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Research Article

Impact of Biochar Application on Soil Physical Health

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Introduction

Soil health is the capability of the soil to sustain plant, animal or living beings and it functions as a vital living ecosystem. Soil health indicators include physical, chemical, and biological indicators. Soil physical health is the ability of soil to meet requirements of plants for water, aeration and strength over time and indicators include soil bulk density, porosity, water retention, aggregate stability, etc. that are directly related with the crop productivity and water use efficiency. Nowadays, soil health becomes a critical factor to manage and sustain for human as intensive use of chemical fertilizers have degraded soil health as well as polluted groundwater which leads to low and stagnating yields of the crop [1]. To improve soil physical health and at the same time reduce soil degradation, there is need to adopt an integrated use of organic and inorganic fertilizers. Organic fertilizers consist of farmyard manure, compost, biogas slurry is having high decomposition rate [2]. So, alternative organic fertilizer that is biochar can be applied which is recalcitrant to decomposition for longer period and able to maintain organic carbon status in the soil. Biochar is the product of the pyrolysis of the crop biomass that provides a significant opportunity to transform agricultural residues from the environmental liability to the valuable assets. Biochar is rich in carbon produced by the thermal decomposition of the organic material either in partial or complete absence of oxygen [3]. Therefore, application of biochar in soil has the potential to stabilize organic matter content, helps in carbon sequestration and increases agricultural productivity.

Keywords: Soil health; water retention; aggregate stability; ground water; crop productivity

Importance of Biochar Application in Soil

Biochar can be used as an organic amendment in the soil as it helps in improving the soil physical properties. Biochar is having high porosity and surface area which enables it to retain water and nutrients and also act as habitat for beneficial micro-organisms to grow [4]. Biochar helps to increase water holding capacity of soil because of its porous nature and results in improving water use efficiency. This is because application of biochar would retain more water from irrigation and reduce the frequency of irrigation, hence sustaining and optimizing the limited water available for crop production. Biochar also alters pore size distribution in the soil by reducing proportion of drainable pores [5] and increasing mesopores [6]. The resultant increase in the mesopores with the application of biochar in the soil helps to increase the ability of the soil to retain more plant available water.

Impact of Biochar Application on Soil Physical Properties

The literature on the impact of biochar on soil physical properties is still lacking and soil physical properties are directly related with the soil hydrological properties. Thus, an improved understanding of how soil physical and hydraulic properties respond to biochar application is critical to overall soil performance [7]. Biochar amended soil retained 15 % more moisture content as compared to controlled treatment [8]. Table 1 shows the data of

water holding capacity of the soil as affected by different treatments of biochar with nitrogen. It can be seen clearly from the data that combined application of biochar with nitrogen fertilizer resulted in increase in the water holding capacity of the soil as compared to the individual application of nitrogen fertilizer due to higher surface area and porous nature of biochar. Biochar has lower bulk density (<0.3 Mg m^{-3}) than that of mineral soils (1.3 Mg m^{-3}); therefore, application of biochar can reduce the overall total bulk density of the soil which is generally required for most plant growth [9]. Table 2 shows the impact of biochar application on soil bulk density in the upper 15 cm of soil depth for different soils. Biochar increases porosity by 8.4% [10], wet aggregate stability by 3 to 226% and available water by 4 to 130% [7] and decreased penetration resistance of soil by 22.57% [11]. Biochar provides organic binding agents that help in increase in the aggregate stability of soil. It is well known that aggregate stability of the soil is directly correlated with concentration of organic matter in soil. Application of biochar follows two trends i.e., it decreased saturated hydraulic conductivity and infiltration rate in coarse textured soils and increased it in fine-textured soils. The first trend is the decrease in saturated hydraulic conductivity and infiltration rate in coarse textured soils is due to the clogging of macropores with the fine biochar particles (<2mm) that interacts with soil inorganic particles and fill the pore space resulting in decrease in water flow. And second trend is the mixing of large biochar particles with small inorganic clay particles results in increased pore space and hence increases saturated hydraulic conductivity and infiltration rate [12]. Improvement in all these properties of the soil would lead to the proper aeration and water supply to the crop which will help in obtaining higher crop productivity as well as water use efficiency [13-15].

Table 1: Water holding capacity of the soil as affected by different biochar treatments in maize crop.

Treatments	Water holding capacity
BN_1 (Biochar @ 7.5 t ha^{-1} + 75 kg N ha^{-1})	45.19a
BN_2 (Biochar @ 7.5 t ha^{-1} + 150 kg N ha^{-1})	44.14a
N_1 (N @ 75 kg ha^{-1})	40.91b
N_2 (N @ 150 kg ha^{-1})	40.77b

Table 2: Impact of biochar application on soil bulk density in the upper 15 cm of soil depth for different soils.

Location	Soil	Study type	Study duration	Biochar feedstock	Biochar temperature °C	Biochar rate Mg ha^{-1}	Bulk Density	Decrease in bulk density	Reference
India	Sandy Loam	Field	3 yr	Corn stalk	350-400	0	1.42a		Pandian et al., 2016
						2.5	1.37ab	-4	
						5	1.36b	-4	
China	Clay Loam	Field	2 yr	Corn residue	400	0	1.35a		Xiao et al., 2016
						10	1.30ab		
						20	1.24b	-9	
						30	1.23b	-10	
Italy	Silty Clay Loam	Field	3 mo	Wheat bran	800	0	1.07a		Andrenelli et al., 2016
					1200	14	0.93b	-15	

Conclusion

Application of biochar improves soil physical health by decreasing soil bulk density due to its porous nature, increases water holding capacity of soil, and improves aggregate stability and water transmission characteristics of the soil. The results of the biochar application in soil depend upon the type of biomass used to make biochar, temperature of pyrolysis, particle size of biochar, etc. The improved soil physical health will ultimately lead to higher crop productivity. Under limited resource conditions, the optimum productivity can be achieved with biochar application along with lower dose of chemical fertilizers and lower irrigation levels. Biochar can be a viable option to use in integrated nutrient management instead of individual application of chemical fertilizers that are deteriorating soil health and polluting ground water.

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