CHAR-AMENDED ACID FARM SOILS – EFFECTS ON SOIL CHEMISTRY AND WHEAT GROWTH

S.M. Griffith, G.M. Banowetz, and D. Gady

Introduction

On-farm gasification of agricultural residues, the non-food byproducts from crop harvests, could provide a means to generate value-added income from the production of fuel or electrical generation. The ash-like combustion by-product, char, produced during the process also has potential value as a soil amendment for a variety of purposes including field crop production or even as a sorbent.

Char produced from gasification is different from biochar produced by pyrolysis because gasification is conducted in the presence of a restricted amount of oxygen, which promotes partial combustion at temperatures of 650 to 800°C or higher. In contrast, pyrolysis is conducted under anaerobic to extremely low oxygen conditions at temperatures between 400 and 500°C. Relative to the current knowledge of the chemical bio-characteristics and utility of biochar produced from pyrolysis, there is a scarcity of data concerning char produced from the gasification of biomass, especially with respect to its use as a soil amendment.

Due to the lack of data characterizing char produced from herbaceous biomass, particularly with regards to its use as a soil amendment and subsequent effects on soil chemistry and plant growth, this study characterized char produced by gasification of Kentucky bluegrass seed screenings (KBss) and compared it to char produced from wood biomass. Wood char was included because it's the most commonly studied type of char and the potential for producing wood char in the Pacific Northwest with its abundant horticultural and forest industries. KBss char used in this study was produced in a farm-scale gasifier where the biomass was converted to a syngas containing methane, carbon monoxide, and hydrogen. The syngas was used to partially fuel a diesel generator to produce electricity. We recognize that the high surface to mass ratio KBss char byproduct could have utility as a soil amendment if it had characteristics which protected against damaging acid soil conditions, provided crop nutrients, sequestered C, or helped trap and conserve soil water under dryland farming conditions, or be used as a chemical sorbent. If demonstrated under controlled conditions, we reasoned that this utility could enhance farm profit, soil quality, and resource conservation.

The objective of the study was to determine the effect of char as a soil amendment on wheat growth and identify various soil parameters that might explain measured growth effects.

Materials and Methods

A replicated greenhouse pot study was conducted using wheat. Single plants of wheat (Triticum aestivum L. cv. Madsen; a widely planted cultivar in the state of Washington, U.S.A.) were grown for 74 days (wheat Feekes stage 5) in 650 cm^3 black plastic pots, containing either a Freeman or Bernhill soil (acid farm soil, Spokane, WA, U.S.A) with different percentages of either KBss or wood char (0, 2.6, 6.7, 14.4, and 33.7 % by volume). Due to slight differences KBss and wood char density, the final mass concentration of KBss char to soil was 0, 4, 12, 25, and 58 g kg^{-1} and for wood char, 0, 7, 17, 37, and 86 g kg^{-1}. The KBss char was produced at 600 to 650 °C and the wood char produced from conifer tree cuttings in a downdraft gasifier at 1200 ºC. The gasifiers were small-scale units located on-farm.

Results and Discussion

Wheat shoot dry mass accumulation significantly (P<0.05) increased with increasing concentrations of soil amended wood or KBss char. At the highest concentration of KBss char (58 g kg^{-1}) shoot dry mass increased by 1.68-fold in the Freeman soil, but root dry mass was unaffected. Amended Bernhill soil with 58 g kg^{-1} KBss char increased shoot dry mass 1.94-fold and root dry mass 1.46-fold. In contrast, amendment of Freeman soil with wood char at 86 g kg^{-1} enhanced shoot dry mass by 2.78-fold and root dry mass 2.06-fold. This same level of amendment of Bernhill soil with KBss char increased shoot and root dry mass by 2.43- and 2.79-fold, respectively.

Wood and KBss char amendments did not significantly (P<0.05) affect wheat seedling emergence when mixed with Freeman or Bernhill soils. Plants grown in the Freeman soil-wood char mixtures had higher leaf chlorophyll content (SPAD readings) over plants grown in Freeman soil alone, whereas KBss char had no affect on leaf chlorophyll concentration over either soil alone.

We measured wheat root and shoot tissue concentration of ten plant nutrients of after 74 days of growth to determine the effect of added char on elemental uptake. We found that the addition of increasing concentrations of KBss char to Freeman or Bernhill soil consistently enhanced shoot K, P, S, Zn, and Mg, and to some extent S, and significantly reduced Ca content compared to plants grown in soil alone.

Wood char mixed with Freeman or Bernhill soil had consistently higher concentrations of K, P, and Mn (Bernhill soil only), and P but had lower Ca, Cu, and S concentrations. Iron concentrations were highest in roots over shoots in all treatments and root Fe concentrations were lower with increasing char concentrations. The inverse was true for Ca. Calcium shoot concentrations exceeded root Ca concentrations and Ca concentrations declined in shoot with increased char concentrations, but not in roots. Addition of char lowered Al uptake by wheat in both soils.

The KBss and wood chars alone had a pH of about 11 while the pH of the two soils was approximately 4.5. The electrical conductivity (EC) of the chars alone was about 53-fold greater than the soils (~70 uS), with a cation exchange capacity (CEC) of 55 meq $100g^{-}1$, about five-fold greater than the soils. Increasing char concentrations in soils raised soil pH in a linear fashion. Amended soil pH increased from 4.5 (soil alone) to a maximum of 7.0 after char was added to the soil at a concentration of 86 g kg^{-1}. This was probably the greatest contributing factor favoring improved growth of wheat by improving soil nutrient availability and root uptake.

Conclusion

Findings of this study are the first showing the effects of KBss and wood char on the growth of wheat. Greenhouse grown wheat in soil amended with char showed a dramatic increase in growth with increasing soil char concentrations. Mineral nutrition was significantly enhanced which most likely resulted from a “liming” effect by the added char. The rise in soil pH with added char most likely contributed reduced soil Al availability to plant roots, thus limiting Al root uptake and potential plant Al toxicity common in low acid soils. Low farm soil pH and associated crop Al toxicity is a current concern on eastern Washington and western Idaho farmland that were historically covered with forest vegetation (Koenig et al., 2011).

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