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Using charcoal as a soil amendment in poly-bagged nurseries of rubber (*Hevea brasiliensis* (Muell.) Arg.) in Sri Lanka

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Introduction

Rubber is being grown in Sri Lanka over an extent of 122,000 ha on rolling to undulating terrains that receive monsoon rains. Inherently less fertile soils in these landscapes are degrading due to cultivation of rubber as a mono-crop for more than 125 years and poor adoption of soil management practices. Decrease in soil organic carbon reserves and top soil erosion could be identified as major causes of soil degradation in these lands. In order to increase the land productivity, arresting further degradation and improving soil fertility status is essential.

Various organic soil amendments have been recommended for land application to enhance soil fertility [1], but their residence time is so short under hot and humid climatic conditions in tropical environments [2], that constant application is required to achieve sustainable fertility improvement. Although the land application of biochar (BC) could be a viable and sustainable technology to arrest further degradation of these soils [3], agronomic effectiveness of this technology in rubber plantations is yet to be evaluated. The objective of this study was to determine the response of rubber plants to charcoal application, using poly-bagged plants under nursery conditions.

Methodology

Commercially available timber mill charcoal was ground to pass through 2-mm sieve, mixed with soil (Typic hapludult) at a rate of 1% (w/w) and filled into polyethylene bags (15×45 cm lay flat dimensions). Five treatments, (1) soil only, (2) soil+recommended rates of NPKMg fertilizer, (3) soil+charcoal only, (4) soil+charcoal+50% recommended rates of NPKMg fertilizer, (5) soil+50% recommended rates of NPKMg fertilizer, and were arranged according to a completely randomized design under field conditions. There were 20 single plant poly-bags per treatment. Growth and nutrient uptake of plants were measured at two important growth stages (pollarding of the successfully bud-grafted seedling plant and when the new scion is 3 month old: i.e., 4 and 8 months after planting, respectively). Soil properties were measured at the beginning and end of the experiment.

Results and Discussions

The used charcoal had a pH of 9.55 and a CEC of 15.9 cmol(+) kg^{-1}. Organic matter content was 824 g kg^{-1} and total N content was 2.6 g kg^{-1}. The mineral content of it was 17.6% and were rich in exchangeable K, Mg and Ca, 2662, 407 and 5181 mg kg^{-1}, respectively.

Growth of the seedling and scion plants had been significantly retarded in charcoal applied treatments compared to those in soil + NPKMg applied treatments (Table 1). Compared to plants in the recommended fertilizer treatment dry matter contents of the seedling and scion plants in the 1% charcoal only treatment decreased by 43 and 36%, respectively.

Table 1. Growth and leaf nutrient contents

Treatment	Seedling dry matter		Scion dry matter		Leaf N		Leaf P		Leaf K		Leaf Mn	
	g $plant^{-1}$		g $plant^{-1}$		%		%		%		µg g^{-1}	
soil only	15.7	c	11.8	b	1.96	b	0.15	b	0.70	c	112	ab
soil+recomnd fertilizer	28.7	a	15.8	ab	2.98	a	0.25	a	1.07	b	171	a
soil+1% charcoal only	16.4	c	10.1	b	2.32	ab	0.24	a	1.31	a	36	c
soil+1% charcoal + 50% recomnd. fertilizer	24.3	b	14.8	ab	2.48	b	0.24	a	1.33	a	101	b
soil+50% recomnd. fertilizer	28.7	a	18.3	a	2.78	a	0.19	ab	1.04	b	119	ab

* Values followed by the same letter in a column are not significantly different at $p<0.05$.

However, addition of 50% of the recommended fertilizer together with 1% charcoal improved the growth but not up to the level of the two fertilizer only treatments.

Charcoal added plants showed nutrient deficiency symptoms similar to N and Mn. Leaf analysis data confirmed that N and Mn contents in the plants were significantly low in the charcoal added treatments (Table 1). Low N status in charcoal treated plants could be attributed to the high C/N ratio of the charcoal used [4]. Readily decomposable forms of organic C present in charcoal [5] could increase demand for soil available N by microorganisms resulting the N deficiency. Increase in microbial growth due to improvements in the habitable space may be another reason for reduction in N availability in soils amended with charcoal. In our study, application of charcoal with 50% of the current fertilizer recommendation did not improve the leaf N levels compared to that in the charcoal only treatment. This suggests that N fertilizer applied was not enough to improve leaf N status when charcoal is applied at a rate of 1%.

Generally, Mn availability is not a problem in rubber growing soils in Sri Lanka due to low pH in these soils, even though the Mn concentrations are low [6]. Application of high alkaline charcoal (pH=9.55) increased the soil pH by 1.4 units immediately after charcoal addition and the soil pH was still 0.5 units higher than pH in charcoal treated soils at the end of the 8 month experiment period. Therefore, low availability in Mn after charcoal addition could expected to be due to the increase of the pH.

Interestingly, application of charcoal has improved P nutrition, in addition to K and Mg nutrition, of the plant compared to those in the soil only treatment (Table 1). K and Mg improvements could be due to the high K and Mg contents in the used charcoal. The liming effect of the charcoal which increased soil pH and completely removed exchangeable Al observed in BC amended soils even at the lowest rate (10 Mg ha^{-1}) of BC application [7]. In addition to the increases in soil pH towards neutral values, BC could influence mycorrhizal abundance and/or functioning resulting an increase in bio-available P in soils amended with biochar [8].

Conclusions

Beneficial effects of land application of BC could be realized in rubber plantations only if its agronomic effectiveness is ascertained. Results of this preliminary study using poly-bagged nursery plants of rubber revealed that application of 1% (w/w) timber mill charcoal, commercially available in Sri Lanka, has negative impact on the growth of the rubber plant. However, these effects could be attributed, at least in part, to the availability of plant nutrients, such as N and Mn, which could easily be altered by judicious application of chemical fertilizers. Therefore, further investigations on different rates and types of charcoal with different N and Mn rates are needed in order to realize the benefits of land application of BC in rubber plantations.

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