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Role of biochar in agricultural production and impact on environment: A mini review

CK Dotaniya[1], Rajeev K Niranjan[2], Abhishek Khandagle[3], Uttam Kumar[4], Sandeep Mohbe[5], Priyanka Jadon[6], RK Doutaniya[7]

[1, 3-6] Department of Soil Science & Agricultural Chemistry, ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh, India
[2] Department of Environment Science, Nehru Degree College, Lalitpur, Uttar Pradesh, India
[7] Department of Agronomy, O.P.J.S. University Churu, Rajasthan, India

Abstract

Biochar is a solid material obtained from the carbonization of biomass. 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 may be added to soils with the intention to improve the soil health, improve soil fertility, and sequester carbon. 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.

Keywords: biochar, environment, soil health, agricultural production

Introduction

Biochar is charcoal used as a soil amendment. It is a stable solid, rich in carbon, and can endure in soil for thousands of years. Biochar is the carbon rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air. Biochar is defined as carbonized biomass obtained from sustainable sources and sequestered in soils to sustainably enhance their agricultural and environmental value under present and future management. This distinguishes it from charcoal that is used as fuel for heat, as a filter, as a reductant in iron making or as a colouring agent in industry or art (Lehmann and Joseph, 2015). The maintenance of a threshold level of organic matter in the soil is crucial for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform its agricultural production and environmental functions Izaurralde *et al.* 2001 [1]. The term 'biochar' denotes black carbon formed by the pyrolysis of biomass, i.e. by heating biomass under oxygen-free or stress environment, so that it is not subject to complete combustion Kuhlbusch 1998 [3] and Suman *et al.* 1997 [5]. Biochar, a porous material, can help retain water and nutrients in the soil for the plants to take up as they grow. Biochar, a porous material, can help retain water and nutrients in the soil for the plants to take up as they grow. Biochar, due to its aromatic structure and long mean residence time in the soil (more than 100 years) has the potential for long-term carbon sequestration in the soil by Jha *et al.* 2010 [2]. Due to its adsorption ability, some biochars 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 the solid product remaining after biomass is heated to temperatures typically between 300°C and 700°C under oxygen-deprived conditions, a process known as "pyrolysis. In contrast to the original biomass feedstock that mainly contains cellulose, hemicellulose, and lignin, biochar falls into the spectrum of materials called "charcoal" or "black carbon" but excludes black carbon derived from fossil fuels or non-biomass wastes. Biochar can be produced from almost as many types of feedstock as there are types of biomass including agricultural wastes, rice husks, bagasse, paper products, animal manures, and even urban green waste. However, focus is placed on use of "true wastes" in order to minimize disruption to local carbon and nutrient recycling.

Resource and Research Methods

The details of materials used various journals and books from internet were used to study. Various publications dealing with Biochar in Agricultural production were surveyed. All information summarized in this review. All information summarized in this review refers to use of Biochar in agricultural production and impact of environment based on literature sources providing relevant information.

How Biochar is Made

Biochar is made using a process called pyrolysis. The porous charcoal like biochar was once any kind of organic biomass. Pyrolysis involves placing the biomass into a special oven before heating in the presence of little or no oxygen. The result is a stable solid material rich in carbon content that can effectively capture carbon and lock the carbon into the soil. Temperatures required by this process vary and a different type of biocharis produced depending on the feed biomass used and the temperature reached in the pyrolysis process. The materials are used to make in biochar such as Dairy, poultry, agricultural and other waste materials, eg. Poultry Liner, Paper Sludge, Dairy Manure, Green Waste, Wood Waste, Rice Hulls, Algae Waste, Straw, Pig Manure, Cotton Trash, Nut Shells, Woody Weeds, Switch Grass etc.

Biochar production Technologies

Biochar production systems are generally classified as pyrolysis, gasification or carbonization systems.

Pyrolysis Systems

Pyrolysis systems use kilns, retorts, and other specialized equipment to contain the baking biomass while excluding oxygen. The reaction vessel is vented, to allow pyrolysis gases to escape. Pyrolysis gases are often called “syngas”. The process becomes self-sustaining as the syngas produced is combusted, and heat is released. There are two types of pyrolysis systems in use today: fast pyrolysis and slow pyrolysis. Fast pyrolysis tends to produce more oils and liquids while slow pyrolysis produces more syngas.

Table 1

Slow Pyrolysis	Fast Pyrolysis
Relatively low reactor temperatures (450- 650 °C)	High reactor temperature (>700 ^{0}C)
Operating at atmospheric pressure	High heating rates, ranging from 10-50 °C /s
Very low heating rates, ranging from 0.01-2.0 °C /s	High heating rates, ranging from 10-50 °C /s

Gasification Systems

Gasification systems produce smaller quantities of biochar in a directly heated reaction vessel with introduced air. The more oxygen a production unit can exclude, the more biochar it can produce. Biochar production is optimized in the absence of oxygen.

Carbonization

Hydrothermal carbonization: Biochar is obtained by applying high pyrolytic temperature (200–250°C) to a biomass in a suspension with liquid under high atmospheric pressure for several hours.

Flash carbonization: Aflash fire is lights up at an elevated pressure at the underneath of a packed bed biomass. The fire travels in an upward direction through the carbonization bed against the downward flow of air supplied to the process.

Properties of fresh Biochar

- High mineral content, especially Ca (for low pH soils), K. Mg and P with relatively higher solubility.
- Reactive surfaces that can complex soil organic and mineral matter and toxic substances.
- A high concentration of oxygenated functional groups especially carboxylic and phenolic.
- A high redox potential.
- High micro/meso pore volume for adsorption of gases and liquids.
- Soluble or easily oxidized surface organic molecules (especially aliphatic) that are produced in low temperature pyrolysis.
- Can be modified by conditioning including post treating the biochar with minerals, nutrients and/or microorganisms.
- Measured in the lab, made from clean biomass, may be different thanbiochar made from field residue or stored biomass that has been in contact with soil, manures or fertilizers.
- May change as biochar interacts with microbes, soil organic and mineral matter, and plant roots. Biochar ages – like wine.

Agriculture Benefits of Biochar

Many studies exclaimed that the application of biochar on the soils can enhance the content of organic matter in the soils and improves the fertility of the soil. There are number of studies, which show that by the addition of biochar in the soils it will result in the better soil texture, more porosity, good structure, and density and particle size distribution.

1. Improving soil for crop production- Biochar soil amendment improves crop productivity mainly by increasing nutrient use efficiency and water holding capacity. However, improvements to crop production are often recorded in highly degraded and nutrient-poor soils, while its application to fertile and healthy soils does not always increase crop yield. Since biocharsare produced from a variety of feedstocks, certain contaminants can be present. Heavy metals in biochar may affect plant growth as well as rhizosphere microbial and faunal communities and functions.

2. Nutrient availability in soils- By incorporating biochar in the soils, it will result in the better soil texture, more porosity, good structure, and density and particle size distribution. As biochar have higher porosity and more surface area it will help in the providing space for microorganisms which are beneficial for the soil and also help in binding of important anions and cations and increase cation exchange capacity (CEC).

3. Increase in the production of crop- Increase in the crop production happens because of the increase in soil fertility due to biochar, the growth of seeds increased and crop yield also increased significantly as compare to the soils not having biochar. A study revealed that the increase in radish dry matter happened due to the presence of Nitrogen fertilizer along with biochar but there was no increase in the yield even with highest rate of 100 t ha^{-1} in the absence of nitrogen fertilizer. Another study claimed the increase in the yield of maize grain by almost 98% with the application of biochar at the 15 and 20t ha^{-1}. A lot similar results were observed in the soil of paddy rice in China, where by the addition of 10 and 40 t ha^{-1} of biochar the yield of rice increased by 12 to 14% in the soils with no added fertilizer, and with the addition of Nitrogen fertilizer 8.8 to 12.1% increase in the yield, respectively.

Environmental Impact of Biochar-

Biochar can be a simple yet powerful tool to combat climate change. Biochar sequestration is considered carbon negative as it results in a net decrease in atmospheric carbon dioxide over centuries or millennia time scales. It can make a big difference in the fossil fuel emissions worldwide and act as a major player in the global carbon market with its robust, clean and simple production technology. As organic materials decay, greenhouse gases, such as carbon dioxide and methane (which is 21 times more potent as a greenhouse gas than $CO_{2)}$, are released into the atmosphere. Instead of allowing the organic matter to decompose and emit CO_2, pyrolysis can be used to sequester the carbon, remove circulating CO_2 from the atmosphere, and store it in virtually permanent soil carbon pools, making it a carbon-negative process. Biochar can also provide an extremely powerful means of reversing desertification. In most semiarid and desert climates, the soil is nearly void of soil organic carbon (SOC), and thus has the potential to absorb massive quantities of carbon. Generally, the amount of carbon in the soil is a direct indication of soil quality: the greater the amount of SOC, the higher quality the soil. Higher carbon stocks have a direct correlation with increased agricultural yields, higher plant moisture absorption, improved soil tilth, and higher levels of soil biological activity.

Conclusion

Biochar application in the fields helps in increasing the soil fertility, improved soil texture, improved sorption for nutrients which then helps in reducing the use of fertilizer which leads to the decrease in pollution through fertilizer run off. Biochar is highly efficient in increases in the crop production and yield. There is need to monitor the changes in physical, chemical, hydrological and ecological settings of the soil under the long-term application of biochar. One of the major benefits of biochar is that it’s helping in combating with climate change by sequestering the carbon dioxide from the atmosphere. It can also be used for the rehabilitation of destructed landforms. Biochar is posing many benefits to the environment agriculture and economy in the longer run, so it is highly recommended to incorporate it in agriculture practices.

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