Effect of biochar application at different adding rates on garlic (Allium sativum) growth and production

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Abstract. Biochar is a solid and carbon-rich product obtained from the thermal treatment of biomass, which have been widely used in agricultural production and environmental remediation. However, it is unknown whether biochar addition have positive effect on the growth and production of garlic (Allium sativum), an important edible vegetable in China. Thus, we investigated the effects of a wood wastes derived biochar addition at rates of 1.5% and 3% (w/w, 1.5%BC and 3%BC) on the germination, growth, and production of garlic using a pot experiment. The results showed that 1.5%BC significantly increased the weight of fresh roots by 29%, indicating that the 1.5%BC promoted the garlic production. However, the higher dosage treatment (3%BC) slightly inhibited the seedling growth, and decreased the garlic production. Our findings provide useful information for developing biochar-based technology to improve garlic production.

1. Introduction
Biochar is a solid, carbon-rich product obtained from pyrolyzing biomass under oxygen-limited conditions[1]. Recently, biochars have been developed into functional materials for soil improvement and environmental remediation due to the low cost and excellent properties such as abundant functional groups, high surface area, and high reactivity[1-2]. Previous studies showed that the biochar application into soil could stimulate plant growth through improving soil quality and increasing nutrient availability in the soils[3-4]. Garlic (Allium sativum) is the commonly edible vegetable with medicinal potentials. More recently, epidemiological, experimental and clinical evidence have revealed that garlic possess a wide range of health benefits, such as lowering of blood lipids and blood pressure[5]. Due to continuous cropping of garlic for many years, the increase of pests and diseases of garlic and the decrease in the yield and quality of garlic cloves have severely restricted the development of the garlic industry. Therefore, it is urgent to weaken the harm caused by continuous cropping through improving the soil. However, it is unknown whether biochar addition has positive effect on the growth and production garlic. Therefore, the objectives of this study were to investigate the effect biochar addition at different rates on the growth and production of garlic using a pot experiment. The findings of this study could provide effective basis for improving garlic planting and yield through improving the degraded soil.
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 surface (0–20 cm) soil samples were randomly collected, air-dried, ground to pass a 2-mm sieve, and thoroughly homogenized. Biochar was produced by blended wood wastes collected from local furniture factories at 450 °C for 6 h in a self-designed carbonization furnace using slow pyrolysis, and was ground to pass a 2-mm sieve. The biochar properties were previously reported [6].

2.2 Pot experiment
Garlic (Allium sativum) 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 pots (40 cm in length, 22 cm in width, 12 cm in depth) used in this study were filled with 14 kg soil or biochar-soil mixture, and were cultivated for one week at 65% of maximum water holding capacity (WHC) in a greenhouse before seed sowing. After one week, six seeds of garlic were sowed in each pot. The germination rate in each pot was recorded daily. During the cultivation, all pots were maintained at 65% of the maximum WHC. After 93 days of cultivation, the chlorophyll (CCI) of garlic shoots were measured using chlorophyll detector (CCM-200, OPTI-sciences, USA), then the shoots and roots of the garlic were separately harvested. The stem diameter and height of the garlic shoots were measured using a vernier caliper (500-173, Mitutoyo, Japan) and a ruler, respectively. The fresh biomass of shoot and root were recorded.

2.3 Statistical analysis
All results were expressed as the mean values (n = 6). Error bars presented in the results represent the standard deviation. Significant differences between the treatments were analyzed using a one-way analysis of variance (ANOVA) with Duncan’s multiple range test (P = 0.05) using Statistical Product and Service Solutions Software 20.0 (SPSS 20.0)

3 Results and discussion

3.1 Effects of biochar on garlic seed germination
The germination rate and potential of garlic seeds in the soil treated with different dosage of biochar is shown in Figure 1. Compared with CK, no significant difference (P > 0.05) in the germination rates and germination potential was observed in the 1.5%BC, indicating that the biochar added at 1.5% had no effect on the seed germination. However, 3%BC treatment decreased the germination potential by 12.7% relative to the CK, indicating that the higher dosage addition of biochar at 3% could have negative effect on seed germination.
Figure 1. Effects of biochar application on germination rate (a) and potential (b) of garlic seeds. The bars represent standard deviation of the means ($n = 6$). 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 garlic seedling. The bars represent standard deviation of the mean values ($n = 6$).
Figure 3. Effects of different dosage of biochar on garlic CCI (a), stem diameter (b), fresh weight of garlic shoot (c) and root (d). The bars represent standard deviation of the means (n = 6). Different letters among different treatments indicate significant differences, which were analysed by Duncan’s test (P = 0.05) using SPSS 20.0.

3.2 Effects of biochar on garlic seedling growth

During the cultivation, the shoot height of the garlic seedling gradually increased, the addition of biochar inhabited the height of shoot significant in the early stages of cultivation, but had no significant effect at the end (Figure 2). This suggested that biochar did not promote plant height growth. As shown in Figure 3, the biochar addition had no effect on CCI, stem diameter of the garlic seedling. Particularly, the higher dosage (3%BC) caused a slight decrease (10.7%) in stem diameter relative to CK. This was consistent with the germination potential in the 3%BC treatment (Figure 1). Fresh weight of the garlic shoot (Figure 3c) showed the same trend with the CCI and stem diameter. However, the 1.5%BC treatment slightly increased in the biomass of fresh shoot (Figure 3d), indicating that the 1.5% probably is a suitable dosage for garlic growing. Similarly, 1.5%BC significantly increased the weight of fresh root by 29%. These results partly validated our hypothesis that biochar could promote the garlic growth and production. The positive effects were probably due to the nutrients (e.g., K, Ca, Na) released from the biochar for garlic growth[7-8]. The negative effect observed in the high dosage treatment was probably due to organic substances such as phenols released by high-dosage biochar inhibited plant growth. This was in line with the previous study reported by Huang et al. (2017), who found the application of biochar at a high rate of 5% induced adverse impact on soil function[9]. Therefore, it is very important to choose a suitable dosage of biochar during its application for agricultural production.
4. Conclusions
Our results revealed that low dosage of biochar addition (1.5%) effectively increased garlic production, whereas the high dosage of biochar (3%) inhibited its growth and production. Our findings provide useful information for selecting suitable biochar to enhance garlic production.

Acknowledgments
This study was supported by Shandong Key Research and Development Program-Science and Technology Innovation Project (2018CXGC0304).

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