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Effect of Biochar Amended to the Soil of a Peach Orchard in Western Colorado

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Introduction

Colorado peaches are an important specialty crop with superior quality and excellent market acceptance due to the unique growing conditions (desert climate, high altitude, high levels of solar radiation) and harvesting at the tree-ripe stage. Peach production (concentrated in the western slope of CO) totals over the last ten years have ranged from 12,000 to 17,000 tons with estimated values of 28 to 35 million dollars with ca. 10% of them coming from organic production (USDA-NAAS, 2002 and 2017). However, peach production in CO is threatened by environmental stresses, such as diminishing water supplies, cold damage, and alkaline soils. Deterioration of soil physicochemical and biological properties due to orchard floor management practices (low quality of irrigation water, excessive use of herbicides and fertilizers) exacerbates the poor health of these soils, and jeopardizes the sustainability of fruit production. Biochar, an organic rich soil amendment, is one agricultural technology with potential to deliver improved water retention and increased soil fertility.

Objectives: 1) evaluate and quantify the impact of biochar amended to the soil on orchard soil chemical, physical and biological properties, as well as on soil nutrient and water availability
2) determine biochar associated relationships with peach tree nutrient status, tree physiology and growth, as well as on floral bud cold hardiness, fruit yield, and fruit quality in a peach orchard

Methods

'Suncrest' peach trees (*Prunus persica*) using 'Viking' as the rootstock were planted at the CSU's experimental orchard in Western Colorado Research Center-Orchard Mesa (WCRC-OM) in a complete randomized 6 x 3 block design in May 2015 in replicated blocks that had previously received and incorporated biochar (1.5 m wide) in the following rates: 0, 5, or 25 tons/ha in peach orchard.

Picture 1. The peach orchard in WCRC-OM, Grand Junction CO, before planting in 2015, where the distribution of the replicated blocks of the different biochar rates are shown (left), and the appearance of the 5th leaf 'Suncrest' peach trees (May 2019, right). R4 and R5 are abbreviations of row 4 and 5.

Results

Total and organic carbon significantly increased in the soil of the high biochar concentration. Inorganic N, N mineralization and microbial biomass were not affected by biochar. Similarly, through an extensive series of soil analyses biochar amended to the soil prior to orchard establishment did not significantly affect soil chemical, physical and biological parameters tested (**Table 1**) except of the decrease of nitrate availability in early summer months (**Figure 1**). Biochar amendment over four growing seasons and through the establishment phase of the orchard increased tree size as was measured by trunk cross sectional area (TCSA, **Table 2**), but did not affect peach tree nutrient status, floral bud cold hardiness (**Table 3**), leaf stomatal conductance, net photosynthesis (**Figure 2**), yield and fruit maturity and quality parameters tested (**Table 4**) during the fourth growing season.

Table 1. Effect of biochar on peach orchard soil organic matter content (OMC), cation exchange capacity (CEC), pH, nitrate (NO_3^-) and ammoniacal (NH_4^+) nitrogen concentration, for the first three years after planting. Values in rows per year followed by the same letter are not statistically different (P<0.05).

	Year 1		Year 2		Year 3	
Orchard soil physicochemical properties	Control	25t Biochar/ha	Control	25t Biochar/ha	Control	25t Biochar/ha
OMC (%)	2.0b	2.1a	1.8b	2.0a	1.73b	1.93a
CEC (meq 100 g^{-1})	25.0a	23.4a	23.2a	22.3a	24.0a	23.0b
pH	7.8a	7.8a	8.3a	8.3a	8.2b	8.3a
NO_3^- & NH_4^+ nitrogen (ppm)	46.3a	28.2b	13.5a	12.8a	12.2a	10.3a

Table 2. Effect of biochar on peach tree growth as was determined by trunk cross sectional area (TCSA) during the establishment phase of the peach orchard. Values in rows per year followed by the same letter are not statistically different (P<0.05).

TCSA (cm^2)	Control	25t Biochar/ha
At planting	1.6a	1.1b
Year 2	18.1b	21.1a
Year 3	30.4b	34.9a
Year 4	38.2b	43.6a

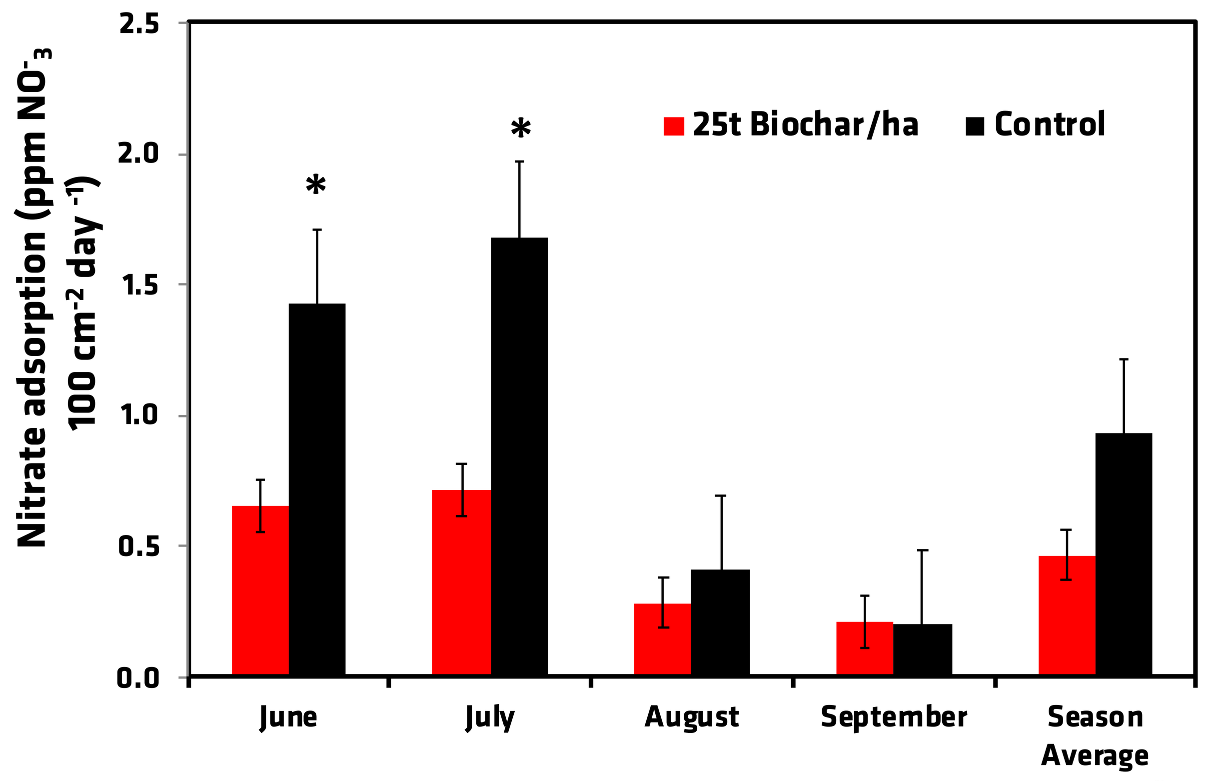

Figure 1. Daily adsorption rate of nitrate (NO_3^-) per 100 cm^2 of anion exchange membrane at a depth of 0-10 cm in soil, over different months of the growing season of Year 2. Asterisks indicate significant differences (*P*<0.05).

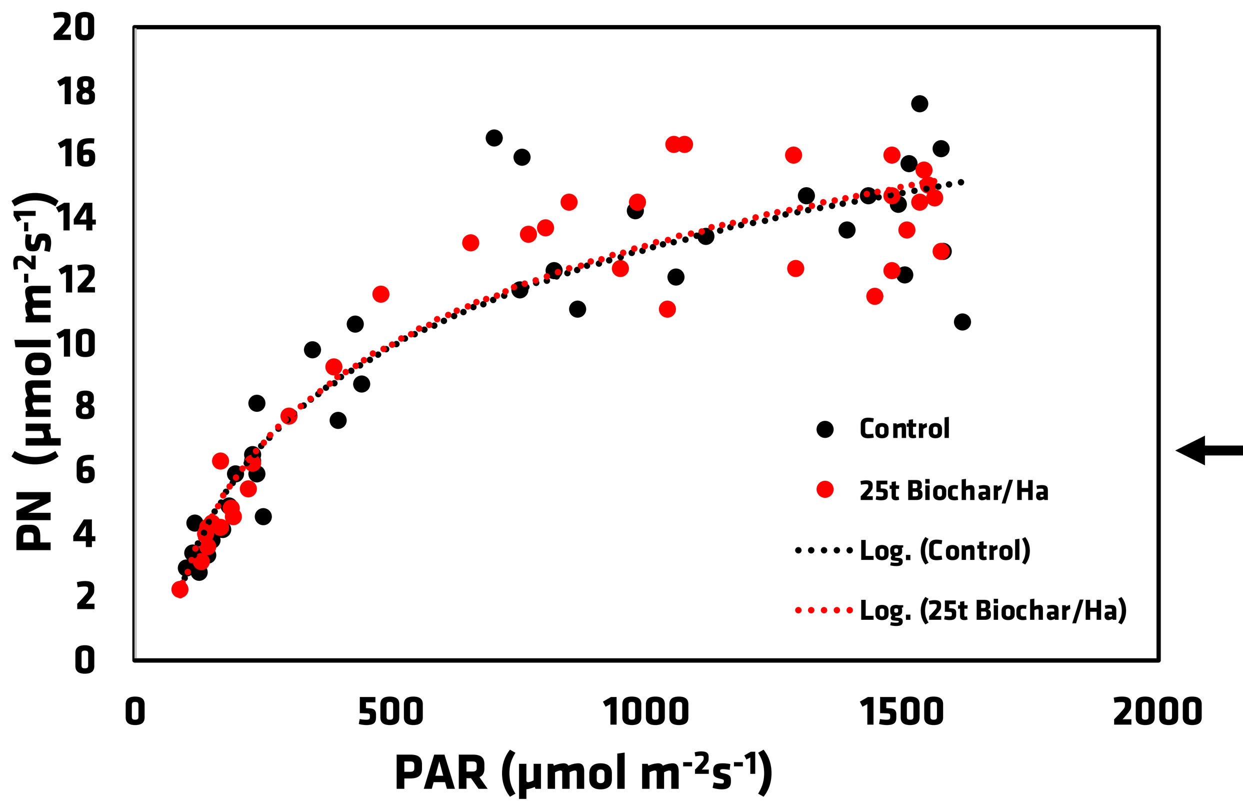

Figure 2. Mid day net photosynthetic rate (PN) for different levels of photosynthetically active radiation (PAR) for both treatments as measured by PP Systems Ciras-2 Portable Photosynthesis System. Least Squares Means determined to be statistically similar by ANCOVA (P=0.94)

Table 3. Effect of biochar on peach floral bud cold hardiness following artificial freezing test using differential thermal analysis (DTA) in November 14, 2017 (Year 3).

Lethal Temperature (LT, °C)	Control	25t Biochar/ha
LT_{10}	-16.4	-16.3
LT_{50}	-18.5	-18.2
LT_{90}	-20.3	-19.8

Table 4. Effect of biochar on peach fruit harvest maturity and quality as was determined by dry matter content (DMC), soluble solids concentration (SSC), fruit firmness (FF) and index of absorbance difference (I_{AD}).

Peach quality & maturity	Control	25t Biochar/ha
DMC (%)	16.36a	16.17a
SSC (%)	14.69a	14.90a
FF (N)	34.85a	34.04a
I_{AD}	0.44a	0.44a

Conclusion: Biochar could be a valuable tool for management of orchard soils that are either degraded or have poor nutrient status; however, it could take time to observe significant changes in crop attributes after biochar addition

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