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Study of biochar on growth and yield of Choy Sum (*Brassica chinensis* L.*var parachinensis*)

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Abstract The effect of biochar on the growth and yield of choy sum was investigated at harvesting time for 7 weeks after sowing in a pot experiment. The effect of biochar on the growth and yield of vegetables and the effects of biochar on the physiochemical properties of the soil were recorded. The results revealed that using wood biochar at the ratio of 4 t h^{-1} significantly increased height, width leaves, number of leaves, chlorophyll content, fresh and dry weight of the plant compared to the control treatment. In term of soil properties, biochar application in soil increased soil pH, while electrical conductivity (EC) was not altered. Thus, addition biochar to the soil can be one of the best practices to overcome any biotic stress in soil and increased the crop productivity.

Keywords: Biochar, Choy sum, Growth

Introduction

Biochar is an organic carbon rich material produced via pyrolysis of agricultural bio-waste such as wood chip or crop straw under an oxygen-limited environment (Lehmann, 2007). Biochar is one of the three products resulting from the carbonization process other than bio-oil and syngas. Pyrolysis process convert biomass to solid (biochar), liquid (bio-oil) and gas (Boateng *et al*., 2006). The conversion of agriculture wastes into value added products such as biofuel and biochar has attracted tremendous interest attributed to the high energy demand and concerns over greenhouse gas emission as well as worldwide soil degradation (Ainatul *et al*., 2012). Biochar has a porous appearance, when it is mixed with compost or organic matter, this porous substance in the soil helps to store nutrients from fertilizers and is the address of microorganisms, helping to release nutrients to plants for a long time. Reduces fermentation time and reduces nitrogen discharge. As a result, the soil mixed with bio-char has a greater nitrogen content, reduces fertilizer

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consumption. One of the features of biochar is to reduce soil density (Laird *et al*., 2010) due to its high porosity material. The bulk density of the biochar is between 0.25 – 0.30 g/m^3 (Zhang *et al*., 2010). It was able to reduce soil density due to a phenomenon called dilution effect, and also caused soil particles to form clay granules. In addition, biochar can also adjust the pH of the soil, essential nutrients for plants are available in a neutral pH range of approximately pH 6.5 – 7.5 (Mengel and Kirkby, 2001). Biochars liming effect, high water holding capacity and capability to increase crop nutrient availability might be the main actors behind the positive effects. However, the idea of incorporating biochars in soil has an historical background. Modern day's objective to use biochar in soils are mainly for the carbon sequestration purpose. Biochar can effectively sequester in soil for hundreds to thousands of years (Lehmann and Joseph, 2015). The application of biochar to soil can influence a wide range of soil constraints such as high availability of Al, soil structure and nutrient availability (Chan *et al*., 2007), bioavailability of organic (Yu *et al*., 2009) and inorganic pollutants, cation-exchange capacity (CEC), and retention of nutrients (Singh *et al*., 2010). Indeed, several studies have shown that biochar application to soil can (i) improve soil physical and chemical properties (Mukherjee and Lal, 2013), (ii) enhance plant nutrient availability and correlated growth and yield (Biederman and Harpole, 2013; Jeffery *et al*., 2011), (iii) increase microbial population and activities (Jaafar *et al*., 2014), and (iv) reduce greenhouse gas emissions through C sequestration (Crombie *et al*., 2015).

Biochar can also adsorb pesticides, nutrients, and minerals in the soil, preventing the movement of these chemicals into surface water or groundwater and the subsequent degradation of these waters from agricultural activity. Thus, the aim of this study was to evaluate growth and yield of choy um (*Brassica chinensis* L.*var parachinensis*), in application of biochar.

Materials and methods

Plant material and experimental conditions

The experiments were laid out in a complete randomized design (CRD). The pot experiment was consisted of seven different treatments with 4 replicates each. The treatments were: 1. control (T1), 2. biochar 2 t/ha (T2), 3. biochar 4 t/ha (T3), 4. biochar 6 t/ha (T4), 5. biochar 8 t/ha (T5), 6. biochar 10 t/ha (T6) and 7. biochar 12 t/ha (T7).

Raw materials used in the production of biochar was *Leucaena leucocephala* (Lam.). Biochar was produced traditionally in a charcoal kiln (350–450 ℃) and then crushed to particle size below 2 cm.

This study was conducted in greenhouse located at department of plant technology production. The treatment matrix comprised gradually increasing biochar and soil levels obtained by using the six different biochar's amounts (2, 4, 6, 8, 10 and 12 t/ha) and one control (no amendment) resulting in seven different treatments which were replicated four times each.
The different application amounts biochar was added to the soil. Common plant nursery pot (6 x 6 x 4.5 inch) was used as pot media. Sowing was done using the 5 seeds per pot. All pots were arranged in a completely randomized design. Watering every day in morning and evening, fertilize urea (46-0-0) at 21 days after planting. Plants were harvested after 35 days when fully mature.

Plant measurements and medium analysis

Vegetable plants were harvested at 35 days after sowing, uprooted vegetable plants were taken to the laboratory. Roots of the plants were removed. Data on growth parameters such as plant height (cm), number of leaves, leaf width (cm), SPAD chlorophyll meter reading (SCMR), fresh weight (cm), dry weight (cm), fresh root weight (cm), dry root weight (cm) were collected (dry weight: by drying in an oven until weight stabilization at 70 ^{0}C). Soil samples incorporated with biochar were collected before planting and after harvest for determination of physiochemical properties of the samples.

Statistical analyses (calculation of means and standard deviations, differences of means) were performed using the Statistical Analysis System (SAS). Significant variations were further analyzed by Duncan's new multiple range test (DMRT) at 5% significance level.

Results

Growth and yield

The addition of biochar to soils resulted in increased growth and yield of Choi sum. Study of the average plant height at 35 days after planting were significant statistical differences ($p \leq 0.05$). T3 and T6 giving the same plant height of 39.5 cm, and T7, T4, T5, T2, and T1 giving a plant height of 33.0, 32.7, 32.3, 32.2 and 30.8 cm, respectively (**Table 1**). The number of leave in the T3 and T6 were significantly different from T1, T2, T4 and T5 and T7 with the same average number of leaves of 15.2. However, T2 and T7 provided the same of 11.5 and T1, while T4 gave the lowest number of 11.3. Leaf width has significant statistical differences ($p \leq 0.01$). The maximum leaf width found in T3 of 23.0 cm, not significantly different from T6 (22.3 cm). Leaf width of T4, T7, T5, and T2 were 18.1, 17.6, 16.9 and 16.8 cm, respectively. The effect of treatment on leaf color, there were significant differences as shown in Table 1. It was observed in T6 where plant heigh was significantly higher in leaf color of 74.3 (SPAD), but similar to T3 with leaf color of 74.2 (SPAD). The T4 and T5 had the similar leaf color of 65.5 (SPAD), while T1 gave the lowest leaf color of 64.4 (SPAD).

Table 1. Effect of biochar addition into soil on plant height, number of leaves, leaf width and chlorophyll content (SPAD of Choi sum after 35 days planting

Treatments[1/]	Plantheight (cm)	number of leaves (leaf)	leaf width (cm)	SCMR (SPAD)
1	30.8[c]	11.3[b]	15.9[c]	64.4[b]
2	32.2[bc]	11.5[b]	16.8[bc]	66.0[b]
3	39.5[a]	15.2[a]	23.0[a]	74.2[a]
4	32.7[b]	11.3[b]	18.1[b]	65.5[b]
5	32.3[bc]	11.8[b]	16.9[b]	65.5[b]
6	39.5[a]	15.2 [a]	22.3[a]	74.3[a]
7	33.0[b]	11.5[b]	17.6[b]	65.2[b]
F-test	*	*	*	*
CV (%)	3.15	3.70	3.47	5.25

Description: (*) Significant; (ns) non significant
[1/]The treatments were: T1: control, T2: biochar 2 t/ha, T3: biochar 4 t/ha, T4: biochar 6 t/ha, T5: biochar 8 t/ha, T6: biochar 10 t/ha and T7: biochar 12 t/ha
Means within a column followed by different letters are significantly at the 0.05 probability.

There were highly significant differences ($P<0.05$) among the biochar ratio on plant fresh and dry shoot weight at harvesting as shown in Table 3. It was found that T3 have a maximum weight of 288.4 g but not significant difference with T6 (287.3 g). However, T2, T4, T5 and T7 were not significantly different from T1. For shoot dry weight was similar to fresh shoot weight with T3 and T6 are given a high weight of 15.4 and 15.9 g (not significant). While, T2, T4, T5 and T7 were not significantly different from T1. There were not significant differences between the biochar ratio on plant fresh and dry root weight. Fresh root had a weight between of 21.0-21.2 g, and dry root was between of 2.1-2.5 g.

Table 2. Effect of biochar addition into soil on shoot and root weight of Choi sum after 35 days planting

Treatments[1/]	fresh shoot (g)	dry shoot (g)	fresh root (g)	dry root (g)
1	264.5[b]	12.4[b]	21.2	2.5
2	262.9[b]	12.5[b]	21.0	2.1
3	288.4[a]	15.4[a]	21.0	2.4
4	266.9[b]	12.6[b]	21.0	2.2
5	265.0[b]	12.4[b]	21.1	2.4
6	287.3[a]	15.9[a]	21.0	2.4
7	262.0[b]	12.4[b]	21.0	2.3
F-test	*	*	ns	ns
CV (%)	4.64	11.49	1.78	11.74

Description: (*) Significant; (ns) non significant
[1/]The treatments were: T1: control, T2: biochar 2 t/ha, T3: biochar 4 t/ha, T4: biochar 6 t/ha, T5: biochar 8 t/ha, T6: biochar 10 t/ha and T7: biochar 12 t/ha
Means within a column followed by different letters are significantly at the 0.05 probability

Physical and biological properties of mixed media before and after planting

The total bulk density of the before planting media was 1.10-1.23 g/cm^3 as shown in Table 3. The result showed that the total bulk density before planting media was lower than after planting media. The T1 showed the highest total bulk density of 1.23 g/cm^3, and the lowest total density was found in T7 with 1.10 g/cm^3. The total bulk density of the after planting media was 1.16-1.44 g/cm^3 as shown in Table 3. The total porosity of the before planting media was 73-88 % as shown in Table 3. The result showed that the total porosity after planting media was lower than before planting media. The T1 showed the lowest total density of 73 %, and the highest total porosity was found in T7 with 88%. The total porosity of the after planting media was between of 66-80 %.

Study of electrical conductivity (EC) and pH of before and planting media as shown in Table 4. It was found that the EC value of before planting media of 0.80 - 1.10 dS/m and the EC value after planting media of 0.56-0.85 dS/m. The pH of the before planting media was between 7.20-7.80 and the after planting media was between 7.00-7.30.

Table 3. Effect of biochar ratio in to soil on bulk density and porosity before and after planting

Treatments	bulk density (g/cm^3)		porosity (%)	
	before	after	before	after
1	1.23	1.44	73	66
2	1.15	1.23	78	67
3	1.15	1.22	80	68
4	1.17	1.22	80	75
5	1.11	1.21	85	71
6	1.12	1.20	86	80
7	1.10	1.16	88	80

Not statistically calculated

Table 4. Effect of biochar addition into soil on pH and E. C. before and after planting

Treatments	EC (dS/m)		pH	
	before	after	before	after
1	0.80	0.75	7.20	7.30
2	0.90	0.65	7.40	7.00
3	1.10	0.75	7.70	7.10
4	1.10	0.85	7.80	7.40
5	0.80	0.56	7.40	7.00
6	0.80	0.67	7.50	7.00
7	0.80	0.75	7.70	7.10

Not statistically calculated.

Discussion

A study of the rate of biochar mixed with growing soil in 7 treatments as follows: 1. control (T1), 2. wood biochar 2 t/ha (T2), 3. wood biochar 4 t/ha (T3), 4. wood biochar 6 t/ha (T4), 5. bamboo biochar 2 t/ha (T5), 6. bamboo biochar 4 t/ha (T6) and 7. bamboo biochar 6 t/ha (T7). It was found that the height of plant in T3 and T6 higher in width leaves, number of leaves, chlorophyll content, fresh and dry weight than in other treatments. The addition of biochar improves the soil structure. As a result, increasing ability to carry water and plants are growing better (Carter *et al*., 2013). Mixing biochar with soil at a rate of 2 t/ha resulted in lower growth results. The amount of biochar directly effects on plant growth or changes in the chemical composition of the soil. In addition, biochar is mixed at a rate of 6 t/ha, resulting in reduced growth and yield of vegetables. The effect of biochar in plant production variability depending on plant species and biochar additional rate (Jeffery *et al*., 2011).

Several studies have reported a positive effect of using biochar on crop yields with rates of 5–50 tonnes per hectare with appropriate nutrient management. A single application of 20 t ha^{-1} biochar resulted in an increase in maize yield by 28–140% (Major *et al.*, 2010). Often there has been a reported increase in yields, which is directly related to the addition of biochar as compared to the control (without biochar) (Lehmann *et al*., 2003). However, in some cases, growth was found to be depressed (Mikan and Abrams, 1995). The experiments conducted by Rondon *et al*. (2007) resulted in a decrease in crop yield in a pot experiment with nutrient deficient soil amended with biochar at the rate of 165 tons per hectare. An experiment conducted in the United States showed that peanut hull and pine chip biochar, applied to 11 and 22 tons per hectare, could reduce corn yields below those obtained in the control plots with standard fertilizer management (Gaskin *et al*., 2010). Thus, the control of the rate of application of biochar is necessary to prevent the negative impact of biochar.

According to the study of the physical properties of planting mixed media. The result showed that the total bulk density before planting media (1.10-1.23 g/cm^3) was lower than after planting media (1.16-1.44 g/cm^3). The pH of the before planting media was between 7.20-7.80 and the after planting media was between 7.00-7.30. The alkalinity is inherited by biochar through the pyrolytic process which also converts biomass acids into the bio-oil component during the process (Laird *et al*., 2010; Yuan and Xu, 2011). Biochar contains alkaline components such as organic anions and inorganic carbonates (Yuan *et al*., 2011a). This effect explained the result of increasing pH value obtained with increasing amount of biochar application. The pH has not directed effect on the growth of crops, but affects the benefits of plant nutrients and regulates the activity of microorganisms in planting media. Furthermore, with increasing biochar application rates could increase the ameliorating effects of biochar on soil pH (Yuan *et al*., 2011b). The altered soil generally became less acidic when biochar with a higher pH value was applied to the soil (Yuan *et al*., 2011b). The EC value of before planting media (0.80 - 1.10 dS/m) was higher than after planting media (0.56-0.85 dS/m) in all mixed with biochar. From these results, it is clear that biochar contained ionic elements being potentially plant-available. Hossain *et al*. (2010) showed a significant rise in EC after biochar additions, which might be largely due to the fact that their biochar was produced from sewage sludge which is very mineral-rich, contrasting to our biochar which was produced from wood and bamboo. Steiner *et al*. (2007) reported that hardwood-derived biochars tend to contain considerable carbonate concentrations which might lead to an increased release of plant-available salts from the compost into the soil environment.

The biochar mixed media on the growth and yield of Choi sum vegetable has been studied. It was found that using biochar at the ratio of 4 t/h promotes high growth on n the height, width leaves, number of leaves, chlorophyll content, fresh and dry weight of the plant. Thus, addition of biochar to the soil can be one of the best practices to overcome any biotic stress in soil and to increase the crop productivity. However, the rate of biochar suitable for each plant grown should be studied.

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