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The influences of poultry litter biochar and water source on radish growth and nutrition

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Undergraduate Research Articles

The influences of poultry litter biochar and water source on radish growth and nutrition

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ABSTRACT

Many row-crop fields today have declined in soil fertility due to poor management practices and overuse of pesticides. Under these conditions, plant nutrient uptake can be sub-optimal. There are several soil amendments that can be used to improve soil quality and plant growth. This study focused on the addition of biochar to the soil and the use of structured water to enhance plant growth. Biochar is produced by pyrolysis of organic feedstocks. Previous studies which focused on biochar have shown an increase in plant yield, nutrient availability in the soil, and soil water holding capacity. Structured water is the liquid crystalline state of water which has unique characteristics due to the ordering of the hydrogen bonds in the water molecules. There have been numerous claims in the natural and organic health literature about the benefits of structured water in human and animal health, but little has been reported in the scientific literature concerning plant growth response. This study was conducted to evaluate the effect of biochar and structured water on the growth and nutrient content of radishes (*Raphahus sativa* L.). Data showed that the water type used had the most significant response. Biochar and tap water had a significant and positive interaction. Tap water and biochar used together resulted in higher yield, leaf area, plant fresh weight, and nutrient contents as the rate of biochar increased. Radish growth showed a negative response to structured water in almost every circumstance.

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MEET THE STUDENT-AUTHOR

Julia Allen

I was born in Lubbock, Texas, but grew up in Fayetteville, Ark. In high school I was in band and was an accomplished flutist and progressed to drum major. I chose the University of Arkansas to pursue a degree in Environmental, Soil, and Water Science with minors in Wildlife Habitat Management and Crop Science. I plan to pursue a M.S. degree in Crop and Soil Science after graduation. I have served as an officer in our departmental club for the past three years. To broaden my knowledge, I studied conservation in Scotland during the summer of 2013. While pursuing my studies, I have been apprenticing with a jeweler for the past 5 years and have learned to handcraft jewelry. I enjoy marksmanship, music, and art.

I would like to thank Dr. Longer for all his guidance on this project and Dr. Gbur and Lichen Hao for their help with the statistical analysis and the creation of the graphics.

INTRODUCTION

In most agricultural settings, soil fertility declines due to improper management (Laird et al., 2010). In order to support the projected population growth, more agriculture output will be required (Schult and Glaser, 2012). However, currently, soil degradation is becoming a more common problem worldwide due to climate change and over use from a rapidly expanding population which demands an increase in food supply. Plant uptake, leaching, runoff, and volatilization cause nutrient depletion over time. Yearly or periodic fertilizer applications are used to compensate for the loss, though this is usually a temporary and often costly solution (Laird et al., 2010). The application of biochar (BC) to agricultural fields may contribute to a long-term solution for increasing and maintaining minerals in the soil (Laird et al., 2010).

Biochar is carbonized biomass created from organic feedstocks which have undergone pyrolysis. Pyrolysis is defined as heating at extremely high temperatures in the absence of oxygen (Chan et al., 2007). Studies have indicated that BC is composed primarily of polyaromatic carbon and can resist decomposition for hundreds or more years (Doydora et al., 2011). This implies that BC may factor into a long-term solution for increasing and sustaining soil fertility due to the potential for this carbonaceous material to persist in the soil and provide benefits for extended periods of time.

Biochar can be made from essentially any type of organic matter. Two common sources for BC production are plant waste and animal waste (Chan et al., 2007). Biochar from plant material has high carbon content while other macro and micronutrients occur in smaller quantities. Biochar derived from wood has higher carbon concentration, around 70%, and has been associated with increased leaf area, leaf dry weight, and fruit yield (Lehmann et al., 2003). Poultry litter BC does not contain as high of carbon concentration, anywhere between 27% and 42%, but does contain larger concentrations of nitrogen (N), phosphorus (P), and potassium (K) compared to those made from plant matter (Revell et al., 2012a and 2012b).

Poultry litter based BC is becoming a favorable soil amendment option due to the vast amounts of feedstock being produced and the growing need for environmentally friendly ways of disposal. Poultry litter is high in phosphorus. One common use of poultry litter is land application to increase plant available nutrients. In areas with numerous poultry operations, excessive land applications of litter has led to a build-up of soil-test P and is a major contributor to surface water eutrophication (Moore and Miller, 1994). Converting poultry litter into BC is a viable option that can reduce costs and lead to sustainable agriculture (Revell et al., 2012a). Since BC often increases soil pH (Laird et al., 2010), traditional liming costs may also be reduced.

Most BC research has identified numerous benefits from its use as a soil amendment. Soil cation exchange capacity (CEC), pH, water holding capacity, and nutrient availability have all been shown to increase with application of BC (Adams et al., 2013). Biochar is alkaline by nature. The liming value of BC is roughly 30% $CaCO_3$ depending on the product origin (van Zwieten et al., 2010).

Numerous studies have shown BC can increase crop productivity, crop yield, and soil microbial biomass (Noguera et al., 2012). Positive yield results have been found when BC and N fertilizer are used on crops. Chan et al. (2007) conducted research to evaluate the effects of BC and N fertilizer interactions in the growth of radishes. Two rates of BC were used in the study: 50 t/ha and 100 t/ha. The results of this study showed a 320% increase in radish dry matter when 50 t/ha of BC and N fertilizer were combined.

Another relatively new area with the potential for study is the effect of "structured water" on plant growth. Structured water (SW) is the liquid crystalline form of water that has several unique characteristics when compared to water that has not undergone "structuring" (Pangman, 2011). In order to structure water, tap water (TW) is run through a vortex. Many units are sold that attach onto a faucet or can be installed into pipe work to create the vortex. Vortex structuring units alter the molecular structure of the water which removes the suspended solids and contaminants and keeps the beneficial minerals (Betterton, 2012). Differences have been detected in molecular stability, a negative electrical charge, greater viscosity, molecular alignment, and an improved ability to absorb a certain spectra of light (Pangman, 2011).

Structured water has to do with how water interfaces within cells. According to Pangman (2011), the water molecules line up and become ordered. In most water, hydrogen bonds are random. In SW, the hydrogen bonds gain some molecular stability while in motion. This is what happens when water molecules lose their randomness and become ordered. These ordered water molecules can create a few million molecular layers when a hydrophilic interface is present. Most constituents within cells are hydrophilic interfaces. The water molecules also contain a charge. Each molecule in the lineup has the opposite charge of the molecule beside it. This chain of charges acts like a battery and gives the SW energy (Mercola and Pollack, 2011).

Structured water is not a new concept but it is not well known. Among those in the scientific community who know about SW, according to Mercola and Pollack (2011), there is much controversy surrounding the concept and it has even been described as a hoax due to lack of scientific evidence. It was included as a factor in this research because it has grown in popularity with organic farmers and has provided yield and nutritional increases in numerous undocumented testimonies. One user of SW, Calvin Bey—retired from the USDA Forestry Service and now an organic farmer—uses SW in his personal gardens and has seen impressive growth and production without using fertilizer additives. The average tomato plant in his garden produced approximately 100 pounds of fruit in a growing season (C. Bey, pers. comm., 11 October 2013). The objectives of this study were to assess the effects of different rates of BC and SW on radish growth and plant nutrient development. Our hypothesis was that radish leaf area, total fresh weight, and root fresh weight would be greatest for radishes grown with 5000 kg/ha application rate of BC and watered with SW and that they would also have the highest plant nutrient content.

MATERIALS AND METHODS

The soil used in this study was obtained from a landowner in western Washington County, from a small field adjacent to his commercial organic vegetable garden. This soil had experienced 10 years of chemical-free operation prior to sampling. The soil was classified as a Captina silt loam (fine-silty, siliceous, mesic, Typic Fragiudult) and described as prime farmland by the Natural Resource Conservation Service (USDA, 2013). The two main factors under study in this project were BC and SW. The BC used in this study was derived from pyrolysed poultry litter as described previously in the Introduction. The BC used in this study was obtained from BioEnergy Systems, LLC based in Fayetteville, Ark. The nutrient content analysis is depicted in Table 1. The SW was donated by Calvin Bey for use in this project.

Radishes, *Raphahus sativa*, members of the Brassica family and grown worldwide, were used for this study due to their quick maturation time and being well suited for greenhouse culture. Radishes were grown from seed. Seeds were planted directly into the treatments.

This experiment was conducted in the Rosen Alternative Pest Control Center Greenhouse located on the University of Arkansas campus, in Fayetteville, Ark. The experiment was initiated on 30 October 2013 and ended on 5 December 2013. The study was established as a completely randomized design. There were 6 treatments: three rates of biochar and two water types. Each treatment was replicated 12 times.

Seventy-two 1-L plastic non-reactive pots were used. They were washed and sterilized prior to planting. A single coffee filter was placed in the bottom of each pot to prevent soil leaking from the base. Each pot was filled with approximately 1 L of the growing media which was a blend of 45% soil, 45% perlite, and 10% compost. The compost was uniform in appearance and texture and was

Table 1. Compositional analysis of BioEnergy Systems, LLC (BES) biochar.

Measured Property (unit)	Value
pH (pH units)[a]	10.2
Electrical Conductivity (µmhos cm^{-1}) [a]	16680
P (mg kg^{-1})[a]	7076
K (mg kg^{-1})[a]	26412
Ca (mg kg^{-1})[a]	3217
Mg (mg kg^{-1})[a]	3071
S (mg kg^{-1})[a]	3525
Na (mg kg^{-1})[a]	6880
Fe (mg kg^{-1})[a]	32
Mn (mg kg^{-1})[a]	190
P (mg kg^{-1})[b]	46915
K (mg kg^{-1})[b]	72298
Ca (mg kg^{-1})[b]	67904
Mg (mg kg^{-1})[b]	15298
S (mg kg^{-1})[b]	10486
Na (mg kg^{-1})[b]	19919
Fe (mg kg^{-1})[b]	2453
Mn (mg kg^{-1})[b]	1397
Zn (mg kg^{-1})[b]	1261
Cu (mg kg^{-1})[b]	801
%Total N[c]	3.00
%Total C[c]	32.03

[a] pH (1:2 soil ratio), Mehlich-3 extractable (1:10 ratio) Analysis by SPECTRO ARCOS inductively coupled plasma spectrometer.
[b] Total Recoverable Metals, EPA method 3050, measured on Spectro Arcos inductively coupled plasma spectrometer.
[c] Total N and C by combustion, Elementar Variomax.

produced from lawn and plant waste. Biochar was then ground to a fine powder and weighed to the appropriate values and added to their respective pot. The BC was then incorporated into the top few centimeters of growing media in each pot. These rates were equivalent to BC applications to each pot at the following rates: 0 kg/ha, 5000 kg/ha, and 10,000 kg/ha.

The filled pots were transported from the preparation lab to the greenhouse and flushed with either SW or TW and allowed to drain overnight. When the soil settled, 3 radish seeds were planted per pot. The radishes were watered daily with 50 mL of their respective water type. Half of the radishes were watered with TW and the other half were watered with SW. Upon germination, each pot was thinned to one uniformly sized radish per pot. The radish pots were randomized and rotated weekly from one end of the bench to the other to avoid any biases from sunlight and air flow differences.

After the radishes completed their growth cycle, they were harvested and analyzed for total fresh weight, root fresh weight, leaf area, and root mineral content. Total plant and root fresh weights were determined by weighing at harvest on a Mettler analytical balance at the 0.00 g level of precision. Leaf area was analyzed using a LI-COR leaf area meter, LI-3100C Area Meter, (LI-COR Environmental and Biotechnology Research Systems, Lincoln, Neb.). Radish mineral content was determined with a Digital Hand-Held "Pocket" Refractometer PAL (ATAGO U.S.A., Inc.) which measures the amount of light refracted through a liquid, which can be used to detect sugar and mineral content of a liquid or slurry. The roots of the radish were pressed until liquid emerged. This liquid was used for the analysis. This instrument is often referred to as a BRIX meter. BRIX measures the amount of dissolved solids. The higher the value, the better the quality and flavor.

The data were analyzed using SAS PROC MIXED (SAS Institute Inc., Cary, N.C.). A completely randomized analysis of variance was performed to find the main effects and the interaction effect on the measurements. Estimates were calculated for each variable within each treatment. Significant differences in total fresh weight, root fresh weight, and leaf area were based on $P = 0.05$. Significant differences in BRIX measurements were based on $P = 0.10$.

RESULTS AND DISCUSSION

Radishes were used in this study due to their quick maturation time of approximately 30 days. Radishes are a vigorous, easy-to-grow, cool-season vegetable with potential for multiple crops per year. They are valued because of their ease of planting, their low management, and they can be eaten directly from the garden.

Fresh weight was significantly higher for radishes watered with TW than the radishes watered with SW ($P < 0.05$) (Fig. 1). The mean fresh weight for plants watered with TW was 15.34 g. Biochar application rates did not have a statistically significant influence on radish fresh weight (data not shown).

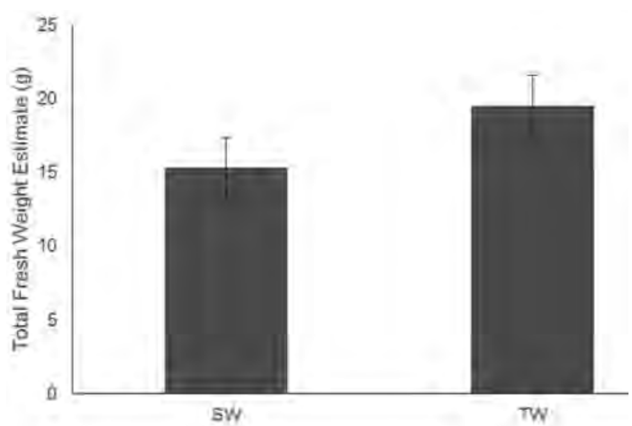

Fig. 1. Estimated total radish plant fresh weight for structured water (SW) and tap water (TW) treatments. Error bars indicate standard error.

The main effects of water type and BC were evaluated for their independent influences on root fresh weight. Water type alone had a statistically significant response ($P < 0.05$). Plants watered with TW had a larger mean root fresh weight (7.61 g) than those watered with SW (4.82 g) (Fig. 2). However, BC alone had a significant negative affect on the radish root fresh weight ($P < 0.05$) (Fig. 3). Mean root fresh weight decreased significantly when 1.00 g of BC was applied compared to the 0.00 g control.

Leaf area was affected by water type ($P < 0.05$) (Fig. 4) but not by BC application rate (data not shown). The average leaf area for radishes watered with TW was 300.80 cm^2; whereas plants watered with SW only averaged 257.83 cm^2 (Fig. 4).

The BRIX measurements showed a statistically significant interaction between water type and BC application ($P < 0.10$) (Fig. 5). Tap water alone gave a mean BRIX reading of 3%. The BRIX measurement increased to 3.79% for radishes treated with 10,000 kg/ha of BC and watered with TW. However, the treatments combining BC and SW had a very different reaction. When plants were only influenced by SW, the mean BRIX reading was 3.4%. When 5,000 kg/ha of BC was added, BRIX measurements dropped to 2.5%. With 10,000 kg/ha of BC added and watered with SW, the BRIX reading went back up slightly to 3.08%, which is still less than the plants with no BC added.

When examining the effect of water type on radish growth, TW outperformed SW in total fresh weight, root weight, and leaf area compared to SW. There was no interaction between the water type and the biochar rate except in the BRIX measurements.

Similar to the results found in the study by Chan et al. (2007), total weight and root weight were not affected by BC alone. Chan et al. (2007) saw a positive effect when BC was combined with N fertilizer. Van Zwieten et al.

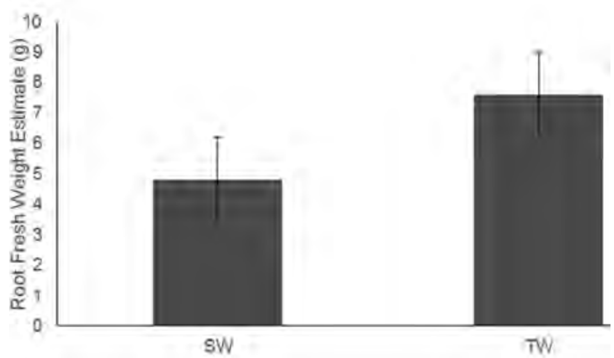

Fig. 2. Estimated root fresh weight for structured water (SW) and tap water (TW). Error bars indicate standard error.

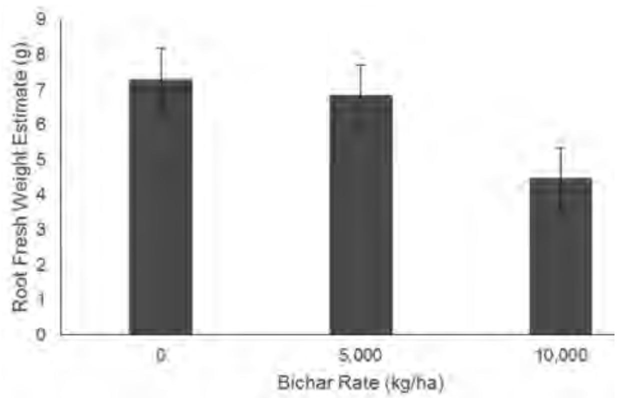

Fig. 3. Estimated root fresh weight for each biochar application rate. Error bars indicate standard error.

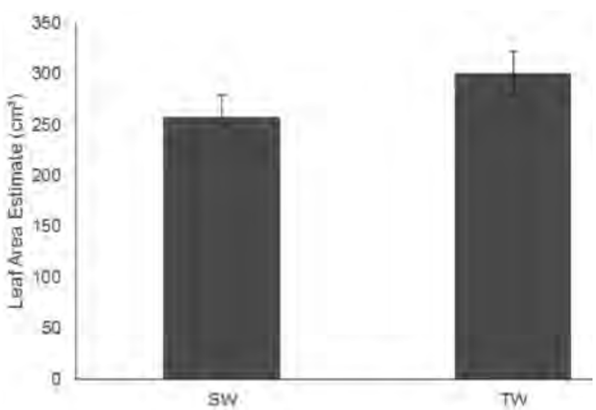

Fig. 4. Estimated leaf area for each structured water (SW) and tap water (TW) treatment. Error bars indicate standard error.

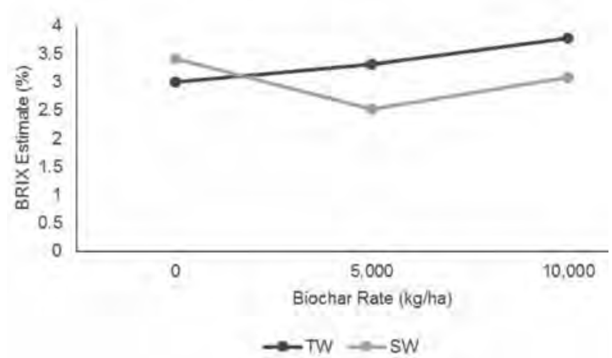

Fig. 5. Changes in BRIX estimate for each biochar treatment with structured water (SW) and tap water (TW) treatments. Error bars indicate standard error.

(2010) also concluded that biochar and N fertilizer had a significant interaction. As the rate of BC and N fertilizer increased, there was a significant increase in radish total weight compared to the control and to BC without N fertilizer. The results from our study indicate that BC did not significantly affect plant growth by itself but did have a positive effect on radish nutrient content when BC was combined with TW and a negative effect when in combination with SW as shown in Fig. 5. This interaction was significant ($P < 0.10$). When the interaction between TW and BC is examined for nutrient content, as the BC rate increases, BRIX measurement estimate increased.

Unlike the testimonies for the benefits of SW, our study showed that SW had a statistically significant ($P = 0.05$) negative impact on the growth parameters we examined in the radishes. Mercola and Pollack (2011) claims that drinking SW can be beneficial to cellular health in humans with the inference that all cellular health might benefit. In our study we saw that SW seemed to have the opposite effect of what we expected and hypothesized. We predicted that plants watered with SW would grow more vigorously and be larger, healthier plants than the radishes watered with TW. Total fresh weight, root weight, and leaf area were all significantly smaller for radishes watered with SW.

In summary, the data analyses indicated that the type of water used for irrigation had the most pronounced influence on radish growth and development. Analysis of variance values are displayed for the main effects and interaction effects in Table 2. Plants watered with TW had higher total fresh weights, root weights, and larger leaf areas. There was also an interaction between the water type and BC. When TW and BC were combined, the nutrient content increased as the BC rate increased. When SW and BC were combined, nutrient content was lower for plants that had BC added to the soil. Based on the results of this study, further trials to examine the effects of SW and the interaction between BC and water type would be appropriate.

Table 2. Analysis of variance table for main effects and interaction effects.

Source	DF	BRIX	RFW[a]	FW[b]	AREA[c]
BC	2	0.1793	0.0413	0.6572	0.1279
WATER	1	0.1190	0.0049	0.0001	0.0092
*BC*WATER*	2	0.0595	0.6948	0.5336	0.3698

[a] Root fresh weight.
[b] Fresh weight (total).
[c] Leaf area.

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