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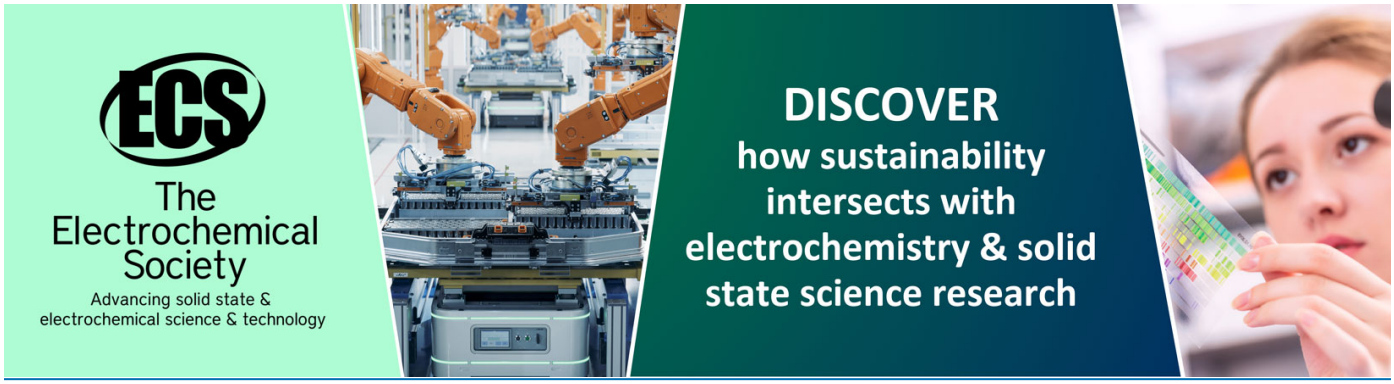

Effect of adding biochar with wood vinegar on the growth of cucumber

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Abstract. The chemical fertilizers are abused to improve crop yields, which cause lots of soil problems (e.g., soil compaction and native nutrient loss). We thus investigated the potential of the combination of biochar and wood vinegar as a new type of fertilizer to replace the traditional fertilizer. The results in this study showed that the combined addition of biochar with wood vinegar had the greatest promotion effect on the plant growth of cucumber. Compared to the control treatment, the biochar addition with wood vinegar significantly increased the plant height, root length, root volume and root tips by 29.7%, 117%, 121% and 76.1%, respectively. These positive effects could be attributed to the benefits of the addition of biochar with wood vinegar treatment on improving soil fertility, increasing nutrient supply, and further stimulating plant growth. Overall, the combination of biochar and wood vinegar could be a promising fertilizer to promote plants growth and enhance crop yields.

1. Introduction

In the past decades, the demand of global food increased dramatically due to the rapid increased population. With the increasing environment pollution and climate issues, the development of China 's agricultural is facing a huge crisis. To solve this problem, chemical fertilizers are abused to improve crop yield, resulting in a series of soil environmental problems, such as soil compaction and the loss of soil nutrients [1]. Biochar acting as a promising soil amendment, which is produced from the pyrolysis of waste biomass under a limited or no oxygen condition [2], can improve soil physico-chemical properties, promote plant growth and ameliorate soil pollution [3]. Jeffery et al. reported that biochar could promote plant growth in soils by increasing soil organic carbon (SOC) content and water holding capacity [4]. However, the addition of biochar not always causes consistent yield increase. Vaccari et al. reported that the biochar addition increased the availability of NH_4^+, P and K, but not improved the yield of tomato [5]. Additionally, wood vinegar, a liquid by-product that obtained from the condensed vapors generated during the biomass pyrolysis, had been reported to enhance the crop yields and the nutrient uptake by plants followed by its application into agricultural soils [6]. And Meanwhile, there is limited study on the combine effects of biochar and wood vinegar on plant growth and the corresponding mechanisms are still unclear. Thereby, the major objective of this study is to investigate the effects of the biochar addition with or without wood vinegar into the agricultural soils on the growth of cucumber.

2. Materials and methods

2.1 The preparation of samples

The surface soil (0-20cm) used in this study was collected from a farmland, located Qingdao, Shandong province, China. The field-moist soil samples were thoroughly mixed, gently passed through a 2-mm sieve, and air dried for 14 days. The poplar (*Populus trichocarpa*) was pyrolyzed at 500 °C for 5 h to produce the woody biochar and the wood vinegar (the liquid by-product collected from the cooling systems after pyrolysis process). All the biochar samples were ground to pass through a 0.5-mm sieve using a pulverizer (GM200, Retsch, Germany) for further analyses and pot experiment. The wood vinegar was standed for 3 months under darkness and then the upper component was collected for further analyses and pot experiment.

2.2 Characterization of biochar

FTIR analysis was carried out to characterize the organic functional groups in the biochar sample. The biochar powders were mixed with spectrum pure KBr at ratio of 1:100 (w/w) fully, and the spectra of mixture were recorded in a 4000-400 cm^{-1} region by a fourier transform infrared spectrometer (FTIR, GX, PerkinElmer, USA) . The surface morphology of the biocahr was observed using a scanning electronic microscope (SEM,S4800, Hitachi, Japan).

2.3 Experimental design

Cucumber (*Cucumis sativus L*) were cultivated in a glasshouse, where the temperature was kept at 24 °C during the incubation. Afterwards, 75-g air-dried soil was packed into a nursery box for a 30 days of pot experiment. The prepared biochar was incorporated into the soils at a rate of 1.5% (w/w), hereafter referred to as the BC treatment. The wood vinegar used as a leaf fertilizer was fertilized on the cucumber at the rate of 0.02% (v/v), hereafter referred to as the WV treatment. The combined application of biochar with wood vinegar into the soils and the plant leaves at the rate of 1.5% (w/w) and 0.02% (v/v), respectively, which was referred to as the BCW treatment. The deionized water treatment was used as the control check (CK) and all the tests were performed in four replicates. After the 30 days of incubation, the root parameters including root length, root volume, root surface area and root tip number were measured by a root system scanner (Expression 1680, Epson, USA) and analyze with a WinRHIZO Pro 2005b (Canada).

2.4 Statistical analysis

All the data in this study were expressed as mean values. Error bars presented in the results represent the standard deviation. Significant differences among the treatments were analyzed using 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. Result and discussion

3.1 Characterization of biochar

Abundant adsorption peaks were found in biochar (Figure 1a), including -OH at 3400 cm^{-1}, aliphatic -CH_2- at 2950 cm^{-1}, 2882 cm^{-1} and 1421 cm^{-1}, C-O-C stretching vibrations at 1050 cm^{-1}, ester C=O at 1746cm^{-1}, aromatic C=O at 1640 cm^{-1} (C=O of quinones or conjugated ketones) and out-of-plane deformations of C-H at 796 cm^{-1}. The results indicated that the poplar-derived biochar contained abundant functional groups. Moreover, large amounts of pores can be observed in the biochar by the SEM micrograph (Figure 1b). Therefore, the biochar acting as a promising soil amendment, will potentially improve the physico-chemical properties of the soils, such as enhancing the porosity and cation exchange content [7].

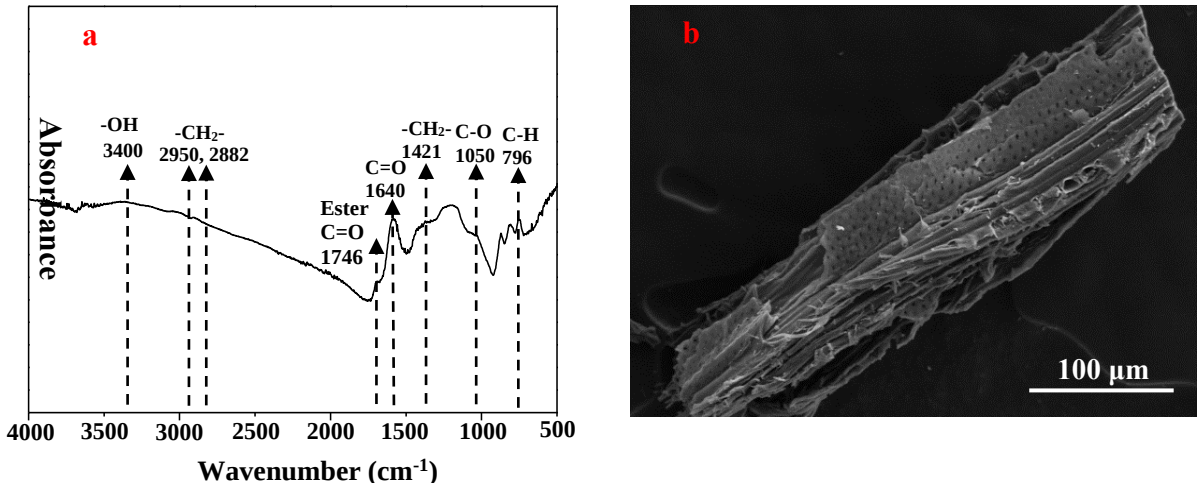

Figure 1. FTIR spectra (**a**) and SEM image (**b**) of the biochar from poplar at 500 °C.

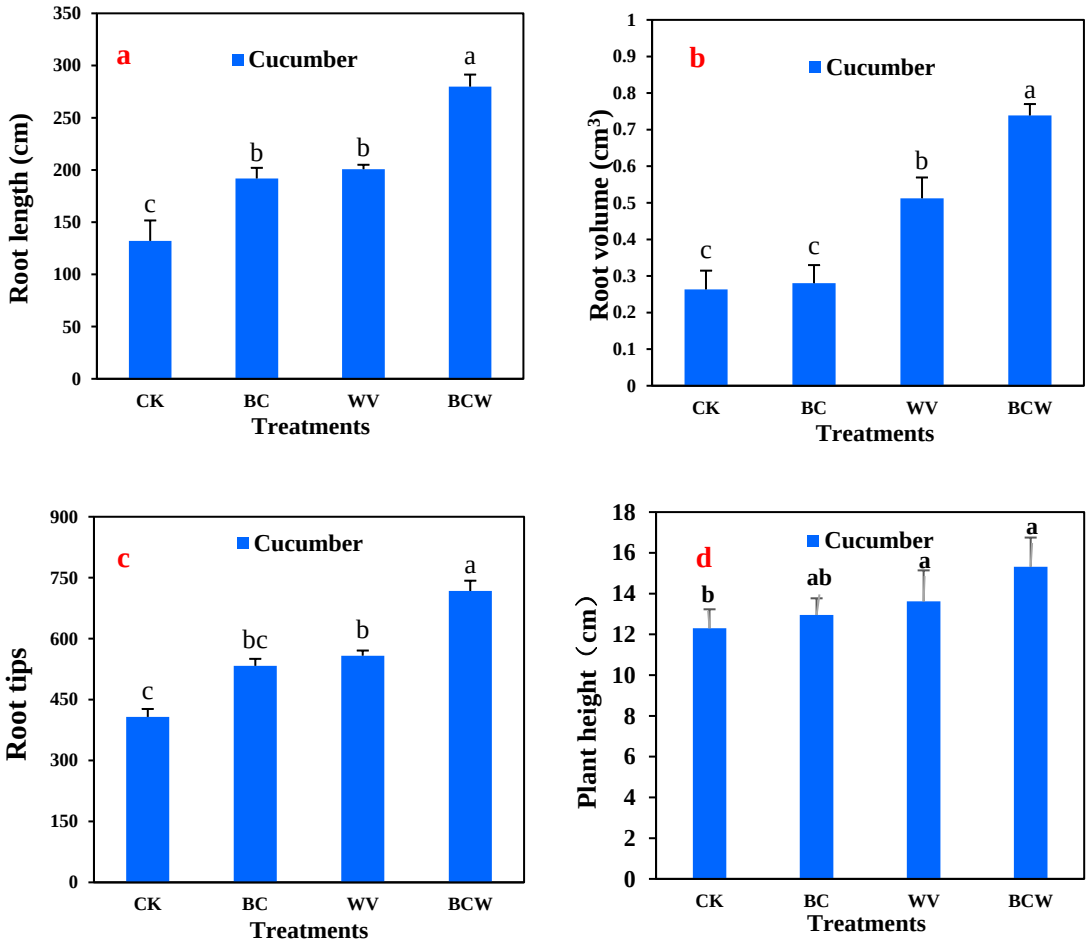

Figure 2. Effects of adding biochar and wood vinegar on the plant growth of cucumber.

CK, BC, WV and BCW indicate the plants was treated with deionized water, biochar, wood vinegar and the combination of biochar and wood vinegar, respectively. The different letters among different treatments indicate the significant differences, which were analyzed by Duncan's test (P = 0.05) using SPSS 20.0. Error bars represent standard errors of the mean (n = 4).

3.2 Effects of adding biochar and wood vinegar on the cucumber growth

As shown in Figure 2, the wood vinegar alone addition significantly increased the plant height, root length, root volume and root tips of cucumber by 20.2%, 45.2%, 7.8% and 30.9%, respectively, compared to that of the CK treatment. Consistently, the biochar alone addition also obviously increased the growth parameters of cucumber, compared to the CK treatment. Moreover, the combined addition of biochar with wood vinegar showed the greatest promotion effects on the growth of cucumber, which significantly increased the plant height, root length, root volume and root tips of cucumber by 29.7%, 117%, 121% and 76.1% than that in the CK treatment, respectively. These results showed that the combined addition of biochar with wood vinegar had the greatest promotion effects on the plant growth in contrast with the other treatments, which was mainly attributed to the following reason, i.e., improving the soil physico-chemical properties, such as loosening soil structure, improving soil acidity, elevating soil cation exchange capacity (CEC), and consequently benefiting the N and P translocation from soil to plant [7]. In addition, the wood vinegar could stimulate the growth of plants through increasing the chlorophyll content and enhancing photosynthetic rate and root vigor [8]. Thus, the combined addition of biochar with wood vinegar could significantly promote the plant growth over the biochar and wood vinegar adding alone.

4. Conclusion

The results from the pot experiments revealed that the combination of biochar with wood vinegar could maximize the promote effects of biochar and wood vinegar on the growth of plants. The mechanisms for promoting the plant growth may be attributed to the multiple benefits on the improvement of soil fertility, nutrient supply and translocation to the plant after the biochar and wood vinegar amendment. These effects offer an overall unique beneficial condition for the plantgrowth, and the specific mechanisms still deserve further research.

Acknowledgements

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