Effects of Biochar on Morphological Characters of Rice Stem

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Abstract. Biochar has good anatomical structure and physical and chemical properties, and it comes from a wide range of sources. It is of great significance in soil improvement, crop yield increase and environmental improvement. In this study, a japonica rice was used as material. It used four biochar levels to research the effects of biochar on the morphology of rice stem. The results showed that appropriate application of biochar can increase plant height, especially the length of second internode increased significantly. With the increase of biochar, the stem diameter of basal internode (I1) and the second internode (I2) increased significantly, there was an increasing trend of base stem wall thickness, but the difference was not significant. The dry weight per unit length and the dry weight per unit volume will increased with the increase of biochar. The effects of biochar on rice stem strength and lodging resistance should be further studied.

1. Introduction

Biochar generally refers to the biomass such as wood, crop waste, plant tissue or animal bones which were produced under the condition of hypoxia and the relatively low temperature (< 700 °C)[1,2]. It annually produces about a billion tons of agricultural and forestry waste in China. Only the stalks of maize, rice, wheat and other staple crops were 638 million tons. More than 50% of it is burned or abandoned along with large emissions of greenhouse gases. Valuable resources are not effectively used but become serious pollution sources. Biomass carbonization technology is recognized as one of the feasible technical measures to solve the problem of climate change. It has the characteristics of low production cost, ecological safety, wide source of raw materials, no pollution and large area promotion [3]. The comprehensive utilization of biochar can largely solve the complex problems in sustainable development, energy conservation and consumption reduction, environmental protection and governance. In the field of agriculture, the researchers conducted a lot of exploration about the effect of biochar on soil and crops. It preliminary confirmed that biochar have great effects in improving soil structure and physical and chemical properties, crop production, controlling environmental pollution and increasing agricultural carbon sinks, reducing greenhouse gas emissions [4,5]. Biochar has important practical significance and application value in repairing soil barriers, improving cultivated land productivity and crop productivity, promoting sustainable agricultural development and safeguarding national food security [6]. The inherent structural characteristics and physical and chemical characteristics of biochar have a certain impact on soil bulk density, water content, porosity,
cationic exchange capacity and nutrient content after it is applied into soil, thus directly or indirectly affecting soil microecological environment [7]. Biochar plays a role in promoting growth and increasing yield of different crops. Rice is the most important food crop in China, lodging is an important limiting factor of rice production, which not only seriously affects yield, but also directly reduces quality. The effects of biochar on the morphological characteristics of rice stem were researched in this study.

2. Materials and Experimental Design
The potted experiment was made in Shenyang institute of technology in 2017. The diameter of the potting was 25 cm, and the height of it was 22 cm. The test soil was sandy loam. Add 15kg soil which was screened over 5mm mesh per pot. The experimental rice was Qiutian xiaoding. The biochar which was supplied by Liaoning Jinhefu Agricultural Development with a pH of 9.23, it contains 1.53% nitrogen, 0.78% phosphorus and 1.68 % potassium.

Four treatments were set in the experiment. No biochar was added in the control (C0). 10g biochar was added per kg of dry soil in treatment 2(C1), the equivalent of 123g biochar per potting. 20g biochar was added per kg of dry soil in treatment 3(C2), the equivalent of 246g biochar per potting. 40g biochar was added per kg of dry soil in treatment 4(C3), the equivalent of 492g biochar per potting. The design of randomized block experiment was repeated 3 times for each treatment, with 6 pottings for each repeat. Each potting contained 8.6 kg soil (water content was 12.25% and dry soil weight was 7.5 kg). After fully mixing biochar with soil, the soil was deposited for one week. Uniform growth vigor of seedlings were selected to transplant with three holes in each potting and one plant in each hole, on May 26. After transplantation, nitrogen (urea, 300 kg hm$^{-2}$), phosphate (diammonium phosphate, 225 kg hm$^{-2}$) and potassium (potassium sulfate, 225 kg hm$^{-2}$) were applied, and ear fertilizer was added before heading stage.

3. Measurement Content and Method
Three pottings were taken for each treatment and three main stems were taken for each potting 30 days after heading. A total of nine main stems were combined into one sample. The plant height, height of gravity center, fresh weight per culm, internode length, internode fresh weight, internode anti-fracture and lodging index were measured.

- **Plant height**: the length of the ground to the top of the ear was the plant height.
- **Height of gravity center and single stem fresh weight**: put the stalk (cut off the underground part) on a fulcrum, move the stalk around to keep the stalk level, measure the length of the fulcrum to the end of the stalk, and weigh the fresh weight of single stem.
- **Internode length and internode fresh weight**: cut from the joint of the stalk and divide the stalk into several internodes. The first internode of base is called the first internode and is represented by I1. In turn, they are internodes 2 (I2) and internodes 3 (I3). Measure the length of each internode and weigh the fresh weight of each internode (with sheath).
- **Internode external diameter and stem wall thickness**: The internode was truncated from the middle, and the outer diameter of the long axis and the short axis were measured with a vernier caliper. The average value was taken as the thickness of the internode. The thickness of the long axis and the short axis at four intersection points with the stem wall was measured. The average value was taken as the thickness of the stem wall.
- **Internode volume**: the internode volume is regarded as an approximate hollow cylinder, D is for internode diameter, T is for stem wall thickness and L is for internode length, and V is for the internode volume.

$$V=\pi L (DT-T^2)$$  \hspace{1cm} (1)
Internode dry weight per unit length and internode dry weight per unit volume: dry weight per unit length of internode = dry weight / internode length, dry weight per unit volume of internode = dry weight / internode volume.

The data were analyzed using one-way analysis of variance (ANOVA) in SPSS 17.0. The means were separated using Duncan's new multiple range method (SSR) at an alpha level of 0.05. Figures were constructed using Excel 2013.

4. Results

Effects of biochar on the morphological characters of rice. It can be seen from table 1 that the plant height treated with different carbon application was shown as C1>C2>C0>C3. The difference between C1, C2 and C3 was significant, while the difference between C0 and C3 was not significant. Plant height of C1 and C2 increased by 7.00% and 6.67% respectively, and that of C3 decreased by 6.42%. With the increase of carbon fertilizer, the height of gravity center of C1 and C2 moved up by 2.35% and 5.72%, and that of C3 moved down by 3.98%. The length of basal internode (I1): C1 and C2 increased by 3.16% and 20.78% respectively, the difference were not significant, and C3 significantly decreased by 28.06% compared with C0. The length of second internode (I2): C1 and C2 increased by 19.54% and 13.21% respectively, and C3 decreased by 6.66%. The differences between C1, C2, C3 and C0 were significant. The length of third internode (I3): C1 and C2 increased by 7.22% and 2.32%, and C3 decreased by 7.26% respectively, showing no significant difference. It can be seen that carbon application had a great influence on the length of the three internodes, it had the greatest influence on the second internode. C0 had the lowest internode diameter. C2 had the largest internode diameter of I3, and C3 had the largest internode diameter of I1 and I2. Most of the difference in internode diameter between four treatments reached a significant level.

Table 1 Effects of biochar on the morphological characters of rice stem

| treatment | Plant height(cm) | Gravity center height(cm) | Internode length(mm) | Internode diameter(mm) |
|-----------|------------------|---------------------------|-----------------------|------------------------|
|           |                  |                           | I1 | I2 | I3 | I1 | I2 | I3 |
| C0        | 85.3ab           | 42.5ab                    | 10.9a | 15.2c | 15.0ab | 5.2d | 4.4c | 4.1b |
| C1        | 91.8a            | 43.5ab                    | 11.2a | 18.9a | 16.2a | 5.4c | 5.1b | 4.1b |
| C2        | 91.4a            | 45.0a                     | 13.7a | 17.5b | 15.4a | 5.5b | 5.1b | 4.4a |
| C3        | 79.9b            | 40.8b                     | 7.8b | 14.2c | 13.9b | 5.7a | 5.2a | 4.1b |

Different letters in the same column meant significant difference at 0.05 level.

Effects of biochar on rice stem wall thickness and internode dry weight. Figure 1 showed that the stem wall thickness of the basal internode (I1) had the tendency of increasing between different treatments, but the differences were not significant. The dry weight per unit length of internodes, the third internode (I3) was C2<C0<C3<C1, the basal internode (I1) and the second internode (I2) were C0<C2<C1<C3, indicating that with the increase of carbon application, the plumpness of internode increased. The dry weight per unit volume of the third internode (I3) was C2<C0<C3<C1, that of the basal internode (I1) was C2<C0<C1<C3, and that of the second internode (I2) was C2<C1<C0<C3, the differences were not significant.
Figure 1. Effects of biochar on rice stem wall thickness and internode dry weight

a: stem wall thickness between different biochar treatment, b: dry weight per unit length of internode between different biochar treatment, c: dry weight per unit volume of internode between different biochar treatment. SWT: stem wall thickness, DW/L: Dry weight per unit length of internode, DW/V: Dry weight per unit volume of internode. I1: the basal internode, I2: the second internode, I3: the third internode. Different letters in the same column meant significant difference at 0.05 level.

Relationship between several morphological characters of rice stem. It can be seen from table 2 that plant height was significantly positively correlated with the gravity center height. The internode length was significantly negatively correlated with stem wall thickness, it was significantly positively correlated with the dry weight of internode, and it was negatively correlated with dry weight per unit length of internode. The internode diameter had a positive correlation with stem wall thickness and dry weight per unit length of internode, reaching a significant or extremely significant level. The stem wall thickness was positively correlated with dry weight per unit length of internode.

Table 2 Correlation coefficients between morphological characters of rice stem (n=12)

| Item | PH  | GCH  | IL  | ID  | SWT  | DW  |
|------|-----|------|-----|-----|------|-----|
| GCH  | 0.9264** |      |     |     |      |     |
| IL   | 0.4817 | 0.4633 |     |     |      |     |
| ID   | 0.0150 | 0.0373 | -0.4722 |     |      |     |
| SWT  | -0.2355 | -0.1120 | -0.6149* | 0.6076* |      |     |
| DW   | 0.4762 | 0.4105 | 0.6044* | 0.1455 | -0.2449 |     |
| DW/L | -0.1353 | -0.1968 | -0.7679** | 0.7531** | 0.5961* | 0.0175 |
PH: Plant height, GCH: Gravity center height, IL: Internode length, ID: Internode diameter, SWT: stem wall thickness, DW: Dry weight of internode, DW/L: Dry weight per unit length of internode.

*and** significant at 5% and 1% probability levels respectively.

5. Conclusion
This study used four biochar levels to research the effects of biochar on the morphology of rice stem. It proved that the length of internode between the base of C1 and C2 increased with the increase of carbon. As the height of center of gravity increased, the thickness of stem wall decreased. The elongation of internodes decreased the stem wall thickness. With the increase of biochar, the stem diameter of I1 and I2 increased significantly. There was an increasing trend in the dry weight per unit length and the dry weight per unit volume with the increase of biochar. The effects of biochar on rice stem strength and lodging resistance should be further studied.

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