EFFECTS OF BIOCHAR APPLICATION TO SOILS ON SEEDLING GROWTH OF WHEAT

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Abstract

Biochar is a carbon-rich byproduct that arises from pyrolyzing organic compounds under high temperature and oxygen starved conditions. It has been shown that biochar improves the physical and chemical soil quality, enhances nutrient availability and reduces the acidity.

In this work, we examined the effect of biochar on seed germination and seedling growth of wheat (Triticum aestivum L.) under different soil conditions. The study was carried out as pot experiments using infertile and fertile type of soils with or without biochar applications.

Germination percentage, shoot length, shoot fresh weight and shoot dry weight of wheat were measured at the end of the experiment. In both soil types, no significant difference in germination percentage was found between treatments. Shoot growth parameters were increased significantly after low and medium dose of biochar application in infertile soil. On the other hand, biochar had not positive or negative effect on these parameters in fertile soil.

Key words: *biochar, wheat, germination, seedling growth*

1. INTRODUCTION

Biochar is a carbon-rich byproduct that arises from pyrolyzing organic compounds under high temperature and low or zero oxygen concentrations (Lehmann & Joseph 2009; Sohi et al. 2010). It is a very stable compound, can remain in the soil for long periods of time and plays an important role in sequestration of carbon. Therefore, the long-term stability of biochar in soil can contribute to a decrease of CO_2 emissions into the atmosphere (Ahmad et al. 2014). It has been shown that application of biochar improves the physical and chemical soil quality, enhances nutrient availability and reduces the acidity (Lehmann et al. 2003; Novak et al. 2009; Karhu et al. 2011). Consequently, biochar exhibits a great potential in agricultural use, such as increasing soil productivity and yield output (Sohi et al. 2010; Jeffery et al. 2011).

Wheat is an important cereal crop and is an integral part of daily diet of over 70% of the population of the world (Tang et al. 2011). It is grown on about 200 million hectares in a range of environments and supplying about 9% of world food demand (Anthoni et al. 2004; Feng et al. 2008). Therefore, global wheat production must continue to increase to meet the increasing demand of population growth (Singh et al. 2007). Achieving this goal is very difficult because of reduced water availability and poor soil conditions (Erekul & Köhn 2006; Feng et al. 2008).

Cereal yields have increased very slowly during the past 30 years due to low rainfall and poor soils. Water deficiency and infertile soils impose important limits on the productivity of crops although farmers have access to enhanced varieties and fertilizer inputs (Cassman 1999). Maintenance and enhancement of soil quality in arable areas is important to sustaining agricultural productivity and food security for future generations (Reeves 1997). Consequently, increased attention has been given recently to improve soil quality by using organic amendments such as compost (Ouédraogo et al. 2001) and biochar (Chan et al. 2007).

In recent years, more studies have been conducted to determine the effect of biochar on germination and seedling growth of various plants. Generally, positive (Oh et al. 2012; Budi & Setyaningsih 2013; Saxena et al. 2013) and neutral (Free et al. 2010; Sun et al. 2014) effects of biochars were found in these studies. A dose-dependent negative effect on germination and seedling growth was also found in some studies (Solaiman et al. 2012). From the results of these studies, it seems that feedstock of biochar, soil type and biochar concentration in soil have an important role on these parameters.

In this work, we examined the effect of biochar on seedling growth of wheat (*Triticum aestivum* L.) under different soil conditions. The study was carried out as pot experiments using infertile and fertile type of soils with or without biochar applications. Based on the previous studies (mentioned as above), we hypothesized that low and medium concentrations of biochar will enhance the seedling growth of wheat under infertile soil conditions.

2. MATERIALS AND METHODS

2.1. Biochar Preparation

Biochar was obtained from a local biochar producer and was produced from a typical fast pyrolysis process of pine wood. It was ground mechanically to pass through a 1-mm mesh stainless steel sieve for the further use.

2.2. Soil Collection

Two different soil types were selected for the pot experiment. The first one was collected from an agricultural field and had a good soil texture. The second one was collected from an infertile area with poor growth. Both soil samples were air-dried and sieved through 2-mm mesh prior to use.

2.3. Experiment

Wheat seeds were sterilized with sodium hypochlorite (3% w/v) for 5 minutes and washed extensively with distilled water. After that, 10 seeds were placed in pots containing soils amended with different concentrations biochar (Table 1). Four pots were used for each soil type and treatment. The experiment was repeated twice. All pots were kept in a greenhouse under natural light and temperature conditions. The plants were watered with half-strength Hoagland nutrient solution twice a week. The aboveground parts (shoots) of plants were harvested after 6 weeks. Germination percentage (%), shoot length (cm), shoot fresh weight (mg) and shoot dry weight (mg) were measured for each soil type and treatment. In order to determine dry weight, plant samples were placed in a pre-heated oven at 70 °C for 48 h.

2.4. Statistical Analyses

The data sets were analyzed by one-way analysis of variance (ANOVA) to assess the effect of treatments (different biochar applications) on seed germination and shoot growth. Data normality and homoscedasticity were verified using the Shapiro-Wilk test and Bartlett's test before each analysis, respectively. If needed, logarithmic and square root transformations were done. Post-hoc comparisons were conducted with Tukey's honestly significant difference test at $\alpha = 0.05$.

Table 1. Concentrations of biochar in soil (w/w)

Treatment code	Biochar concentration (%)	Soil concentration (%)
B0	0	100
B1	5	95
B2	10	90
B3	20	80



Figure 1. Study soil amended with different concentrations of biochar

3. RESULTS AND DISCUSSION

In both soil types, no significant difference in germination percentage was found between treatments (Figure 2). Our results are in accordance with previous reports which showed that biochar applications do not significantly affect the seed germination of maize (Free et al. 2010) and grass (Sun et al. 2014). On the other hand, Solaiman et al. (2012) showed that feedstock of biochar and concentration of application significantly affect the seed germination.

Furthermore, it was suggested that depending on source of biochar, it may contain high concentrations of nutrients that can inhibit seed germination (Gaskin et al. 2008; Solaiman et al. 2012).

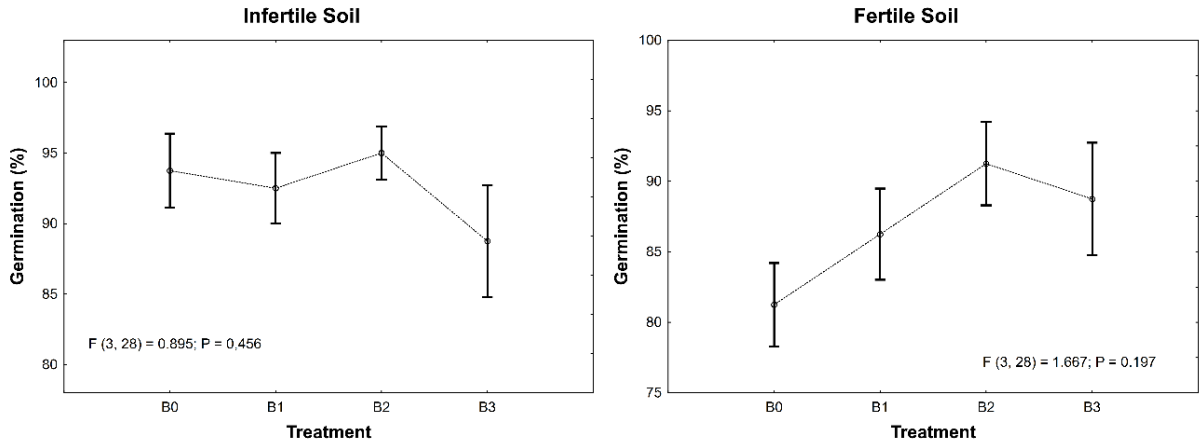


Figure 2. The effect of biochar application to soils on seed germination of wheat

An increased number of studies were carried out recently to determine the effects of biochar application on seedling growth (Free et al. 2010; Oh et al. 2012; Budi & Setyaningsih 2013; Sun et al. 2014). Generally, positive and neutral effects of biochars were found in these studies. Our results showed that shoot growth parameters such as shoot length, shoot dry weight and shoot fresh weight are stimulated by low (B1) and medium (B2) concentrations of biochar application in infertile soil (Figure 3, 4 and 5). However, this stimulation was not achieved at the highest concentration of biochar (B3). Our findings are consistent with Solaiman et al. (2012) which have indicated that high rate of biochar application may have negative effect on seedling growth.

On the other hand, biochar had not positive or negative effect on shoot growth parameters in fertile soil, with one exception. (Figure 3, 4 and 5). B3 treatment resulted in a significant decrease in shoot length compared with B0 (Figure 3). Our findings indicated that type of soil strongly influences the seedling

growth response to biochar. Consequently, application of biochar can not only improve the soil quality, but also stimulate the seedling growth of plants in infertile soils.

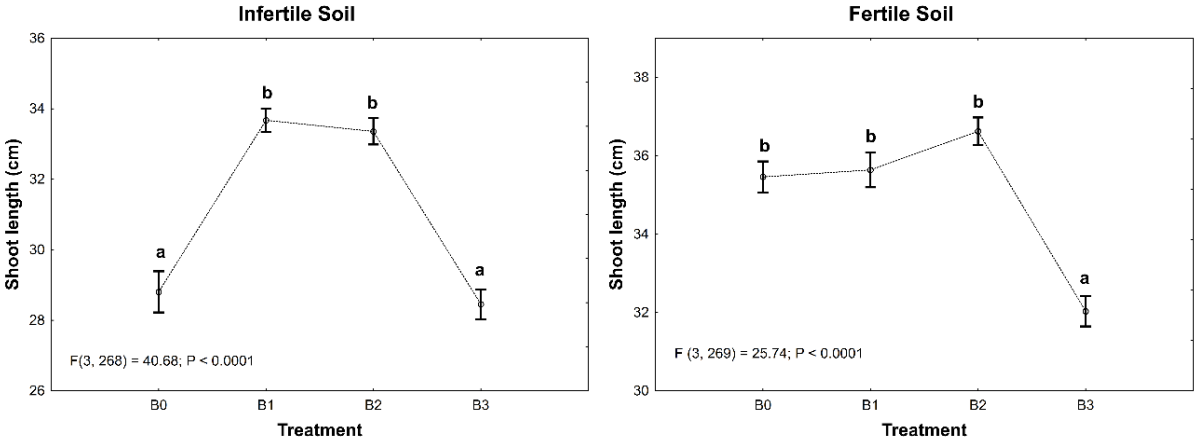


Figure 3. The effect of biochar application to soils on shoot length of wheat

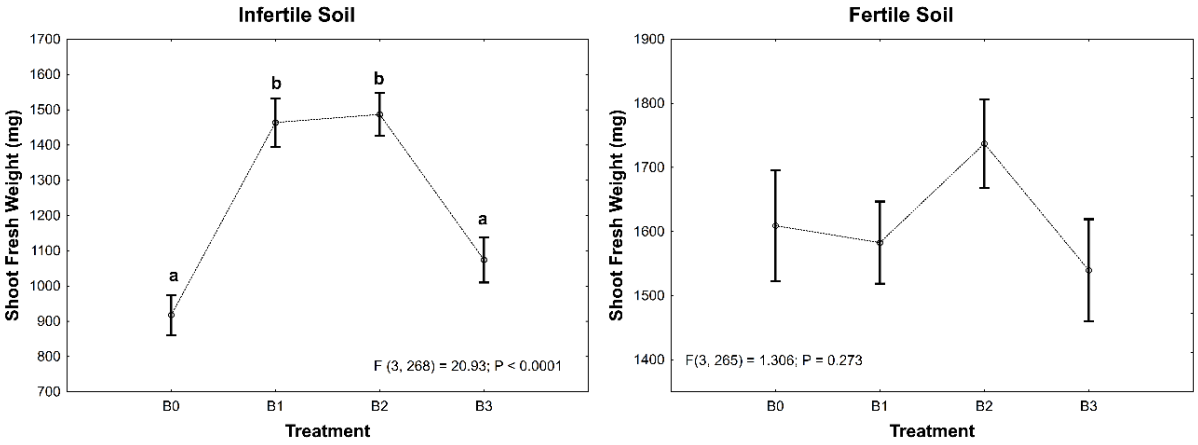


Figure 4. The effect of biochar application to soils on shoot fresh weight of wheat

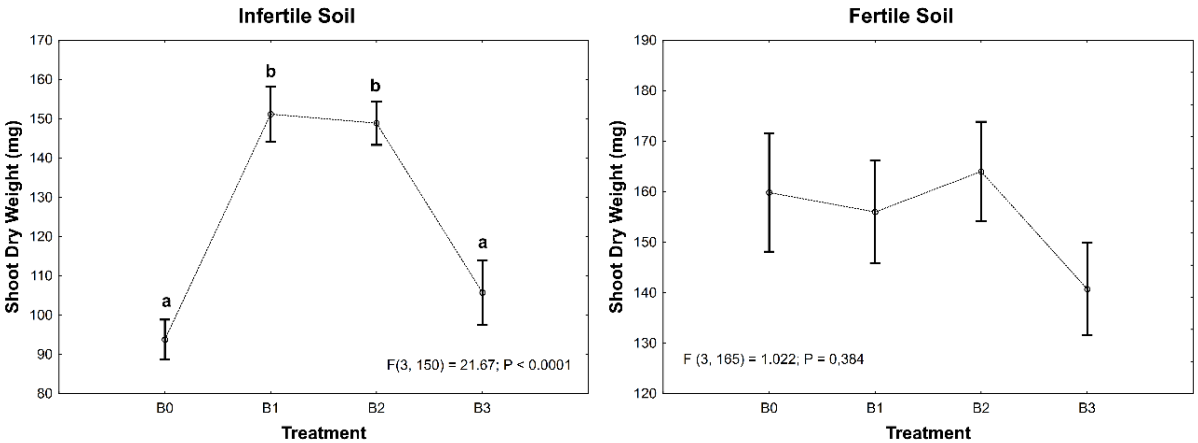


Figure 5. The effect of biochar application to soils on shoot dry weight of wheat

4. CONCLUSION

Biochar application did not affect the germination percentage of wheat seeds for both soil type. However, our results clearly showed that the addition of biochar to infertile soil promotes the seedling growth of wheat significantly.

It seems that the use of biochar as a soil amendment could have huge potential in agriculture, as apart from benefits in terms of carbon sequestration. More research is still needed to better elucidate the physiological and biochemical effect of biochar on plant growth.

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REFERENCES

Ahmad, M, Rajapaksha, AU, Lim, JE, Zhang, M, Bolan, N, Mohan, D & Ok, YS 2014, 'Biochar as a sorbent for contaminant management in soil and water: a review', *Chemosphere*, vol. 99, pp. 19-33.

Anthoni, PM, Freibauer, A, Kolle, O & Schulze, ED 2004, 'Winter wheat carbon exchange in Thuringia, Germany', *Agricultural and Forest Meteorology*, vol. 121, pp. 55-67.

Budi, SW & Setyaningsih, L 2013, 'Arbuscular mycorrhizal fungi and biochar improved early growth of Neem (*Melia azedarach* Linn.) seedling under Greenhouse conditions', *Journal Manajemen Hutan Tropika*, vol. 19, pp. 103-110.

Cassman, KG 1999, 'Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture', *Proceedings of the National Academy of Sciences*, vol. 96, pp. 5952-5959.

Chan, KY, Van Zwieten, L, Meszaros, I, Downie, A & Joseph, S 2008, 'Agronomic values of greenwaste biochar as a soil amendment', *Soil Research*, vol. 45, pp. 629-634.

Erekul, O & Köhn, W 2006, 'Effect of Weather and Soil Conditions on Yield Components and Bread-Making Quality of Winter Wheat (*Triticum aestivum* L.) and Winter Triticale (*Triticosecale* Wittm.) Varieties in North-East Germany', *Journal of Agronomy and Crop Science*, vol. 192, pp. 452-464.

Feng, Z, Kobayashi, K & Ainsworth, EA 2008, 'Impact of elevated ozone concentration on growth, physiology, and yield of wheat (*Triticum aestivum* L.): a meta-analysis', *Global Change Biology*, vol. 14, pp. 2696-2708.

Free, HF, McGill, CR, Rowarth, JS & Hedley, MJ 2010, 'The effect of biochars on maize (*Zea mays*) germination', *New Zealand Journal of Agricultural Research*, vol. 53, pp. 1-4.

Gaskin, JW, Steiner, C, Harris, K, Das, KC & Bibens, B 2008, 'Effect of low-temperature pyrolysis conditions on biochar for agricultural use', *Transactions of the ASABE*, vol. 51, pp. 2061-2069.

Jeffery, S, Verheijen, FG, Van Der Velde, M & Bastos, AC 2011, 'A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis', *Agriculture, Ecosystems & Environment*, vol. 144, pp. 175-187.

Karhu, K, Mattila, T, Bergström, I & Regina, K 2011, 'Biochar addition to agricultural soil increased CH_4 uptake and water holding capacity–results from a short-term pilot field study', *Agriculture, Ecosystems & Environment*, vol. 140, pp. 309-313.

Lehmann, J, da Silva Jr, JP, Steiner, C, Nehls, T, Zech, W & Glaser, B 2003, 'Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments', *Plant and Soil*, vol. 249, pp. 343-357.

Lehmann, J & Joseph, S 2009, *Biochar for Environmental Management: Science and Technology*, Earthscan, London & Sterling.

Novak, JM, Busscher, WJ, Laird, DL, Ahmedna, M, Watts, DW & Niandou, MA 2009, 'Impact of biochar amendment on fertility of a southeastern coastal plain soil', *Soil Science*, vol. 174, pp. 105-112.

Oh, T, Shinogi, Y, Chikushi, J, Lee, Y & Choi, B 2012, 'Effect of aqueous extract of biochar on germination and seedling growth of lettuce (*Lactuca sativa* L.)', *J. Fac. Agr., Kyushu Univ*, vol. 57, pp. 55-60.

Ouédraogo, E, Mando, A & Zombré, NP 2001, 'Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa', *Agriculture, Ecosystems & Environment*, vol. 84, pp. 259-266.

Reeves, DW 1997, 'The role of soil organic matter in maintaining soil quality in continuous cropping systems', *Soil and Tillage Research*, vol. 43, pp. 131-167.

Saxena, J, Rana, G & Pandey, M 2013, 'Impact of addition of biochar along with Bacillus sp. on growth and yield of French beans', *Scientia Horticulturae*, vol. 162, pp. 351-356.

Singh, RP, Huerta-Espino, J, Sharma, R, Joshi, AK & Trethowan, R 2007, 'High yielding spring bread wheat germplasm for global irrigated and rainfed production systems', *Euphytica*, vol. 157, pp. 351-363.

Sohi, SP, Krull, E, Lopez-Capel, E & Bol, R 2010, 'A review of biochar and its use and function in soil', *Advances in Agronomy*, vol. 105, pp. 47-82.

Solaiman, ZM, Murphy, DV & Abbott, LK 2012, 'Biochars influence seed germination and early growth of seedlings', *Plant and Soil*, vol. 353, pp. 273-287.

Sun, Y, Gao, B, Yao, Y, Fang, J, Zhang, M, Zhou, Y, Chen, H & Yang, L 2014, 'Effects of feedstock type, production method, and pyrolysis temperature on biochar and hydrochar properties', *Chemical Engineering Journal*, vol. 240, pp. 574-578.

Tang, YL, Jun, LI, Wu, YQ, Wei, HT, Li, CS, Yang, WY & Chen, F 2011, 'Identification of QTLs for Yield-Related Traits in the ecombinant Inbred Line Population Derived from the Cross Between a Synthetic Hexaploid Wheat-Derived Variety Chuanmai 42 and a Chinese Elite Variety Chuannong 16', *Agricultural Sciences in China*, vol. 10, pp. 1665-1680.