Impacts of Varying Biochar Rates With and without Compost of Pepper and Cauliflower Yields

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Biochar is a carbonaceous material that is known for its high cation exchange capacity, porosity, and high surface area. It could be made using materials such as switchgrass, mixed-wood, and oak, among other materials, which has been thermally decomposed at high temperatures in low oxygen environments for varying periods of time. Biochar as a soil amendment could act as a "container" for nutrients and is hypothesized to impact nutrient leaching. Available nutrients are bound to surface exchange sites on biochar, which are in abundance due to the high surface area. In theory, these nutrients then would be more readily available to plants. If these nutrients are accessible, plants could potentially have increased growth rates and potential increases in yield. This study evaluates the impact of biochar in combination with compost on pepper and cauliflower growth characteristics and yield, and available soil nitrate using ion exchange membranes.

Materials and Methods

The experiment was conducted at the Iowa State University Horticulture Research Station. The experimental design was a split-plot randomized complete block design with biochar as the whole plot and compost as the subplot factor. Biochar was purchased from Royal Oak in Roswell, Georgia, and applied at four rates: 0, 500, 1,000, and 2,000 lbs. per acre. The subplot compost treatment comprised of 0 and 9,680 lbs. per acre rate of compost. Compost was sourced from the Compost Facility. All biochar treatments except 2,000 lbs. per acre rate of biochar were applied using broadcast method. The 2,000 lbs. per acre rate was applied using a variable rate drop spreader. All biochar and compost treatments then were incorporated with tillage. Plastic mulch was laid with guard rows set between treatments. The red bell pepper *(Capsicum annum)* Red Knight X3R and cauliflower *(Brassica oleracea)* Snow Crown were transplanted. Each subplot had a 20 ft. long row of pepper and cauliflower as the data row and a guard row on either side.

Live plant measurements on bell pepper

Leaf chlorophyll content was collected using a soil-plant analysis development (SPAD) meter. Six plants within each treatment were selected for analysis. On each of the plants, fully developed leaves from the growing point were selected for SPAD measurements. Three SPAD measurements were collected from each plant and averaged. Stem diameter, right above the soil level, was taken on the same six plants from each treatment. Plant height, base of the plant to the terminal bud, was measured on the same six plants from each treatment.

Yield data

Bell peppers were harvested at maturity. Peppers were harvested multiple times during the growing season. Fruits were considered mature when these were fully red, dense, and blocky. Harvested peppers were sorted into marketable and non-marketable categories. The non-marketable category was further broken down into specific defects. Weights and number of fruits for each category were recorded.

Cauliflower was harvested at maturity. Signs of this included a fully developed head at or greater than 4 in. in diameter. Cauliflower was graded into marketable and non-marketable category. Head weights and number of heads were recorded. Diameter of marketable heads within each treatment was collected.

Pepper plant biomass

Once harvest was over, two plants from each treatment were used to collect shoot biomass data. A handsaw was used to cut plants at base of stems, near initial site of cotyledons. Above-ground plant biomass was dried in an oven for 18 days at 153°F after which dry weight was collected.

Ion exchange membrane

Ion exchange membrane strips were installed every 10 days. Upon installation of membranes, strips that had already been in the soil for 10 days were removed. These strips then were cleaned with deionized water in the lab. The catchment of soil water of the strips was extracted using potassium chloride (KCl) immediately following removal from the field. The KCl-extractant solution was plated with a reagent on a microplate and allowed to color for six hours. Microplate readings were taken and absorbance assessed.

Results and Discussion

Pepper SPAD, stem diameter, and height. There was no treatment interaction between the biochar and compost. There were no significant differences for SPAD, plant height, and stem diameter between biochar treatments (Table 1). Compost treatment did not show significant difference in SPAD or plant height, however, there were significant differences between stem diameters, with compost treatment showing higher value.

Pepper Yield. There was no treatment interaction between the biochar and compost. Pepper yield showed no statistically significant treatments differences based on biochar or compost application rates (Table 2). There were no treatment differences in weights and number of fruits that had blossom end rot, sunscald, rotting, or were small in size.

Cauliflower yield. Cauliflower showed statistically significant differences between marketable numbers of heads within subplot treatments (Figure 1). There was an interaction between compost and biochar for this variable with a p-value significance level of 0.0369. Overall, among the no compost rates, 0 lbs. per acre of biochar was the least yielding. The 500 lbs. per acre biochar plus no-compost treatment produced higher number of marketable heads when compared to 0 lbs. per acre biochar plus no-compost. Similarly, the 2,000 lbs. per acre biochar plus compost did well when compared to 500 lbs. per acre biochar plus compost. Suggestions for application of biochar to receive optimal yield without compost would be 500 lbs. per acre. In combination with compost, suggested application rates of biochar would be 2,000 lbs. per acre. Biochar rates significantly affected brown discoloration of cauliflower heads; however, the response was mixed (Table 3). The 1,000 lbs. per acre biochar rate increased brown discoloration over 500 lbs. per acre rate, but subsequently the 2,000 lbs. per acre rate showed a decline.

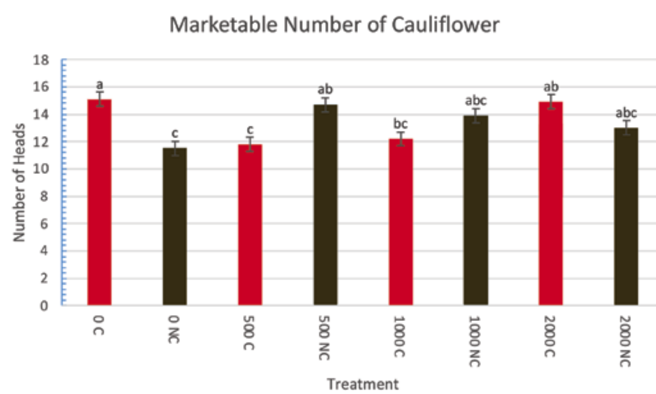

**Figure 1. Average number of marketable cauliflower per treatment at ISU Horticulture Research Station. Data reported from 20 plants in each treatment. C=Compost and NC=No-compost. 0, 500, 1,000, and 2,000 depict biochar rates in lbs.
per acre.**

Table 1. Average SPAD, plant height (cm), and stem diameter (mm) of bell pepper plants at the ISU Horticulture Research Station. Data collected from six plants from each treatment.

Treatment	SPAD	Height (cm)	Stem Diameter (mm)
Biochar[z]			
0	62.0	17.7	14.9
500	64.7	17.6	14.3
1,000	64.4	18.0	14.3
2,000	63.9	17.3	14.6
Significance	0.1853	0.8730	0.8039
Fertility[y]			
No compost	63.9	17.8	14.2b[x]
Compost	63.6	17.5	14.8a
Significance	0.5940	0.6146	0.0476

[x] Mean separation within columns and treatments using Fisher's protected t-test; means followed by same letter(s) are not significantly different (P ≥ 0.05)
[y] Compost application at 9,680 lbs. per acre
[z] Biochar rates expressed in lbs. per acre

Table 2. Average pepper marketable and nonmarketable yield at the ISU Horticulture Research Station. Yield data reported from 25 plants in each treatment.

Treatment	Marketable		Blossom End Rot		SunScald		Rotting		Small-sized	
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)
Biochar[z]										
0	132.2	30.8	13.8	2.2	15.7	3.1	14.4	2.8	38.2	5.3
500	123.4	32.1	12.4	2.0	17.8	3.5	16.0	3.4	31.8	4.5
1,000	118.7	28.3	14.8	2.2	15.8	3.1	16.5	3.3	29.3	4.1
2,000	139.9	33.4	12.1	2.1	18.3	3.9	16.2	3.4	28.3	3.9
Significance	0.3801	0.4413	0.5731	0.9642	0.7083	0.6097	0.8788	0.8259	0.1282	0.1277
Fertility[x]										
No compost	126.8	29.8	15.1	2.4	16.6	3.3	14.7	3.0	34.2	4.8
Compost	130.3	32.5	11.4	1.9	17.2	3.5	16.8	3.4	29.6	4.2
Significance	0.5700	0.1688	0.0707	0.1102	0.8217	0.7001	0.2137	0.2917	0.3030	0.3799

[x] Compost application at 9,680 lbs. per acre
[z] Biochar rates expressed in lbs. per acre

Table 3. Average cauliflower marketable and nonmarketable yield at the ISU Horticulture Research Station. Yield data reported from 20 plants in each treatment.

Treatment	Yellow Discoloration		Brown Discoloration		Purpling		Pest Damage		Average Diameter
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Average width from 4 heads (cm)
Biochar[z]									
0	0.74	0.50	0.43b [y]	0.57 ab	1.01	0.79	1.31	1.37	43.8
500	0.98	1.19	0.11 b	0.10 b	1.78	1.80	1.34	1.29	47.3
1,000	1.65	1.96	1.34 a	1.40 a	1.11	1.05	0.74	0.74	44.7
2,000	0.81	1.21	0.40 b	0.34 b	0.73	0.64	1.00	1.25	46.5
Significance	0.3654	0.2589	0.0608	0.0422	0.3835	0.2386	0.5937	0.6661	0.6141
Fertility[x]									
No compost	1.12	1.45	0.54	0.65	1.05	0.90	0.86	0.88	48.2
Compost	0.99	1.04	0.61	0.56	1.26	1.24	1.31	1.41	43.2
Significance	0.4969	0.2409	0.7686	0.5505	0.8055	0.6293	0.2329	0.1414	0.8354

[x] Compost application at 9,680 lbs. per acre
[y] Mean separation within columns and treatments using Fisher's protected t-test; means followed by same letter(s) are not significantly different (P ≥ 0.05)
[z] Biochar rates expressed in lbs. per acre