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Review on role of bio-char in soil quality

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Abstract
Soil quality is the capacity of soil to function, within its natural or managed ecosystems, to sustain productivity, enhance water and air quality, support human and animal health, and habitation. The balance between life and destruction often depends on how we manage our soil resource. Soil provides the medium for plant growth that are essential for human and animal nutrition, recycling and detoxification of organic materials and recycling of many nutrients and global gases. Mismanagement of the soil resource can lead to from nutrient imbalance in soil, soil pollution, intensive tillage developed a hardpan layer in soil. Biochar has been used to improve soil quality and increase the cation exchange capacity, sorption capacity retain nutrients and filter harmful chemicals from degraded soil.

Keywords: Soil quality, recycling, biochar, productivity, sorption capacity

Introduction

Biochar play specific role to enhanced soil quality such as - Enhancing soil structure, increasing water retention and aggregation, decreasing acidity, reducing nitrous oxide emissions, improving porosity, regulating nitrogen leaching, improving electrical conductivity, improving microbial properties. When biochar is applied to the soil, it stores the carbon in a secure place for potentially hundreds or thousands of years. Biochar also contributes to the mitigation of climate change by enriching the soils and reducing the need for chemical fertilizers, which in turn lowers greenhouse gas emissions. The improved soil fertility also stimulates the growth of plants, which consume carbon dioxide.

Biochar is a basic input for mitigating climate change and improving soil quality, as well as reducing waste and producing energy as a byproduct. Biochar is a charcoal-like substance that's made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis (Elangovan R, 2014) [4]. Although it looks a lot like common charcoal, biochar is produced using a specific process to reduce contamination and safely store carbon. During pyrolysis organic materials, such as wood chips, leaf litter or dead plants, are burned in a container with very little oxygen. As the materials burn, they release little to no contaminating fumes. During the pyrolysis process, the organic material is converted into biochar, a stable form of carbon that can't easily escape into the atmosphere. The energy or heat created during pyrolysis can be captured and used as a form of clean energy. Biochar is by far more efficient at converting carbon into a stable form and is cleaner than other forms of charcoal.

Biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. Biochar also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution. Biochar, a porous material, can help retain water and nutrients in the soil for the plants to take up as they grow. Due to its adsorption ability, some bio chars have the potential to immobilize heavy metals, pesticides, herbicides, and hormones; prevent nitrate leaching and faecal bacteria into waterways; and reduce N_2O and CH_4 emissions from soils. Biochar is a multi-faceted strategy to mitigate climate change. Biochar is increasingly being recognized by scientists and policy makers for its potential role in carbon sequestration, reducing greenhouse gas emissions, renewable energy, waste mitigation, and as a soil amendment. Biochar also known as charcoal, black carbon, soot, and char, is a broad class of materials produced from the incomplete combustion or pyrolysis of organic materials such as wood, wood by-products, plant residue, manure, petroleum, and petroleum by-products (Antal and Grønli. 2003) [1].

Soil quality can be defined as the fitness of a specific kind of soil, to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen *et al*. 1997) [6]. Soil, like air and water, is a fundamental natural resource supporting a variety of ecosystem goods and services to the benefit of the mankind. While production function of soil was recognized long back, importance of conservation and enhancement of ecosystem services rendered by soil (e.g., carbon sequestration, water purification, and recharge of ground water, control of populations of pathogens, biological nitrogen fixation and biodiversity conservation) has been realized only in the recent past. A concern for maintain/improving soil quality arose long after that for water and soil.

Sequestration of carbon in soil

Krull *et al.,* (2008) showed the role of biochar to sequester carbon in the soil can be attributed to the relative stable nature and, therefore, long turnover time of biochar in soil and is of particular relevance to the solution of climate change. While it is difficult to estimate how long newly created biochar will stay in the soil but few authors suggest that it could be for as long as five thousand years. Liang *et al.,* (2008) [15] concluded that charring of the organic material, much of the carbon becomes fixed in to a more stable form and the resulting product of biochar is applied to the soil, the carbon is effectively sequestered. Woolf *et al.,* (2010) [21] says that the use of biochar to tie up carbon has the potential to reduce current global carbon emissions by as much as 10 per cent.

Lehmann *et al.* (2006) [16] evaluated 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.

Enhanced Nitrogen content in soil

Rondon *et al*., (2007) [19] viewed the potential, magnitude and causes of enhanced biological N_2 fixation (BNF) by common beans (*Phaseolus vulgaris* L.) through biochar additions. Biochar was added at 0, 30, 60, and 90 g kg^{-1} soil, and BNF was determined using the isotope dilution method after adding 15 N-enriched ammonium sulphate to a Typic Haplustox cropped to a potentially nodulating bean variety in comparison to its non-nodulating isoline, both inoculated with effective *Rhizobium* strains. The proportion of fixed N increased from 50 per cent without biochar additions to 72 per cent with 90 g kg^{-1} biochar added. Although total N derived from the atmosphere (NdfA) was significantly increased by 49 per cent and 78 per cent with 30 and 60 g kg^{-1} biochar added to soil respectively, NdfA decreased to 30 per cent above the control with 90 g kg^{-1} due to low total biomass production and N uptake. 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) [13].

Biochar additions not only affect microbial populations and activity in soil, but also plant microbe interactions through their effects on nutrient availability and modification of habitat. *Rhizobia spp*. living in symbiosis with many legume species is able to reduce atmospheric N2 to organic N through a series of enzymatic reactions. This BNF is regarded as an important opportunity to mitigate N deficiency in cropping systems worldwide. BNF significantly decreases, however, if available NO3 concentrations in soils are high, and if available Ca, P and micronutrient concentrations are low. With large biochar concentrations, available NO3 concentrations are usually low and available Ca, P and micronutrient concentrations are high, which is ideal for maximum BNF (Lehmann *et al*., 2003b).

Enhanced soil organic carbon

Glaser *et al.,* (2002) [5] 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. Nigussie *et al*., (2012) [17] 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 Liang *et al*. (2006) [16].

Improving water quality

Laird (2008) [11] concluded 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.

Neutralization of acidic soil

Khanna *et al.,* (1994) [7] says that the capacity of biochar ashes to neutralize the acidic soil. 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 of the soil. Thus, there could be a chance for Al and Fe to bind with the exchange site of the soil. Biochar has a greater ability than other soil organic matter to adsorb cations due to its greater surface area, grater negative surface charge and greater charge density (Liang *et al*., 2006) [16]. Biochar‘s specific surfaces, being generally higher than sand and comparable to or higher than clay, therefore will cause a net increase in the total soil specific surface when added as an amendment (Downie *et al*., 2009) [9].

Reduce density of the soil

Liang *et al*. (2006) [16] reported that biochar has a very porous nature and improved soil aggregation, its application to soil should improve soil aeration. Application of biochar can reduce the overall bulk density of the soil.

Modify soil structure

Downie *et al.,* (2009) [3] observed that incorporation of biochar into soil can alter soil physical properties such as structure, pore size distribution and density with logical implications in soil aeration, water holding capacity, plant growth and soil workability. Kolb (2007) [8] showed that biochar can be experimentally linked to improved soil structure or soil aeration in fine-textured soils.

Increase water availability

Glaser *et al*. (2002) [5] reported that Amazonian charcoal-rich anthrosols had field water retention capacity 18 per cent higher than surrounding soil that had no char. The possible mechanisms by which coal-derived humic acids improve soil physical properties are the formation of oregano mineral complexes by functional groups of the humic acids. The hydrophobic polyaromatic backbone reduces the entry of water in to the aggregate pores leading to an increased aggregate stability and water availability.

Increase nutrient availability

Glaser *et al.* (2002) [5] reported that when biochar is applied to soil it helps to retain the nutrients which remain available to plants thus increasing the plant growth and yield. Higher nutrient availability for plants is the result of both the direct nutrient additions by the biochar and grater nutrient retention. Longer-term benefits for nutrient availability include a greater stabilization of organic matter, concurrent slower nutrient release from added organic matter, and better retention of all cations due to a greater CEC. Biochar may contribute to an increase in ion retention of soil and a decrease in leaching of dissolved OM and organic nutrients ‘as they found higher nutrient retention and nutrient availability after charcoal additions to tropical soil.

Chan *et al.* (2008) [2] concluded that the biochar helps to retain the applied N and avoids N leaching, thus enhancing the soil N availability leads to enhanced yield. Significant additional yield increases, in excess of that due to N fertiliser alone were observed when N fertiliser was applied together with the biochar, highlighting the other beneficial effects of their biochar.

Enhance microbial population

The soil microorganisms play a vital role in functioning of soils. Kolb *et al*. (2009) [9] reported that, charcoal addition affected the soil microbial biomass and microbial activity, as well as nutrient availability. When added to soil, biochar caused a significant increase in microbial efficiency as a measure of units of CO2 released per microbial biomass carbon in the soil as well as a significant increase in basal respiration (Steiner *et al*., 2008) [20]. Further, organic fertilizer amendments along with biochar led to increases in microbial biomass, efficiency in terms of CO2 release per unit microbial carbon, and population growth. Biochar addition to soil increased N fixation by both free living and symbiotic diazotrophs (Rondon *et al*., 2007) [19].

Pietikainen *et al*., (2000) concluded that biochar was applied it stimulated higher bacterial growth rates and can be explained by better attachment to the surface of the biochar and possibly physical protection of microorganisms within the pore structure. Biochar may act as a habitat or safe site for soil microorganisms involved in N, P or S transformations. Biochar certainly has the capacity to support the presence of adsorbed bacteria from which the organisms may influence soil processes

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