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Benefits of Biochar on the Agriculture and Environment - A Review

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Abstract

The agricultural soil or land is fertilized using fertilizers (natural or synthesized). Synthesized ones may be effective in the beginning but later have side-effects on the crop. Bio-fertilizers or natural ones are mostly used but they cannot sustain the fertility of the soil for longer periods. This can be solved by adding charcoal to the soil. As charcoal is one of the purest forms of carbon, it helps in sequestering the carbon captured from carbon dioxide emissions thereby retaining the quality of soil. It helps the bound and clumped ions to dissociate and move freely all through the soil. This solution was found by some of the researchers in the recent years. As we know, the charcoal could be the decay of anything. Researchers have found a new method to sustain the fertility of the soil for a long time. That is by using biochar instead of the random charcoal. Biochar is the form of charcoal that is only produced from plant organic matter which helps in absorbing carbon dioxide (CO2) from the air and fertilizing the crop.

Keywords: Soil nutrients; Biochar; Pollution

Introduction

Depletion in soil organic matter and soil nutrients, decline in agricultural productivity and changes in climate due to anthropogenic activities are posing great threats to the sustainability of agricultural production in the tropical regions [1,2]. Chemical fertilizers have undoubtedly played a vital role towards increasing the agricultural productivity over past half century [3]. Declining soil quality and loss in per capita land area demanded the increase in inorganic fertilizer use. However, the use of chemical or inorganic fertilizers for improving the agricultural yield and soil fertility is not a sustainable approach; rather, it has been widely took in that the excessive use of inorganic fertilizers mainly nitrogen, has the ability to deteriorate soil environment and can also lead to the mineralization of organic matter [4,5]. Although the global population has been fed owing to these practices of green revolution for almost last half century but these practices have become environmentally destructive, unsustainable and are also unable to satisfy the needs of population [6]. So it is becoming important to restore the contaminated sites by using organic fertilizers. Among organic fertilizers, the use of biochar is quite a novel approach having potential benefits to both environment and agriculture.

Application of Biochar to soil as a technique to improve the quality of soil has emerged in recent years. It has the ability to aid in coping up with the greenhouse gases (GHG) and is helpful for carbon sequestration [7,8]. Various evidences and studies showed that the utilization of biochar can be extremely useful for the improvement of Soil organic Carbon [9], capacity of water holding [10,11], stimulating soil microbes, increasing the microbial activity and biomass [12], decreasing in needs and leaching of fertilizers, availability and retention of nutrients, soil aeration [13,14], bettering the growth and yield of crop growth as well as reducing the fluxes of greenhouse gases through anthropogenic activity and increase in sequestering carbon [15].

Environmental Benefits of Biochar

Role in dealing with climate change

Due to the burning of fossil fuels and decomposition of biomass, excessive amount of carbon dioxide is being released in the atmosphere increasing the carbon levels in the atmosphere. However applying biochar on these soils can help decrease the emission of carbon dioxide as biochar has the ability to store 50% of the carbon from feedstock [16]. Biochar is highly stable and that's what makes it restrain the emission of carbon dioxide from organic decomposition significantly and it also plays a vital role in controlling the release of methane and nitrogen dioxide from the soil.

A study revealed that by applying biochar made up of municipal bio-waste almost 90 to 100 percent of nitrogen dioxide can be suppressed in dampened Typic Hapludand in a small scale laboratory experiment [17]. Another study reported that mixing of 20 g of biochar in 1 kg of soil has the ability to reduce the emission levels of nitrogen dioxide up to 80% in grass pots and almost 50% in soybean [18]. This reduction in the release of nitrogen dioxide happens because of the aptitude of biochar to adsorb and retain the ammonium in soils and then lessen the availability of nitrogen for denitrification process [16,19]. Studies showed that the agricultural soils contribute 12% in the total methane emissions globally, and most of that is from paddy rice soils. The emissions of methane from the soil treated with biochar mainly depend on the type of soil, the properties of biochar and water condition [20]. In the fields, methane emissions were 34% higher from the fields which are treated with biochar. However, the emissions of nitrogen dioxide were found 40-51% less in soils than that of those soils which are not treated with biochar. These facts show that global warming gases from soils decreases by amending soils with biochar [21].

Reducing pollution of waterways

Application of biochar on the soil helps in the reduction of offsite pollution. It increases the retention of nutrients like phosphorous and nitrogen in the soils, aid in decreasing the leaching of nutrients of soil in to the groundwater and helps in saving the nutrients from erosion due to the surface water flow. When the loss of nutrients is controlled in the soil, nutrients availability for the cultivation of crop increases thus reducing the amount of fertilizer required for the growth of crops. Reduction in leaching has been verified in many greenhouse studies [22] and can be predicted by realizing the adsorption behavior. As far as the erosion is concerned, there has not been any separate study conducted for that yet but it can be expected that the nutrients soluble in soil are less likely to be eroded as compared to those nutrients which are attached or adsorbed on the surface of soil sediments.

By the pyrolysis of animal manures, a significant amount of

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reduction can be achieved in the mobility of phosphorous of animal manures [23]. This technique will help in reducing the weight and volume of the manures and will make the disposing off of waste easier. It also has the ability to convert the soluble inorganic phosphate present in the manure into the adsorbed phosphate in biochar. There is a need of an extensive study to explore more such behaviors and properties of this charred manure and it should strongly emphasize of phosphorous dynamics with biochar.

Scrubbing of air pollutants with biochar amendments

Studies showed that Pyrolysis seems to propose added opportunities as by the application of biochar into the soil leads to scrubbing of greenhouse gases namely carbon dioxide, sulfur oxides and nitrogen oxides from flue gas which decreases their emission [24]. During an exothermic process, carbon dioxide is precipitated on the surfaces of Biochar. This process could be helpful for the reduction of carbon emissions in the atmosphere due to the burning of fossil fuels. Simultaneously, the precipitation process results in to the formation of biochar which highly rich in nitrogen content that could be used as a substitute of nitrogen based fertilizers [24]. Such benefits require furthermore investigations.

Reduction of hazardous materials of environment

Biochar is highly efficient as it has the ability to sorb major environmental contaminants for the soil. Many organic pollutants are being sequestered by using biochar to alter their effects on the environment eventually. Due to its resisting nature towards microorganisms and its extraordinary sorption affinity, biochar acts as a critical binding phase for different organic pollutants in the environment. There are carbonized and non-carbonized type of organic matter in the biochar which plays the great role in sorption, as the sorption of pollutants is done by these carbonized and non-carbonized sections of biochar which depends on their bulk and surfaces [25,26]. To exemplified, it is reported that sorption of pesticides using the biochar made up of incompletely burned wheat and rice residues is 400 to 2500 times highly efficient than that of normal soil. Another report showed that charcoals derived from red gum have the efficiency to sorb Diuron-a pesticide, from the polluted soil. Studies revealed that charcoal works best in high temperatures (e.g., 8508°C) and their capacity enhances. This helped it to the higher surface area and micropores.

Zhang study showed that biochar derived from Pinus radiata have the higher efficiency for the sorption and desorption of a pollutant named phenanthrene from the soil. Cao et al. studied that the biochar made up manure derived from dairy have the sorption capacity for heavy metals like lead and other organic contaminants. These studies showed that the sorption capacity of soil for hydrophobic organic compounds is higher when treated with biochar but this depends on the carbon levels of that soil, the properties of biochar and the time required by the soil and biochar to contact with each other [27]. A study conducted on organic compounds showed that the heavy metals present in the soil immensely affect the adsorption of organic pollutants on biochar and also interfere with their transport and fate. Biochar is more likely to adsorb organic contamination like persistent organic pollutants (POPs) as they have high affinity for biochar because it is naturally occurring [28]. Chen and Yuan in 2011 found out that by applying biochar to the soil contaminated with poly aromatic hydrocarbons (PAHs) can help the sorption of PAHs from the soil [29].

Agricultural 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. 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. Many researches provided evidences that by the addition of biochar the growth rate of crop increased, quality of water improved, reduction in nutrient leaching, reduction in acidity of soil, more water retention, and decrease in fertilizer use. In the presence of added nutrients, the nutrients uptake by plants increased, growth rate increased significantly by the application of biochar in soils [30].

Improving soil for crop production

Any process related to the production of bio energy tends to negatively affect the land and leads to excessive accumulation and removal of biomass from the land. These extremely exhausting procedures have the potential to degrade the soils excessively, poses negative effects on the productivity of soil, causes habitat destruction, and off site pollution. These problems can be resolved by the application of biochar through pyrolysis in combination with organic matter as it helps in recovering almost about half of the amount of original carbon. Moreover, biochar is also considered to be highly effective in the restoration of the fertility of soils. Many researches confirmed that the use of biochar leads to the improvement of the soil productivity [7]. The extraordinary properties and benefits of the use of biochar are not only limited to only to the area which was disturbed for obtaining biomass to generate bio energy but it has the ability to remain persistent in the soils for almost two to three years [9]. This shows that if the biochar is applied to the lands which are not used for bio energy production, it will increase the fertility of soil and will help in reducing the pollution of soil of that land from the inorganic chemicals.

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) [31]. Biochar application leads to the increase in pH of the soil and that leads to improved availability of phosphorous and potassium [10]. When biochar is applied on the soil, oxidation process is observed on the surface of particles. The reason for the reported high CEC is the oxidation of aromatic carbon which leads to the formation of carboxyl groups [32]. The increase in CEC aids in increasing the fertility of soil, as the nutrients will remain attached to the soil opposing the leaching process because of CEC. When highly oxidized organic matter attached with the surface it will create negative charge on the surface. This results in the decrease of positive charge on the sites. However, the results from the studies showed that the effect of biochar is more expected on the soils having macro pores [33].

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 [34]. Another study claimed the increase in the yield of maize grain by almost 98% with the application of biochar at the 15 and 20 t ha^{-1} [35]. 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.

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. 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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