NUTRIENT AND HEAVY METAL STATUS OF SOILS UNDER RUBBER-PINEAPPLE INTERCROPPING IN COMPARISON TO RUBBER-COVER CROP SYSTEM AND NATURAL FOREST

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Soil pH, organic carbon, available nutrients and contents of heavy metals in soil in young rubber plantations under pineapple intercropping were compared with cover crop established plantations and natural forest. A total of 82 and 21 soil samples from rubber-pineapple intercropping system and rubber-cover crop system respectively were collected from surface layer (0-30 cm) of selected fields, including estates and small holdings in the central region of Kerala. Soil samples (15 nos.) were also collected from natural forest within the region of the study. Processed samples were analysed for pH, OC (%), available nutrients and phyto-available heavy metals such as Pb, Cd, Cr, Cu, Zn, Mn and Fe. Compared to soil under rubber-cover crop system, significant decrease in soil pH, available calcium and magnesium, and significant increase in available P and K were observed in soil under rubber-pineapple intercropping system. Phyto-available heavy metal status of the soils showed significantly higher cadmium and iron contents, and significantly lower lead, chromium, copper and manganese contents in rubber-pineapple intercropping system, compared to rubber-cover crop system. Comparison with soil under natural forest showed significantly lower pH and available calcium and magnesium, significantly higher copper content, and a build of available P in both the rubber based systems. Arsenic and mercury contents in soils of all the three systems were below detection limit.

Keywords: Cover crop, Heavy metals, Natural forest, Rubber-pineapple intercropping

Intercropping with pineapple is widely practiced in immature rubber plantations in the initial four years particularly in the central region of Kerala. This is a good source of income for farmers during the unproductive phase of rubber plantation. Experiments conducted in RRII indicated that scientific intercropping with pineapple improved growth of rubber and sustained soil properties (RRII, 2008).

Pineapple intercropping in young rubber is an intensively managed agricultural system involving high rate of addition of nutrients, manures, pesticides, herbicides and hormones. In a survey conducted in central Kerala, Jayasree *et al.* (2006) observed that the quantity of fertilizers applied to pineapple far exceeded the recommended doses.

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Excessive use of fertilizers, organic manures and pesticides can be harmful to the soil ecological environment as these materials may contain some toxic contaminants such as heavy metals (Quishlaqi and Mooe, 2007; Zoffoli *et al.*, 2012). Soil contamination with heavy metals is a major environmental problem, and an important factor limiting the growth of plants (Fernandes and Henriques, 1991; Haung *et al.*, 2009). Trace metals such as Zn, Cu, Mn and Fe are essential to plant growth and are called micro nutrients, but at high concentrations, they are toxic to plant growth. Metals such as Cd, Cr, Pb, As and Hg have no known useful functions in plants; they have toxic effects on living organisms and are often considered as contaminants (Sharma and Agarwal, 2005).

The objective of the present study was to compare the nutrient and heavy metal status of soils under rubber-pineapple intercropping system with that of soil under rubber-cover crop system and natural forest.

The present study was conducted by collecting soil samples from immature rubber plantations, including estates and small holdings in central Kerala. Immature rubber plantations in the third year of planting, with pineapple intercrop or legume cover crop were selected for the study. Composite soil samples from 0-30 cm depth were collected from each selected field. While 82 fields with pineapple intercrop were sampled, 21 fields with legume cover crop were sampled. For comparison, soil samples were also collected from 15 different locations in a natural forest in the Kalaketty region of Erumely Forest Division which falls within the region of study.

The soil samples were air-dried and sieved through 2 mm sieve. Soil pH was determined in a 1:2.5 soil:water suspension using a glass electrode pH meter. Soil organic carbon was estimated by Walkley and Black method as described by Jackson (1973). Available phosphorus was extracted by Bray 11 reagent and estimated by spectrophotometry using the molybdenum blue method (Bray and Kurtz, 1945). Standard methods were followed for determining available potassium, calcium and magnesium (Jackson, 1973). Phyto-available heavy metals *viz.* lead, cadmium, chromium, copper, zinc, iron and manganese were extracted using 0.1N hydrochloric acid and estimated by Atomic Absorption Spectrophotometry (Baker and Amacher, 1982; Menzies *et al.*, 2006). All the data were analysed by independent *t* test.

Figure 1 shows the variations in soil pH under the three different systems studied. pH of soil under rubber- pineapple intercropping (4.54) was significantly lower than that of rubber-cover crop system (4.76), and the pH of both these systems were significantly lower than that of the soil under natural forest (5.05). Significantly lower soil pH in rubber plantations compared to forest soils has been reported earlier by several authors (Karthikakuttyamma, 1997; Ulaganathan *et al.*, 2010). An assessment of fertility changes in rubber plantations in different agro-climatic regions of Kerala also showed a significant decline in soil pH as a result of prolonged rubber cultivation (Jacob

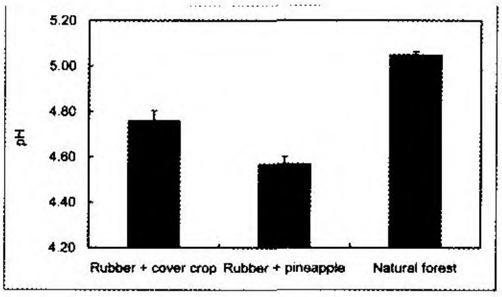

Fig. 1. Soil pH of different systems

et al., 2012). Further reduction in soil pH in pineapple intercropped areas might be due to the intensive agromanagement practices followed, such as application of acid forming fertilizers. Soil acidification due to continuous application of nitrogenous fertilizers such as urea is well documented (Khonje *et al.*, 1989; Jolly *et al.*, 1979).

Soil organic carbon (%) and available nutrients (mg kg^{-1}) are shown in Table 1. Organic carbon of pineapple-intercropped and cover- cropped soils (1.67% and 1.66% respectively) were comparable and significantly higher than that of soil under natural forest (1.01%). Though the soil samples were collected from well inside the forest, the presence of undergrowth in the area was less and there were signs of erosion. This might be the reason for the low organic carbon status observed in the forest soil. An increase in soil organic carbon status due to pineapple intercropping and cover crop establishment was observed in a previous field experiment on the influence of different intercrops on growth of rubber and soil physico-chemical properties (George *et al.*, 2012). In rubber-pineapple intercropping system, repeated application of organic manures to pineapple is a routine cultural practice.

Available phosphorus content in soil under rubber-pineapple intercropping (39.55 mg kg^{-1}) was significantly higher than that of the soil under rubber-cover crop system (23.99 mg kg^{-1}), and both these systems showed significantly higher available P content than the soil under natural forest (1.95 mg kg^{-1}). A build up of available P in rubber growing soils, especially in intercropped areas due to the continuous application of rock phosphate was reported by several authors (Ulaganathan *et al.*, 2010; George *et al.*, 2012). Jessy *et al.* (2005) observed significant increase in available P status of soil due to pineapple intercropping in rubber, and suggested the possibility of reducing the dose of phosphorus fertilizers to rubber and intercrops. Available potassium in soil under rubber-pineapple intercropping was significantly higher than

Table 1. **Organic carbon (%) and available nutrients (mg kg^{-1}) in soil**

	System	OC	Available P	Available K	Available Ca	Available Mg
1.	Rubber + cove crop	1.66	23.99	65.82	81.38	27.02
2.	Rubber + pineapple	1.67	39.55	91.35	55.90	14.15
3.	Natural forest	1.01	1.95	85.76	136.42	73.24
t stat	Rubber + cove crop *vs* Rubber + pineapple	NS	*	*	**	**
t stat	Rubber + cove crop *vs* Natural forest	**	**	*	**	**
t stat	Rubber + pineapple *vs* Natural forest	**	**	NS	**	**

** Significant at P<0.01

* Significant at P<0.05

rubber-cover crop soil, due to the intensive application of K fertilizer to pineapple plants, *i.e.* 320 kg K_2O ha^{-1}. Rubber-cover crop system showed significantly lower av. K content compared to natural forest.

Available calcium showed significantly lower values in soil under rubber- pineapple system (55.90 mg kg^{-1}) compared to rubber-cover crop system (81.38 mg kg^{-1}), and both these systems showed significantly lower values than the forest soil (136.42 mg kg^{-1}). Available magnesium content also was significantly lower in soil under rubber-pineapple system (14.15 mg kg^{-1}) than the rubber-cover crop system (27.02 mg kg^{-1}), and both these systems showed significantly lower levels than the forest soil (73.24 mg kg^{-1}). The decline in calcium and magnesium status in pineapple intercropped areas might be due to the uptake by pineapple plants without supplementing these nutrients. Also, in the case of rubber-pineapple system, there is no recycling of pineapple litter, whereas cover crop recycles back to soil and hence there is less depletion of calcium and magnesium in rubber–cover crop system. Decline in calcium and magnesium status of rubber growing soils compared to forest soils was observed in other studies also, probably due to repeated rubber cultivation and through timber removal (Ulaganathan *et al.*, 2010; Karthikakuttyamma, 1997). Soils with low pH also tend to have low concentrations of calcium and magnesium (Silva *et al.*, 2006) and compared to forest soil, significantly lower pH was observed for soil under both the rubber systems.

Content of bio-available heavy metals such as lead, cadmium, chromium, copper, zinc, iron and manganese (mg kg^{-1}) in the soil are shown in Table 2. Lead content of soil under rubber-pineapple intercropping was significantly lower than the other two systems which were comparable, probably due to uptake by plants. Cadmium is regarded as one of the most toxic heavy

Table 2. **Phyto-available heavy metals in soil (mg kg^{-1})**

	System	Pb	Cd	Cr	Cu	Zn	Fe	Mn
1.	Rubber + cover crop (n=21)	3.38	0.03	0.28	26.17	1.43	36.39	32.96
2.	Rubber + pineapple (n = 82)	2.78	0.06	0.22	16.43	1.33	49.95	19.52
3.	Natural forest (n=15)	3.69	0.02	0.33	2.27	1.12	33.71	61.14
t stat	Rubber + cove crop *vs* Rubber + pineapple	**	**	NS	**	NS	**	**
t stat	Rubber + cove crop *vs* Natural forest	NS	NS	NS	**	*	**	**
t stat	Rubber + pineapple *vs* Natural forest	**	**	*	**	NS	**	**

** Significant at P<0.01

* Significant at P<0.05

metals in the environment. Cadmium content of soils in the study area, in general was low, and ranged from 0.02 mg kg^{-1} in forest soil to 0.06 mg kg^{-1} in pineapple intercropped rubber growing soils. Cadmium content was significantly higher in soil under rubber-pineapple intercropping in comparison to soil under rubber-cover crop system which, in turn was comparable with forest soil. The observed increase in Cadmium content in pineapple intercropped areas might be due to the excessive use of agro-inputs such as phosphate fertilizers and organic manures which might contain cadmium as a contaminant. Rock phosphate, the major P fertilizer used in rubber and pineapple cultivation is reported to contain cadmium in trace levels (Auer, 1977; Javied *et al.*, 2009). Chromium content of soils in rubber-pineapple intercropping system was comparable with soil under rubber-cover crop system and was significantly lower than the forest soil.

Copper status of soils in rubber-pineapple intercropping system (16.43 mg kg^{-1}) was significantly lower than the rubber-cover crop system (26.17 mg kg^{-1}), and both these systems registered significantly higher copper content than the forest soil (2.27 mg kg^{-1}). This accumulation of copper in rubber growing soils is likely the result of continuous application of copper fungicides in rubber plantations. In mature rubber plantations, about 4.5 kg ha^{-1} copper is added annually through the use of copper fungicide. Copper addition through fungicides in immature rubber plantations is about 2.5, 3.75 and 5.0 kg ha^{-1} during the first, second and third year respectively. A study on the impact of continuous application of copper fungicides in the traditional rubber growing tracts of Kerala and Tamil Nadu observed significantly higher total and available copper levels in soils of sprayed plantations compared to unsprayed plantations and virgin lands, and in some areas, the total copper level exceeded the permissible limit of 100 mg kg^{-1} soil (KAU-RRII, 2000). Study on heavy metal contents in cocoa plantations of Cross River State, Nigeria showed soil contamination with copper resulting from the use of copper based fungicide against *Phytophthora* pod rot disease (Aikpokpodion *et al.*, 2010).

Zinc status of both the rubber based systems was comparable and rubber-cover crop soil showed significantly higher zinc content than forest soil. Significantly higher concentration of iron was observed in soil under rubber-pineapple intercropping, in comparison to rubber cover-cover crop and natural forest.

Manganese content in soil under rubber-pineapple intercropping (19.52 mg kg^{-1}) was significantly lower than the soil under rubber-cover crop system (32.96 mg kg^{-1}), which might be due to the uptake of manganese by pineapple plants. Silva *et al.* (2006) reported that pineapples are well adapted to acid soils containing large amounts of soluble manganese, and pineapple plants can absorb relatively large amounts of manganese resulting in iron deficiency. Both the rubber based systems showed significantly lower manganese status than the forest soil which had a manganese concentration of 61.14 mg kg^{-1}.

Ten per cent of the soil samples were analysed for 0.1 N HCl extractable arsenic and mercury contents by ICP-AES technique, and they were below the detection limit.

Results of the present study showed significant decline in soil pH and available calcium and magnesium, and significant increase in available phosphorus and potassium in soil under rubber-pineapple intercropping compared to soil under rubber-cover crop system. There was significant increase in cadmium and iron contents and significant decrease in lead, chromium, copper and manganese contents in the soils in pineapple intercropped area compared to cover cropped area. Compared to soil under natural forest, both the rubber based systems showed significantly lower pH and available calcium and magnesium. Compared to forest soil, significantly higher copper content and a build up of available P were also observed in soil under both the rubber based systems. The changes in nutrient and heavy metal status of soils under rubber clearly show the need for close monitoring of soil properties of rubber plantations, and devising appropriate management strategies to maintain sustainability.

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