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Short Communication

Biochars for Carbon Sequestration and Soil Health Augmentation

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Biochar application in the soil is preliminary deemed as an inexpensive mode of sequestration of soil organic carbon (SOC) and concurrently boost soil health and soil fertility with other sustainable agronomic advantages. The focus of this article is on current research and developments on biochar application to soil for advancements, challenges and solutions.

Rising of environmental problems associated with combustion of fossil fuel, its exhaustion and increasing oil price are required an alternative energy resource. In recent years, thermo-chemical decomposition of biomass is attracting for generating fuel. During the process of carbonization of biomass, gas (syngas) and liquid (bio-oil) products are generated and regarded as alternate fuel to fossil fuels. The third byproduct generates as a byproduct during smoldering of biomass is biochar, which is a carbon rich stable solid charcoal. A word 'biochar' was introduced in 1990's which inspired by combining the 3 initial characters of two words i.e. biomass and charcoal and also entered in Oxford English dictionary. Biochar is majorly produced by the process of pyrolysis or gasification, wherein the biomass is heated up in absence of oxygen. The high biochar yield is achieved (~50%) by direct thermal decomposition (i.e. pyrolysis process) of biomass at 400°C to 500°C. However, above this temperature (i.e. gasification process; > 700°C), high yield of liquid (bio-oil) and gas (syngas like H2, CO, CO_2, hydrocarbons) fuel components are achieved with only 20% biochar content [1]. In production advancement, process of flash carbonization [2,3] and torrefaction [4,5] has also been demonstrated as the potential methods for producing high yield of biochar. A study demonstrated thermo-catalytic depolymerization for the industrial scale biochar production (~50% yield) by the use of microwaves [6].

The biochar is often activated by physical (also called gas activation) or chemical (like, basic chemicals: KOH, NaOH, NH_3, K_2CO_3; acidic chemicals: HCl, H_2SO_4 etc.) procedures before its application to introduce functional groups and to enhance the specific surface area and pore fraction [7,8]. Various raw biomasses like rice straw, almond shell, walnut shell, olive stone, palm oil shell, sewage sludge, soybean oil cake, safflower seed press cake, has been studied for physical and chemical activation for increasing surface topography and structural properties [9]. In general, the processed biochar used in soil application is a finely grained and highly porous charcoal, which is extremely important in soil amendments. The high porosity of biochar helps soil to retain nutrients, water and also works as a habitat for soil microorganism. Additionally, biochar has also found to improve the protection against some soil-borne diseases. The presence of carbon in biochar prevents its degradation and thus, it can persist in soil for thousands of years [1,10]. The high concentration of sodium, phosphorous, calcium and potassium in biochar can be utilized as nutrient by plant or it may be used as a nutrient source of microorganism. Each pore in biochar provides the void volume to allow growth of soil beneficial microorganism, and increase the moisture and air quantity result in increase in growth rate of plants. Conversion of agricultural waste into a powerful soil health enhancer (i.e. biochar) with many promising benefits can be used to conserve cropland diversity, prevent deforestation and most importantly to reduce the national food insecurity. Based on various research findings, figure 1 is presenting the benefits of biochar that comprises but not limited to:

1. Increased water retention capacity of soil
2. Reduction in the leaching of water-soluble nutrients
3. Abatement in soil acidity
4. Reduced leaching of nitrogen into ground water
5. Minimized emissions of nitrous oxide
6. Increased cation exchange capacity (CEC) of soil to improve soil fertility
7. Increased persistance of beneficial soil microbes
8. Influencing seed germination, early growth of seedlings and crop production
9. Increased earth-worm abundance, liming effect and priming effect.

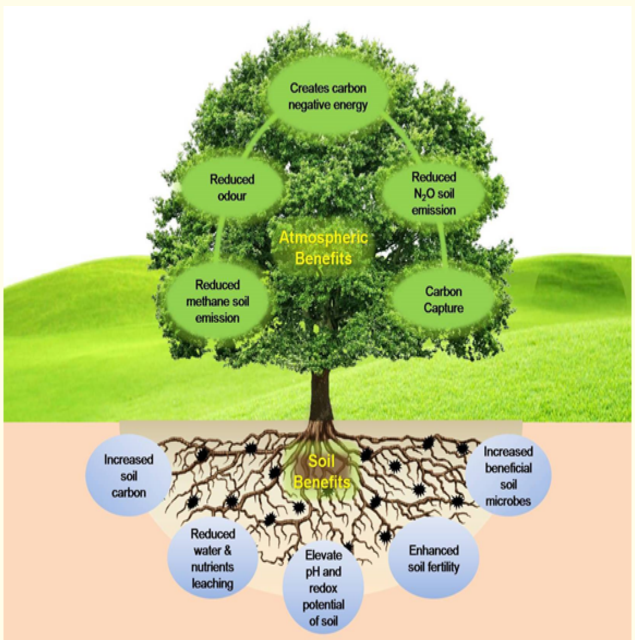

Figure 1: Sustainable application of biochar for atmospheric and soil benefits.

Biochar can augment almost any soil, however, the impact of amendments in soils can depend on the type of biochar, its production parameters, regional soil conditions and the amount of biochar applied to soil. Low rainfall fields or nutrient-poor soils will most likely notice the highest impact by addition of biochar. A study demonstrated that the use of 10% biochar in soil reduced 80% contaminants level in plants, even when the pesticides use was also reduced by upto ~80% [11]. Findings of another study suggest that the use of biochar reduced the leaching of critical nutrients from sandy soil followed by higher uptake of nutrients by plants to increase productivity [12]. Biochar can improve the yields of plants which requires elevated pH and high potash. Biochar has majorly carboxyl, hydroxyl and phenolic functional groups, which react with hydrogen ions in the soil followed by reduced hydrogen ion concentration and thus increase the pH of the soil. Yuan., *et al.* (2011) has reported that biochar produced from biomass of rice, corn, peanut, mung beans and faba beans are having basic pH (from 7.69 to 10.35) and their use as a soil amendment can neutralize the pH of acidic soils [13]. It is suggestive that the biochar application reduced the use of nitrogen fertilizers in agriculture field thereby reducing its emission during production and transportation. In comparison to non-enriched soil (quickly depleted its fertility), biochar-enriched soil is considered to sustain agriculture production for indefinite period. It is worth to mention that type of biochar shows hygroscopic nature, which attracts its potential application in soil for high water and nutrient retention. In contrast, the high sorption capacity of biochar can reduce the efficacy of applied pesticides that are required for weed and pest control [14,15].

Intensive research on biochar into manifold aspects is underway globally. Biochar has been investigated in diverse applications including adsorption, catalysis, soil conditioning, fuel cells, supercapacitors, hydrogen storage, etc [9]. However, considering its potentials in agriculture by amendment of soil health have been reported by many research groups in last two decade. A recent statistics shows that the trend in biochar research for augmenting the soil health is paving the way for improving agriculture practices. There were 6093 articles found on 'Science-Direct' that included the keyword 'biochar', and out of that 3896 articles included the keyword 'biochar agriculture', published from 2008 to 2018 (Figure 2).

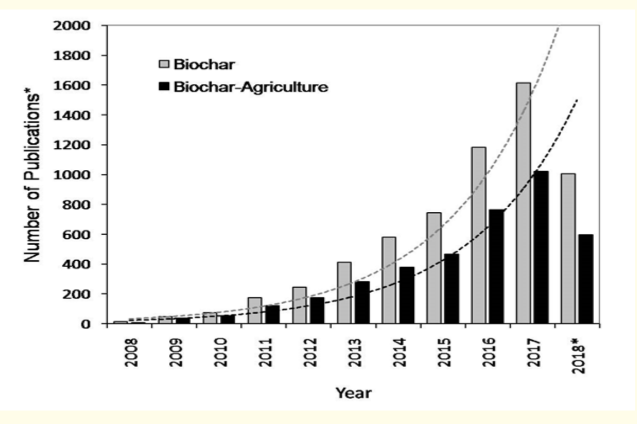

Figure 2: Literature review of research on biochar and its applications in agriculture. The publication trend lines are showing radical increase in the biochar research with respect to time (* represent the publication in respective key domain till March 22, 2018).

Based on above data, ~64% research on biochar application is focused in agriculture sector. A recent study provides evidence that biochar can enhance carbon sequestration in soils due to prolonged residence time [16]. Although, reduced carbon-mineralization using biochar is evident by ^{13}C isotope signatures [17]. A recent combined spectroscopy-microscopy study published in Nature-article suggest that the biochar application reduced the co-localization of polysaccharides-carbon and aromatic-carbon by reducing the carbon metabolism due to carbon stabilization in biochar-activated soil [18].

The biochar research has progressed considerably with important key findings on agronomic benefits, carbon sequestration, greenhouse gas emissions, soil fertility and health, removal of hazardous pollutants etc. However, there is a disconnect can be noticed between the preparation of biochar and its returning to soil. The reason is still having a lack of knowledge about the appropriate preparation from various raw biomasses and proportionate use of biochar to soil for better conditioning and prevention of soil health. Nevertheless, it is noteworthy that although biochar based soil enrichment has been broadly studied as a potential technology, several aspects are still need to be re-evaluate by systematic studies. For example, as discussed above that the use of biochar reduced the pesticides amount for the removal of contaminants. Contradictory to this, several studies has reported the potential use of biochar in the remediation of pesticides-contaminated soil. This in turn made no significant impact on the global market at present. Thus more research is required before definitive recommendations can be made to end-users regarding the effects of biochar application across a range of soils, climates and land management practices.

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