Effects of biochar application at different rates on chili growth

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Abstract. Biochar is a solid carbonaceous residue from biomass pyrolysis under anaerobic conditions. It has been well-known that biochar enhances plant growth and improve soil quality as the soil amendment. However, for chili (Capsicum annuum L), it is unknown whether biochar addition has any effect on its productivity. Thus, we studied the effects of different dosages of biochar addition at rates of 1.5% and 3% (w/w, 1.5%BC and 3%BC) on the germination and growth of chili using a pot experiment. The results show that the 3%BC increased the weight of fresh shoots and roots by 17.4% and 14.6%, respectively. However, the addition of biochar has no pronounced effect on the chili yield. Therefore, it is very important to choose the appropriate biochar and addition proportion for its application in agricultural soils.

1. Introduction
Biochar is pyrolyzed from biomass at anaerobic conditions, which gives sundry physical and chemical characteristics that can improve the capability for remediating toxified soils, increasing photosynthesis, improving carbon sequestration, reducing GHG emission, combating soil erosion, etc[1-2]. Previous studies have shown that biochar played beneficial role in the enhancement of crop yield as a fertilizer and the improvement of soil quality as a soil conditioner[3]. Chili (Capsicum annuum L), as a food additive and raw material in medicine, has been cultivated throughout the world for hundreds of years and is one of the most economical and agriculturally important vegetable crops all over the world[4]. However, it is unclear whether biochar addition has any effect on its growth and fruit production. Thus, the objective of this study was to investigate the effect biochar addition at different rates on the growth and production of chili through a pot experiment.

2. Materials and methods

2.1 Soil and biochar
Soil samples were collected from a farmland in Qingdao (N 120°30'24" and E 36°9'45"), China. The soil samples were collected from the surface (0–20 cm) of soil randomly, air-dried, ground to pass a 2 mm sieve, and thoroughly homogenized for further experiment. Biochar was produced by blended wood wastes collected from local furniture factories, the wastes was pyrolysis at 450 °C for 6 h in a self-designed carbonization furnace using slow pyrolysis. The biochar was ground to pass a 2 mm sieve and stored in a brown glass bottle for further experiment.
2.2 Pot experiment
Chili (Capsicum annuum L) was selected as the test plant. The biochar was added into the soil at rates of 0%, 1.5% and 3% (w/w), labeled as CK, 1.5%BC and 3%BC, respectively. The plastic pot (57 cm in length, 32 cm in wide, 20 cm in depth) used in this study were filled with 30 kg the soil or biochar-soil mixture. Three seeds of chili were sowed in each plastic pot. All pots were placed in a greenhouse and maintained at 65% of the maximum water holding capacity (WHC) during the cultivation. The germination rate in each pot was recorded daily. The stem diameter of chili and the plant height were recorded using a vernier caliper (500-173, Mitutoyo, Japan) and a ruler during the incubation. The chili fruits were collected at day of 80, 102, 115, 129, 153 and 180, respectively. After the 180 days of incubation, the shoots and roots of the chili were separately harvested. The yield of chili fruits, the fresh and dry biomass of shoots and roots were recorded.

2.3 Statistical analysis
All results were expressed as the mean values (n = 3). The standard deviation was represent as error bars. Significant differences among the treatments were analyzed. Analysis of variance (ANOVA) with Duncans multiple range test (P = 0.05) was performed with Statistical Product and Service Solutions Software 20.0 (SPSS 20.0).

3. Results and discussion

3.1 Effects of biochar on chili seed germination
The germination rate of the chili seeds in the soil treated with different dosage of biochar is shown in Figure 1. Compared with CK, no significant differences in the germination rates were found (P > 0.05) between the CK and biochar treatments. The germination rate in the 3%BC treatment was close to that of the CK. The 1.5%BC treatment increased 9.10% relative to CK. This was similar to the study of Meschewski, who found that no stimulation of earlier plant emergence was observed in any soil following biochar additions vs the controls[5].

Figure 1. Effects of biochar application on chili germination rate. The bars represent the standard deviation of the means (n = 3). The small letters on the bars indicate significant analysis, which were analysed by Duncan’s test (P = 0.05) using SPSS 20.0.
Figure 2. Effects of biochar application on shoot height of the chili. The bars represent the standard deviation of the means (n = 3).

Figure 3. Effects of different dosage of biochar on chili height (a), stem diameter (b), fresh weight of chili shoots and roots (c) and dry weight of chili shoots and roots (d). The bars represent the standard deviation of the means (n = 3). Different letters among different treatments indicate significant differences, which were analyzed by Duncan’s test (P = 0.05) using SPSS 20.0.
Figure 4. Effects of different dosage of biochar on the total chili yield over time (a) and the final total chili yield (b). The bars represent the standard deviation of the means (n = 3). Different letters among different treatments indicate significant differences, which were analyzed by Duncan’s test ($P = 0.05$) using SPSS 20.0.

### 3.2 Effects of biochar on chili growth

During the cultivation process, the shoot height of chili gradually increased over time, and the plant height basically stabilized around the 110th day (Figure 2). As shown in Figure 3, the biochar addition had no significant effect on the plant height and stem diameter of chili. In particular, the higher dosage (3%BC) resulted in a slight increase (8.25% and 2.46%) in plant height and stem diameter compared to CK. However, the lower dosage (1.5%BC) caused a slight decrease (0.64% and 2.81%) in plant height and stem diameter relative to CK, indicating that the 1.5% probably is an unfavorable dosage for chili growing. The addition of biochar promotes the growth of chili as shown from both fresh and dry weight changes (Figure 3). The higher dosage (3%BC) increased the fresh weight and dry weight of shoots by 17.4% and 16.3%, which had a more significant effect than the lower dosage (1.5%BC). As for chili roots, the higher dosage (3%BC) slightly increased the fresh weight and dry weight by 14.6%, 18.4%, respectively and its effect was more significant than the lower dosage (1.5%BC), it probably results from the biochar positively impacting soil quality and fertility, improving nutrient cycling, reducing nutrient leaching from soil, and stimulating soil microbial activity [6]. The biochar had no significant effect on the yield of chilis (Figure 4). The addition of biochar slightly reduced the yield of chilis, which reduced 7.37% at lower dosage (1.5%BC) and 4.56% at higher dosage (3%BC), which is in coincidence with the research of Zheng et al, who found the addition of peanut shell biochar alone showed no pronounced effects on the vegetable yield in the four successive seasons [7]. Therefore, it is very important to choose the appropriate biochar and proportions during its application for agricultural production.

### 4. Conclusions

Our results revealed that the addition of biochar had no significant effect on the germination, plant height and stem diameter of chili. 1.5%BC and 3%BC treatments increased the fresh weight of shoots and roots relative to the CK, indicating that the addition of biochar promoted the growth of chili. The addition of biochar has no pronounced effect on the chili yield. The results of our study provide useful information for selecting the appropriate biochar to improve the chili yield.

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