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The Potential of Biochar as a Fertilizer Supplement and Soil Amendment

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Introduction

Nutrient runoff from agricultural activities as a result of land applications of commercial fertilizers and animal manures has become a concern for aquatic and agronomic research. Excess nutrients that do not get assimilated by crops or adsorbed onto soil particles have increased potential to be transported into water bodies via surface runoff. Thus, farmers and researchers have looked for ways of increasing crop yields while simultaneously reducing the migration of applied nutrients from agricultural or crop fields. Some of these methods include no-tillage farming, variable rate fertilizer applications and foliar fertilization. However, there is one product that has the potential to provide essential plant nutrients and promote soil health over time while encouraging environmental stewardship. This product is biochar.

Biochar Background Information

Biochar is a charcoal-like substance created from the burning of biomass materials in supervised conditions of low oxygen, called pyrolysis (Lehmann, 2007; Roberts et al., 2010) (Figure 1). A wide array of organic materials can be used to create biochar (Barrow, 2012) such as poultry litter, crop residues and various hardwood species. Knowledge of these

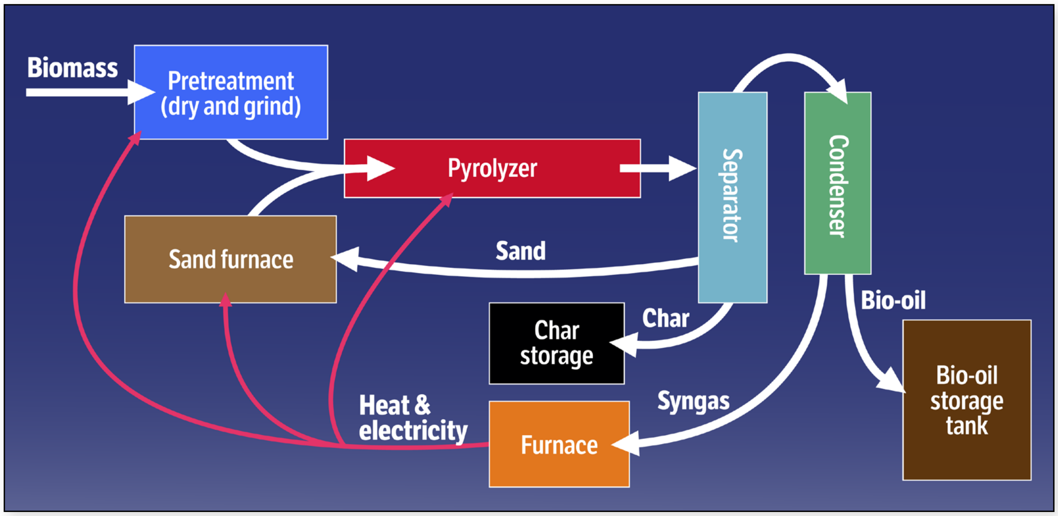

Figure 1. Diagram of the pyrolysis process and subsequent generation of biochar. Image adapted from the Agricultural Research Service, U.S. Department of Agriculture (ars.usda.gov).

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biochar origins is crucial to its use, as each source has different chemical and physical parameters affected in the pyrolysis process. Although biochar is known to be abundant in the plant essential nutrients nitrogen (N) and phosphorus (P), the source, pyrolysis temperature and the texture of the resulting biochar product all contribute to its efficacy as a fertilizer supplement and soil amendment (Burke et al., 2014).

Agronomic Benefits of Biochar

When biochar is incorporated into the soil, it can remain there for a prolonged period of time as a nutrient source for a myriad of plant species. The nutrients contained within biochar can be accessed by either fibrous or taproot systems when developing root hairs come into contact with a biochar particle. The root hairs obtain biochar nutrients similar to when they encounter a granule of synthetic fertilizer. Depending on the texture of the finished biochar product (granular or pelletized, Figures 2 and 3), biochar particles are characterized by increases in surface area, which is advantageous to root nutrient uptake and assimilation (Tenenbaum, 2009).

Research has shown that plant uptake of biochar can lead to increases in crop yield (Liu et al., 2013), plant dry matter and leaf area (Burke et al., 2014), of which the latter is a critical component of plant development in regard to sunlight interception and photosynthetic activity. Additionally, in some row crops, biochar has been observed as reducing the stem length between nodes which favors a plant's emphasis on secondary stem and fruit production while having positive interactions in conjunction with commercial fertilizers (Burke et al., 2014).

Benefits of Biochar to Soil Properties and Processes

Biochar's longevity in the soil can provide numerous benefits in terms of fertility, structure and overall health (Barrow, 2012). As a part of the agronomic philosophy,

Figure 2. Granular-textured biochar from a mixed- hardwood species.

Figure 3. Pelletized poultry litter biochar. Ruler shown for scale.

"fertilize the soil", biochar has the possibility to remain a stable source of nutrient retention (Mullen et al., 2010) for successive growing seasons without undergoing loss mechanisms such as volatilization and denitrification. This nutrient retention can also have an impact on soil test results and fertilizer recommendations for an individual growing season. In particular, the amount of fertilizer applied before and/or during the growing season may be substantially decreased (Renner, 2007) thereby reducing production costs.

In the soil, biochar can improve structure by increasing the number of soil pores (Tenenbaum, 2009), which are important for gas, water and nutrient movement. Thus, application of biochar could serve to remediate hard, clayey or compact (i.e., high-bulk density) soils, such as soils found in the Arkansas Delta, which would allow for more effective root penetration throughout the soil profile. This modification of soil pores can enhance soil biological activity by providing organisms, such as earthworms, additional pathways in which to facilitate the mixing of soil horizons, thereby possibly increasing the overall depth of the top arable soil layer.

Limitations of Biochar

The main limitations to biochar production and its subsequent use as an amendment in agriculture deal with economics, logistics and demand. To generate sizeable amounts of biochar, production facilities would need to be tailored to accept and store suitable quantities of biomass materials to be used in the pyrolysis procedure. Chambers for pyrolysis would also have to be specially constructed to restrict the presence of oxygen while also allowing for the collection and storage of other pyrolysis byproducts such as tarry oils and energy-rich gases. Another economic consideration involves biochar refinement and how to create its desired texture for future use.

Ideally, biochar production plants would be regionally located within a certain radius close enough for effective delivery and possible customer pickup. Long distance transportation costs of any kind can be quite a detriment to an operating system's budget even though a refined biochar product can still be viable long after it is created. Compounding these logistical issues is assessing consumer demand for biochar as both a fertilizer supplement and a soil amendment. Generations of farmers and producers have consistently relied on commercial fertilizers and animal wastes to sustain crop and forage yields. Transitioning to biochar would seemingly require outreach programs, extensive promotional campaigns and conducive research regarding its agronomic benefits.

Additional concerns about biochar involve its rates of application. Numerous biochar studies at the University of Arkansas over the past decade have used a variety of application rates to assess its efficacy in crop production. Figure 4 shows a cotton trial conducted in 2012 at the University of Arkansas Agricultural Experiment Station in Fayetteville that used rates equivalent to 2,000 and 4,000 kilograms per hectare (kg/ha) (Burke, unpublished data). Biochar has also been used in greenhouse experiments with radish (Allen, 2014) and in field trials with corn (Brantley et al., 2014), both at rates equivalent to approximately 5,000 and 10,000 kg/ha at the University of Arkansas. Although these studies found benefits to using biochar in crop production, there remains no state recommended biochar application rates due to the complexities of the pyrolysis process, the individual chemical and physical characteristics of a chosen biochar source and the inherent spatial variability of Arkansas soils.

Figure 4. Field-applied poultry litter-based biochar in a cotton trial at the University of Arkansas Agricultural Experiment Station in Fayetteville, Arkansas. Biochar pellets are seen on and embedded in the soil surface.

Conclusion

Biochar has the potential to alleviate numerous agricultural concerns such as the surface runoff of applied nutrients and the gradual degradation of aquatic systems due to ineffective nutrient management. Biochar can be created from a wide range of biomass materials, but knowledge of the biochar source is critical when applying it to a certain soil type or for a particular crop due to the chemical and physical parameters unique to each source before and after undergoing pyrolysis. Although barriers such as logistics and customer demand exist to impede the wide-scale implementation of biochar, it's two-fold benefit of being a fertilizer supplement and a soil amendment cannot be underestimated.

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