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The Effect of Bamboo Biochar on Crop's Productivity and Quality in The Field Condition

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Biochar converted from the biomass then applying to soil to improve crop productivity is not a new agricultural technique in the world. Aiming to let farmers know about the benefit of biochar, then expanding biochar utilization in large scale, a field experiment was conducted at Itoshima, Fukuoka city, Japan, in which three root crops namely sweet potato, carrot, and radish were selected and cultivated at three level of bamboo biochar amendment 0% (control), 2% and 4% per soil surface weight (about 30 cm soil depth is expected). Crop's yield and quality were the main targets, which were analyzed after harvesting. The data we got showed that 4% of bamboo biochar had good effects on both fresh weight and quality (total sugar content; dry matter) of those three crops. The fresh weight increased up to 47.2% for radish and 14.2% for carrot. The dry matter content enhanced from 4.7 to 6.9% for sweet potato; 0.8% for carrot. The total sugar content of sweet potato was enhanced significantly comparing with that of control at p level $p<0.05$, from 13.6 g/l of control to 18.1 g/l and 26.7 g/l of 2% treatment and 4% treatment, respectively.

Key words: *bamboo biochar, field condition, production, quality.*

INTRODUCTION

Biochar, one solution for biomass, recently is paid much attention from privates and organizations because of its function on environmental protection and soil improving. It is made when biomass heats in a closed container with little or no available air (Lehmann and Stephen, 2009). The 2000–year–old biochar application as a soil enhancer shows that biochar can hold carbon, boost food security, increases soil biodiversity, and discourage deforestation. This process creates a fine–grained, high porous charcoal that helps soils retain nutrients and water ("biochar @ www.biochar–international.org," n.d.). Althought, it is not yet known how long it takes for biochar to integrate with the soil and express its benefit, biochar represents as a stable form of carbon thus provides a good carbon storage strategy as a soil amendment (Galinato *et al.*, 2011).

A review of biochar impact on soil properties base on previous research shows that, it has good effect on some soil physical properties such as reducing soil bulk density (Bussher *et al.*, 2011; Mukherjee and Lal, 2013; Mankasingh *et al.*, 2011; Leonard Githinji, 2013; Herath *et al.*, 2013), increases the water retention capacity (Uzoma, 2011), increases soil pH, EC, CEC of acidity soil (Abewa *et al.*, 2014). Other it's impacts such as soil's aggregation or porosity greatly depend on soil type, biochar's rates and types (Busscher *et al.*, 2011; George *et al.*, 2012; Busscher *et al.*, 2010; Leonard Githinji, 2013; Herath *et al.*, 2013; Rahman *et al.*, 2011).

Biochar application to soil can serve as a source of nitruents, C, and habitat for microorganisms, thereby increasing microbial activities in soils (Thies and Rillig, 2009). Biochar also can be a direct nutrient source for plants. It has been found to contain many plant nutrients, including N, P, K, Ca, Mg, S and micronutrients (Gaskin *et al.*, 2008). Biochar application has resulted in increased nutrient availability in soils and increased nutrient uptake in plant (Gaskin *et al.*, 2010; Hossain *et al.*, 2010; Novak *et al.*, 2009), as well as increased crop's productivity such as maize (Cornelissen *et al.*, 2013), soybean (Yooyen *et al.*, 2015), tomato (Yilangai *et al.*, 2014); lettuce and cabbage (Carter *et al.*, 2013), rice yield (Kang *et al.*, 2016).

Bamboo is a very popular plant in the world, especially in Asia countries. People cultivate bamboo to service for their purpose such as decoration, construction, food, etc. Bamboo is known as an easy growing and generating plant. Reported by the UN Food and Agriculture Organization (FAO), China's bamboo resource in 2010 was over 5.71 million hectares (14.1 million acres) (Buckingham *et al.* 2013), involving more than ten million bamboo farmers, providing 35 million jobs (Buckingham *et al.* 2011; Yiping and Henley 2010; Hogarth and Belcher 2013; Xiang 2010). However, the rapid growth of bamboo forest then turns into monoculture forest is the reason of decreasing biodiversity, soil nutrition and damaging soil's physical structure (Song *et al.*, 2011; Yiping and Henley, 2010; Buckingham *et al.*, 2011).

The bamboo biochar itself has high porosity, about five times greater and the absorption efficiency ten times higher than those of wooden charcoal. Beside, its high carbon content is suggested that its application as a big pool of carbon sequestration in soil together with soil enhancement. (Hernandez–mena *et al.*, 2014);

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("bamboo–for–biochar–production, n.d.).

This study aimed to get the clear view of bamboo biochar impact on crop's growth, yield and their quality. Root crops namely sweet potato, radish and carrot were choosen to test because their harvesting part created and developed inside the soil. We hypothesized that bamboo biochar application should enable to increase the size and diameter of tube in particular and fresh weight in general as well as promote the crop's quality.

MATERIAL AND METHODS

Material

The bamboo biochar produced by open furnace (figure 1) was applied to the soil surface (about 30 cm depth) at the rate of 0%, 2% and 4% per soil weight. The dry bamboo was cut, put in a furnace then burnt. When all the material was burnt for a while, added water into the furnace till no white smoke emitted.

Compost, chemical fertilizer NPK 14:14:14, black plastic covering (for sweet potato), seeds of carrot, radish and sweet potato cutting were also used.

Methodology

Biochar and Soil information

Biochar and soil pH were probed using a pH meter (HORIBA LAQUAtwin B–712); biochar EC was identified by a conductivity meter (HORIBA LAQUAtwin B–771) with 1:10 (w/v) suspension of biochar in deionized water. Their bulk density was determined by measuring the weight of compact soil or biochar in 100 cm^3 steel cylinders. The concentration of elemental C, H and N were determined by using an elemental analyzer.

Fig. 1. Biochar making methodology.

Fig. 2. The experiment location.

Experiment setup

Location: Itoshima, Fukuoka Prefecture, Japan.

Figure 2 shows the location of the experiment was at Itoshima, Fukuoka prefecture of Japan.

Experiment preparation and implementation

Soil was prepared carefully by plough machine and cleaned from grass firstly, then 3 soil beds were made with 5 meters length per bed. Each bed was relative with one rate of biochar amendment 0%, 2%, 4%, respectively.

Timing and amount application of irrigation and chemical fertilizer were the same among three beds. (No chemical fertilizer amendment for sweet potato)

Sweet potato was planted on 28th of May, 2016 and harvested on 1st of November 2016.

Carrot and radish were sowed on the 8th of September, 2016 and harvested on 6th of December, 2016.

Crop's data collection

Sweet–potato: fresh yield (gram) was weighted right after harvesting; The sweet–potato dry content was weighted after dried in oven at the temperature 105˚C to unchanged weight.

Carrot: fresh yield, length, diameter and dry weight were measured right after harvesting.

Radish: fresh yield, length, diameter and dry weight, were measured right after harvesting.

Crop's quality analysis: Sweet potato, radish and carrot were kept in frozen condition then extracted before analyzing. The total sugar content (glucose and fructose) of sweet potato, carrot and radish were measured by RQ flex 10 meter base on the procedure number 116136 of Merckmillipore website ("Test–Azúcar–total–(glucosa–y–fructosa), MDA_CHEM–116136 @ www.merckmillipore.com," n.d.). Ascorbic acid content of white radish was also tested by RQ flex10 meter base on the procedure number 116981 of Merckmillipore website ("Test–Ácido–ascórbico, MDA_CHEM–116981 @ www.merckmillipore.com," n.d.).

Meteorological data collection

Meteorological data were collected from the Japan Meteorological Agency website http://www.jma.go.jp/jma/index.html

Among all climate factors, temperature and rainfall are the most important ones that impact on crop's germination, growth, yield and quality.

Figure 3 shows the temperature and rainfall in the year of 2016 comparing with average ones of during 20 previous years. During one month from the end of july to the end of august in year 2016, temperature was higher than that of 20 years average about 2 to 3 degree Celsius, and the rainfall was approximate zero value. After this period, the reainfall was increased and much higher than average one. Those climate factors were abnormal and they might affect to the growth and yield of sweet potato, carrot and radish.

Statistical analysis

The statistical differences among treatments in this study were identified by analysis of variance (ANOVA) in combination with Fisher's least significant difference (LSD) test. The difference among values was considered statistically significant at $p<0.05$; $p<0.1$. Data analysis was performed using SPSS 20.0 version.

RESULTS AND DISCUSSION

1. Biochar and soil information

Some physicochemical properties of bamboo biochar and soil used in this experiment are listed in Table 1. The pH, carbon content (C%), C/N ratio of bamboo biochar are much higher than those of soil. Contrarily, the bulk density of bamboo char is much less than that of soil.

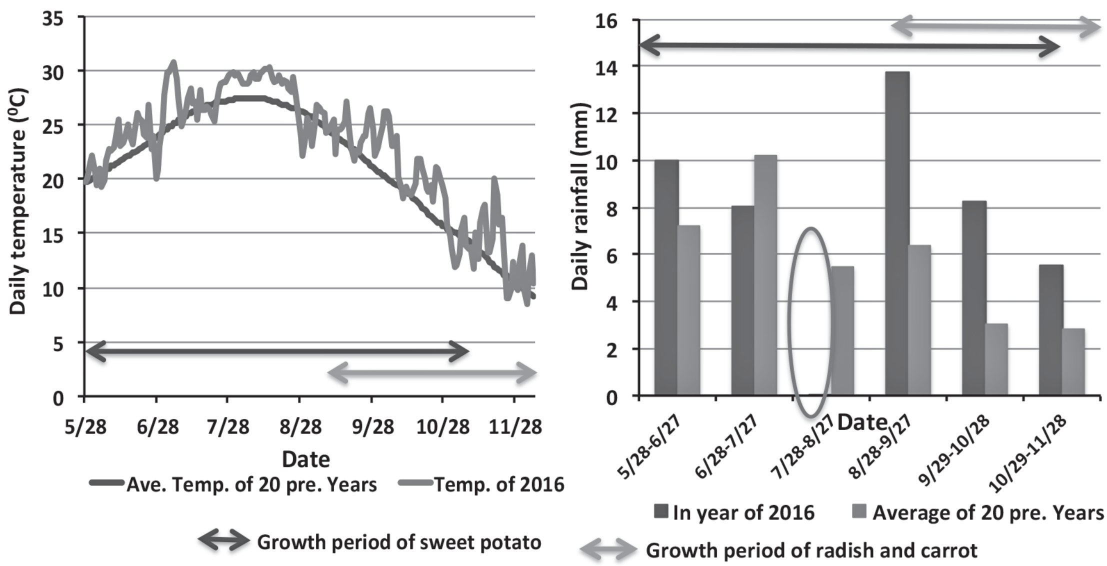

Fig. 3. The temperature and rainfall during crop's cultivating period at the site of experiment.

Table 1. Soil and biochar information

Properties	Bam. biochar	Soil
H (%)	1.36	0.89
C (%)	85.44	1.95
N (%)	0.62	0.18
C/N ratio	137.81	10.83
Electrical conductivity (1:10 mS cm^{-1})	0.79	–
pH (1:10 w/v)	9.3	6.5
Bulk density (g/cm^3)	0.23	1.13

(–) non available

2. The effect of bamboo biochar on sweet potato yield and quality

Data from Table 2 showed that, by applying biochar, the fresh yield of sweet potato increased but not statistically significant difference, the increasing percentage was from 3.2 to 8.2%. However, the fruit quality characters including dry matter and total sugar content, enhanced significantly at the level of $p<0.05$ under biochar application at both rates 2% and 4%. The dry matter content and total sugar content of control were the lowest, 32.7±1.7% and 13.6±0.2 (g/l), respectively. While those ones of biochar 4% were the highest, the dry matter content was 39.6±0.5% and the total sugar content was 26.7±0.4 (g/l).

3. The effect of bamboo biochar on carrot yield and quality

The impact of bamboo biochar on the carrot was quite different comparing with the one of sweet potato. There were some contrastive biochar impacts between diameter and length; between yield and quality of carrot. While the diameter slightly increased at biochar application treatments comparing with control, the length reduced even significantly at level $p<0.05$ for 2% treatment. While the carrot fresh weight at 4% biochar mixture increased significantly at $p<0.1$ comparing with control, the quality characters, including dry matter content and total sugar content, were not change, even reduced significantly for total sugar content at 2% biochar application. <Table 3>

4. The effect of bamboo biochar on white radish yield and quality

From Table 4, data indicated that biochar amendment at the rate 4% could slightly increase the length and diameter of radish, since had effect to increase the fresh weight at significant level of $p<0.05$. The increasing percentage was from 4.7% to 47.2%, at rate of biochar amendment 2% and 4%, respectively. For the radish quality, while the total sugar content seems the same among treatments, the dry matter content and ascorbic acid content reduced at significant level for 4% treatment.

Table 2. Yield and quality of sweet potato in the experiment

Treatment	Yield		Quality	
	Fresh yield (kg/m^2)	Yield increasing compare with control (%)	Dry matter content (%)	Total sugar content (g/l)
0%	4.0±0.4	–	32.7±1.7	13.6±0.2
2%	4.1±0.3	3.2	37.4±0.5*	18.1±0.2*
4%	4.3±0.3	8.2	39.6±0.5*	26.7±0.4*
LSD10%	*0.6*		*1.7*	*0.5*
LSD 5%	*0.7*		*2.1*	*0.6*

– Different letter shows the significant difference at p value p<0.1.
– Character (*) shows the significant difference at p value p<0.05.

Table 3. Yield and quality of carrot at the experiment

Treatment	Yield				Quality	
	Length (cm)	Diameter (cm)	Fresh yield (g/crop)	Yield increasing compare with control (%)	Dry matter content (%)	Total sugar content (g/l)
0%	13.4±1.0	3.8±0.3	81.9±6.6a	–	9.9±0.9	56.5±2.2
2%	11.3±0.9*	3.9±0.3	82.2±8.7a	0.3	10.7±0.1	44.3±0.9*
4%	13.7±0.6	3.8±0.1	93.6±5.4b	14.3	10.7±0.9	57.6±1.1
LSD10%	*1.3*	*0.4*	*11.20*		*1.2*	*2.4*
LSD5%	*1.6*	*0.5*	*14.1*		*1.5*	*3.0*

– Different letter shows the significant difference at p<0.1.
– Character (*) shows the significant difference at p<0.05.

Table 4. The yield and quality of radish

Treatment	Yield				Quality		
	Length (cm)	Diameter (cm)	Fresh yield (g/crop)	Yield increasing compare with control (%)	Dry matter content (%)	Total sugar content (g/l)	Ascorbic acid content (mg/l)
0%	20.6±3.1	6.3±0.7a	433.8±26.1	–	5.9±0.1a	46.5±1.5	131.7±3.0
2%	19.0±1.2	6.6±0.5a	454.2±90.8	*4.7*	5.5±0.6a	45.3±0.4	130.3±1.6
4%	23.5±2.5	7.2±0.5b	638.4±45.3*	*47.2*	5.2±0.4b	47.6±1.1	119.3±1.5*
LSD10%	*3.8*	*0.9*	*96.0*		*0.6*	*1.8*	*3.2*
LSD5%	*4.8*	*1.1*	*120.9*		*0.8*	*2.2*	*4.0*

– Different letter shows the significant difference at p<0.1.
– Character (*) shows the significant difference at p<0.05.

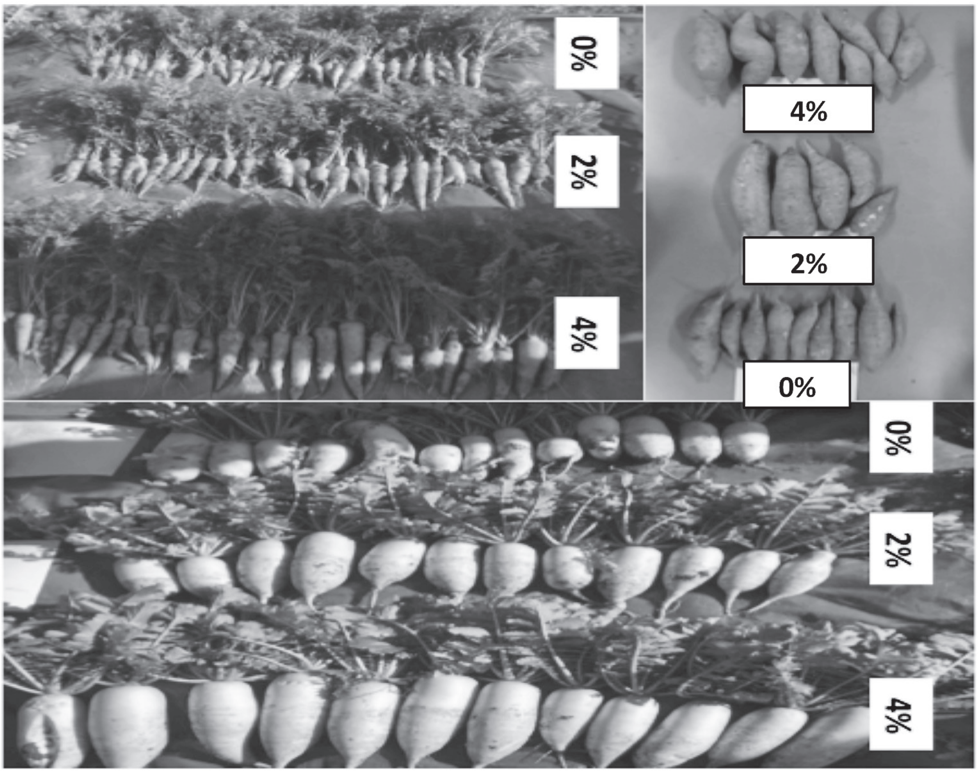

Fig. 4. The sweet potato, carrot, radish in the experiment.

CONCLUSSIONS

The temperature and rainfall in the year 2016 were abnormal. Those climate conditions might affect the growth and yield of crops in the experiment.

Among treatments of without and with bamboo biochar, the 4% biochar application treatment showed that it was the best. It enabled to increase the quality of sweet potato at significant level $p<0.05$ by enhancing the dry matter and total sugar content up to 6.9% and 96.3%, respectively. It could also slightly increase length (2.9 cm) and diameter (0.9 cm) of radish; significantly increased fresh weight of radish at p value $p<0.05$, the increasing percentage was up to 47.2%; significantly increased carrot's fresh yield at p value $p<0.1$, about 11.7 gr/crop (14.3% increasing).

This experiment had just been conducted in small scale in one season, those data we got were the first ones, they could not reflect all the effect of bamboo biochar on crop in different climate conditions and with different soil types. To get the specific conclusion, the same experiment should conduct in different regions in two or three seasons more.

AUTHOR CONTRIBUTIONS

T. T. T. Hien designed the study, performed the experiments, analyzed the data and wrote the paper. Y. Shinogi designed the study, performed the experiments, supervised the writer. A. Mishra and D. D. Viet performed the experiments.

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