PROBLEM AND RESEARCH OBJECTIVES

Agriculture in Arizona accounts for about 70% of the total State's water use. In addition, flood and furrow irrigation, known to have poor (<50%) irrigation efficiencies, are the primary methods of water delivery to Arizona crops. Sandy soils, such as those present in Red Rock and the Yuma valley do not retain water efficiently and require more irrigations than loamy Arizona soils, to maintain adequate water supplies to crops during the growth season.

Agricultural soils in AZ usually contain less than 1% total organic carbon (TOC), but are usually rich in carbonate minerals. A study by Artiola and Pepper (1992) measured the TOC of an agricultural field that had received ten consecutive yearly applications of eight dry mT ofbiosolids.ha$_{-1}$. They found no significant change in the TOC content in the top 1.5 m of the soil. This is because the carbon mineralization rates are very high (>70% annually), precluding significant organic carbon accumulations in soils even from repeated biosolids applications.

Biochar, also known as charcoal or black carbon, is produced by pyrolysis (oxygen-limited combustion) of biofuels such as agricultural residues. Research has demonstrated that the highly porous nature of biochar materials allows then to act as sponges and modify the soil texture, thereby increasing soil water holding capacities. These effects (that need to be quantified and studied further) are likely to be maximized in light-textured sandy soils. The beneficial effects of biochar-amended soils may extend many years due to the refractory (chemically and biologically stable) nature of this carbon form with estimated half-lives in the soil environment ranging from 100-1000s of years. Therefore, these and other benefits (CO_2 emissions reductions, carbon storage, and energy production) may make these materials ideal soil amendments.

We determined how the addition of biochar, derived from various Arizona biochar (derived from AZ forest pine wood residues) affects some physical properties of a loamy sand, semi-arid alkaline soil. The ability of soils to retain water is linked to their texture and organic matter content. We looked at changes in soil water holding capacities with varying biochar loading rates of biochar, using laboratory and greenhouse studies. We also measured the effects of biochar additions to a light-textured, alkaline soil with changes in the biomass production of two plants and plant survival rates under induced water stress.

METHODOLOGY

Arizona pine forest waste woodchips, obtained from the Forest Service via Arizona Power Service (APS), were used to produce biochar using a 50,000BTU wood gas stove. Biochar was produced using slow pyrolysis (batch mode) with a biochar internal temperature of 450-500 ^{o}C and a yield of about 20% by mass. Two greenhouse (GH) studies were undertaken to test the viability of biochar as a soil amendment in AZ soils that are typically alkaline, moderate to high pH, and well-drained. A well-characterized loamy sand soil from the Red Rock (RR), AZ, Agricultural Experiment Station was selected. The GH experiments were conducted using 3-gallon pots with 8 replications and a randomized block design using drip irrigation. Two plants were selected, romaine lettuce, a C3 (cool season) vegetable, and Bermuda grass a C4 (warm season) grass. Given the low particle bulk density of PFW biochar, measured at 0.22 g per cubic cm, two application rates were selected: 2% and 4% by weight biochar to RR soil – being equivalent to 40 and 80 tons of biochar per hectare (to a 15cm depth), respectively.

Lettuce results: No significant differences in germination rates were observed in any of the treatments or control, all exhibiting a 95% success. However, during the first month of growth biochar treated lettuce pots displayed significant stunted growth, particularly in the 4% treatment pots (compared to controls), but plant in the biochar treatments began to recover during the second month. All plants where harvested after 2.5 months of growth and fresh weight plant matter yields were measured. An ANOVA analysis (n=8) of the data ranked (at the 95%CI) the 2% biochar higher than the control and significantly higher than the 4% biochar treated soil. At the 99%CI the 2% biochar treatment was only marginally higher than the control.

Bermuda grass results: Germination proceeded normally in all pots. Clippings were collected from pots, as soon growth exceeded 2.5-3", once a week for two months. Statistical analysis of dry biomass again placed the 2% biochar treatment above the other two treatments at the 95%CI, but not at the 99%CI. Pots were water –stressed for one month and grass clippings were collected every week for 4 weeks. Biomass dry weight yields increased as a function of biochar treatment, these being significantly higher above the control at the 99%CI at the 4% and 2% biochar application rates. During this period the grass in the control pots died or went dormant after 14-16 days. Seven days later most of the grass in 2% biochar pots had similar symptoms. And about 6 days later most of the 4% biochar pots looked gray and showed no growth. Irrigation was restarted but after two weeks none of the control pots showed signs of life, about 50% for 2% pots had marginal/spotty growth (in the form of runners) and all of the 4% biochar pots showed growth considered normal, having recovered from the water stress period with no apparent ill effects.

PRINCIPLE FINDINGS AND SIGNIFICANCE

This study demonstrated that biochar can be produced from forest and woodland pine forest waste, produced in large quantities (more than 4 million tons per year in AZ) from normal silvicultural practices and drought-related changes AZ forests. Pine forest waste biochar is relatively low in alkalinity (~1-5%), a desired trait for AZ soils, and has an extreme porosity (measured at ~86%). Pine forest waste biochar can sorb twice its weight in water under field conditions. A water stress test on Bermuda grass suggests that biochar-amended soils may prevent severe damage to turf grass, extending its survivability for up to two weeks. Greenhouse growth experiments have also shown benefits in the form of increased biomass production may be had when Bermuda grass is planted in a light sandy soil amended with 2% biochar. Romaine lettuce, which is sensitive to soil salinity changes, benefited from biochar applications at the 2% rate compared to the control. But we observed stunted plant growth at the 4% biochar rate. Although eluent salinity did not change significantly across treatments, there was a measurable increase in the eluent pH of pots with biochar amendments (up to 0.3 units), perhaps affecting plant growth at the early stages, despite normal germination rates. Preliminary observations on an ongoing greenhouse study using the same pots reseeded with lettuce, suggest that poor plant growth responses, observed in the first study, may be temporary. As the biochar "ages" in the soil, the equilibration of alkaline species with carbon dioxide lowers its solution pH (after several wet/dry/leaching cycles). In this second trial we observed again, no changes in germination rates (~95% across all treatments), and very similar plant growth rates in all the pots, including those amended with 4% biochar. After harvest a statistical analysis of the plant biomass ranked the 4% and 2% biochar treatment significantly higher (@99% C.I.) than the control.

We can cautiously conclude that the addition of PFW biochar to sandy, alkaline soils may require a period of "aging" before pH-salinity sensitive vegetables like lettuce can benefit. Conversely, warm season grasses, and possibly other species tolerant to extreme pH-salinity soil conditions, may adapt quickly to a soil amended with PFW biochar, becoming more drought-resistant.