

## THE EFFICIENCY OF RICE HUSK BIOCHAR APPLICATION TO GROW BRASSICA JUNCEA (*Brassica juncea* (L.) Czern.) IN THE EXPERIMENTAL POTS OF LOAMY SAND SOIL

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### ABSTRACT

Biochar was produced from rice husk at temperature from 276 to 760 °C. The objective of the study was to determine the influence of the biochar application to loamy sand soil on crop growth and nutrient balances under greenhouse conditions in Hue city. Loamy sand soil was collected in Huong Chu commune, Huong Tra town. Pot experiments with *Brassica juncea* (*Brassica juncea* (L.) Czern.) were conducted in three different types of biochar quantity into soil such as 15 g/pot (765 g/m<sup>2</sup>), 30 g/pot (1531 g/m<sup>2</sup>) and 60 g/pot (3062 g/m<sup>2</sup>). Chemical fertilizer was applied to the soil at rates of 12.2 ÷ 24.5 g N/m<sup>2</sup>, 10.3 ÷ 20.6 g P<sub>2</sub>O<sub>5</sub>/m<sup>2</sup> and 12.0 ÷ 24.0 g K<sub>2</sub>O/m<sup>2</sup>. Experimental results showed that biochar application changed soil quality, resulted in improving the growth of *Brassica juncea*. We will report the difference of nitrogen and phosphorus balances (crop uptake, leaching, retention, etc.) in experimental pots. Our results indicated that the use of biochar from agricultural by-products would be beneficial for farmers, the environment under soil and climatic conditions in Thua Thien Hue province.

*Keywords:* nutrient, nitrogen, phosphorus, loamy sand soil, rice husk biochar.

### 1. INTRODUCTION

According to Lehmann J. and Joseph S. (2009), biochar was the carbon- rich product obtained when biomass is heated in a closed container with little or no available air. In more technical terms, biochar is produced by so-called thermal decomposition of organic material under limited supply of oxygen (O<sub>2</sub>), and at relatively low temperatures (< 700 °C) [1]. The agricultural wastes in Viet Nam are quite diversity, is emitted to environment or is burnt out on fields with a large quantity every year. This is one of the potential sources of biomass to serve the needs of cooking and biochar production. Biochar research has been investigated by many authors around the world and Vietnam [1 - 7]. Some researches had shown that the application of biochar in soil can have a lot of benefits such as improving soil quality; increasing water retention, moisture and reducing soil compactness [1, 3]; increasing the crop yield [3]; increasing the saturation in upland rice terraces [2]. The application of biochar increased organic carbon (OC), pH and ion exchange capacity (CEC) in soils [3]. The application of biochar from

*Acacia magnum* also can increase pH, Ca, CEC, penetrability in soil and reduce Al [2]. The addition of biochar to coastal acidification in the Southern of United States also increased soil pH, organic matters, Mn and Ca, but reduced S and Zn [2]. For sandy soils, biochar application did not significantly affect CEC in soil. In addition, biochar enhanced biological activity in soil due to nitrogen fixation of *Phaseolus vulgaris* L.; of earthworms and microbial biomass [2]. There was the effect of rice husks biochar and its potential to improve soil acid quality [2, 3]. In Japan, there was the effect of applying two types of biochar from rice straw and husk to the growth of Komatsuna (*Brassica rapa perviridis*) and nutrient concentrations in leachate [5]. In Vietnam, there was the effect of biochar and foliar fertilizers on growth and yield of tomato grown on sandy soil in greenhouse [6]. Biochar application is very suitable for low rainfall, arid soil and nutrient poor areas. Therefore, we have studied the effect of rice husk biochar (RHB) to growing *Brassica juncea* on loamy sand soil in Thua Thien Hue province, so we investigated the effects of biochar on yield and vegetable growth as well as the ability to improve the soil quality in pot experiments under greenhouse conditions.

## 2. MATERIALS AND METHODS

### 2.1. Materials

Rice husk was collected in Huong So ward, Hue City. Feedstock was dried at temperature 30 °C for 4-5 days. RHB was produced by a 2 m<sup>3</sup> anaerobic furnace. The pyrolysis time was from 2 to 8 hours. The temperature was increased from environmental temperature to pyrolysis temperature in the range of 276 ÷ 760 °C. The K-type thermometer (Extech, TM100, USA) was used to check the temperature, observing the smoke and steam. We took RHB out when the furnace temperature reduced to air temperature. RHB samples were then milled, sieved through the sizes (0.15 ÷ 0.45 mm) to study material size. Experiments using sandy soils were taken in Phu O village, Huong Chu ward, Huong Tra town, Thua Thien Hue province. This research used to *Brassica juncea* (*Brassica juncea* (L.) Czern.) from Tan Nong Phat company for sowing.

### 2.2. Experimental design

Table 1. Experimental pots design of vegetable growth.

Sample	Experiment (Repeat 3 times)	Biochar RHB	12.2 g N/m <sup>2</sup> and 24.5 g N/m <sup>2</sup>	10.3 g P <sub>2</sub> O <sub>5</sub> /m <sup>2</sup> and 20.6 g P <sub>2</sub> O <sub>5</sub> /m <sup>2</sup>	12 g*K <sub>2</sub> O/m <sup>2</sup> and 24 g K <sub>2</sub> O/m <sup>2</sup>
		(g/pot)	g/pot (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	g/pot KH <sub>2</sub> PO <sub>4</sub>	g/pot KCl
DC1	No Biochar- (No fertilizers)	0	0	0	0
CN1	No Biochar- (Fertilizer 1)	0	1.131	0.384	0.169
CB2	Biochar 1- (Fertilizer 1)	15	1.131	0.384	0.169
CB3	Biochar 2- (Fertilizer 1)	30	1.131	0.384	0.169
CB4	Biochar 3- (Fertilizer 1)	60	1.131	0.384	0.169
CN5	No Biochar- (Fertilizer 2)	0	2.262	0.768	0.338
CB6	Biochar 2-(Fertilizer 2)	30	2.262	0.768	0.338

In which: \* 6.63 g K<sub>2</sub>O/m<sup>2</sup> is applied as KH<sub>2</sub>PO<sub>4</sub>; the rest (5.37 g) is applied as KCl.

Experimental arrangement was shown in Table 1. Each pot contained 3 levels of biochar weight of 15 g/pot (765 g/m<sup>2</sup>); 30 g/pot (1531 g/m<sup>2</sup>) or 60 g/pot (3062 g/m<sup>2</sup>). Control sample (ĐC1) was soil sample without biochar and fertilizer. Total number of vegetable trials were 21 pots (7 treatments x 3 replicates = 21 pots). Number of seeds for each pot were 5 seeds/pot (1.63 g/m<sup>2</sup>). There was simultaneous and similar cultivation for all pots. Seeds before sowing were soaked in warm water (45 °C) for 30 minutes to help germinate quickly and evenly. Sowing seeds in the afternoon then they easily intake water. Pot experiments were housed in greenhouse with rain cover, deployed at household in Thuan Hoa ward, Hue City. Placement of experimental pots in the form of ladder with completely random distribution (CRD). Irrigation water was applied for every 3 days. Total water was irrigated 6800 mL/ 36 days. The water quantity was irrigated 1000 mL for initial day, 400 mL per 3 days from 3<sup>rd</sup> day to 18<sup>th</sup> day, 600 mL per 3 days from 21<sup>st</sup> day to 30<sup>th</sup> day. On the 33<sup>rd</sup> day, water was irrigated 1000 mL. On the 36<sup>th</sup> day, we collected samples of vegetables (leaves, roots), soils and leachate.

### **2.3. Methods**

- Sampling and preservation: The leachate was stored in a polyethylene bottle for 3 days after every irrigation event (TCVN 6663-3:2008, TCVN 5999:1995). Soil samples were collected in the fields at cultivating layer from 0 to 20 cm, packed in plastic bags and brought to the laboratory for natural drying and complied with Vietnamese standards (TCVN 4046:1985, TCVN 7538-2:2005, TCVN 2683:2012 and TCVN 6647:2000). We collected vegetable sample according to TCVN 9016:2011. After sowing, we observed the germinated seeds. We counted the number of germinated seeds each day at 7 am, until the number of germinated seeds in each pot remained unchanged, then stopped counting. After collecting vegetable, we counted the number of leaves, defined the height and width of leaves, stem length by tapeline (Professional, China, 1÷ 5000 mm).

- Analysis of samples: Some parameters were analyzed according to Vietnamese standards or international standards such as pH<sub>leachate</sub> (TCVN 6492:2011), pH<sub>soil</sub> (TCVN 5979:2007) by using pH meter (Hach, Sension+ pH3, Spain); total phosphorus of leachate- TP<sub>leachate</sub> (SMEWW4500P B: 2012; SMEWW 4500P E:2012), total nitrogen of leachate- TN<sub>leachate</sub> (SMEWW 4500N C:2012) by using UV- VIS spectrophotometer (JASCO, V530, Japan); organic carbon (OC) (TCVN 8726:2012), bulk density (d<sub>i</sub>) (TCVN 6860:2001), moisture (W<sub>b</sub>) and water holding capacity (W) (TCVN 4196:2012) and the texture of soil (soil was shaken through the sieve and was weighed by using analytical balance (Shimadzu, AU220, Japan). Harvested vegetable was separated into upper and root parts, immediately weighed and dried at 70°C for 1 week. TN and TP contents were determined after the Kjeldahl digestion (TN- TCVN 6498:1999; and TP- TCVN 4052:1985). After the harvest of vegetable, soil samples were destructively collected from two layers: the upper (7.5 - 8.0 cm) and lower layers (6.5 - 7.0 cm).

- Statistical analysis: Microsoft Excel was used to calculate sample analysis results and to draw charts.

## **3. RESULTS AND DISCUSSION**

### **3.1. Some characteristics of biochar and loamy sand soil**

The results in Table 2 showed some characteristics and properties of RHB and loamy sand soil. Based on the material size classification of the International Biochar Initiative (IBI, 2015),

this RHB had particle texture. Other physicochemical characteristics of RHB were detailed in the study of Tran Thi Tu [8]. The soil had a bulk density of 1.4 g/cm<sup>3</sup>, which was compacted soil type and low moisture. Porosity is good for farming. The satisfactory level of soil grading was sandy soil classification according to international land classification and Kachinski classification [9]. Soil quality had poor nutrient.

Table 2. Some physical and chemical properties of RHB material and studied soil.

Subject	Bulk density, d1 (g/cm <sup>3</sup> )	Proportion, d	Porosity (%)	Moisture, W <sub>b</sub> (%)	Drying coefficient, K	Water holding capacity, W (%)
RHB	0.2	1.78	88.8	7.8	1.078	474
Soil	1.4	2.64	45.8	5.5	1.055	-
Subject	pH <sub>H2O</sub>	pH <sub>KCl</sub>	OC (%)	TN-N (%)	TP-P (%)	K <sub>2</sub> O (%)
RHB	7.89	8.03	5.8	0.32	0.2	0.13
Soil	6.11	4.59	1.31	0.17	0.15	0.22
Subject	Texture (% of particle levels)					
RHB	Gravel 8.0 ÷ 16.0 mm	Gravel 4.0 ÷ 8.0 mm	Kernel 2.0 ÷ 4.0 mm	Kernel 1.0 ÷ 2.0 mm	Powder 0.5 ÷ 1.0 mm	Powder < 0.5 mm
	0	6	75	10	5	4
Soil	Coarse sand 2.0 ÷ 0.2 mm		Fine sand 0.2 ÷ 0.02 mm		Limon 0.02 ÷ 0.002 mm	Clay < 0.002 mm
	29.5		57.5		7.5	5.5

### 3.2. The evaluation of moisture retention of RHB on loamy sand soil

Figure 1 showed the water balance to grow vegetable during 36 days. The experiment pots with biochar were improved of the soil moisture and reduced of the leachate because of some useful physicochemical characteristics mentioned above. Figure 2 showed the effect of biochar on soil layers. Formulations had added biochar to increase retaining water in soil, evapotranspiration and vegetable water; reducing water leachate; increasing soil moisture and pH. There were significant differences between the experimental formulas. There was no significant difference in the effect of fertilizer on water retention in soil. The upper layer with biochar created increasing the soil moisture, and kept water better than the lower layer. The upper layer had the type of 2 and 3 biochar levels which increased the moisture of 16.4 % and 37.5 % compared to DC1; whereas the non-supplemented biochar formula only increased by 6.7 %. There was a significant difference between the experimental formulas at 1 % significance level. The lower layer also had a higher moisture content but with a lower ratio than the upper layer. Besides, biochar had an alkalinity (pH<sub>H2O</sub> = 7.89), when applied it into the soil to make increasing the soil pH value.

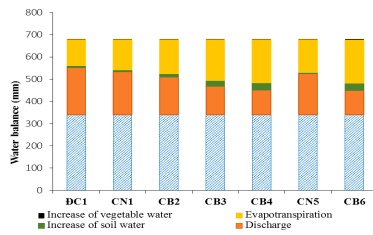


Figure 1. The water balance of pot experiments.

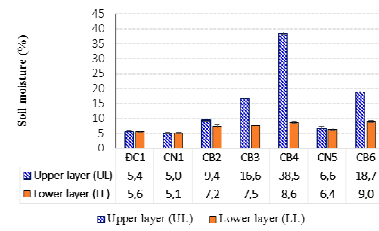


Figure 2. Soil moisture of pot experiments.

### 3.3. Evaluation of nutritional balance in vegetable growth

Nutrient leaching and retention: The results showed that experiments with biochar such as CB2, CB3, CB4 and CB6 contributed significantly to retention of nutrients (TP and TN) in the soil and reduced TP and TN in leachate compared to the control sample (Figure 3, Figure 5 and Figure 6); also uptaked the TP and TN in the roots and leaves of *Brassica juncea* (Figure 4). The upper layer has an ability to hold TP, TN better than the lower layer without biochar. Because RHB has a porous structure, many voids contribute to increase surface contact, increase adsorption, and retain nutrients on the surface of the biochar and soil.

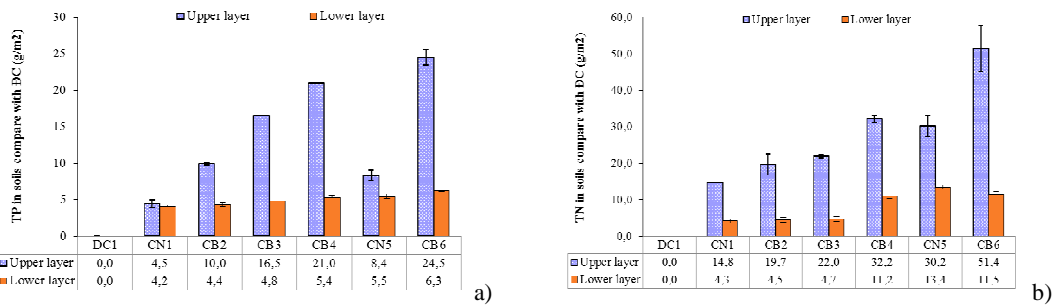


Figure 3. Increasing TP (a) and TN (b) in soils compared with control soil sample.

Besides, soil containing biochar helps to retain TP in the soil and reduce the amount of TP released into the water source. Therefore, biochar contributed to soil improvement, more porous and facilitates vegetable to grow more favorably than DC1. In addition, the dried biomass of vegetable with biochar has a higher yield than that without biochar soil. Mean number of leaves per tree in formulas supplemented with biochar and fertilizer was higher than that of DC1. The number of leaves had the coefficient of variation (CV) reached 2.72 %, and the least significant difference at 1 % level of significance ( $LSD_{0,01}$ ) reached 0.28. So, there was a significant difference between the treatments of 1 %. The experiments of biochar supplementation such as CB2, CB3, CB4 and CB6 increased fresh and dry weight from 159 %, 227 %, 333 % and 525 % respectively compared to DC1 (Figure 6). Formulation of fertilizers at levels 1 and 2 increased plant biomass of 16 % and 122 %, respectively. The fresh and dry weight had  $CV = 2.89 \%$ ,  $LSD_{0,01\text{fresh}} = 1.82$  and  $LSD_{0,01\text{dry}} = 0.27$ . There was a significant difference between treatments at 1 % significance level.

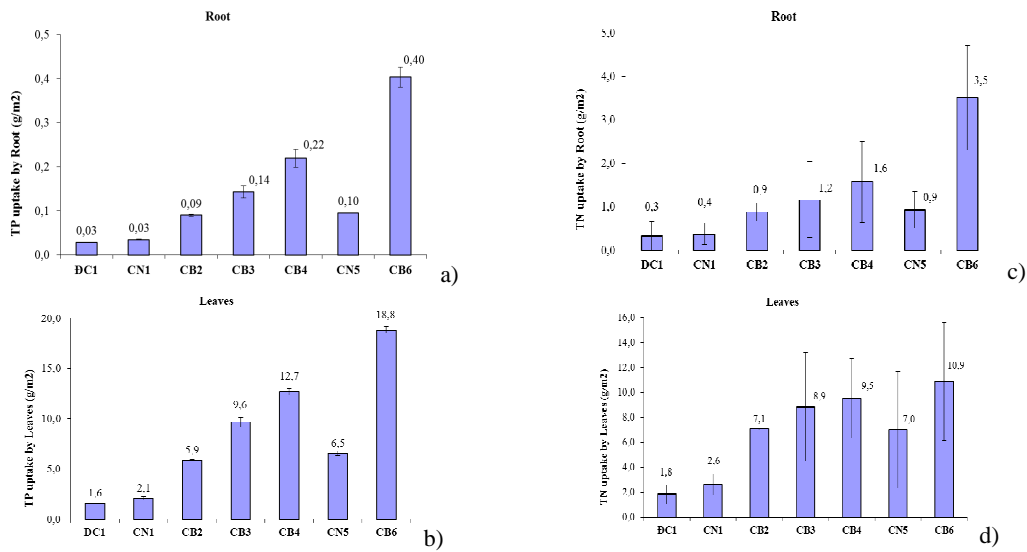


Figure 4. TP (a, b) and TN (c, d) uptake by the roots and leaves of *Brassica juncea*.

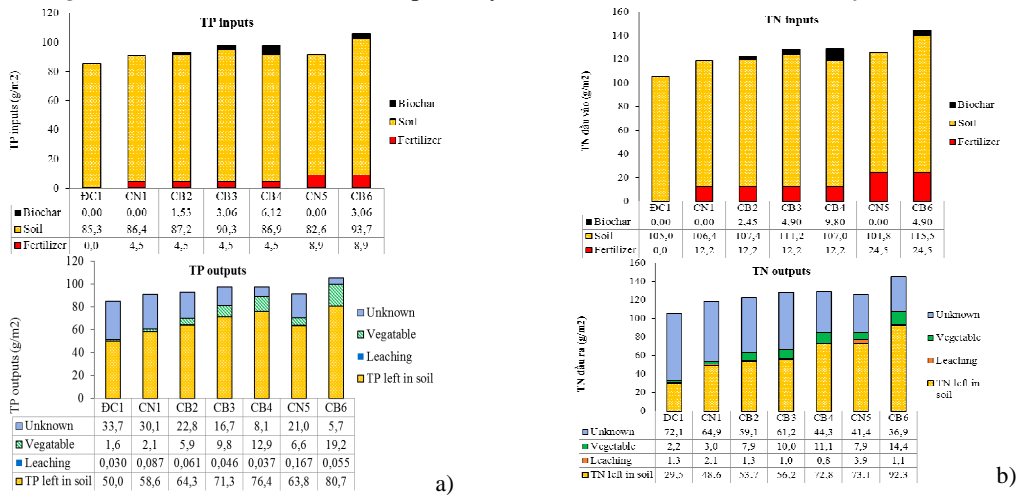


Figure 5. The balances of TP (a) and TN (b) in pot experiments.

The CB2, CB3, CB4 and CB6 samples with biochar and fertilizer could increase vegetable height, root length and leaf width compared to the control sample. There was a significant difference between the formulas at 1 % significance level. Growth rate of stem foliage of CB2, CB3 and CB4 samples reached 15.4 %, 20.3 % and 26.3 % respectively for 3 biochar levels (765 g/m<sup>2</sup>, 1531 g/m<sup>2</sup> and 3062 g/m<sup>2</sup>) and the same fertilizer level 1 compared to ĐC1. Growth rate of stem foliage of CB6 reached 40.8 % for the double fertilizer level and biochar 2. Meanwhile, CN1 and CN5 samples with fertilizer and without biochar only could increase 8.3 % and 23.1 %, respectively compared to ĐC1. The biochar application on soil to plant tomato also had similar results. Sample with biochar could improve leaf numbers, height, and yields compared to the control sample. Increasing biochar levels were also enhanced a plant productivity [6]. This result was consistent with studies by other authors as Chan K. Y. et al. [3] and Van Zwieten L. et al. [7]. Therefore, biochar can improve soil physicochemical properties such as increasing soil porosity, moisture, water retention and nutrient) [1]; increase fertilizer using efficiency [3];

increase microbial population in the soil due to chemical substances in biochar that had stimulate plant growth at low concentrations [4].

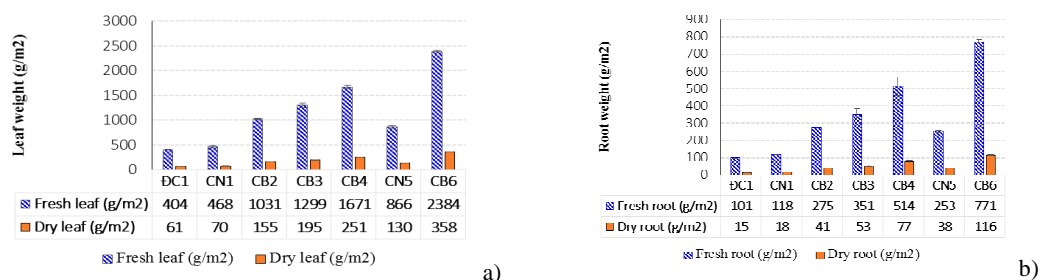


Figure 6. The weight of leaves (a) and roots (b) in 1 m<sup>2</sup>.

#### 4. CONCLUSIONS

The evaluation of biochar effect on soil quality and growth of vegetable on loamy sand soil showed that CB2, CB3, CB4 and CB6 samples with biochar and fertilizer could increase the ability of retaining water in soil, reducing leachate; enhance soil moisture and pH value. CB2, CB3, CB4 and CB6 samples could improve a plant height, root length, leaf width and average leaf number compared to the control sample. Studying nutrient balance of phosphorus and nitrogen showed that CB2, CB3, CB4 and CB6 samples with biochar significantly retained TP, TN in soil and reduced TP, TN in leachate compared to DC1. The upper layer with biochar had the ability to keep TP, TN better than lower layer without biochar. In addition, the biochar formula increases nutrient uptake in roots and leaves of vegetable. Thus, the application of biochar on loamy sand soil contributes to improving soil quality and crop yield.

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