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Application of Biochar on Land for Improving Soil Health–A Review

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ABSTRACT: The use of biochars can improve agricultural production because they can store applied nutrients and fertilizer and release them gradually to crop plants. As a result of biochar's capacity to prevent nutrients from evaporating from the crop root zone and to hold onto water and nutrients for an extended length of time, crop yields may increase and fertilizer needs may decrease. In contrast to composts, which are frequently added to soils for agricultural production, biochars are a source of nutrients indirectly through the subsequent decomposition of organic matter. Applying biochar to the soil has the following benefits, it sequesters carbon in the soil, boosts soil productivity especially on poor soils, enhances water retention, boosts water quality, lowers greenhouse gas emissions from the soil, stimulates microbial activity, and can be used as a biofuel and renewable energy source. The major use of biochar application in soil is to improve the soil health and fertility and in addition to mitigate climate change especially sequestering carbon. The utility of the biochar from various waste is a promising way of recycling and it could improve the health of the degraded soils, poor soils and barren lands.

Keywords: Biochar, microbial activity, broadcasting, traditional banding, soil amendments.

INTRODUCTION

Biochar can improve soil available nutrient and increase microbial activity, when applying biochar to soil for improving its fertility, the biochar should ideally be located near the soil's surface in the root zone, where the bulk of nutrient cycling and uptake by plants takes place. Certain systems may benefit from the application of biochar in layers below the root zone, for example during landscaping for C sequestration or if using biochar for moisture management. Similarly, if biochar were to be applied to soil solely for C sequestration purposes, placement deeper in the soil, for example in new landscaping or construction areas, would be desired since microbial activity that can degrade biochar carbon is reduced deeper in the soil profile. When deciding how to apply biochar to soil, the specific cropping system must be taken into consideration.

The likelihood of wind and water erosion losses of biochar is reduced when biochar is thoroughly incorporated into soil, however, plowing and soil mixing are not possible or desirable in all cropping systems, at all times.

In conventional field cropping systems, biochar should ideally be managed using traditional farm machinery and incorporated into routine field operations. This will ensure that the costs of using biochar are kept as low as possible. For example, biochar can be applied and incorporated together with lime, since lime is often applied as a fine solid which must be well incorporated into soil (Julie Major, 2010).

Broadcasting. The majority of biochar field trials reported to date used this method for incorporating biochar into soil (Yamato *et al*., 2006; Steiner *et al*., 2007; Asai *et al*., 2009; Major *et al*., 2010). Broadcasting can be done by hand on small scales or on larger scales by using lime/solid manure spreaders or broadcast seeders. Moistened biochar materials may be better suited to application with manure spreaders than lime spreaders. Incorporation can be achieved using any plowing method at any scale, including hand hoes, animal draft plows, disc harrows, chisels, rotary hoes, etc. Moldboard plowing is not recommended as it is unlikely to mix the biochar into the soil and may result in deep biochar layers (Blackwell *et al*., 2009). As mentioned above, wind losses from applying and incorporating fine biochar materials can be significant.

Traditional banding. Banding of seeds and fertilizers is a routine operation in mechanized agriculture, and involves applying an amendment in a narrow band, usually using equipment that cuts the soil open, without disturbing the entire soil surface. Banding allows biochar to be placed inside the soil while minimizing soil disturbance, making it possible to apply biochar after crop establishment. However, the amounts of biochar that can be applied in this way are lower than those which can be achieved by broadcast applications. Wheat yields in Western Australia were improved by banding biochar (Blackwell *et al*., 2007). When working by hand, biochar can be applied in furrows opened using a hoe and closed after applying biochar.

Mixing biochar with other solid amendments. Mixing biochar with other soil amendments such as manure, compost or lime before soil application can improve efficiency by reducing the number of field operations required. Since biochar has been shown to sorb nutrients and protect them against leaching (Major, 2009; Major *et al*., 2009; Novak *et al*., 2009), mixing with biochar may improve the efficiency of manure or other amendment application.

Mixing biochar with liquid manures. Biochar can also be mixed with liquid manures and applied as slurry. Fine biochars will likely be best suited to this type of application using existing application equipment, and dust problems associated with these would be addressed. Biochar could also be mixed with manure in holding ponds and could potentially reduce gaseous nitrogen losses as it does when applied to soil (Rondon *et al*., 2005; Yanai *et al*., 2007; Spokas *et al*., 2009).

Targeted biochar applications in precision agriculture. Where high-resolution data on soil characteristics and farm machinery equipped with geographical positioning systems are available, it would possible to apply biochar preferentially to areas of fields where fertility is low (Julie Major, 2010).

Biochar as soil amendment. Biochar, a byproduct of the pyrolysis process, is biomass-derived black carbon intended for use as a soil amendment. It is analogous to charcoal manufactured through traditional or modern pyrolysis methods, and to black carbon found naturally in fire ecosystems. Biochar is used as a soil amendment to improve soil nutrient status, C storage and/or filtration of percolating soil water (Lehmann and Joseph 2009). Biochar from pyrolysis and charcoal produced through natural burning share key characteristics including long residence time in soils and a soil conditioning effect (Glaser *et al*., 2002). Biochar has an inherent energy value which can be used to maximize the energy output of pyrolysis. However, research has shown that application of biochar to soil may be more desirable as it can increase soil organic carbon (SOC), improve the supply of nutrients to plants and there for enhance plant growth and soil physical, chemical, and biological properties (Glaser *et al.*, 2002; Lehmann *et al.*, 2003; Rondon *et al.*, 2007). Regardless of its commercial market value, biochar presents an opportunity to return site nutrients lost from biomass removal projects, which may overshadow other potential uses.

Abebe Nigussie *et al*. (2012) reported that application of biochar on chromium polluted and unpolluted soils a significantly ($p<0.01$) increased the mean values of soil organic C and total N. The highest values of organic carbon and total nitrogen were observed in soils amended with 10 t ha^{-1} maize stalk biochar. The increase in organic carbon and total nitrogen due to addition of biochar could be resulted from the presence of high amount of carbon and nitrogen in the maize stalk. The highest values of organic carbon at biochar treated soils indicate the recalcitrance of C-organic in biochar. High organic carbon in soils treated with biochar has been also been reported by Lehmann (2007); Solomon *et al.* (2007); Liang *et al*. (2006).

Tryon (1948) investigated the effect of biochar addition on available moisture in brown podzolic forest soils of three different textures - sandy, loamy and clayey. In this study, it was found that biochar addition may be ill-suited to soils that have high clay content (unless perhaps they are waterlogged) soil and useful tool in the reversal of desertification to sandy soils.

Laird (2008) suggested that biochar can act as a liming agent if high in pH and reducing transfer of pesticides and nutrients to surface and ground water thereby improving water quality. Arocena and Opio (2003); Khanna *et al.* (1994) also reported the capacity of biochar ashes to neutralize the acidic soil. Another reason for the increase in soil pH due to application of biochar could be because of high surface area and porous nature of biochar that increases the cation exchange capacity (CEC) of the soil. Thus, there could be a chance for Al and Fe to bind with the exchange site of the soil. The decrease in exchangeable Al and soluble Fe in biochar amended soils was also reported by Agusalim *et al*. (2010). According to Agusalim *et al*. (2010) Al and soluble Fe was decrease in biochar amended soil is due to the increase in CEC. The correlation matrix also showed a positive and significant ($P<0.01$; $r = 0.68$) relationship between soil pH and CEC. These results therefore indicate that biochar could be used as a substitution for lime materials to increase the pH of acidic soils.

Biochar as soil carbon sequester. In recent years application of biochar has been increasingly discussed as a mitigation strategy for sequestrating recalcitrant carbon in to agriculture soils, which can at the same time to improve soil fertility (Glaser *et al*., 2002; Marris, 2006). Terra preta soils enable several harvests per year without extra fertilization or they need to move and cut new forest after a few years. It contained significantly higher P content and had larger stock of soil organic matter besides the black carbon than nearby ferrasols (Glaser, 2007; Steiner *et al*., 2008).

Lehmann *et al. (*2006) opined that conversion of biomass carbon leads to sequestration of about 50 per cent of the initial carbon compared to the low amounts retained after burning (3 %) and biological decomposition (<10 - 20% after 5- 10 years), therefore yielding more stable soil carbon than burning or direct land application of biomass. This efficiency of carbon conversion of biomass to biochar is highly dependent on the type of feedstock, but it is not significantly affected by the pyrolysis temperature (within 350 - 500° C). It also revealed that up to 12 per cent of the total anthropogenic carbon emissions by land use change (0.21 Pg C) can be offset annually in the soil. Agricultural and forestry wastes such as forest residues, mill residues, field crop residues or urban wastes add a conservatively estimated 0.16 Pg C Yr^{-1}. The application of biochar to soil can deliver tradable carbon emissions reduction and the carbon sequestered and easily accountable.

Baskar (2003) revealed that organic carbon increased linearly with humic acid levels and its build up was observed till the end of incubation period (180 days after incubation) as against initial status, with the maximum at 30 days after incubation in Alfisols.

Biochar can be produced from agricultural crop residues has proven effective in sorbing organic contaminants. Cao *et al.* (2009) evaluated that the ability of dairy manure - derived biochar to sorb heavy metal like lead and organic contaminant and atrazine. They have also indicated that dairy manure can be converted in to value added biochar as effective sorbent for metal and organic contaminants. Knoblauch *et al. (*2010) observed that only 4.4 and 8.5 per cent of the black carbon added was mineralized to CO_2 under aerobic and anaerobic conditions respectively after an incubation period of three years. Further they have reported that the same amount of organic carbon was added as untreated rice husk, 34 per cent of the applied carbon was released as CO_2 and CH_4 in the first season. The direct seeded rice recorded the highest chlorophyll content, nitrogen and phosphorus uptake and quality parameters resulted with biochar @ 7.5 t ha^{-1} treatment (Sai Surya Gowthami *et al.,* 2022). The biochar is a sustainable tool to restore the degraded soil ecosystems and it is considered as eco friendly technique as compared to synthetic fertilizers. Biochar has become a promising stabilizer in methane mitigation in agriculture sector and may help to reduce green house emissions as well (Dar *et al.,* 2019).

CONCLUSION

It is well recognized that biochar can enhance the physical and chemical characteristics of soil, enhancing its fertility and productivity. Other advantages of adding biochar to soils include lowering methane and nitrous oxide emissions, nutrient leaching into groundwater, and soil contaminant levels, among others. Agriculture benefits from biochars' are capacity to hold onto water and nutrients in the surface soil strata for extended periods of time because it prevents nutrients from evaporating from the crop root zone, potentially increases crop yields, and lowers the need for fertilizer. Improved soil quality, a decrease in nitrate load in soil and groundwater, a rise in humification, the ability to retain nutrients and water, and tolerance to drought conditions are further advantages of applying biochar to soil. In future the biochar should be utilized as soil amendment (broad casting, traditional banding, mixed in soil, mixed with liquid fertilizers and target application in precision farming) for improving the soil health and combating the burgeoning climate market.

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Conflict of Interest. None.

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