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CHANGES IN SOIL PH, ORGANIC MATTER, PHOSPHORUS AND POTASSIUM UNDER SUCCESSIVE PLANTING CYCLES OF RUBBER (*HEVEA BRASILIENSIS*)

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ABSTRACT

The effect of cultivation of *Hevea* in consecutive replanting cycles on the alteration of some important soil properties was studied in comparison to natural forest. There was gradual decrease in soil pH in all the three depths from first to the third planting cycle. However, there was a trend toward less variability in soil pH as the mean pH declines, thus the likelihood that rubber-grown soils are closer to acid/base balance and are more strongly buffered. In general, the organic matter content of the topsoils under rubber was considerably higher in all the planting cycles compared to lower depths, but significantly lower than that in the forest soil. The build up of available phosphorus in top soil progressively increased after each rubber planting cycle. The rubber plantations had comparable amounts of soil available potassium in second cycle and significantly highest in third cycle as that of forest surface soil layer. The study reveals, soils become more acidic in third rubber planting cycle, and rubber plantations of 90-100 years old starts maintaining its phosphorus status comparable to that of natural forest.

INTRODUCTION

Rubber (*Hevea brasiliensis*) plantations in Kerala were earlier raised in freshly cleared forest areas where soil fertility conditions were better compared to cultivated soils of the same agro-climatic zones. The luxuriant vegetation in tropical forests depends mainly on the recycling of nutrients, a vital link in the conservation of the fragile ecosystem. The *Hevea* ecosystem can attain levels similar to that of the more luxuriant humid tropical evergreen forest systems (Sivandyan and Moris, 1992). None-the-less, rubber plantations are now in verge of completing the third cycle of cultivation, the trees are normally cut down enmasse and removed after the economic life span of every 30-32 years and hence repeated cycles of planting takes place. This will leads to removal of massive amounts of biomass as well as soil nutrients. The continuous relay cropping involves significant recycling of nutrients, and the nutrient management in monocultures based on the assumption of infinite capacity of soil to maintain the stand and replenish the enormous nutrient export from the land after energy rotation. Thus, understanding of the nutritional changes in the continuous relay cropping, as often express soil-plant relationship is important for the sustainable management of soil fertility levels. It is also extremely important to develop and compare forest soil fertility evaluation programme in order to assess soil fertility, nutrient depletion rate due to the rubber plantations. The objective of the present paper was to study the changes in soil pH, organic matter and major soil nutrients consequent to cultivation of rubber in consecutive replanting cycles, in comparison to natural forest.

MATERIALS AND METHODS

The study area lies between 76 20' to 76 55' E and 11 9' to 9 33' N, r epresenting the traditional rubber growing belt in Kerala, India. The sites for collection of soil samples were identified at Nilambur, Chimoni, Vithura and Mundakayam, where forest, and rubber in three stages namely first, second and third cycle exist. The areas have an annual rainfall ranging from 2000-3500 mm and the average maximum and minimum temperature are 28.0°C and 24.5°C, respectively. The soils under study are formed from basement complex rocks, chiefly hypersthein bearing gneisses and granulites belonging to charnokites group (ICAR report, 1999). Soil samples from 0-15, 15-30 and 30-45 cm depth interval were collected representing each location at different replanting cycles. The samples were air-dried, pulverized and passed through a 2 mm sieve before analysis. Standard methods were followed for determining soil pH (soil / water ratio

= 1:2.5), organic carbon (OC), cation exchange capacity (CEC) and available phosphorus (P) and potassium (K).

RESULTS AND DISCUSSION

Soil pH

Changes in soil pH at varying depth from rubber plantations of different replanting cycles is shown in figure 1. The data revealed that continuous cultivation of rubber for three cycles brought about a significant decrease in soil pH in all the three depths. The average soil pH values were 5.05 for forests and 4.88 for rubber plantations. When the pattern of soil pH of each of the cycle was compared with forest, it was seen that values of the third cycle (4.65 pH) were significantly lower than that of the forest and there was a gradual decrease in pH from first to the third cycle (Fig. 2).

The pH of a soil layer, in particular the surface soil layer is a function of the composition of the soil parental material and of subsequent acid and alkali addition and removal from the layer. Decrease in pH over a 50-year period has been reported for a wide range of soils formed on granite, sedimentary rocks and basalt (Bromfield *et al.*, 1983; Kennedy, 1986). Acidification processes in soils have been recently discussed by Kennedy (1986), Helyar *et al.*, (1988) and Helyar and Porter (1989). According to Helyar and Porter (1989), soil layer may be acidified by net acid addition from acids produced in the inorganic and organic carbon cycles, or in the N, Fe, S, Al, and Mn cycles. The carbon cycle contributes acid in proportion to the amount of organic anion accumulation as soil organic matter, plus exports of organic anions in products. The nitrogen cycle contributes acid in proportion to the amount of nitrogen leached or lost in run-off following entry to the ecosystem via dinitrogen fixation, or an ammonium, ammonia, organic N or urea fertilizers (Cregan and Helyar, 1986).

The results show there is a trend toward less variability in soil pH ($r^2 = 0.903^{**}$) as the mean pH declines, thus the likelihood that such soils are closer to acid/base balance and are more strongly buffered by dissolution of clay minerals and Al oxides (Chartres *et al.*, 1990). It is likely that the surface soil is less acidic than the subsurface layers as noticed in the present study because of the return of organic anions (i.e., organic acids which have pK values above that of the soil pH and are added to soil as the dissociated anion) and bases in plant material (Ritchie and Dolling, 1985). Additionally, oxidation of organic anions will be greatest at the surface and this will tend to increase soil pH (Kennedy, 1986). A further explanation may be that soil faunal activity is insufficient in these soils to ensure adequate mixing in the topsoil, and to prevent the development of higher pH (surface) strata rich in organic matter and nutrients.

Soil organic matter

Results on changes in organic matter content of the soil due to cultivation of rubber in

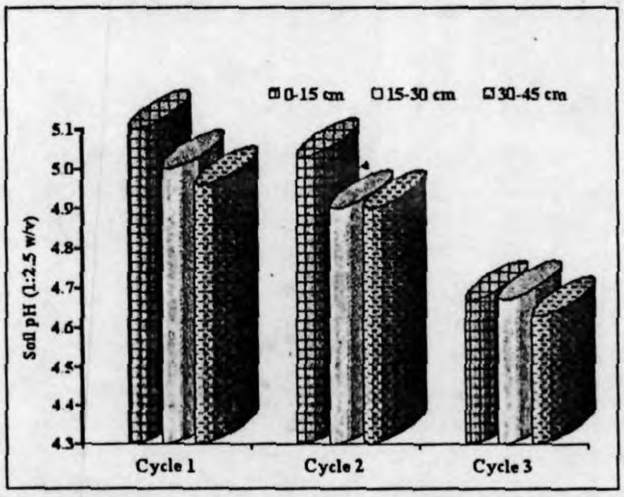

Fig 1. Changes in soil pH at varying depth from rubber plantations of different planting cycles

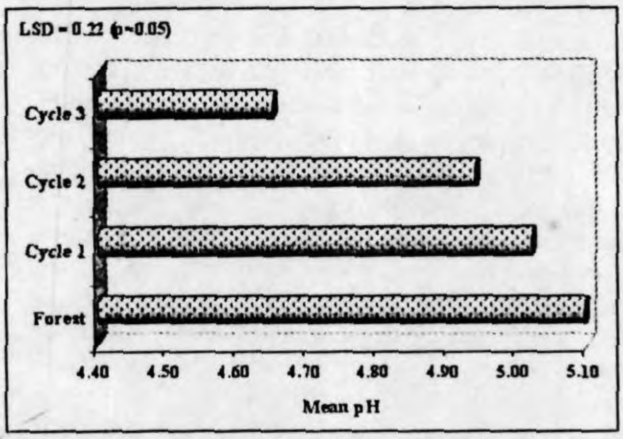

Fig 2. Changes in soil pH at different planting cycles of rubber and corresponding forest

the first, second and third cycle as compared to adjacent virgin forest are presented in Table 1. In general, the organic matter content of the surface soil layer was considerably higher in all the planting cycles compared to lower depths. The high content of organic matter in topsoil is probably the result of biomass and litter cycling. When each cycle was compared separately with forest soil, it was seen that organic matter content in all the three depths were significantly lower than that in the forest. When the average organic matter content in 0-60 cm depth was considered, there was a gradual increase in the organic matter status from first to the third cycle and there was no significant difference among plantations of first, second and third cycle.

Several workers indicated that changing land use and fertilizer management practices are among the factors that most affect the organic matter status in soils (Rice and Rogers, 1993; Ajwa and Tabatabai, 1994). Many studies have established that agronomic practices such as cultivation, residue management, and fertilization regulate microbial activities, which in turn mediate that processes of organic matter turnover and nutrient cycling (Biederbeck *et al.*, 1984; Doran and Smith, 1987). Moreover, long-term cultivation causes reductions in total organic carbon and microbial biomass C, and affects the activity of nitrification and denitrification enzymes (Groffman *et al.*, 1993). Further, cultivation with long-term input of nitrogen fertilizers and total tree harvesting may lead to changes in N and C mineralization caused by N enrichment of soil organic matter and changes in the micro-environment (Adams and Boyl, 1982; Ajwa and Tabatabai, 1994)

Soil phosphorus

The data on mean available phosphorus content of the soil from the forest are not significantly different from that of rubber plantations in first and second cycle. However, the rubber plantations in third cycle contained significantly higher available phosphorus content than the forests, and the first and second cycles of plantations (Fig. 3a). After each planting cycle, the available phosphorus content in soils increased significantly. The build up of available phosphorus in the surface layer (0-15 cm) progressively increased after each planting cycle (Fig. 3b). However, progressive cultivation of rubber led to decrease in available phosphorus content in lower layers.

The plant available phosphorus in soils is influenced not only by parental material but also by cultivation management. Indeed, most of these soils have been fertilized over many years to supply plants with phosphorus, regardless of native phosphorus status. However, only a small percentage of fertilizer phosphorus is taken by crops and most of the applied phosphorus remains in the soil in forms sparingly available to plants. Further, added phosphorus accumulates in soil during long-term cultivation (Tabi *et al.*, 1990) due to low fertilizer efficiency and/or as adsorbed P on surfaces of soil particles (Beck and Sanchez, 1994), and as P associated with amorphous Al and Fe oxides (Wagar *et al.*, 1986; Beck and Sanchez, 1994). Formation of these intermediate P products is reversible and some phosphate returns to the soil solution when solution P is reduced, thus supports the build up of phosphorus in topsoil layer as in the present study.

Table 1. Changes in soil organic matter content (mean of four locations) from rubber plantations at different planting cycles and corresponding forest.

Depth (cm)	Organic matter (g/kg)	Forest Rubber Plantations			
		Cycle 1	Cycle 2	Cycle 3	Mean (3 cycles)
0-15	42.9	29.5	31.0	35.2	31.9
15-30	32.6	22.6	25.0	23.1	23.1
30-45	26.5	12.9	12.6	16.6	14.0
Mean	34.1	22.4	22.9	25.0	

CD (p=0.05) for comparison of rubber and forest – 5.2

CD (p=0.05) for comparison of forest and cycles of rubber – 7.4

Soil Potassium

The data on changes in available potassium content at varying depth from rubber plantations of different replanting cycles is given in Table 2. The mean available potassium content of the virgin forests and first, second and third cycles were not significantly different from one another. However, the trend indicated that with planting of rubber, a decrease in available potassium content ensues after which a gradual build up of potassium is accomplished by the third cycle. The forest and rubber growing soils at the 0-15 cm depth had similar and the highest amount of potassium (Table 2). The average potassium content (three depths) of the forest soil was significantly higher than the rubber cultivated soil. However, the topsoils of rubber plantations had comparable amount of potassium in second cycle and significantly highest in third cycle as that of forest surface soil layer. Adams and Boyle (1982) reported a more rapid increase in K immediately after clear cutting of trees. They suggested that K is released from applied fertilizer and surface organic matter by mineralization, then this nutrient is initially taken up luxuriantly by tree plants and therefore, reduction in plant uptake in the mid or end of the cycle. Thus, potassium probably moves through the soil with counter ions by the rapid ion concentration and ion pair formation (Snyder and Harter, 1984), having little interaction with the soil exchange complex (Boyle, 1975).

CONCLUSIONS

It can be concluded that soil approaching 90-100 years old of rubber plantation starts maintaining its fertility (esp. phosphorus) in comparison to first and second planting cycles, similar to that of natural forest. However, in replanted rubber the case is likely to be quite different, soil nutrient reserves are likely to be depleted at replanting and nutrient deficiencies may be expected as the crop draws further soil nutrient reserves. Hence, replenishment of soil nutrients may seem sound good and it is essential to consider manuring extra than normal on the conservative principle of ensuring satisfactory establishment of the young rubber and to enhance

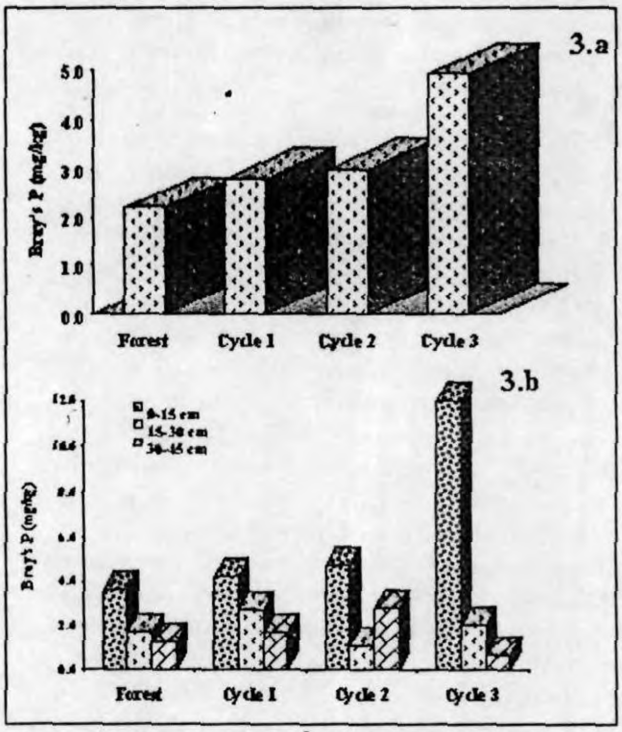

Fig 3. Changes in soil available phosphorus content at different planting cycles of rubber and corresponding forest

Table 2. Changes in soil potassium content (mean of four locations) from rubber plantations at different planting cycles and corresponding forest.

Depth (cm)	Available	Forest Rubber Plantations			
	Potassium (mg/kg)	Cycle 1	Cycle 2	Cycle 3	Mean (3 cycles)
0-15	79.9	69.6	78.0	88.0	84.6
15-30	65.0	77.7	44.0	63.0	50.3
30-45	69.1	32.0	33.0	45.0	36.8
Mean	71.2	48.3	51.8	72.0	

CD (p=0.05) for comparison of rubber and forest – 5.78

CD (p=0.05) for comparison of forests and cycles of rubber – 6.69

the biomass potential of *Hevea* stands as well as its true nutrient bank status.

It is also evident from data presented in this study that there was a gradual decrease in surface and subsurface soil pH from first to the third planting cycle, which will have significant effects on vertical heterogeneity in soil attributes. It was the nature of the proton buffer system in these stands that is well responsive for the higher rates of decomposition, mineralization of nutrient ions and uptake by trees. This is very important factor in the long-term stability of the ecosystem. Moreover, rubber is not a short rotational plant, in the younger stage consume nutrients more for their development and return less, thus surely deserve greater emphasis for the preservation of soil ecosystem.

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