Short Term Crop Response for Municipal Solid Waste Compost on Soil Amended with Refused Tea Derived Biochar in Low pH Soil

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ABSTRACT

Municipal solid waste (MSW), is a growing problem in urban areas of Sri Lanka and it is aggravated due to absence of proper solid waste management systems in the country. Compost production using municipal waste is a common activity in powder form and rarely in pellet form. Further, refused tea has become a rising environmental and commercial problem due to its slow decomposing nature and tough government regulations on disposing and transportation. Accelerated compost production and biochar production using refused tea is being investigated in several studies. This study was focused on utilization of refused tea as biochar in amending low pH soil and evaluating performance of short term crop fertilized with municipal waste compost. The growth and yield characteristics of radish (*Raphanus sativus* L.) plants were used to evaluate the MSW compost+soil amended biochar. Significant increase in vegetative growth parameters and 30 to 55% yield increment over current Department of Agriculture recommendations were observed in radish fertilized with MSW and soil amended with biochar. The yield deference was not significant between MSW powder and pellet form. Thereby 31 to 39 tons/ha of harvest can be achieved by amending soil with 10 tons/ha of refused tea biochar and using MSW compost as fertilizer. Further results revealed that refused tea biochar can be used as a soil amendment to increase the pH in low pH soils.

KEYWORDS: Biochar, Municipal solid waste compost, Radish, Soil amendment, Tea waste

INTRODUCTION

Refused tea is a waste during the course of manufacture of tea as of Tea Control Act of Sri Lanka, No.51 of 1957. Refuse tea is defined as sweepings, tea fluff, red leafs, mature stalks, or any other product obtained in the process of manufacture of tea. About 4-6% total product of made tea is removed as refuse tea (Zoysa, 2005). Annual refuse tea production of Sri Lanka is estimated to be around 20 to 25 million tons (Anon, 2014).

There is a rising illegal market for refuse tea and it has become a challenge for prestige of the Ceylon tea market (Keegel, 1983). Refused tea management practices have a serious impact on environment like burning and dumping into landfills (Bai *et al.*, 2013).

The compost prepared using refused tea could be beneficial for the Agricultural land in many ways, as a soil conditioner, a fertilizer, addition of vital humus or humic acids and as a natural pesticide for soil. It is economical and environmental friendly as it reduces the need for manufactured fertilizer inputs (Rollett *et al.*, 2010). But preparation of compost using refused tea is a slow process due to its chemical nature and bulk of refused tea accumulate year by year leading to many problems.

Biochar is a solid material obtained from the thermo-chemical conversion of biomass in an Oxygen-limited environment (Lehmann and Joseph, 2015). It is a means of managing waste since mass from crop residues, weeds, surplus biomass, grasses, excess forest litter, animal manures, municipal waste, *etc.*, can be used for conversion into biochar (Anon, (2015).

Biochar is a soil amendment that enhance the nutrient retention capacity (NH^{4+}, K^+, Ca^{2+}, Mg^{2+} and OH^-; Lawrinenko, 2014) that reduces the total fertilizer requirements by reducing the loss of nutrients via leaching, high cation and anion exchange capacity, long-term soil carbon sequestration and as an avenue for greenhouse gas mitigation (Lehmann *et al.*, 2006).

Municipal solid waste (MSW) is a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region (Nath, 1993). The four major steps of MSW composting system are collection, separation, size reduction and mixing. Mainly MSW compost powder and pellets are produced. Pellet form is easy to store, transport and incorporate with soil.

Optimum nutrient uptake by most crops occurs at a soil pH near 7.0. Soil pH affects crops in many ways and its effects are mostly indirect, through its influence on chemical factors and biological processes. Thus, reduced fertilizer use efficiency and crop performance can be expected in low pH soil (Nduwumuremy, 2013).

Radish (*Raphanus sativus* L.) is used as a vegetable or salad in Sri Lanka. Radish belongs to family Brassicaceae and it is one of the vegetables that can be grown in all agro ecological regions of Sri Lanka throughout the year if adequate moisture is available (Anon, 2013). There are three main Radish varieties recommended for Sri Lankan conditions as Japan Ball, *Beeralu Rabu* and Table Radish. *Beeralu Rabu* is the recommended variety for low country, and Japan ball is recommended for up country, Sri Lanka (Manawadu and Dahanayake, 2015). *Beeralu rabu* has spindle shape roots, white skin leaves neither lobed nor pubescent. Harvesting time is 45-50 days. The average yield is 20-30 t/ha (Anon, 2013). Due to short postharvest life, it has been used for different field trials worldwide.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Regional Agriculture Research and Development Centre, Makandura, Gonawila (NWP), Sri Lanka from January to May 2016. It is situated in IL_{1a} Agro Ecological Zone where maximum and minimum temperatures were 35.6 °C and 20.8 °C respectively. The soil type is sandy loamy which consists of alluvial soil as a top layer (Anon, 2013). The pH of the soil was 3.7.

Preparation of Biochar

Two different sized metal barrels were used (the bigger being 200 L volume with 56 cm diameter and 84 cm height and small being 110 L volume with 45 cm diameter and 68 cm height). Refused tea was loaded into the smaller barrel and it was placed upside down within the large barrel. Dry hardwood was placed in the space between the two barrels and set fire for 3 h (>300 °C). After complete pyrolysis process it was left to cool overnight.

Crop Establishment and Maintenance

First, biochar was applied to plots two weeks before seed sowing (1 kg/m^2) by mixing it with the top soil up to a depth of 10 cm from bed surface. Basal dressing was added as given in the Table 1 and one week before seed sowing radish seeds var. *Beeralu* were sawn as two seeds per hole (10×25 cm). Top dressing was applied three weeks after seed sowing.

Irrigation was done manually and irrigation intervals were adjusted according to the prevailing weather conditions. Earthing up was done weekly. Manual weeding, pest and disease control and other cultural practices were done according to the recommendations of the Department of Agriculture (DOA). Thinning out was performed three weeks after seed germination leaving one well grown, vigorous, healthy and uniform seedling per planting hole.

Tested Fertilizer Combination

Four types of fertilizer were used with 1 kg/m^2 biochar (Table 1).

Experimental Design

Four treatments were arranged in a Completely Randomized Block Design (RCBD) with four replicates. There were bounded guard rows for whole site and for individual plots.

Data Recording

Data were collected from eight randomly selected plants from each treatment from each replicate.

Vegetative Parameters

Number of Leaves

Number of leaves was counted two weeks after seed sowing and continued weekly.

Canopy Height

Canopy height was measured from the base collar to the tip of the highest leaf two weeks after seed sowing and continued weekly.

Leaf Dry Mass

Dry weight of the leaves were measured at harvesting from six randomly selected plants. Leaves were dried in an oven at 80 °C for 72 h.

Petiole Dry Mass

Dry weight of the leaf petioles were measured at harvesting from six randomly selected plants. Petioles were dried in an oven at 80 °C for 72 h.

Table 1. Tested fertilizer combination

Code	Treatment	Basal dressing kg/ha			Top dressing kg/ha		
		Urea	TSP	MOP	Urea	TSP	MOP
T_0	DOA Recommended fertilizer	85	110	65	85	-	65
T_1	DOA Recommended fertilizer +Biochar	85	110	65	85	-	65
T_2	MSW compost powder + Biochar		2854			2854	
T_3	MSW compost pellets + Biochar		2854			2854	

T_0- Department of Agriculture recommended fertilizer, T_1- Department of Agriculture recommended fertilizer+Biochar, T_2- Municipal solid waste compost powder+Biochar, T_3- Municipal solid waste compost pellets+Biochar, DOA- Department of Agriculture, MSW- Municipal solid waste, TSP- Triple super phosphate, MOP- Murate of potash

Root Dry Mass

Dry weight of the roots were measured at harvesting from six randomly selected plants. Roots were dried in an oven at 80 °C for 72 h.

Yield Parameters

Harvesting was carried out 50 days after seed sowing. Data were recorded as overall yield per plot. Six plants were randomly selected from harvesting and their fresh weight were taken separately as roots, leaves, leaf petioles and tubers. Dry weights were also taken by weighing after oven drying at 80 °C until a constant weight was obtained.

Tuber Dry Mass

Dry weight of the tubers were measured at harvesting from six randomly selected plants. Tubers were dried in an oven at 80 °C for 72 h.

Yield

Fresh weight of total biomass in each replicate per treatment were recorded at harvesting.

Statistical Analysis

ANOVA was used to analyse the data using SAS Statistical software (version 9.4).

RESULTS AND DISCUSSION

Vegetative Parameters

Number of Leaves

Number of leaves were significantly different among treatments amended with biochar and without biochar (Table 2). Department of Agriculture recommended fertilizer had the lowest value (18/plant) while the highest was the same with biochar (29/plant). But Number of leaves of T_1 were not significantly different from MSW compost added treatments.

Canopy Height

Canopy height was significantly different between treatments amended with biochar and without biochar (Table 2). Department of Agriculture recommended fertilizer recorded the lowest (20.7 cm) while T_2 had the highest (29.5 cm) value. Canopy height was significantly different among treatments amended with biochar.

Leaf Dry Mass

There was a significant difference among the treatments in leaf dry mass (Table 2; Figure 1). T_0 recorded the lowest value (32 g/m^2) whereas MSW powder recorded the highest value (96 g/m^2).

Petiole Dry Mass

There was a significant difference among the treatments in petiole dry mass (Table 2; Figure 1). Department of Agriculture recommended fertilizer recorded the lowest value (13.2 g/m^2) whereas T_1 had the highest value (25.2 g/m^2).

Root Dry Mass

There was a significant difference among the treatments in root dry mass (Table 2; Figure 1). Department of Agriculture recommended fertilizer recorded the lowest value (1.36 g/m^2) and the highest value was recorded in DOA recommended fertilizer with biochar (2.68 g/m^2).

Yield Parameters

Tuber Dry Mass

Tuber Dry Mass was significantly different among the treatments (Table 2, Figure 1). The lowest (60 g/m^2) and the highest values (148 g/m^2) were recorded in DOA recommended fertilizer and MSW compost powder with biochar respectively.

Yield

Department of Agriculture recommended fertilizer recorded the lowest yield (1810 g/m^2 ±196 g; Table 2; Figure 2) whereas the MSW pellet with biochar recorded the highest yield (3508 g/m^2 ±462 g).

Table 2. Mean values of quantitative vegetative parameters and yield parameters

T	Vegetative parameters						Yield parameters	
T	Plant/ plot	Leaves/ plant	Canopy height (cm)	Leaf mass DM (g/m^2)	Petiole mass DM (g/m^2)	Root mass DM (g/m^2)	Tuber mass DM (g/m^2)	Yield (g/m^2)
T_0	23	18 ±2^c	20.7 ±3.2^b	32 ±2^d	13.2 ±0.5^c	1.36 ±0.05^c	60 ±3^d	1,810 ±196^f
T_1	22	29±3^a	26.8 ±3.3^a	36 ±5^b	25.2 ±0.5^b	2.68 ±0.07^a	96 ±3^c	2,563 ±281^{dc}
T_2	20	25 ±2^{ab}	29.5 ±3.3^a	96 ±4^a	21.2 ±0.8^a	2.64 ±0.07^a	148 ±3^a	3,425 ±370^{ab}
T_3	22	26 ±4^{ab}	28.1 ±2.5^a	72 ±3^b	25.2 ±0.5^b	2.00±0.03^{bc}	120 ±2^b	3,508 ±462^a
cv		10.87	10.25	12.00	9.46	8.53	9.42	13.99
p		0.0006	0.02	0.0001	0.0001	0.0001	0.0001	0.0001

Means in a column with the same letters are not significantly different at the 0.05 probability level. T- Treatment, DM- Dry matter, T_0- Department of Agriculture recommended fertilizer, T_1- Department of Agriculture recommended fertilizer+Biochar, T_2- Municipal solid waste compost powder+Biochar, T_3- Municipal solid waste compost pellets+Biochar, cv- coefficient of variance, p- significant probability value

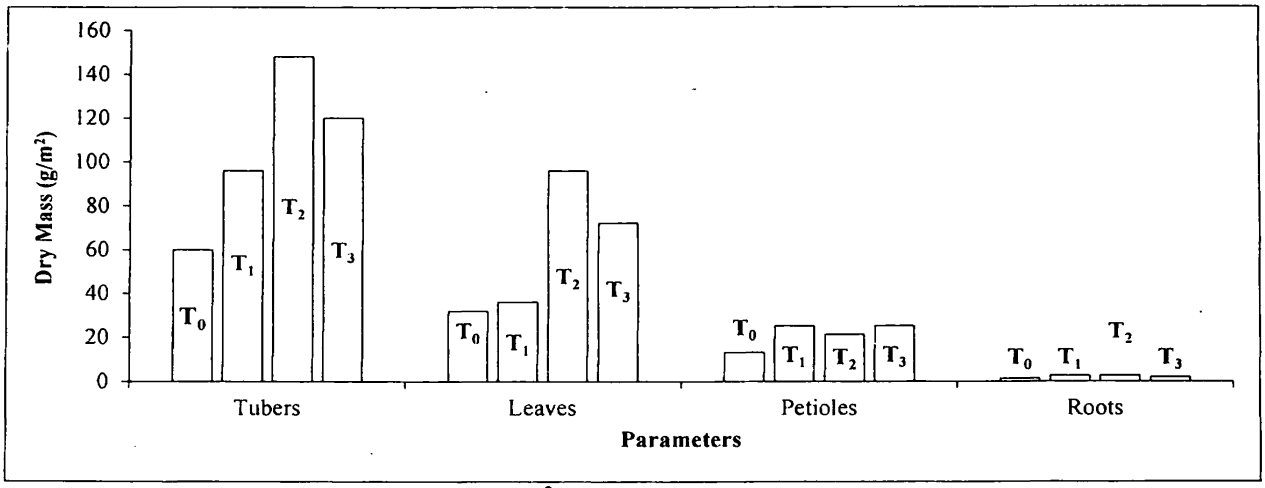

Figure 1. Average plant dry mass (g/m^2). *T_0- Department of Agriculture recommended fertilizer, T_1- Department of Agriculture recommended fertilizer+Biochar, T_2- Municipal solid waste compost powder+Biochar, T_3- Municipal solid waste compost pellets+Biochar*

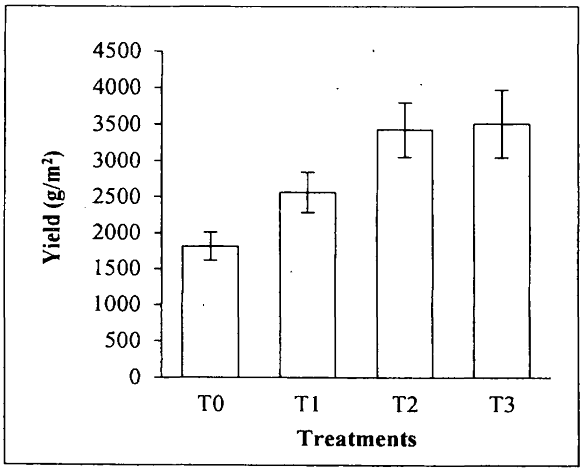

Figure 2. Average plant dry mass (g/m^2). *T_0- Department of Agriculture Recommended fertilizer, T_1- Department of Agriculture recommended fertilizer+Biochar, T_2- Municipal solid waste compost powder+Biochar, T_3- Municipal solid waste compost pellets+Biochar*

The MSW pellet yield and MSW powder yield (3425 g/m^2 ±370 g) were not significantly different.

The results show significant treatment effect in both vegetative and yield parameters. Department of Agriculture recommendation had the lower values for vegetative and yield parameters. The DOA recommendation with biochar shows significantly better performance than DOA recommendation without biochar. The DOA recommended yield productivity is 20 to 30 t/ha. However under the study condition (irrigated water and average day time temperature of 33 °C) the recorded yield with DOA recommended fertilizer was 16 to 20 t/ha. With same conditions, when the recommendation was used with biochar the yield was 22 to 28 t/ha.

Soil pH

The soil used for this research work was acidic (3.72±0.46). The initial pH of biochar was 6.89. After adding biochar the soil pH was improved up to 4.4±0.5 with significant difference.

CONCLUSIONS

Use of biochar with MSW compost increase vegetative growth significantly with compared to DOA recommendations. By combining MSW compost and soil enrichment with biochar, 30 to 55% yield increase can be achieved over current DOA recommended practices for radish. The yield difference was not significantly different between MSW powder and pellet form. It was estimated that 31 to 39 t/ha of harvest can be achieved by incorporating the soil with 10 t/ha of biochar made with refused tea coupled with MSW compost as fertilizer. Although no yield advantage of MSW compost pelleted form was found over powder form storage, transportation and incorporation are easy and economical in pelleted form.

The biochar made from refused tea can be used to increase the soil pH in low pH soils by 18% (0.7 increment) as an average.

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