut pine and hardwood site when compared to forest in South West Georgia.

Soil available phosphorus

Soil P availability did not show any significant variation in rubber soils at both depths, however there was significant variation in the surface soil of forest (Table 2 &3; Fig. 3A&B). The soil available P content was low in forest, where there is no addition of fertilizers. In forest, the highest available P status was observed in August (0.24 mg/ 100 g soil) and it was comparable with that of December (0.16 mg/100 g soil) and June (0.14 mg/100 g soil). When two systems were compared, soil available P status was

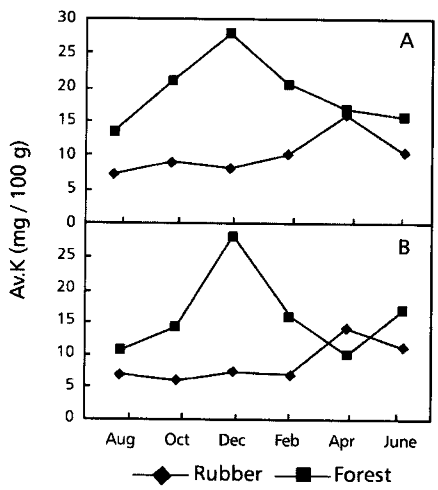

Fig. 4. Variation pattern in soil av. K
A - 0-30 cm; B - 30-60 cm

significantly lower in forest soil during October and April in the surface soil layer and October, December and April in bottom layer. This variation in P availability might be due to the application of slow release phosphatic fertilizers in rubber plantations and high (84-91%) fixation of applied P in rubber soils (Ulaganathan *et al.*, 2005). The diverse species in forest with different P demands also contributed to the variations in P availability. John and Abraham (1995) reported maximum decrease in available P during the summer season among three seasons *viz.* rainy, winter and summer in red loam soils of Kerala under Cassava. Gupta and Rorison (1975) also reported similar decrease in P during summer due to the uptake by the growing vegetation. Weaver and Forcella (1979) reported seasonal variation of P, nitrate, ammonium, pH and K in British *Deschampsia* grasslands. The reason attributed for higher availability in certain seasons is the rapidly growing decomposer population, releasing nutrients more rapidly than they are absorbed by relatively inactive plants. Also P availability decreased in summer because plants growing logarithmically absorb nutrients faster than decomposers release them (Weaver and Forcella, 1979).

Soil available potassium

Significant variation in available K status was observed in rubber and forest at both the depths (Table 2&3; Fig. 4A&B). In rubber, available K status was significantly high during April (15.83 mg/100 g soil) compared to all other seasons in 0-30 cm soil layer. In the bottom layer also, the highest value was observed in April and it was comparable with that of June. In the forest soil, available K status was significantly high in December compared to all other months in both surface and subsurface soil layers. Available K status increased till April and then decreased in rubber in 0-30 cm soil layer and in the 30-60 cm, no definite trend was observed. In forest soil, K availability progressively increased from August to December in both surface and subsurface soil. This may be attributed to the release of K from the decomposing rubber litter following leaf shedding in rubber (Philip *et al.*, 2003). The difference may also be due to the different uptake pattern of plants as reported by Balachandran and Anitha (2000). Comparing between rubber and forest, available K status was significantly higher in forest from August to February at both depths.

The study indicated that differences in temporal variations exist for soil pH, organic carbon and available K contents in rubber and forest soils.

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REFERENCES

Balachandran, P.V. and Anitha, T. (2000). Potassium requirement and response to K application in cereal crops. In: *Use of Potassium in Kerala Agriculture: Proceedings of the Workshop on Use of Potassium in Kerala Agriculture* (Eds. T. Nagendra Rao and K.N. Tiwari). Kerala Agricultural University, Trivandrum, India, pp. 9 -16.

Chavan, K.N., Kenjale, R.Y. and Chavan, A.S. (1995). Effect of forest tree species on properties of lateritic soil. *Journal of the Indian Society of Soil Science*, **43**(1): 43-46.

Gupta, P.L. and Rorison, I.H. (1975). Seasonal differences in the availability of nutrients down a podzolic profile. *Journal of Ecology*, **63**: 521-534.

Hains, S.G. and Cleveland, G. (1981). Seasonal variations in properties of five forest soils in South West Georgia. *Soil Science Society of America Journal*, **45**: 139-143.

Jackson, M.L. (1958). *Soil Chemical Analysis*. Prentice Hall Private Ltd., New Delhi. 498p.

John, K.S. and Abraham, A. (1995). Microbial immobilization and mineralization of nutrients during different seasons of the year. *Journal of the Indian Society of Soil Science*, **43** (1): 47-52.

Koyamu, E.K. and Nambiar, E.P. (1978). Changes in the characteristics of virgin soil brought under plantation crops. In: *Agronomy, Soils, Physiology and Economics of Plantation Crops* (Ed. E.V. Nelliat). PLACROSYM I, Indian Society for Plantation Crops, Kasaragod, India, pp. 3-13.

Lorenz, L. and Lal, R. (2005). The distribution of soil organic carbon in relation to land use and management and the potential carbon sequestration in sub-soil horizon. *Advances in Agronomy*, **88**: 35-66.

NBSS & LUP (1999). *Resource Soil Survey and Mapping of Rubber Growing Soils of Kerala and Tamil Nadu-Project Report*, National Bureau of Soil Survey and Land Use Planning, Indian Council of Agricultural Research, Nagpur, India, pp. 220-230.

Philip, A., Philip, V., George, E.S., Punnoose, K.I. and Mathew, M. (2003). Leaf litter decomposition and nutrient release in a fifteen-year-old rubber plantation. *Indian Journal of Natural Rubber Research*, **16** (1&2): 81-84.

Singh, G., Gupta, G.N. and Kuppusamy, V. (2000). Seasonal variation in organic carbon and nutrient availability in arid zone agroforestry systems. *Tropical Ecology*, **41**(1): 17-23.

Ulaganathan, A., Satisha, G.C., Karthikakuttyamma, M., Ambily, K.K. and Nair, A.N.S. (2005). Phosphorous fractions and fixation of added P in rubber growing soils of Kerala. *Natural Rubber Research*, **18**(1): 31-37.

Weaver, T. and Forcella, F. (1979). Seasonal variation in soil nutrients under six rocky mountain vegetation types. *Soil Science Society of America Journal*, **43**: 589-593.