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Differential Effect of Wheat Straw and Sugarcane Derived Biochars on Microbial and Enzymatic Activities of Rain-Fed Soil

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Abstract: Biochar is a potential source of nutrients and improves soil health, microbial and enzymatic activities. A field experiment was conducted to quantify the effects of different biochar on soil microbial biomass and enzymes activities. Two biochar types (wheat straw and sugarcane @ 5 and 10 t ha^{-1} respectively) were applied using RCBD in rain-fed soil. Our results showed that microbial biomass carbon (MBC) 60% and microbial biomass phosphorous (MBP)38% was relatively higher in sugarcane derived biochar (SCB) applied at 10 t ha^{-1} than untreated soil, while microbial biomass nitrogen (MBN) was not changed significantly throughout all growth periods. Activity of urease (13%), and dehydrogenase (30%) were also high in SCB @10 t ha^{-1}. This study leads toward better understandings, to evaluate the use of various biochars for soil management and to study the microbial and enzymatic activities in the rain-fed region.

Keywords: Biochar, dehydrogenase, microbial biomass, microorganism.

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1. Introduction

Climate change is directly affecting the soil fertility (Clair and Lynch, 2010). The waning food reserves are due to soil infertility and degradation (Brevik, 2013). The increasing population and decreasing food resources are the main problems of the modern world. The biochar was brought forward to sustainably amend the nutrient limiting soils (Ahmad et al., 2016; Chan and Xu 2009; Lehmann and Joseph 2009; Woolf et al., 2010). The biochar is very effective in increasing the sorption capacity and reducing the nutrients leaching (Doan et al., 2015; Paustian et al. 2016; Rasul et al., 2016). Other advantages of biochar application include; decreased runoff and slowed the nutrients release to the growing plant (Laird 2008; Jeffery et al., 2011; Sohi et al., 2010a). The chemical composition of biochar depends on different organic waste materials and pyrolysis conditions used to prepare (Lehmann et al., 2011; Rasul et al., 2017). Biochar addition increase soil microbial biomass (Liang et al., 2010). It is generally discussed that the majority of the carbon in biochar is not available to microbes; it is also clear that biomass derived charcoal increase microbial soil biomass, activity and growth (Steiner et al., 2008). At low temperatures biochar incomplete burning of biomass through which microorganisms take bio-available carbon. Partial burning of biomass also induces immobilization in soil nitrogen which is used by soil (Brewer et al., 2009; Laird et al., 2009).

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Productivity and quality of low fertile soils is improved due to biochar application because it has excellent capability to bind nutrients and heavy metal ions (Atkinson et al., 2010). Different kinds of organic waste materials like sugarcane, wheat straw, vegetable waste, rice husk, farm yard and poultry manure and sewage sludge can be used to prepare biochar under limited oxygen environment, which affect their nutrient contents (Chan et al., 2008). At the initial stage of pyrolysis H and O ions are lost which result in greater amount of the mineral content. Moreover, crop production and soil microbial population can be improved by the application of biochar in soil (Grossman et al., 2010; Jin, 2010; Laird et al., 2009; Steiner et al., 2004). As biochar bring basic cations in soil and have liming prospective on acidic soils; management of agricultural soils becomes very easy with the application of biochar (Laird et al., 2010; Sohi et al., 2010b; Van Zwieten et al., 2010).

For various life processes enzymes act as important activators, therefore, enzymes play significant role in maintenance of soil environment and health (Bandick and Dick, 1999). In the soil enzymatic activity is primarily of microbial origin, these enzymes can be cell-associated, intracellular, or free enzymes. A delicate balance of biological, chemical and physical components of soil helps in soil health maintenance (Igalavithana et al., 2017). Therefore, evaluation of soil health involves contribution of all these constituents. Integrity of terrestrial ecosystems against various is abnormalities i.e., drought, heatwave, insect pest infestation, changing climatic conditions, pollution etc is mainly based on healthy soils (Ellert et al., 1997).

Very little information is available in literature about impacts of application of various types of on soil enzymatic activities and microbial biomass under rain-fed conditions. Therefore, current study was conducted to prepare biochar from wheat straw and sugarcane and quantify their effect on soil microbial biomass and enzymatic activity in rain-fed soil.

2. Materials and Methods

2.1 Biochar preparation and its characteristics

Sugarcane and wheat straw was collected from the local framers and then they were converted into biochar with the use of conventional biochar production tank. Wheat straw and sugarcane were used to prepare biochar in biochar production tank at 350 °C (slow pyrolysis). The biochar of wheat straw (WSB) and sugarcane bagasse (SCB) were ground in a stainless steel mill to 2 mm and showed the following characteristics respectively: pH of 8.8 & 7.66, EC of 1.78 & 1.69 dS m^{-1} (1:10 BC/water), 560 & 645 g kg^{-1} total organic carbon, 2.6 & 2.43 g kg^{-1} phosphorous, 13.8 & 9.27 g kg^{-1} total N, 30 & 33 g kg^{-1} potassium, 47 & 84 µg g^{-1} zinc, 47 & 84 µg g^{-1} iron, 106 & 77 µg g^{-1} manganese and cupper of 13 & 11 µg g^{-1}.

2.2 Soil properties and experimental design

A field experiment was conducted in the year 2014 on sandy clay loam soil having (56% sand, 22.8% silt and 21.1% clay), pH of 7.78 (1: 2.5 soil/water), electrical conductivity (EC) of 0.27 dSm^{-1} (1:5 soil/water), 3.37 gkg^{-1} total organic C (C_{org}), 1.3 gkg^{-1} total N, and 13.5 $mgkg^{-1}$ Olsen P was conducted during the agronomic year 2014.

The average temperature was 24°C±2 (Mean of 3 months) whereas the total rainfall for the study duration was 853 mm. Two different biochar (WSB and SCB) with two different application rate (5 and 10 t ha^{-1}) along with control, were assigned to experimental plots using randomized complete block design. The separation distance between the plots was kept 2 m to avoid the overlapping effect. Biochar was manually incorporated at the depth of 20 cm in each treatment.

2.3 Soil sampling

Soil samples were taken randomly at 3 times (0, 60 and 120 days after biochar application) at depth of 20 cm from each plot and were combined to obtain representative sample /plot. Each sample was divided into two fractions: one was sieved to 2 mm and stored without drying at 4 ^{0}C for measurement of microbial activities and total organic carbon; the other fraction was air dried and sieved (2 mm) for physiochemical analysis.

2.4 Analytical methods

Soil samples were analyzed for pH, EC, total organic carbon (TOC). For soil texture, 40 g of soil was taken in plastic-beaker then suspension was made by adding 40 ml solution of 1% sodium hexameta-phosphate along with 150 ml di water in the beaker and left overnight. After shaking the suspension for 10 minutes it was shifted to a graduated cylinder and values were recorded using boyoucos hydrometer method. ISSS triangle was used to determined soil texture (Gee and Bauder, 1986).

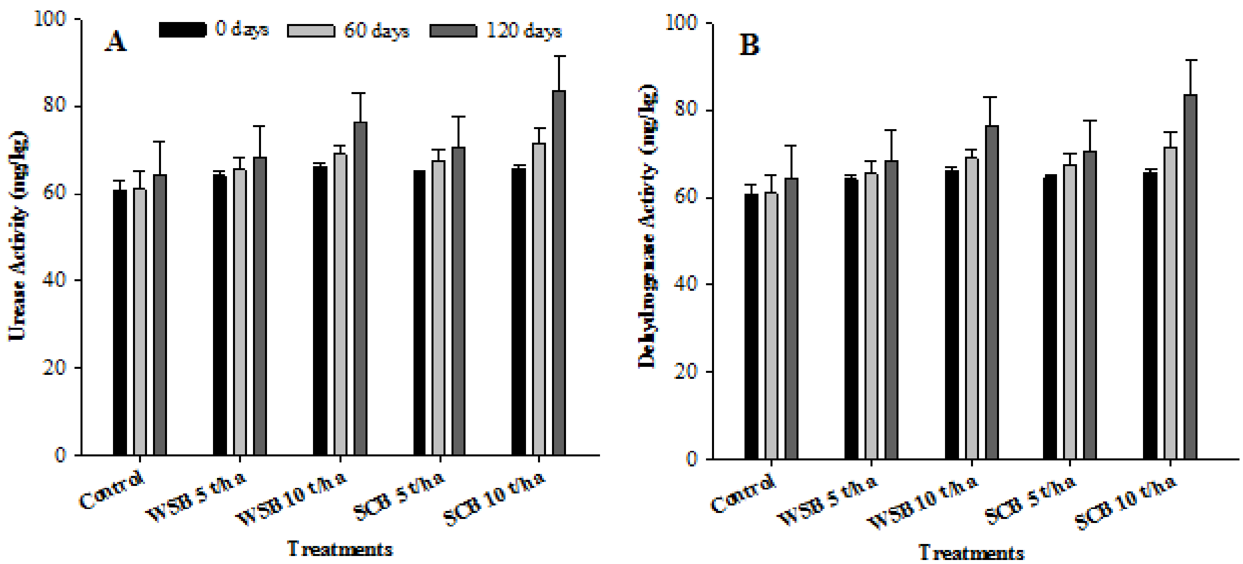

Fig. 1 Temporal changes in soil enzymes (A) Urease, (B) Dehydrogenase in response to application of different rates of wheat straw (WSB) and sugarcane (SCB) biochars.

2.4.1 Soil microbial biomass analysis

Fumigation extraction method was used to estimate soil microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) (Vance et al, 1987; Brooks et al, 1985).

Microbial biomass C (MBC) [1] and Microbial biomass N (MBN) [2] were calculated by using following formulas:

$$MBC = (C_{fumigated} - C_{unfumigated}) \times 2.64 \quad [1]$$

$$MBN = (N_{fumigated} - N_{unfumigated}) \quad [2]$$

2.4.2Soil enzymes analysis

For enzyme analysis Elvazi and Tabatabai, (1977) method was used. Briefly, for soil urease activity analysis; 2.5mL of urea solution was added into 5g of moist soil. Then 50mL of KCl solution was added. The soil solution was shake-incubated at 180 rpm for 30 min. After shaking, it was shifted into an incubator at 37 ^{o}C for 2 hours. Sodium salicylate / NaOH (5 ml) was added into 1:9 clear filtrate and ddH$_2$O solution. Then 2 mL di chlorosis cyanide solution was added and left at room temperature for cooling. After cooling, the optical density at 690 nm was measured (Kandeler and Gerber, 1988). Kapoor and Paroda, (2007) protocol was used to calculate the soil dehydrogenase activity.

2.5 Statistical analysis

Data were analyzed using the procedure analysis of variance (ANOVA) in the SAS software (version 9.1, SAS Institute Inc. Cary, NC, USA). Treatment means were compared using Fisher's protected least significant difference (LSD) test at $P < 0.05$ probability level.

3. Results and Discussion

Urease activity of soil at 60 and 120 days after SCB application (10 t ha^{-1}) was highest (7.9 and 12.7 %) in SCB treatment at 10 t ha^{-1} than control (Fig. 1). The possible increase in urease activity due to biochar addition is might be due to high organic matter contents of biochar. Our results support findings of Lee et al. (2011), they applied various rates of biochar (0, 1, 3, 5 10, 20 and 30 % of soil) and reported that application of 30% biochar produced maximum activity of urease (13.17 fold) as compared to control. Similarly according to Wu et al. (2012) in a 100 day laboratory incubation experiment using wheat straw biochar activity of urease was higher than its straw. At all the two stages (60 and 120 days) SCB 10 t ha^{-1} showed better results than other treatments which were 21, 27 and 34 % higher than control respectively.

At 60 and 120 days highest dehydrogenase activity (17.4 and 30 %) was recorded in SCB at 10 t ha^{-1} than control respectively (Fig. 1). The possible increase in dehydrogenase activity is might be due to increase in organic matter contents. Our results of dehydrogenase activity was in line with Paz-Ferreiro et al. (2011), according to them two different doses of biochar produced from sewage sludge and paralyzed sewage sludge increase the average of soil dehydrogenase activity with high biochar dose and decrease due to high sewage sludge dose. Similarly Marx et al. (2001) explains that biochar addition improved dehydrogenase activity of soil.

Highest microbial biomass carbon (MBC) at 60-120 days was recorded in SCB at 10 t ha^{-1} which was34.28 % and 86.28 % higher than Control. Similarly MBC was 46.3, 69.57 and 47.38 % high in treatment WSB (5 and 10 t ha^{-1}) and SCB 5 t ha^{-1} respectively as compared to control (Fig. 2). Increased MBC can be attributed to high carbon content of biochar leading to higher organic carbon in soil.

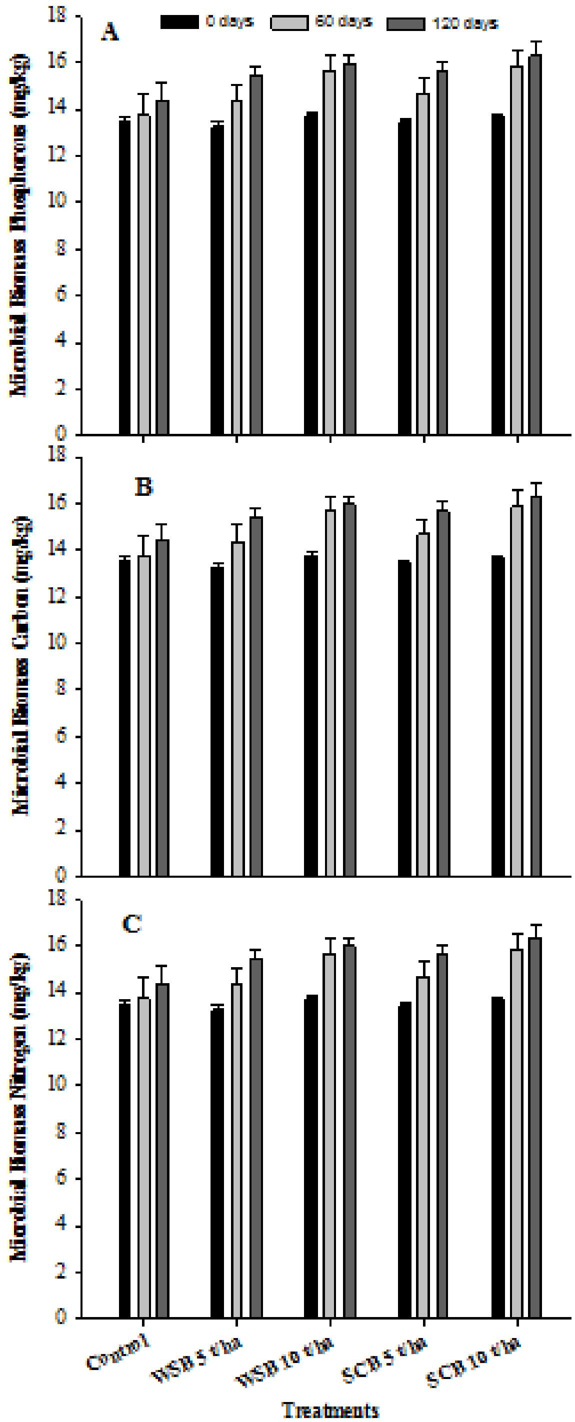

Fig. 2. Temporal changes in (A) phosphorous (B) carbon (C) nitrogen contents of microbial biomass in response to application of different rates of wheat straw (WSB) and sugarcane (SCB) biochars.

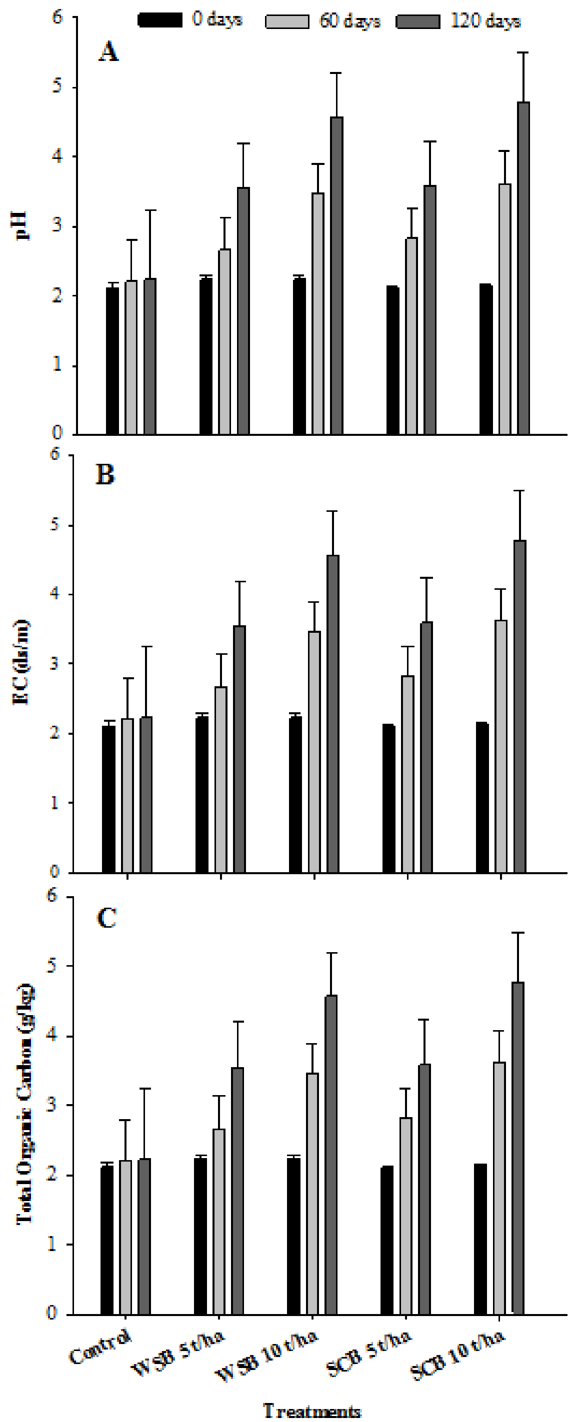

Fig. 3. Temporal changes in soil (A) pH (B) electric conductivity (C) total organic carbon in response to application of different rates of wheat straw (WSB) and sugarcane (SCB) biochars.

Results presented here are in agreement with the findings of Prabha et al. (2013), who examined the biochar on rice in pot experiment and reported that MBC for treatment in which 35 g biochar was used showed batter results. While, microbial biomass phosphorous (MBP) was higher in SCB applied at 10 t ha^{-1} at 60-120 days which was 48.5 and 38.39% higher than control (Fig. 2). Higher microbial population observed in our experiment lead to increased MBP. Large surface area of biochar can provide optimum growing conditions for microbes and subsequently increased microbial population and ultimately higher MBP. The results were in line with Pietikhain et al. (2000), who reported that biochar act as potential habitat for certain soil microbes involved in the transformation of nutrients including N, P and S.

However, significant difference was not observed for microbial biomass nitrogen (MBN) in both types of biochars (Fig. 2). This is might be due to sorption of inorganic nitrogen with biochar. According to Rondon et al. (2007) incorporation of biochar in common beans (*Phaseolus vulgaris*) cause enhancement in biological nitrogen fixation (BNF). They noticed that there was 50 % increase in fixed nitrogen when no biochar was incorporated while it was increased up to 73% when 92 g biochar is incorporated. However, Zavalloni et al. (2011) obtained biochar from hardwood and applied it in field and noticed that there was no influence of biochar on MBN. Dempster et al. (2011) while applying *Eucalyptus marginata* biochar at the rate 0, 5, and 25 t ha^{-1} in soil and noticed that the MBN was remain unchanged.

Maximum EC 0.72 d Sm^{-1} was observed in soil treated with SCB at 10 t ha^{-1} in harvesting stage (120 days), followed by 0.66 dSm^{-1} in the soil treated with WSB at 10 t ha^{-1} in harvesting stage (Fig. 3). This shows that Soil EC was positively correlated with biochar application rate. Observed higher soil EC was due to biochar application generally attributed to ash accumulation. Ash residues are rich in carbonates of alkali and alkaline earth metals, heavy metals, phosphates, sesquioxides, silica and traces of inorganic and organic nitrogen (Raison, 1979). Sugarcane biochar (SCB) at 10 t ha^{-1} showed 63 and 75% higher TOC at 60 and 120 (tasseling and harvesting stages) days as compared to control (Fig. 3). Van Zwieten et al. (2009) and Zhang et al. (2012) reported that, when biochar is prepared from different materials (wheat, farm yard manure etc), the average C concentration in biochar is increased up to 47.6 %. On the other hand, Gaskin et al. (2010) showed that carbon concentration in biochar produced from poultry manure and pine chips increase up to the range of 78%.

4. Conclusion

In conclusion, soil microbial biomass and enzyme activity was positively correlated with biochar application rate. Furthermore SCB biochar at higher rate was proved to be more effective than wheat straw biochar. The information originated from this study is very helpful in evaluating the use of waste products like sugarcane and wheat straw derived biochars for soil and crop management in the rain-fed region. The further investigations need experiments on varieties of biochar sources and vide range of their application rates under different climatic conditions.

Author Contribution: SM, MA, and QH: initiated and designed the research; SM, SB, and MR: performed the experiments; SM, DAS, QS: analyzed the data; SM, SA, MA: wrote the manuscript; MI and QS: assisted with manuscript preparation. All the authors discussed the results and commented on the manuscript.

Conflict of Interest: The authors declare that they have no conflict of interest.

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