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Impact of biochar and organic manures on soil physical properties and crop yield of rice

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Abstract
The physical properties of the soil are very important for agricultural production and the sustainable use of soil. The amount and rate of water, oxygen, and nutrient absorption by plants depend on the ability of the roots to absorb the soil solution as well as the ability of the soil to supply it to the roots. A field experiment was conducted to evaluate the effect of organic manures and biochar on soil properties and crop yield of rice at Organic Farming Research Center, Chatha, SKUAST- Jammu. The treatments were T1= control, T2= 100% N through FYM, T3= 100% N through vermicompost, T4= 50% N through FYM + 50% N through vermicompost, T5= T2+ 1t/ha biochar, T6= T3+ 1t/ha biochar, T7= T4+1t/ha biochar, T8= T2+ 2t/ha biochar, T9 = T3 + 2t/ha biochar, T10 = T4 + 2t/ha biochar. Results revealed that soil bulk density (BD) and crack volume decreased, and infiltration rate (IR) increased with application of organic manures with biochar in comparison with the control. No significant differences were obtained among organic manures treatments. Lowest BD (1.33Mg/m^3) was observed with the combination of 50% N through FYM +50% N through vermicompost + 2t/ha biochar. Irrespective of BD the infiltration rates (IR) was higher in this treatment as compare to control. Maximum crack volume was observed in control plots (14585cm^3/m^2). The highest grain yield of rice crop was recorded with the application of 50% N through FYM +50% N through vermicompost + 2t/ha biochar and was about 83 % higher over the control.

Keywords: Biochar, rice, physical properties, bulk density, crack volume

Introduction

Soil degradation resulting from intensive agricultural use and changing climatic conditions is becoming more and more alarming worldwide and poses a serious threat to global food security. It is estimated that more than half (52%) of all fertile, food-producing soils globally are now classified as degraded, many of them severely degraded (UNCCD 2015) [14]. The world population is currently increasing at a fast rate and is expected to reach 9 billion by 2050. To meet a growing demand for food from a growing population, we need to increase agricultural productivity upto 70%, and food production in the developing world will need to double by 2050 (FAO). Agriculture and the food we eat depend on soil, necessitating the development of novel and environmentally friendly technologies that improve soil health and resilience. Presently, agricultural is one of the highest greenhouse gas emitting sectors of society. Rice is the main staple food crop of India, covering an area of about 39.16 m ha (Anonymous, 2014) [2]. Rice is cultivated mainly through transplanting in puddled field, which results in formation of a hard pan and damages soil structure, though it helps in retention of more water and effective in weed control, but this needs more time, labour and energy. However, puddling delays planting of succeeding crop. In India, about 93 million tons of crop residues are burned each year primarily to clear the fields from straw and stubble after the harvest of preceding crop that leads to cause pollution. As India has high potential to generate crop residues so why not we use these crop residues for making of biochar and give it to the soil as an amendment. Depletion in soil organic matter (SOM) has become one of the major threats to agricultural productivity which affects the soil quality and fertility. Biochar is a carbon rich charcoal based soil amendment that can be designed to help reclaim and improve soils by increasing soil water holding capacity and enhancing fertility. Besides sequestering carbon, biochar is a mixture of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. The major qualities of biochar that makes it attractive as a soil amendment is its highly porous structure, potentially responsible for improved water retention and increased soil surface area, alkaline pH high aromatic C content, carbon negative in nature, high CEC and low bulk density (Chan *et al*., 2007; Sohi, *et al*., 2009; Chan and Xu 2009; Novak *et al*., 2009, Abrol, *et al.2016)* [5, 13, 6, 11, 1].

Research findings indicated lower bulk density with biochar application (Karhu *et al*., 2011) [8] due to high porosity which allows high water holding capacity. Direct incorporation of crop residues into agricultural soil to conserve soil nutrients and organic carbon content can cause considerable crop management problems. For more effective management and disposal of the crop residues, conversion into biochar using the thermo-chemical process is gaining importance. The information on combined application of biochar and compost on soil physical fertility and crop performance is inadequate. The goal of this study was to investigate the changes in soil physical properties in rice crop under puddle condition with combined application of biochar and organic manure.

Materials and Methods

A field experiment was conducted to evaluate the effect of organic manures and biochar on soil properties and crop yield of rice at Organic Farming Research Center, at Sher-e-Kashmir University of Agriculture Science & Technology of Jammu. The experimental soil was sandy clay loam in texture with pH 7.5, medium in organic carbon (0.52 %), available phosphorus (12.32 kg/ha) and potassium (148.4 kg/ha) and low in available nitrogen (257.60 kg/ha). The experiment was conducted in Randomized Block Design (RBD) with 10 treatments replicated three times. The treatments comprised of T1= control, T2= 100% N through FYM, T3= 100% N through vermicompost, T4= 50% N through FYM + 50% N through vermicompost, T5= T2+ 1t/ha biochar, T6= T3+ 1t/ha biochar, T7= T4+1t/ha biochar, T8= T2+ 2t/ha biochar, T9 = T3 + 2t/ha biochar, T10 = T4 + 2t/ha biochar. Recommended Dose of Fertilizers (30:20:10: N: P:K) was applied as per treatment from T2 to T10. The study was conducted using a randomized block design with three replications of 4 m x 3 m plots of each treatment. The rice husk biochar was produced using a farmer's friendly kiln (CRIDA) under limited oxygen supply. The target end stage of biocarbonization was indicated by distinctive thin grey and blue gases for temperature range (350-450 ^{0}C) from top vent with puff of flame. At this stage, the kiln was ready to be sealed with clay and sand sealing mixture to restrict the flow of carrier medium through the kiln for significant yield realization. After cooling the biochar is taken out. Selected properties of the biochar are presented in Table 1.

Table 1: Analysis of biochar derived from rice husk

Biochar	Properties
C (%)	53.5
H (%)	1.6
O (%)	9.2
N (%)	0.09
P (%)	0.15
K (%)	0.5
pH	8.9
Surface area m2/g	112.0
Bulk density g/cm^3	0.28

Soil Sampling and Analysis

Soil samples were taken from the topsoil with 0 cm–15 cm at the time of crop harvest. Collected soil samples were air-dried and grinded with the help of wooden hammer. Processed soil samples passed through a 2 mm sieve and were analysed for pH by using 1: 2 soil: water suspension. Analysis of the soil for different size fractions was done by using Bouyoucos hydrometer method (Bouyoucos, 1962) [4], electrical conductivity of the soil samples was determined by 1:2.5 soils water suspension with EC meter and expressed in dSm^{-1} (Jackson 1967) [7], organic carbon (OC) (Walkly and Black 1934) [16]. Bulk density of the experimental soil was estimated by core sampler method. Infiltration rate of soil was measured by mini disk infiltrometer. To minimize disturbance, we utilized a flexible (<1 mm) ruler to assess cracking depth following rice harvest when the soils were below field capacity. The ruler was inserted to the crack terminus at 5 randomly selected locations in each plot.

Results and discussion

Soil physical properties

Organic manure applications improved soil physical properties through increased soil aggregation, decrease in the volume of micropores while increasing macropores, increased saturated hydraulic conductivity and water infiltration rate and improved soil water-holding capacity at both field capacity and wilting point. Results revealed that biochar and organic manures had significant impact on soil Infiltration rate (IR) (Fig. 1). IR was considerably higher with the application of organic manures in combination with biochar followed by organic manure alone and lowest was recorded in control. Application of 50% N through FYM +50% N through vermicompost + 2t/ha (T10) biochar gave highest soil infiltration rate (1.6 times) over control. Use of biochar increased the soil infiltration rate and decreased the bulk density, which might be due to its high total porosity property, it could retain water in small pores and support water to infiltrate into the soil surface (Asai *et al*., 2009) [3] thus increase water retention capacity. Application of organic manures with biochar have significant effect on soil bulk density (Fig 2). The bulk density of soil decreased with the application of compost, vermicompost and biochar as compared to the control. Application of 50% N through FYM +50% N through vermicompost + 2t/ha biochar decreased soil compaction (1.1 times, Fig. 2) relative to control. Several studies indicated that biochar application could improve soil aggregation (Lu *et al* 2014) [9], decreased bulk density from 1.47 to 1.44 mg m^{-3}, and increase porosity from 0.43 to 0.44 m^3 m^{-3} (Nelissen *et al* 2015) [10] and ameliorate soil compaction by over 10 % (Peake *et al* 2014) [12]. The use of a low-temperature biochar with a higher amount of labile aliphatic functional groups carried by volatile matter can enhance short-term rapid nutrient availability. Soil amendment with biochar can result in decreased bulk density and soil penetration resistance and increased water holding capacity (Abrol *et al*., 2016) [1]. Puddled soils shrink on drying, become compact and hard and produce surface fissures of varying size and shape. After rice, preparation of seed beds with fine tilth for wheat is difficult. Plowing of puddled soil after rice results in the formation of large clods, having high breaking strength (Sharma and Bhagat, 1993) and very large amounts of energy and time are consumed in producing fine seed beds. Data presented in Fig.3 showed that the application of 100% N through vermicompost + 2t/ha biochar decreased soil crack volume (1.82 times) followed by 50% N through FYM+50% N through vermicompost + 2t/ha biochar (1.77 times) is recommended in rice under irrigated condition. The above results are in close conformity with the findings of Vishwambharrao, 2005 [15]. Significant differences in rice yield were produced by the organic manures and biochar application. Application of organic manures in combination of biochar improves the rice yield as compare to the application of organic manure alone. For the organic manures, the application of vermicompost produced the maximum yield followed by FYM (Fig. 4). The highest yield was obtained in T10 treatment (50% N through FYM +50% N through vermicompost + 2t/ha biochar) and the lowest was found in control. Highest rice yield (83%) was recorded with application of 50% N through FYM +50% N through vermicompost + 2t/ha biochar as compare to control.

Efficient use of biochar in agricultural systems is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste, enhance crop yield with concomitant improvement in soil quality. Further, long term experiments are needed for judicious combination of organic amendments and biochar to sustain agronomic productivity and improve soil fertility.

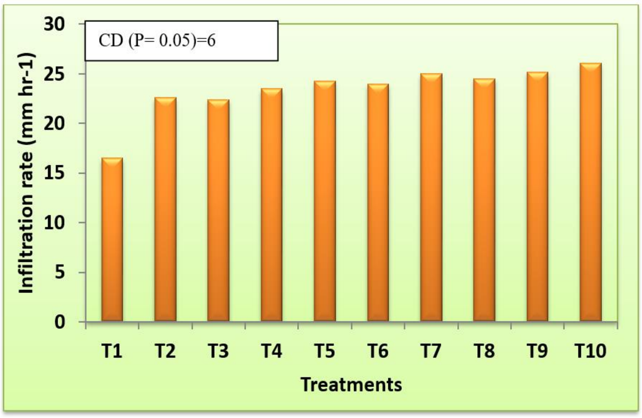

Fig 1: Effect of organic manure and biochar on soil infiltration rate

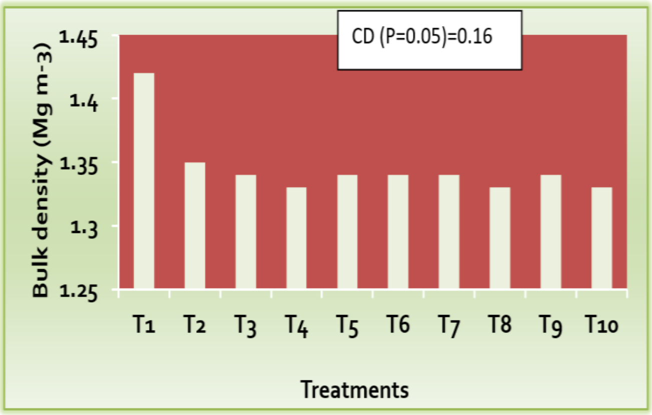

Fig 2: Effect of organic manure and biochar on soil bulk density

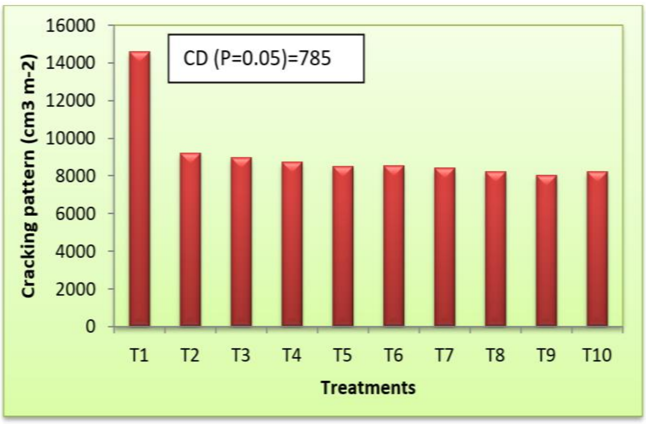

Fig 3(a): Effect of organic manure and biochar on soil crack volume

Fig 3(b): Effect of organic manure and biochar on soil cracking pattern

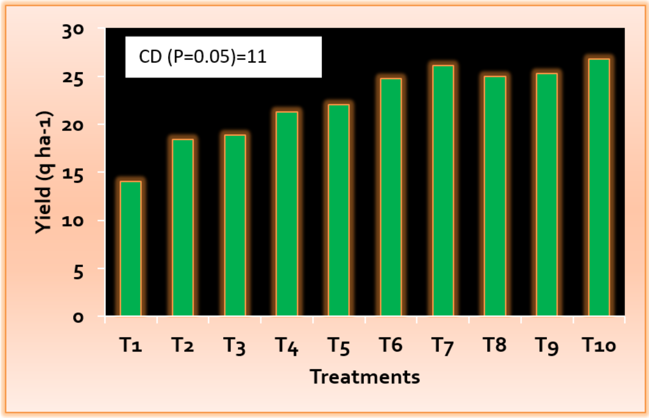

Fig 4: Effect of organic manure and biochar on rice yield

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