IMPACT OF NATURAL RUBBER CULTIVATION ON NUTRIENT STATUS IN TROPICAL SOILS: A CASE STUDY IN KERALA, INDIA

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The impact of rubber cultivation on soil can be assessed precisely if the changes are monitored in the same field itself at different stages of growth. Accordingly two fields in the second cycle of rubber cultivation in the farm of Rubber Research Institute of India, Kottayam, were selected and monitored for soil organic carbon, pH and available nutrients at the beginning of the cycle, after eight years and at the end of the cycle. A decline in soil organic carbon status was observed in both the fields after eight years. However, after 25 years, in both the fields a significant increase was noted. Available phosphorus and potassium improved towards the end of the cycle. It is observed that the available calcium was maintained at the end of the cycle, though an increase was noted in between. The changes in available magnesium status in soil was different in the two fields, however, both the fields maintained the 'medium' status throughout the period of cultivation. Soil pH changes were also slightly different in the two fields. In one field, a slight decrease was noted compared to the initial status while in the other a reverse trend was recorded. In general, in both the fields an increase in organic carbon and available form of nutrients in soil was observed towards the end of the cultivation cycle.

Key words: Available nutrients, Nutrient changes, Organic carbon, Organic matter, Rubber cultivation.

INTRODUCTION

The organic matter and available nutrient status of any agricultural soil system depends to a large extent on the type of crops grown, its duration and the associated cultural and management practices (George *et al.* 2012; Li *et al*. 2012; Abraham, 2015). Addition of organic matter through manures and inorganic nutrients through chemical fertilizers is common in any modern agriculture system, but, their input quantity widely varies among different crops. So also there can be large variations in input of organic matter through litter fall and crop residues in different crop systems such as annuals or perennials.

The normal economic life span of natural rubber tree is 25 to 30 years and the life cycle normally begins in an area after clearing all natural vegetation. After five to six years of growth, the canopy of rubber trees crosses over and organic matter addition through annual litter fall takes place substantially (Philip *et al.*, 2003, Jessy *et al.*, 2009). The rubber trees attain enough girth by the seventh year for the harvest to start with.

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It continues for about 25 years, and thereafter the trees are felled off and a new planting cycle begins. Natural rubber is a common tree crop in Kerala, occupying about 20 percent of the total cultivated area (Chattopadhyay, 2015). Most of these plantations are either in the late second or the third plantation cycle (Ulaganathan *et al.* 2010).

Generally, when agriculture is introduced in forest cleared lands, a declining trend is observed in organic matter and available nutrient contents (Abera and Belachew, 2011; Yang *et al.*, 2004; Murty *et al.*, 2002; Cambardella and Elliott, 1993; Li *et al.*, 2012). In the case of rubber based systems in Kerala, it has been reported that the quantity and quality of soil organic matter declined compared to the nearby forest system (Abraham, 2015). Also, there are reports that as the rubber cycle proceeded, the soil organic carbon and nutrients, except P are gradually declined (Karthikakuttyamma, 1995; Tata, 2011). Cheng *et al.* (2007) reported that in Hainan Island, China, with the increase of stand age of rubber plantation, soil organic matter, total N, available K and available P decreased.

Though there are a few studies and reports comparing the soil nutrient status among different aged rubber plantations in a region or rubber plantations of different cycles with nearby natural forests (Karthikakuttyamma, 1995; Yasin *et al.*, 2010), seldom, reports are seen obtained on soil nutrient changes during the course of a rubber cycle *viz.* just before the planting, after the immature phase completion and at the time of felling the trees in a given field. Hence, this study was carried out in two rubber fields by collecting and analyzing soil samples at the time of planting, eight years after planting (when the immature phase was over) and 25 years after planting (trees were felled on completion of the cycle) by which the impact of one cultivation cycle on soil nutrient status in a specific field could be assessed.

MATERIALS AND METHODS

This study was conducted in two fields in RRII farm (fields 'A' and 'B') at Kottayam, (9°32'N, 76°36'E) where two multi clone evaluation experiments (91 plots in field 'A' and 65 plots in field 'B') were carried out between 1989 and 2014. In these fields, first cycle of rubber cultivation started in 1950s and the second cycle in 1989.

The polybag plants were planted in pits (75 x 75 x 75 cm) filled with soil mixed with 12 kg of farm yard manure. Continuous platform were prepared manually in each row. Stone bunds were raised wherever necessary to prevent soil erosion. The cover crop, *Mucuna bracteata* was established in the periphery of both the fields while *Pueraria phaseoloides* was established in the inner region. Fertilizers were applied in two equal splits annually as per the general fertilizer recommendations (Karthikakuttyamma, *et al.*, 2000). The plots were regularly weeded manually, twice per annum throughout the cycle.

Ninety one and 65 soil samples (0 - 30 cm) were collected from field A and field Brespectively just before the planting in 1989. From these sites, samples were also collected in 1997, just before the regular tapping commenced and in 2014, before replanting commenced.

The soil samples collected were air dried, sieved (2 mm) and subjected to chemical analysis for organic carbon, available P, K, Ca, Mg and pH. Organic carbon was estimated following the Walkley and Black method (1934). Available nutrients and pH were estimated following standard methodologies as described in Jackson (1958).

The available P was extracted using Bray II solution and estimated colorimetrically by Molybdenum blue method. Available K was extracted using neutral normal ammonium acetate and estimated by flame photometer method. Available Ca and Mg were estimated using atomic absorption spectrometer after extracting by neutral ammonium acetate solution. Soil pH was determined using glass electrode in soil water suspension in the ratio 1:2.5.

Independant 't' test was performed to find out the significant difference in the tested parameters between different growth periods *viz.* between 1989 and 1997, 1997 and 2014 and 1989 and 2014. The data generated from the two fields were analyzed separately.

RESULTS AND DISCUSSION

Organic carbon

Soil organic carbon status at various stages of rubber growth in both the fields under study is shown in Figure 1. Both the fields recorded a high content of organic carbon (>1.5 %) before and at the end of the rubber cultivation cycle in both the fields. However, a significant decline in organic carbon was observed at the end of eight years in both the fields. The decline was about 21 per cent in field A and 19 per cent in field B. This decline could be due to two factors, *viz.* loss of organic carbon from the soil and lesser input for enrichment. The loss from the system might have occurred during the initial phases itself as the conditions were very much conducive for faster decomp osition of organic matter. The disturbance of soil during the pit and platform preparations might have permitted more aeration and favored faster decomposition of the organic matter. Also the lack of good ground cover and canopy during the early stages of the plantation allowed fall of direct sunlight and rain to hit the soil surface. Direct sun and rain falling on soil surface accelerate the loss of soil carbon. Though a decline was noticed, the soil maintained

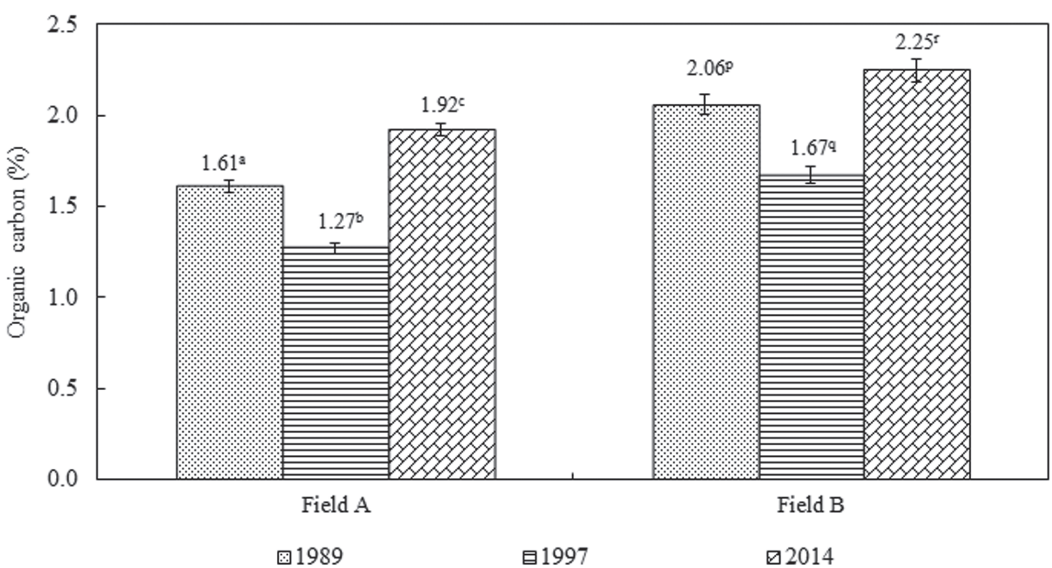

Fig. 1. Organic carbon (%) status in soil at different stages of rubber growth

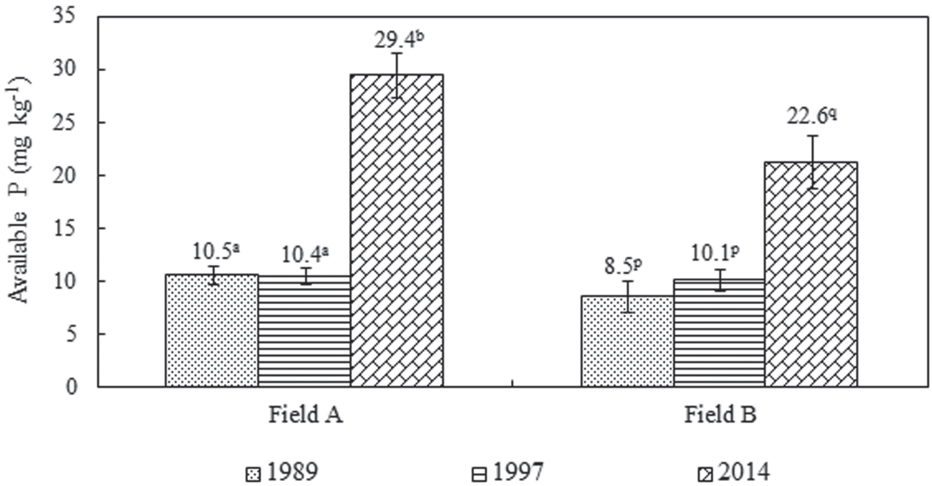

Fig. 2. Available P (mg kg^{-1}) status in soil at different stages of rubber growth

medium (0.75-1.5 %) organic carbon status in field A and high status in field B as per the fertility rating followed in Rubber Research Institute of India (Karthikakuttyamma *et al.* 2000).

By the end of the cultivation cycle, soil organic carbon increased by about 20 per cent in field A and 10 per cent in field B. The major reasons could be the substantial organic matter input through rubber litter fall (Philip *et al*. 2003; Jessy *et al.* 2009), lesser impact of direct sunlight and rain due to the canopy closure (Meti *et al.*, 2009) andthe slower decomposition of rubber based soil organic matter due to the presence of more recalcitrant litter components (Abraham and Chudek, 2008; Philip and Abraham, 2009; Philip, 2014). Also the minimal disturbance of soil under the mature rubber plantations favors less organic matter loss from the system. Natural flora existed in these fields during the mature phase were regularly weeded and this also might have contributed towards building up of organic matter. Similar reports were made from studies in Indonesia by Yasin *et al.* (2010). The initial declining trend in soil organic carbon status upto 10 years and an increase during the mature phase was noticed in their studies.

Available Phosphorus

The available P status in soils at various stages of rubber growth in both the fields is shown in Figure 2. In 1989, the available P status in field A was medium (10 - 25 mg kg^{-1}) and field B was low (< 10 mg kg^{-1}). Though there was no considerable change after eight years, in both the fields,the available P status improved significantly by the end of the cycle. Field A had high available P while field B medium status by the end of the cycle. This buildup has obviously taken place during the mature phase of rubber cultivation. The use of rock phosphate as the source of P in these soils also contributed to the buildup of P. Another reason for this accumulation could be the lesser removal of P by rubber trees through latex and timber compared to other nutrients (Karthikakuttyamma, 1995; Jessy *et al.*, 2012). Phosphorus input through the annual litter fall also may contribute towards the buildup in soil. Buildup in P in

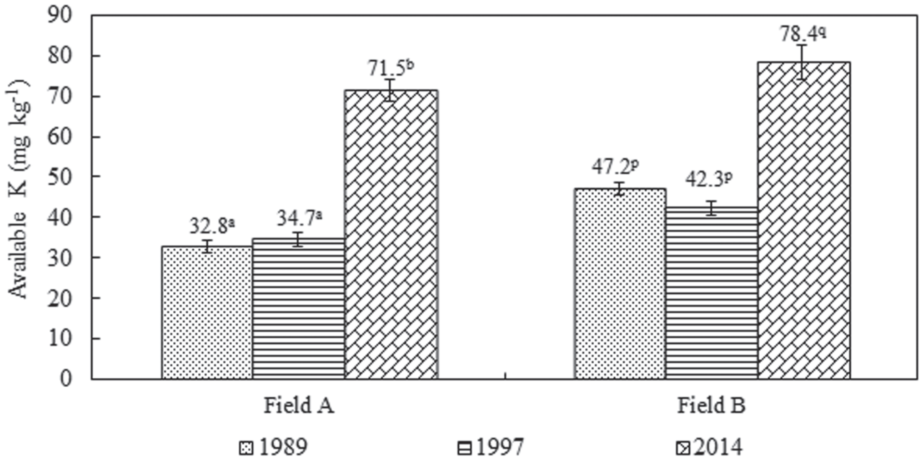

Fig. 3. Available K (mg kg^{-1}) status in soil at different stages of rubber growth

rubber plantations was reported by Karthikakuttyamma (1995) and Ulaganathan *et al.* (2010).

Available Potassium

The available K status increased in both the fields by the end of the cultivation cycle (Fig. 3). The fields were low in this nutrient at the initial phase and did not change considerably by the eighth year. However, both the fields were significantly improved to medium (50-125 kg ha^{-1}) K status by the 25th year. The input of K through fertilizer is comparatively less during the initial four to five years compared to the N and P input in rubber plantations. Further, the chances of K losses through leaching and run off were

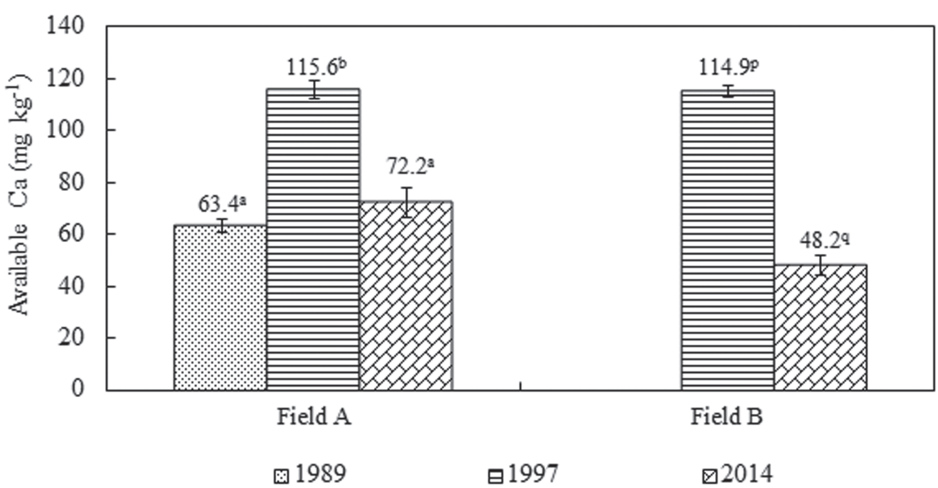

Fig. 4. Available Ca (mg kg^{-1}) status in soil at different stages of rubber growth

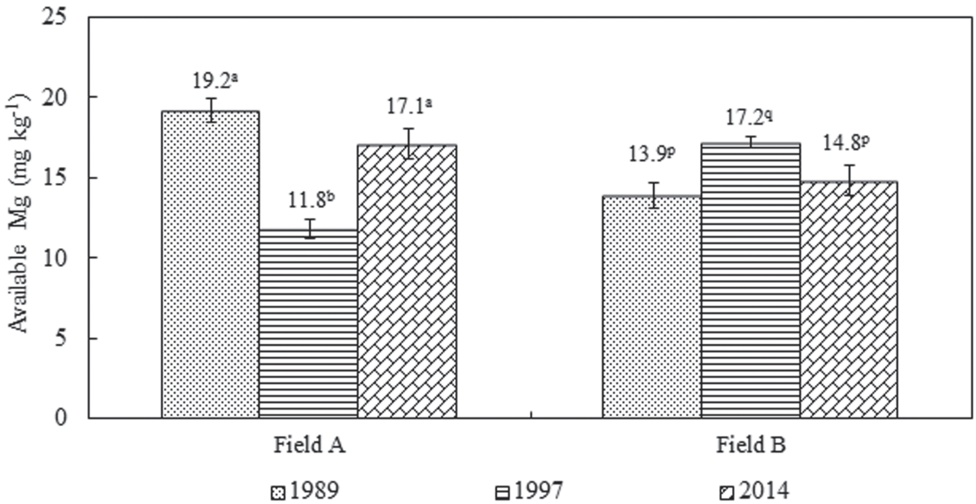

Fig. 5. Available Mg (mg kg^{-1}) status in soil at different stages of rubber growth

quite high during the initial years as the soils were exposed to direct rainfall. But due to canopy closure and consequent interception of rain water, K loss may get minimized during the mature phase of rubber cultivation. This is quite evident from the present results where both the fields had an improved K status during the mature phase compared to the immature phase. It is also to be noted that K input through fertilizer was more during the mature phase. Similar observation of available K buildup in the mature phase of rubber growth was made by Boakye (2015).

Available Calcium

The available Ca status in soils at various stages of rubber growth in both the fields is shown in Figure 4. Only in field A, the initial status could be estimated. In this field, availability of Ca improved significantly by the eighth year and it was comparable with that in the field B. The higher rate of P input through rock phosphates which contains about 38 per cent of Ca during the initial years of cultivation might have contributed to the buildup of Ca status in soil during the initial years as observed in field A.

Though a decline was noted at the end of the cycle compared to the eighth year status, the field A maintained the initial status. The behavior of available Ca is not as in the case of available K. At the end of the cycle, a buildup in available K was noticed, while available Ca had just maintained the initial status, that too after a buildup during the initial stage in the soil system. This could be attributed to the specific nature of Ca ions in the plant system. The Ca ions are rather immobile and get accumulated in plant parts. It is reported that from a 25 year old rubber plantation Ca removal by 300 trees is about 3,500 kg (Jessy *et al*., 2012). Accordingly a decline in soil Ca status may occur by the end of the cycle. It is also to be noted that, the tree biomass during the immature phase is considerably less compared to that at the end of the cycle. Calcium is not a recommended nutrient for rubber plantations

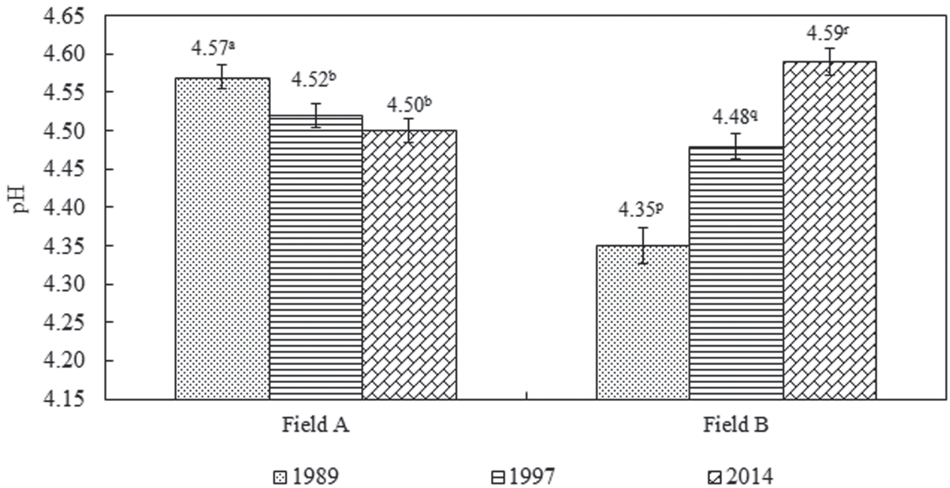

Fig. 6. Soil pH at different stages of rubber growth

in the past and therefore it was not conciously added to soil.

Available Magnesium

The available Mg status in soils at various stages of rubber growth in both the fields under the study is shown in Figure 5. Though changes had been noticed in the available Mg status at various stages, throughout the cycle the status remained as medium (10-25 kg ha^{-1}). The two fields slightly varied in available Mg status after eight years compared to their initial status. The field A had a significant decrease while field B had a significant increase in available Mg status compared to the respective initial status. However, by the end of the cycle, both the fields maintained almost similar available Mg status with respect to their initial stage.

Soil pH

The pH in soils at various stages of rubber growth in both the fields under the study is shown in Figure 6. The soil reactions in the two fields were very strongly to extremely acidic throughout the cycle. However, variations were observed at different stages of rubber growth. The pH declined in field A after eight years. The declining trend was not so prominent in the later phase. However, in field B, a reverse trend was noted. The low pH of 4.35 had increased to 4.48 after eight years and to 4.59 by the end of the cycle *viz.* after 25 years. The reasons for the varying behavior in pH changes in the two fields are not known.

CONCLUSION

Considerable buildup of organic matter in soil was noted in both the fields at the end of the rubber cultivation cycle, *viz.* after 25 years, though a decline was observed during the eighth year. An improvement in available P and K and maintenance of available Ca and Mg were noted in these fields at the end of the cultivation cycle. The soil pH remaind very strongly to extremely acidic and did not undergo drastic changes. The study indicated that the chances of soil nutrient depletion in rubber plantations were more during the immature phase possibly due to initial soil cultivation practices and sparse canopy. The buildup of soil organic carbon towards the end of the cultivation cycle, indicates the possibility of considering natural rubber as a crop that can sequester soil carbon. Maintenance of soil C and nutrients in the mature phase indicates that natural rubber is a 'closed' system with any little leakage of nutrients from the soil.

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