

## RUBBERWOOD BIOCHAR: PRODUCTION AND SOME AGRONOMIC BENEFITS WHEN USED IN RUBBER NURSERIES

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### ABSTRACT

Maintaining an appreciable level of organic matter content and biological activity in soil is important for a sustainable productivity in rubber growing soils. Thermochemical conversion of organic residues and wastes



into a recalcitrant solid product called biochar and land application is an alternative and sustainable technology to enhance soil fertility and plant growth. In raw rubber manufacturing factories, biochar could be easily produced from part of the firewood used employing a retort method with about 25 to 30% conversion efficiency. Rubberwood biochar thus produced is a very alkaline material rich in plant nutrients such as K, Mg and Ca and also has a C content around 80%. Amending rubber growing soils with rubberwood biochar has improved soil fertility parameters and in turn improved the growth of young budding plants. When nursery soils are amended with rubberwood biochar, P and K fertilizer in the currently recommended liquid formulation could be cut-down completely.

**Keywords:** Biochar, *Boralu* series, rubber, rubberwood, soil fertility, young budding

### INTRODUCTION

Fertility decline in soil is one major factor for low productivity in the plantation sector as is the case for agricultural sector. According to a worldwide assessment of soil degradation problems about 61% of agricultural lands in Sri Lanka is badly affected by fertility decline (FAO, 1994). It could be due to many causes, but the foremost are the loss of fertile top soil by water erosion, decrease in soil organic matter reserves, loss of nutrients, acidification and indiscriminate fertilizer use. In order to increase the soil fertility inorganic and organic fertilizers are applied by many growers. Efficiency of inorganic fertilizer usage is improved by applying organic fertilizers. Organic fertilizers not only add carbon into soil but also provide an important source of macro and micro nutrients. They also provide food and energy to microbial community in the soil, who plays a pivotal role in maintaining soil fertility. Hence, maintenance of an appreciable level of organic matter content and microbial activity in soil is of prime importance for the sustenance of any crop production system.

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Commonly adopted practices to increase organic matter content in rubber growing soil are the application of compost, crop residues, green manures, growth of a cover crop and application of animal wastes and manures (Yogaratnam and Silva, 1987). However, under hot and humid conditions in tropical countries such as Sri Lanka, organic matter decomposes very rapidly requiring repeated application in large quantities. Alternatively, organic matter can be thermochemically converted into more a resistant material, named as biochar, and use it as a soil amendment to improve soil fertility and crop production in a sustainable manner (Glaser et al., 2001, Lehman et al, 2003; Lehmann and Rondon, 2006). This technology has been evolved based on the investigations carried out on some very fertile black earth (*Terra Preta de Indio*) found in areas where native Indians in the Amazon forest lived prior to the European invasion of the South American sub-continent. Ironically the Amazon forest is the native place of the rubber tree, now extensively grown in the south and southeast Asian countries.

Biochar is the solid material obtained after heating biomass under no or limited oxygen condition. This process is called pyrolysis. Biochar has a very high surface area and the charge density is also high. This provides a high cation exchange capacity. It has been found that cation exchange capacity of biochar increases with time once applied into soil (Liang et al, 2006). Biochar also has large quantity of pore space which can hold moisture and provide ample habitable space for micro organisms. Plant nutrients such as Ca, Mg, K and sometimes P are rich in biochar. Collectively these properties of biochar has increased pH, cation exchange capacity, microbial activity in soil, nutrient availability and plant available water content is tropical soils (Atkinson et al., 2010; Sohi et al., 2010). Improvements in soil fertility parameters has resulted high plant growth and crop yields.

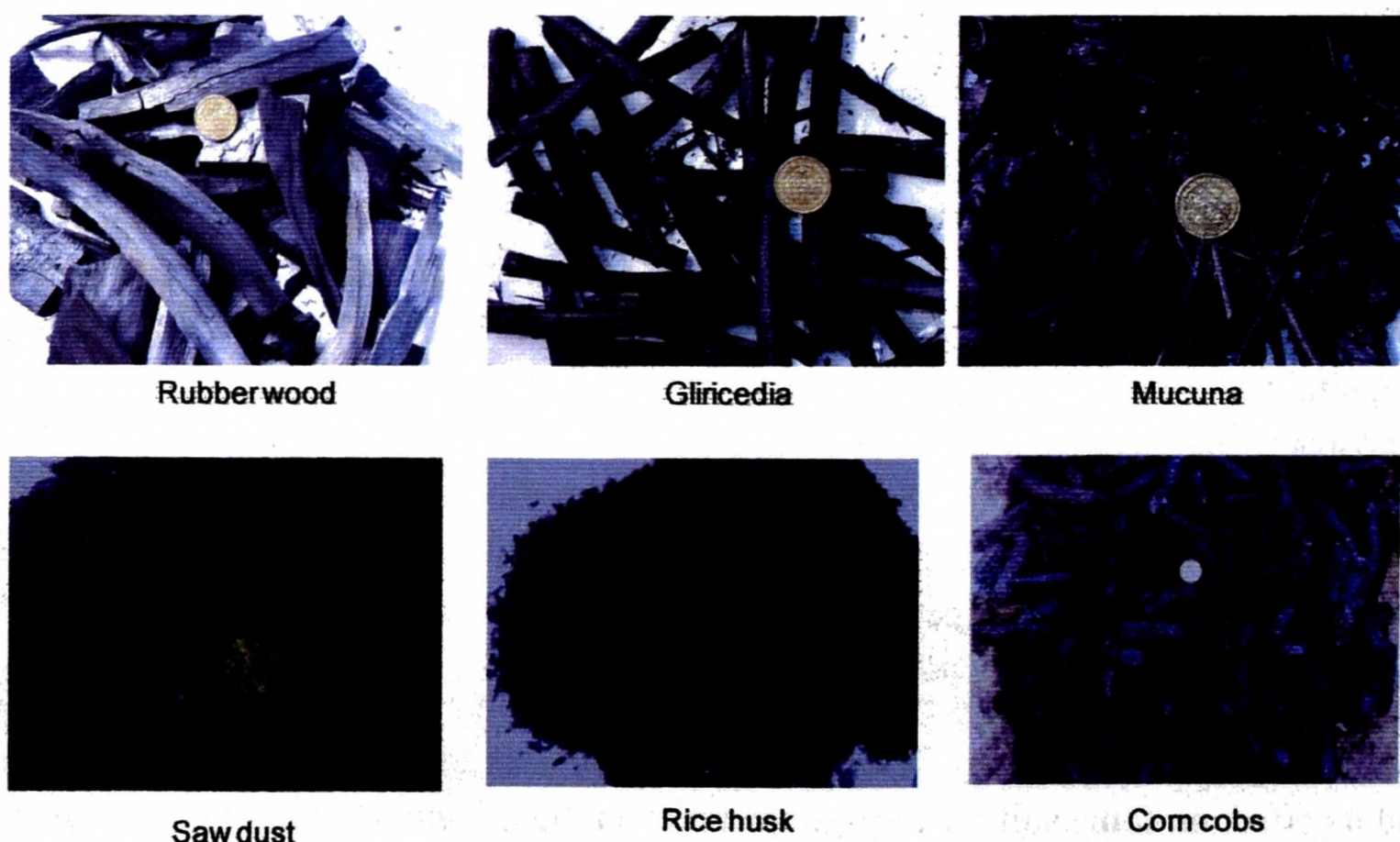
Any biomass could be used to produce biochar but the quality varies depending on the feedstock and the pyrolysis conditions, particularly the temperature. Therefore the effectiveness of biochar as a soil amendment and in turn on plant growth also varies with the type of biochar. Firewood used in raw rubber manufacturing factories and households is mostly rubberwood and after burning only ash is left releasing almost all C and some essential plant nutrients back to the atmosphere. Release of CO<sub>2</sub> to the atmosphere aggravates green house gas effect on global warming. However, by controlling the burning conditions to promote pyrolysis of rubberwood, about 50% of C and considerable amount of plant nutrients can be retained as biochar which then can be used as a soil amendment.

The objectives of this article are to describe a method that can be adopted to produce biochar in raw rubber manufacturing factories, to characterize rubberwood biochar and its effect on some soil fertility parameters and the growth of young budding plants in a commercial nursery.

## Biochar production

Traditional way of producing biochar is to pile up dry biomass in a pit and fire it. When the biomass started to burn rapidly, the pile is covered with earth and allows the pyrolysis to occur and complete. This method not only releases lots of hazardous green house gases to the atmosphere but also recovery of biomass as biochar is very small. In rubber plantations however, a relatively more efficient and environmentally friendly retort method could be adopted.

In the retort method air-dried firewood (~18% moisture w/w), chopped to about 3 – 6 cm thick and 40 cm long pieces, packed tightly into a 30 cm diameter × 45 cm height metal container having few 1-cm diameter holes at the bottom. The length of the chopped firewood however could be varied based on the height of the container used. The container is then closed with the lid, placed in the middle of firewood inside a furnace of a raw rubber manufacturing factory. The firewood in the furnace was then fired. A temperature over 600°C should be maintained inside the furnace by adding firewood periodically. During the pyrolysis, some gases are produced and escaped through the holes in the container. These syngases will be auto-ignited due to the temperature inside the furnace adding heat required for pyrolysis. When the syngas production was exhausted, around 2 to 3 hrs, the container is retrieved from the furnace and the produced biochar was quenched with water immediately to prevent rapid oxidation and self-ignition. About 25-28% dry biomass had been converted into biochar in this method. Plate 1 show biochar produced from different feedstock materials (rubber firewood, *Gliricidia*, *Mucuna* slashings, rubberwood saw dust, paddy husk and corn cobs) available in and around rubber plantations.



**Plate 1. Biochar produced from different sources of biomass available around rubber plantations**

If we assume 0.2kg of firewood is required to dry 1kg of crape rubber (Seneviratne, 2003), for drying of crape rubber produced from a estate having 100ha of mature rubber and 1000kg of YPH requires 200,00kg of firewood. With a nominal biochar production efficiency of 15% this estate has the potential to produce 3 tons of biochar per year from currently use firewood alone. This can be increased if more efficient pyrolysis units could be introduced to factories. Use of other biomass sources available in rubber plantations also helps to increase the capacity of biochar production in a raw rubber manufacturing factory.

### **Characteristics of rubberwood biochar**

Biochar contains about 70-80% carbon, 5-10% mineral matter, 15-20% moisture. Mineral matter in biochar is enriched in plant nutrients such as P, Mg, K and Ca. High concentration of basic cations in biochar gives a strongly alkaline pH (Table 1). Therefore once applied into soil, biochar tends to increase soil pH at least by 1 to 1.5 units soon after application. Dharmakeerthi et al (2012) observed that in a rubber growing RYP soil in the Kalutara region (*Agalawatta* series), the pH was higher by 0.5 to 1 unit even after 9 months after rubberwood biochar application. As could be expected plant available K, Mg and Ca contents in biochar applied soils is high. Rubber growing soils in the country are deficient in K and sometimes Mg. Since the application of biochar could increase the availability of these plant nutrients and change their relative proportions, judicious application of chemical fertilizers in rubberwood biochar amended soils is very important (Dharmakeerthi et al., 2010; 2012).

Carbon content of biochar is about 80% compared to 50% in rubberwood. Not only the carbon content is high in biochar but also these carbon consist of aromatic compounds that are very resistant to microbial decomposition (Baldock and Smerink, 2002). Therefore once applied into a soil, biochar exists in those soils for hundreds of years if not millennia contributing benefits associated with it into the soil-plant system. It has very high surface area per unit of mass, mainly due to creation of micro and nano scale pores during the pyrolysis process. These surfaces are often charged. Once applied into soil and with time the charge density increases significantly (Liang et al, 2006) and remarkably improves plant nutrient retaining properties of the soil. The cation exchange capacity (CEC) of rubberwood biochar is around 14.0 cmol(+) kg<sup>-1</sup>. And amending soils with 2% biochar has increased the CEC significantly from 4.7 to 6.2 cmol(+) kg<sup>-1</sup>. Because of high porosity, biochar can hold lot of soil moisture (Mapa et al., 2012) and provides a habitable space for microorganisms that helps plant growth.

**Table 1. Comparison of properties of a soil, rubber firewood and rubberwood biochar and soil biochar mixture at the end of nursery period.**

Property	Unit	Soil	firewood	Biochar	Soil+2% Biochar
pH		5.3	6.3	9.6	6.5
Cation exchange capacity	cmol(+) kg <sup>-1</sup>	4.7	8.2	13.9	6.2
Organic C	%	0.82	51	80	1.14
Ash content	%	97	0.9	5	-
Total N	%	0.09	0.5	0.5	0.12
Available P	ppm	8	394	747	44
Exchangeable K	ppm	78	2747	6895	160
Exchangeable Mg	ppm	22	311	908	40
Exchangeable Ca	ppm	248	997	9799	379

**Effect on nursery plants**

In order to investigate the effect of rubberwood biochar on the growth of rubber nursery plants, an experiment was conducted with *Boralu* series soils at Paiyagala Estate young budding nursery site. Rubberwood biochar was mixed with soil at 1:16 and 1:8 ratios on volume basis and filled into polybags with 50g HERP. Based on observations from previous experiments (Dharmakeerthi et al., 2010; 2012). Phosphorus and K in the young budding fertilizer mixture recommended for *Boralu* series soils, R/YB/7:9:9:3, were completely removed in biochar added soils. Two other treatments, i.e. with recommended levels of N-P-K-Mg or only N-Mg but without biochar addition were also included for comparison purposes. Growth of young budding plants was measured periodically until the end of nursery period. In addition grafting success and sprouting of the successfully grafted bud patches were also recorded.

**Table 2. Growth, grafting success and sprouting of young budding plants that received rubberwood biochar and/or N-P-K-Mg chemical fertilizers.**

Treatment	Seedling at 14 weeks after planting		Grafting success (%)	Sprouting (%)	Scion at 8 weeks after cut-back	
	Diameter (mm)	Height (cm)			Diameter (mm)	Height (cm)
N-Mg only	8.1 <sup>b</sup>	79 <sup>b</sup>	83 <sup>b</sup>	93 <sup>ab</sup>	7.1 <sup>c</sup>	45 <sup>c</sup>
N-P-K-Mg	8.9 <sup>a</sup>	90 <sup>a</sup>	92 <sup>a</sup>	82 <sup>c</sup>	8.2 <sup>b</sup>	60 <sup>b</sup>
1:16 biochar + N-Mg	8.9 <sup>a</sup>	92 <sup>a</sup>	92 <sup>a</sup>	98 <sup>a</sup>	8.5 <sup>ab</sup>	64 <sup>a</sup>
1:8 biochar + N-Mg	9.1 <sup>a</sup>	90 <sup>a</sup>	95 <sup>a</sup>	89 <sup>b</sup>	8.7 <sup>a</sup>	66 <sup>a</sup>

Values within a column followed by same superscript are not significantly different at p<0.05

The growth of the seedling plant in biochar amended soils was comparable to that in the currently recommended inorganic fertilizer treatment whereas the growth of the scion plant was significantly better in the biochar added treatments. Growth of the plants in these three treatments was better than those that received only N-Mg (Table 2). Comparison of the growth of young budding plants that received 1:16 biochar+N-Mg and N-Mg only is shown in Plate 2. Observations made during this experiment were comparable to those observed by Dharmakeerthi et al (2012) using *Agalawatta* series soils and rubberwood biochar at 1 to 2% on weight basis. Grafting success were more than 90% in all but N-Mg treatment and they were not significantly different. Sprouting was significantly better in the three treatments that did not receive P and K as liquid fertilizers. Root causes for the improved growth of *Hevea* plants in biochar amended soils have yet to be investigated. However, it is speculated that better growth of young budding plants, particularly after cut back, could be due to better and balanced nutrient availability (Laired et al, 2010) and probably be also due to some microbiological interactions (Anderson et al, 2011; Lehmann et al., 2011) in the *Hevea* root rhyzosphere that increased P uptake and/or release of plant growth promoting hormones.



**Plate 2. Comparison of the growth of young budding plants that received 1:16 biochar+N-Mg and N-Mg only**

### Conclusion

Biochar could be made from firewood used in raw rubber manufacturing factories using a simple retort method. This method could be used to convert any other biomass available in and around rubber plantations into biochar. Rubberwood biochar thus produced improves soil fertility parameters. As a result, mixing them with soils used for young budding nurseries could increase the growth of young budding plants and also cut-down P and K fertilizer usage by 100% in these nurseries. Experiments should be conducted to investigate whether similar agronomic benefits could be obtained when rubberwood biochar is applied for immature and mature clearings.

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