The last long effect of bamboo biochar and rice husk biochar application to growth and yield of draft cherry tomato, carrot and spinach

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Abstract

This study evaluated the last impact of bamboo and rice husk biochars on cherry tomato at the first season, carrot at the second season and and spinach at the third season. The experiment was conducted under glasshouse conditions at Hakozaki campus, Kyushu University, Japan. There were 7 treatments, namely Control (no biochar); RH2, RH5 are 2% and 5% per weight of rice husk biochar; UB2, UB5 are 2% and 5% per weight of the open burn bamboo biochar; CB2, CB5 are 2% and 5% per weight of furnance bamboo biochar manufactured with at 500°C. At the first season, bamboo biochar application significantly improved tomato's growth (number of leaves, fresh biomass weight), yield (number of fruit; fresh yield) and quality (total sugar content 56% - 91%). However, the last impact of bamboo biochar on carrot and spinach after tomato were not clear except UB5 and CB2. Besides, rice husk biochar had a positive impact only on tomato's sugar content at the first season and its last effect also was found for spinach's yield at the third season (40%-81%). Finally, the soil physicochemical properties were found few changes in plant available water increasing by 25%-38% and 9%-18% at before and after experiment, respectively; Total soil N aslo increased by 11%-14% after experiment in bamboo treatments compared with that of before experiments.

Keywords: Bamboo; rice husk; biochar; last long, soil property, yield.

1. Introduction

Biochar is produced when biomass is heated in a closed container with little or no available air (Lehmann and Stephen, 2009). Its utilization in large scale in agriculture is expected to improve soil properties, as well as reduce greenhouse gas emissions such as carbon dioxide gas and methane gas (Woolf *et al.*, 2010).

Biochar types vary depending on the raw material, pyrolysis time and temperature. Rice and bamboo are two typical crops in Asia Pacific region. While rice is the most important food crop and 90 % of world's rice is produced and consumed in this region (FAO, 2000), bamboo is a major non-wood forest and wood substitute found in all regions of the world (FAO, 2005). Rice husk is one product of rice production. It is the outermost layer of rice seed and it counts for around 20% of total rice production, equivalent to 154 million tons produced annually in Asian countries (Santiaguel, 2013). The problem here is to manage the rice husk production effectively not only for economic reasons but also to prevent environmental pollution from burning it. Similarly to rice husk, bamboo area covers over 6.3 million km2 in Asian countries (N. Bystriakova *et al*., 2014). It is known as an easy-growing plant and more than ten million farmers are involved with bamboo production, adding up to 35 million jobs (Hogarth and Belcher, 2013). The rapid growth of bamboo forest tends to overpower other plant species and become a monoculture forest, contributing to the loss of biodiversity, soil nutrition, and damaging soil's physical structure (Buckingham *et al*., 2011). Using rice husk and bamboo as biochar raw materials seems to be a good solution that not only helps to solve those environmental problems mentioned above, but also effectively uses the available material in Asia countries.

Many previous papers have evaluated the effects of biochar on physical and chemical properties as well as soil microorganisms (Diamadopoulos, 2016) such as soil pH, bulk density, porosity, water retention, nutrient absorption and microorganisms habit in the soil. There are also numerous papers that identify the impacts of biochar on growth, yield, and quality on crops such as rice, maize, soybean, pepper, etc. (Yilangai *et al.*, 2014). However, there were few papers that compared the effects of rice husk and bamboo biochar on crop, two major materials in Asian regions and how the biochar last long effect to crop's yield. Hence, authors wanted to identify these issues in this study as well as had a firsthand account about it.

2. Material and Methods

2.1. Biochar, soil and compost utilization

Two types of biochar were used in this experiment, namely commercial rice husk biochar (RH) and Bamboo biochar that was pyrolysed at 500°C for 1 hour**.** Biochar was crushed to ≤ 2mm before being mixed with soil. The soil was collected from the soil surface layer (up to 20cm depth) from the field at Kyushu University Farm in Kasua-machi, Fukuoka, Japan.

The soil was clay loamy, which contains 34% sand, 30% silt, and 36% clay. The soil was air-dried and passed through a 2-mm stainless steel mesh sieve. Compost used in this experiment was the fermentation type consisting of mixed bark with sludge; manure of chicken, cow and pig; and plant residue. It was produced by the Dainichi Giken Company, registration number 83201. Compost was mixed with soil at the rate 1:5 (weight/weight).

Biochar, soil pH, and electrical conductivity (EC) were measured by pH meter (HORIBA LAQUAtwin B-712) and a conductivity meter (HORIBA LAQUAtwin B-771) with 1:10 (w/v) suspension of biochar on deionized water. Bulk density of soil and biochar was calculated by the dry weight of soil and compact weight of biochar in 100cm^3 steel cylinder. The concentration of elemental C, H, N were examined using an elemental analyzer.

2.2. Experimental setup

The experiment was set up at a glasshouse in Kaizuka field, Hakozaki campus, Kyushu University (33037'37.8"N; 130025'31.3"E). The three types of biochar were added to the pots at rates of 2% and 5% (biochar weight/soil weight). They were rice husk biochar (RH), open burn bamboo biocha (Uncontrolled temperature bamboo biochar - UB) and the bamboo biochar that produced by furnance at 500°C (Controlled temperature bamboo biochar - CB). Hereafter the treatments will be named RH2, RH5, UB2, UB5, CB2, CB5; totalling 7 treatments in the experiment when counting the control without biochar amendment. Each treatment was repeated 3 times and arranged in a randomized block design. Thus, there were 21 pots in this experiment. The pots were sized 12.5cm x 18cm x 20cm (bottom x top x height) and filled by soil and biochar mixture to a height of 17cm. Tomato (1 plant/pot) was sowed in on 15th March 2016, transplanted in a pot on the 20th April 2016, and harvested the 25th July. The carrot was sown in 15th of September and harvest on 20th of December, 2016 and then spinach with the growth period from 29th December, 2016 to 25th of February 2017. Seven grams of N:P:K (14:14:14) was added to each pot of tomato, 3 grams for carrot and 3 grams for spinach. The same irrigation was supplied among treatments. Some crop's growth, yield and quality parameters including crop height (cm); biomass yield (g); number of fruit; fruit diameter (cm); fresh fruit weight (g); total glucose and fructose content (g/l); ascorbic acid content; and soil physicochemical properties including available water; total N, P, K were observed.

2.3. Plant and soil analysis

The height of tomato at harvest time was measured by the length in cm from the soil surface to the top of crop; Number of leaf: total leaves that crop had during its life; The aboveground and underground fresh biomass yield were observed after harvesting; Fresh yield (gram): (1) for tomato, the total fruit weight of all harvest times at red stage of the ripening color chart (USDA, 1975), (2) for the carot and radish, the fresh yield were measured at the final harvest time. The crop quality was measured for tomato only, the fruits were stored in frozen conditions after harvest and were extracted for analyze the quality. Total sugar was measured by RQflex 10 meter base on the procedure number 116136 (*Total sugar test*)

Soil available water was measured by hanging column and centrifuge methods; soil total N, P, K were determined after wet digestion with salicylic - sulfuric acids and sodium thiosulphate. Then, total N analysis and total P were measured by Gilford 300N spectrophotometer at wavelength 625nm and 710nm, respectively; Total K was identified by using Polarized atomic absorption spectrophotometer.

2.4. Statistical analysis

The statistical differences among the treatments were clarified by analysis of variance (ANOVA) in combination with Fisher's least significant difference (LSD) test, the statistically significant at $p<0.05$. Data analysis was performed by SPSS 20.0 software.

3. Results and Discussion

3.1. Results

3.1.1 The soil, biochar and compost information

Table 1. Data on soil, biochar, and compost used in the experiment

Parameters	Soil	Rice husk biochar **(RH)**	Controlled Bamboo bio. **(CB)**	Uncontrolled Bamboo bio. **(UB)**	Compost
Type	Clay loam soil				
pH H_2O	6.9	9.6	6.9	9.1	6.7
Electrical Conductivity (1:10 mS/cm)	0.16	0.94	0.25	1.05	0.32
Bulk density (g/cm^3)	1.23	0.33	0.37	0.23	0.45
C%	2.25	44.81	75.78	85.44	33.73
H%	0.98	1.54	3.44	1.36	4.21
N%	0.18	0.43	0.45	0.35	2.47
C/N	12.50	104.21	168.40	244.11	13.65

The soil used in the experiment was clay loam soil which included 34% of sand, 30% of silk and 36% of clay. Other physicochemical properties of soil biochar and compost are listed in **Table**

1. The soil pH, C%, C/N ratio showed the lower values than those of rice husk and bamboo biochar, while the bulk density of soil was much larger than that of all biochar and compost. Comparing the carbon percentage of biochar types, bamboo had more C content than that of rice husk. The pH, C/N ratio of compost was the same as those of soil, while its bulk density was similar to that of biochar.

3.1.2. Meteorological data at the experiment site

Whereas crops grown outside would be affected by all weather conditions such as temperature, rainfall, wind velocity, sunlight; crops grown in a glasshouse would be most impacted by temperature. The weather data in **Figure 1** showed that the average temperature in April and May, October and December of 2016 was higher than those of 40 years averages. This weather condition was abnormal and it might impact to crops.

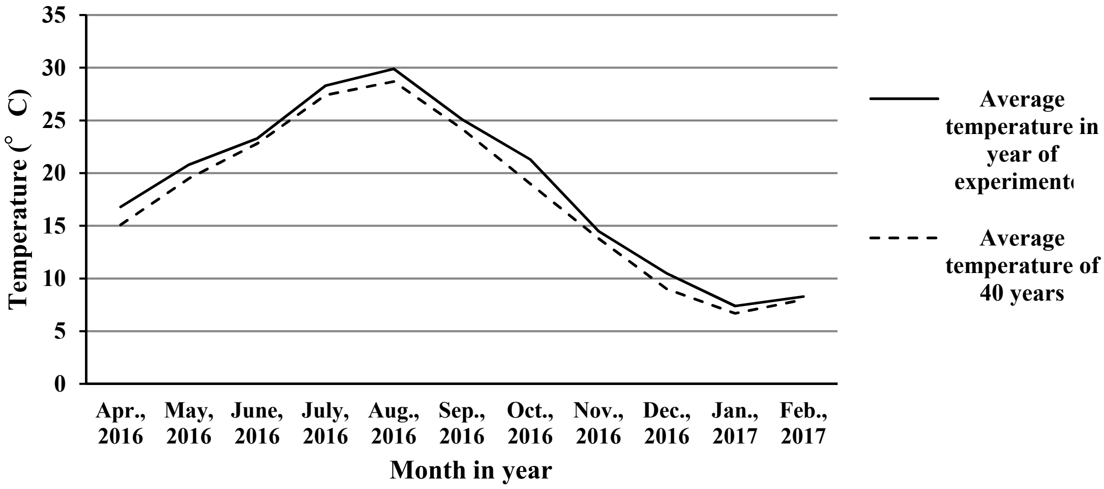

Figure 1. Temperature in year of experiment and average temperature of 40 years

3.1.3. The response of biochar application to crop's growth, yield and quality

a. For Tomato in the first season

The effect of biochar on tomato's growth varied according to biochar types and application rates. Among 7 biochar treatments, the significant impact on tomato's growth only found by the treatment of CB5 for the number of leaves, aboveground fresh biomass weight and underground biomass weight by 20%, 40%, and 114% increased, respectively. Other treatments showed slightly increased or decreased in such above characters in compared with those of the controlled **(Figure 2).**

Accessed the yield and the quality of tomato, authors found that biochar application could increase the tomato's yield in the treatment of UB2, CB2, and CB5 by 23%-25%. Besides, the total sugar content of tomato increased significantly in all biochar treatments by 55%-91% **(Figure 3).**

b. For carrot as the second crop after tomato

The results in Figure 3 showed that the yield of carrot in treatment RH5, UB5 were lower than those of others but there were no significant difference in yield as well as carrot length and diameter **(Figure 4).** It might be the reason that the impacts of biochar was not as good as the first season with tomato due to its physicochemical changed.

c. For spinach as third crop after tomato and carrot

The significant difference was found for the number of leaves (RH2, RH5, UB5, CB2) and fresh yield (RH2, RH5, UB5). The increasing rate in compared with those of control were 26-31% for the number of leaves and 40-81% for fresh yield **(Figure 5).**

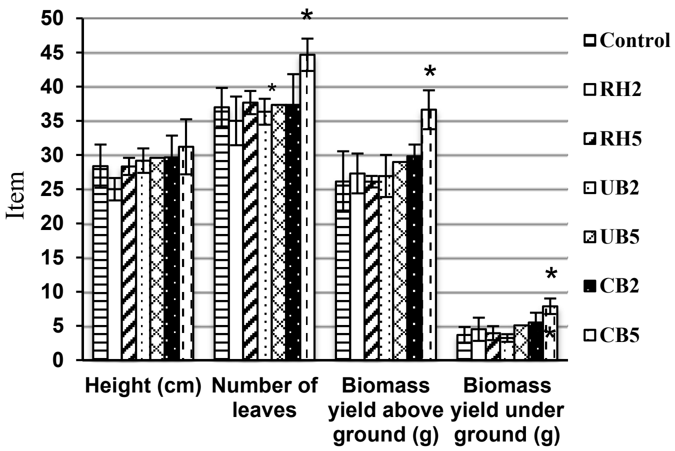

Figure 2. Growth's characters of tomato

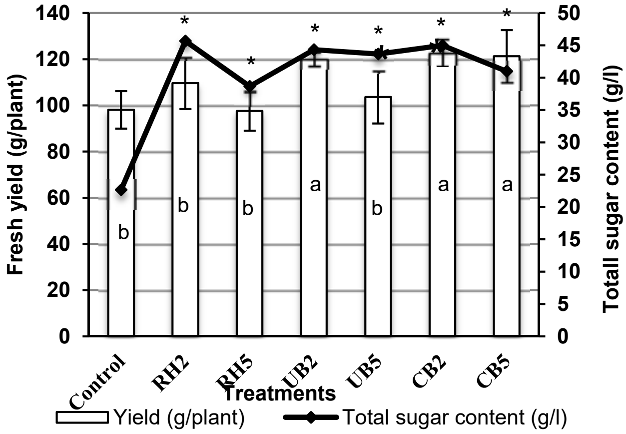

Figure 3. Yield and total sugar content of tomato

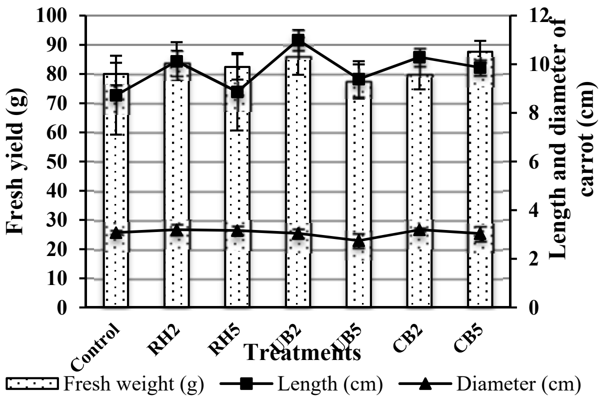

Figure 4. Yield characters of carrot

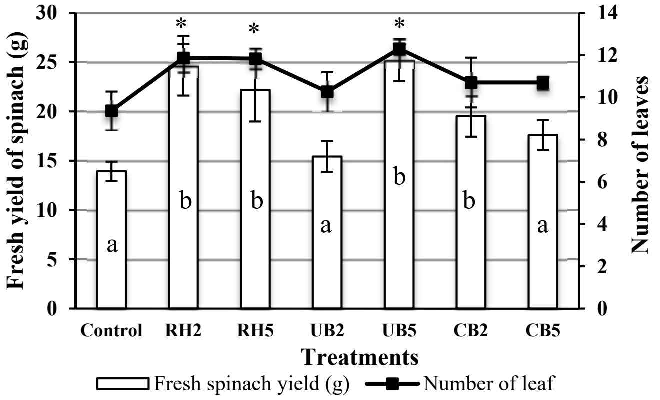

Figure 5. Number of leaves and fresh yield of spinach

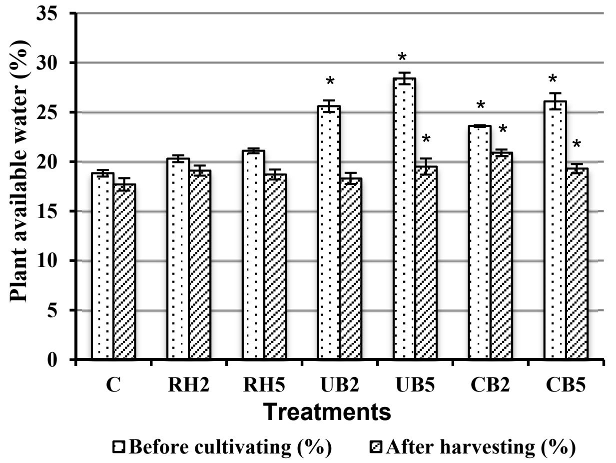

Figure 6. Plant available water atbefore and after cultivation

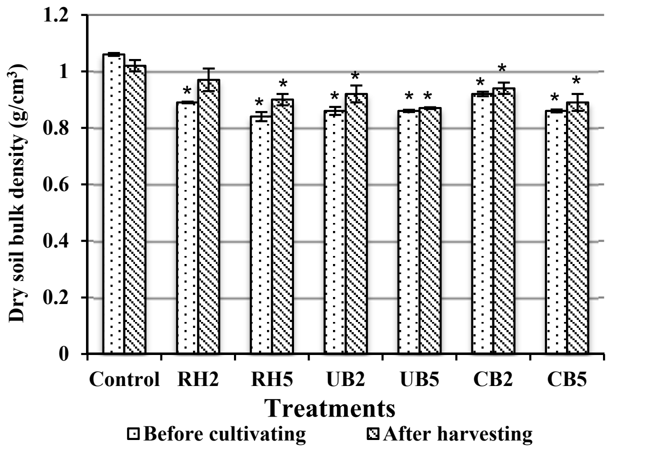

Figure 7. Dry soil bulk density at before and after cultivation

Character "" and small character show the significant difference comparing with control at p value p<0.05*

Mean ± SD: Mean values ± Standard deviation of mean

3.1.4. The changes in soil after biochar application

a. Soil physical properties changed

Biochar amendment helped to increase soil water holding capacity. This ability was found by many studies such as Brantly et al. (2015) for poultry litter and woodchip biochar application to loam soil (Brantley *et al.*, 2015); Aslam et al. (2014) emphasized that soil water holding capacity increased by biochar amendment, but it varied with respect to soil texture and biochar rate (Aslam, Khalid and Aon, 2014). In this study, bamboo biochar significantly increased available water, which was recorded before and after crop cultivation by 25%-38% and 9%-18%, respectively **(Figure 6)**. In contrast, the dry soil bulk density significant decreased in all biochar treatments by 13%-21% after application then tended to increase after 1 year cultivation **(Figure 7)**. This was result of soil compaction due to the movement of clay particle into pores of the soil under irrigation activity. The same results also were found by Jien and Wang in their incubation experiment (Jien and Wang, 2013).

Table 2. Effect of rice husk and bamboo biochar on soil chemical properties after harvesting

Treatment	Total C (%)	Total N (%)	Total P (%)	Total K (%)
Control	2.84	0.22	0.32	0.71
RH2	4.06*	0.21	0.32	0.70
RH5	4.39*	0.22	0.31	0.71
UB2	7.32*	0.19	0.30	0.66
UB5	8.14*	0.22	0.33	0.64
CB2	7.63*	0.26*	0.33	0.71
CB5	8.42*	0.25*	0.34*	0.72
LSD5%	2.31	0.02	0.02	0.05

(*) shows the significant different at $P \leq 0.05$

b. Soil chemical properties changed

The significant difference in compared with that of control was found in total C for all biochar treatments (25-51%), in total nitrogen for treatments of CB2 (14%) and CB5 (18%), and in total P for CB5 (6%) **(Table 2)**.

The increase in total C after biochar application is a very important result that showed the promising of biochar in carbon sequestration since reduce greenhouse gas emission in agriculture field. Furthermore, soil nutrients including nitrogen, phosphorus, patassium are also important indicators for crop cultivation. Biochar with physicochemical absorption capacity would be the reason for increasing the content of nitrogen and phosphorus in biochar treatment, especially for CB5.

3.2. Discussion

Application of biochar increased the available water for plant (**Figure 5)** and increased the total N, P **(Table 3)** in CB2 and CB5, even those results found after 1-year-experiment. The increments were explained by the biochar amendment in soil, a material that could enhance the soil absorption due to its physicochemical properties. Biochar had large surface area, numerous pores and including functional chemical groups that contributed to its high absorption capacity. Many authors also indentifield the soil nutrient enhancement due to biochar application such (Nhan *et al.*, 2017) (Clough *et al.*, 2013) for nitrogen; (Zhang *et al.*, 2016), (Glaser and Lehr, 2019) for phosphorus and (Wang *et al.*, 2018) for potassium. However, high rate biochar amendment would cause of high water absorption as well as high nutrient absorption then created the nutrient deficit for crops. This study results showed that the yield of tomato in all 5% biochar treatments were lower than that of 2% biochar treatments. Besides, soil pH also was a very important factor that decided the impacts of biochar on crop yield. Tomato was a crop that favourited the slightly acidic soil condition. The previous study found that in 6.0-pH-soil, the tomato had more flowers and fruits than those of 7.0- or 8.0-pH-soil (Hojhabrian, 2014). CB was a neutral biochar (pH=6.9), application CB could significantly increase tomato yield in both rates 2% and 5%. In the second season with carrot, it was a crop that prefered loamy or sandy soil to others. The results of this experiment indicated that the soil bulk density (BD) of clay loam soil reduced by biochar amendment but it increased after 1 year. The same results also found by Jien and Wang with the incubation experiment. They identified the reduction of soil BD due to biochar amendment then it enhanced to the field condition after 21 days (Jien and Wang, 2013). This soil condition might not suitable for carrot since no significant in its yield was found. For spinach in the third season, it was a crop that favorited the neutral soil condition. Besides, in the soil, biochar interacted with fertilizer and play the role as a slow-release-nutrient source (Manikandan and Subramanian, 2013). RH, UB were two high pH materials which their values were 9.6 and 9.1, respectively. Used spinach in the third season, RH and UB might as nutrient source as well as provided the suitable living condition for them. The significant in the number of leaves and yield of spinach were found for treatments RH2, RH5 and UB5.

4. Conclusions

Our results indicated that bamboo and rice husk biochar had different last long impacts on crops. In the first season, bamboo biochar showed the positive effects on tomato growth and yield (yield, sugar content, biomass weight), but in the second season, only rice hush char showed the significant impacts on spinach yield and number of leaves. This is the very first conclusion, the experiment had just conducted in one year with limited crop types and climate condition. Other similar research should be conducted to verify the impacts of rice husk and bamboo biochars as well as their last long impact.

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