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The effect of rice husk biochar on soil nutrient status, microbial biomass and paddy productivity of nutrient poor agriculture soils

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A B S T R A C T

The study related to the effects of rice husk biochar (RHB) application on soil microbial aspects and paddy productivity in field condition is scare. Therefore, present study provides fresh insight into the effects of RHB on rice production in field conditions, with some updated information on soil microbial aspects. To study the impact of RHB and CSR-BIO (commercialized bio-formulation), on soil physico-chemical properties, soil microbial biomass (SMB) quantity and paddy productivity, four treatments were set up: control, RHB, CSR-BIO and RHB + CSR-BIO. The RHB with CSR-BIO both the amendments were applied at a rate of 10 t ha^{-1}. Across treatments, the water holding capacity, total -C, -N, -P concentrations and soil moisture content were statistically higher in RHB and CSR-BIO treated soils over the control. The highest SMB-C, -N and -P (408.66 ± 0.57, 83.33 ± 2.08 and 25.66 ± 1.52 μg g^{-1} dry soil, respectively) was recorded in RHB + CSR-BIO treated soil. Across the sampling dates, SMB-C, -N, -P and inorganic-N (ammonium- and nitrate-N) concentrations were minimum on 35 day after transplantation (DAT) (tillering stage-active growth period), and maximum on 105 DAT (maturity stage). The paddy plant growth variables (panicle length, tiller number, rice grain and paddy straw yields) were found higher in treated plots compared to untreated (control) plots, and varied significantly ($P \leq 0.001$) due to treatments. Among the various selected paddy agronomic variables, the application of RHB and CSR-BIO treatment was more pronounced to the yield of rice grains. Results indicate that an increase in the quantity of SMB due to RHB + CSR-BIO addition, improves the soil nutrient status and hence, paddy productivity in nutrient poor agriculture soils. It is suggested that RHB generation from rice husk biochar could be a sustainable crop residues waste management option to enhance the nutrient status, microbial biomass and paddy productivity of disturbed agriculture soils.

1. Introduction

India being an agriculture-dominant country produces > 500 million tons of crop residues annually. The residues of rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard and groundnut are typically burnt on-farm across different states of the India. A large portion of unused crop residues are burnt in the fields primarily to clear the left-over straw and stubbles after the harvest. The problem is more severe in the irrigated paddy agriculture, particularly in the mechanized rice-wheat system of the north-west India. Non-availability of labour, high cost of crop residues removal from the field and increasing use of combines in harvesting the crops are main reasons behind burning of huge crop residues in the fields. Burning of crop residues causes environmental pollution, hazardous to human health, produces greenhouse gases causing global warming and results in loss of beneficial soil microbial diversity and plant nutrients like N, P, K and S. Therefore, appropriate management of crop residues for agricultural use assumes a great significance. Recent research efforts have developed conservation agriculture-based crop management technologies which are more resource-efficient than the conventional practices. However, information about impact of RHB on soil nutrient status, microbial biomass and paddy productivity of nutrient poor agriculture soils is limited. This paper will provide valuable information and will generate awareness about the use of RHB generated from rice crop residues on soil microbial aspects and restoration of disturbed paddy agricultural soil productivity.

The Food and Agriculture Organization (FAO) suggested that by the year 2025, the world population (about 8.5 × 10^9 people), will require substantial enhancement in agricultural production to satisfy the demand (Timmusk et al., 2017). The soil fertility and agriculture

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productivity loss due to low precipitation, soil salinity, soil nutrient leaching and poor agricultural practices, triggered interest to find out the ways for sustainable management of nutrient poor soils to enhance crop rather sustainable (Singh and Pandey, 2013). In general, the increase in crop productivity will lead to sustainable enhancement in the area of farming lands but also somewhat enriching the soil fertility of the existing agricultural land could be the viable option (Mekuria et al., 2017). Therefore, it seems that application of biochar (consist of inherent mineral constituents) to nutrient poor soils, could be one of the potential options to enhance agriculture productivity (Xu et al., 2017). The plant residue biochar, an alternative organic supplement to chemical fertilizers, could be the viable and sustainable way to enhance crop yield (Agegnehua et al., 2017) in degraded nutrient poor soils (Kollah et al., 2015). From a long time, peoples were well interested in the use of biochar derived from plant residues, as soil conditioners to enhance soil physico-chemical properties and crop productivity (Zhang et al., 2017). The use of biochar in agriculture as the possible option to enhance agriculture soil fertility, the adverse impact of chemicalization on soil fertility (Kim et al., 2017), soil microbial biodiversity (Luo et al., 2017) and agriculture productivity can be reduced significantly (Agegnehua et al., 2017).

The SMB serves as the index of microbial nutrients immobilization and mediate many of the major processes during soil nutrient cycling (Singh et al., 2010). Soil available N immobilization by soil micro-flora has been considered as an adaptation for short-term storage of N in nutrient limited ecosystems (Singh and Gupta, 2018). Hence, any disturbances in soil SMB pools could be one of the important factors, which may significantly affect the nutrient availability to plants. As the microbial mediated turnover rate of available soil nutrients is very important for the functioning of different ecosystems (Singh and Gupta, 2018), SMB dynamics and its role in plant nutrition in nutrient-poor soils of dry tropical agro-ecosystems affected by various amendments would be of major significance (Tiwari and Singh, 2017; Vimal et al., 2018). The SMB quantity and its turnover rate in the ecosystems are considered widely as a soil fertility index that governs agro-ecosystem functioning and crop productivity (Singh et al., 2016). The SMB, a living component of agro-ecosystems soils also acts as the available nutrients source for plant uptake during nutrient release following death and decay of the microbial communities (Singh and Kashyap, 2007; Singh et al., 2010). Therefore, any changes in SMB values are recognised as an important indicator of soil nutrient dynamics and agro-ecosystems productivity (Warnock et al., 2010). Although, soil nutrient status, seasonality, soil conditions, temperature and other factors are the important drivers in controlling the functioning of agro-ecosystems, SMB could also be one of the vital factors to affect crop productivity of the tropical nutrient-poor soils (Singh et al., 2010). The reports related to the effect of biochar addition to the agriculture soil on SMB levels are not very clear yet (Rousk et al., 2013). Thus both decrease and increase in the composition of SMB during the rice husk biochar addition to the soil may be possible, and has to be investigated. Though, ample experiments in pot conditions have been carried out concerning the application of amendments to the crop yield, but information on plant residues derived biochar application on SMB dynamics and paddy yields in field conditions are scare.

Recent advances in our understanding of biochar warrant an evaluation of the relationship between its impacts on the soil micro-biota and biomass (Xu et al., 2017). The role of biochar application in soil biological processes therefore, represents a frontier in soil science research, and needs detail investigations. It has been reported that compared to direct addition of rice husk, the incorporation of biochar derived from rice husk into soils could significantly improve the soil physico-chemical properties such as soil moisture content, WHC, BD, available-N nutrients, etc. in the paddy fields (Knoblauch et al., 2011). Thus generation of RHB from rice husk and other crop residues after crop harvesting, may be considered as the very viable crop residues waste management strategy to avoid the on-site burning of crop residues which has been considered as one of the key issues related to air pollution and the loss of soil microbial community and biomass. Study indicated that biochar application was good for acidic and neutral agriculture soil improvements (Agegnehua et al., 2017); however, the effect of biochar amendment to nutrient poor tropical soils is still not investigated. Though, investigations have been carried out concerning the application of several organic and inorganic amendments on the crop yield (Zhang et al., 2010; Xu et al., 2017; Kim et al., 2017; Luo et al., 2017), however, information is scare for the use of crop residue mediated RHB and microbial inoculants on SMB dynamics and its correlation with paddy yields in field conditions. Therefore, in this study we investigated the impact of RHB derived from rice husk on SMB quantity and paddy agronomic variables in the disturbed soil of dry tropical farming land.

Sustainable degraded agriculture land management approaches such as organic farming, novel microbial inoculation with suitable bio-inoculant carriers have been considered as key tools for combating the loss of soil fertility and crop productivity (Seneviratne et al., 2011). The inoculation of bio-filmed bio-fertilizers (BFBFs), developed from agriculturally important microbes, in combination with suitable amendments, has been demonstrated to speed up the restoration of degraded land soil fertility within short period of time (Seneviratne and Kulasooriya, 2013; Singh et al., 2016). Evidently, the direct inoculation of beneficial microbial consortia in combination with suitable supporting soil amendments/carrier material can be a viable and new efficient tool to contribute significantly in enhancement of microbial density and biomass, which can help considerably to agro-ecosystem sustainability and crop productivity (Singh, 2015). Therefore, in this experiment, the CSR-BIO, a commercial bio-formulation consortia prepared from agriculturally beneficial microbes (Damodaran et al., 2013), was used with cow dung manure (as carrier material) and RHB as soil conditioner. We hypothesized that the addition of RHB with CSR-BIO mixture will have positive effects on soil physico-chemical properties, SMB levels and paddy productivity. It may also be further assumed that the application of RHB in combination with novel microbial bio-formulation mixture (CSR-BIO) would increase synergistically the soil available inorganic-N nutrients to paddy plants in nutrient deprived soils. Since, application of RHB in combination with CSR-BIO as a supporting amendment, from nutrient poor agriculture soils are lacking therefore, to find out the answers of above raised questions and arguments, we conducted an experiment in field condition to assess the impact of CSR-BIO and RHB application on soil nutrient status, microbial biomass-C, -N and P quantity and paddy agronomic variables.

2. Materials and methods

2.1. Description of study site and climatic conditions of the area

The field experiments were conducted at Agriculture Research Farm of Babasaheb Bhimrao Ambedkar University located in Lucknow, Uttar Pradesh (India) 26° 46′ 05.51″ N Lat. and 80° 55′ 39.50″ E Long, with average altitude of 100–355 msl. The study area experiences a hot subtropical climate with extreme warm summer and cool dry winter seasons. In general, the normal onset of monsoon in the study region experienced in 3rd to 4th week of June and continued up to September. The average precipitation received during the wet season of late June–October, ranged from 900 to 1100 mm annually (Singh et al., 2011). The soil of the selected study paddy field is nutrient deprived (low organic C and N) having moderate water holding capacity, sandy and slightly alkaline in nature (Singh et al., 2011).

2.2. Experimental set-up and paddy cultivation

After removing the plant debris and rock stones from the surface, land preparation was done manually on 25 June 2015. Total 12 experimental plots, each having dimension of 3 × 2 m area, were