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Influence of Biochar on Soil Quality and Yield Related Attributes of Wheat (*Triticum aestivum L.*)

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Abstract: Wheat is the main staple diet especially for human in the rural areas of Pakistan. Low grain yield of wheat grain is due to poor fertilization of nutrients in the soil. For this, a study was conducted at Soil and Water Testing Laboratory for Research, Multan, Pakistan to determine the importance of application of biochar in controlled environmental conditions for wheat productivity. The yield of wheat crop improved through application of biochar and various combinations of inorganic fertilizers. Moreover, biochar and supplementation of recommended doses of macro and micronutrients not only enhanced the yield significantly, but also improved the soil characteristics and amid them, improved organic carbon levels and improved soil water holding abilities. This study is a paradox for the scientific community as a base for recommending the use of biochar on large scale spectrum as policy matter and as a novel approach to improve wheat production and soil properties.

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1. Introduction

Multan belongs to arid ecological zone of Pakistan having high temperature and windstorms in summer. This high temperature causes fast decomposition of organic matter in the soil and thus percentage of organic matter is very low in Multan. Due to this reason, chemical and physical characteristics of the soils remain problematic and put an adverse impact on the yields, thus total production is far behind the potential of the soil (GOP, 2014).

Wheat (*Triticum aestivum* L.) is the staple diet in Pakistan. It is the most important crop and cultivated on the largest acreage in almost every part of the country. It contributes 10.3% to the value added in agriculture and 2.2% to GDP. Its productivity has been increased in all major cropping system representing the diverse and varying agro-ecological conditions (GOP, 2014).

Biochar is a carbon rich product created when any biomass is heated to temperature greater than 250^{o}C in low or absence of oxygen (Antal and Gronli, 2003). During the conversion volatile compounds are released. These compounds can be combusted to produce energy as well. Biochar is also very stable in soils. It can remain in soil for many thousands of years. Biochar is also very important for providing a method of carbon sequestration. The narrow (Carbon:Nitrogen) C:N ratio through biochar is assimilated by living entities such as plants for the sustainability of production function to serve the humanity. The hypothesis of this study was that applications of biochar could impact different physico-chemical properties of the soil and that yield of wheat could be improved when grown under the existing environmental conditions (Ascough et al., 2009).

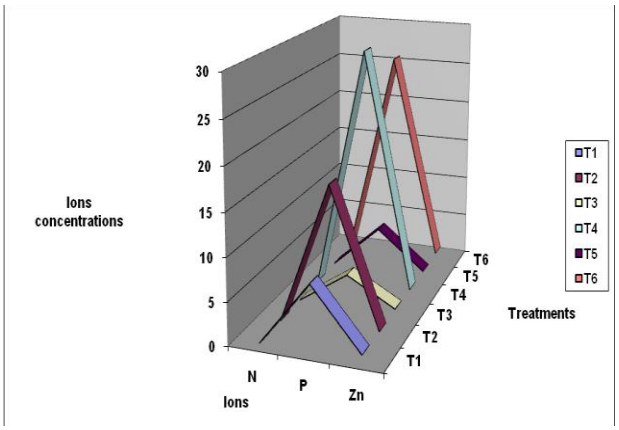
Being organic in nature, biochar puts a good impact on soil physical and chemical characteristics such as pH, CEC (cation exchange capacity), porosity, bulk density and water holding capacity, which significantly affect crop growth. Agronomic parameters (grain yield, number of nodes, number of tillers, number of flag leaves and macro and micronutrients in plant shoot), soil physical and chemical properties (water holding capacity, available N, P and K; micronutrients i.e. B, Mo, Zn, Mn, Fe etc) were significantly improved with increasing biochar application in combination with commercial fertilizers (Uzoma et al., 2011). Keeping in view the

above discussion, this study was planned to find out biochar impact soil quality as well as on yield parameters of wheat.

2. Materials and Methods

A pot experiment was conducted at the Soil and Water Testing Laboratory for Research, Multan, Pakistan during 2013. The treatments included different levels of biochar with NPK and micronutrients before sowing the crop i.e. T_1: Control, T_2: NPK + micronutrients (as recommended), T_3: NPK + Biochar (1%), T_4: NPK + micronutrients (as recommended) + Biochar(1%), T_5: NPK + Biochar (2%) and T_6: NPK + micronutrients (as recommended) + Biochar (2%). The layout of the experiment was CRD (complete randomized design) with six treatments and four replications. The recommended doses of NPK @ 103:84:62 kg ha^{-1} was applied in the form of urea, diammonium phosphate and potassium sulphate respectively. Micronutrients (B, Mn, Zn and Cu @ 1.5:5:5:5 kg ha^{-1}) were applied in liquid form in the form of H_3BO_3, $MnSO_4$, $ZnSO_4$ and $CuSO_4$ respectively.

Soil samples were analyzed for pH by pH meter (McLean 1982); electrical conductivity of soil extract by Rhoades (1982); soil organic matter (OM) by Walkey and Black (1934) method; total nitrogen by Bremer and Mulvancy (1982); available phosphorus by Olsen and Sommers (1982) and available potassium by Richards (1954). Data on spike length, number of nodes, leaves; tiller and fertile tiller, total dry matter yield production (at15% moisture) were collected after harvesting of crop.



Fig, 1. Impact of biochar and micronutrient treatments on nitrogen, phosphorous and zinc contents of soil.

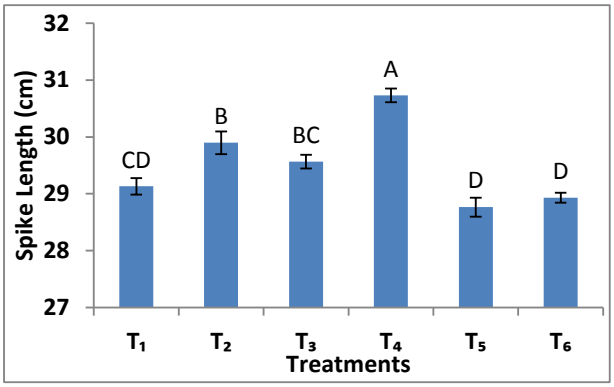


Fig. 2. Impact of biochar and micronutrients on spike length (cm) of wheat.

Treatment were ranked by Least Significant Difference (LSD) test at $P \leq 0.05$ (Steel et al., 1997). Various statistical computations were run on Statistix 9 for Windows (Analytical Software, Tallahassee, USA).

3. Results

The chemical analysis of soil showed that pH of the soil was a little basic but lectrical conductivity ranged from 2.0 to 3.6 dSm^{-1}. T_5 treated soil had high percentage of organic matter (Table 1). Similarly ion concentration in soil is presented in Fig. 1. The biochar and micronutrient application had significant effect on spike length of wheat. More spike length was observed at T_4 treatment and least one was observed at T_5 treatment. Whereas at T_2, T_3 and T_1 minor differences in spike length were present (Fig. 2). It was observed that number of nodes per pot were the highest in the treatment 4, which had 1% biochar applied along with recommended doses of NPK and micronutrients (Fig.3). This treatments had a significant improvement in number of nodes per pot over control.

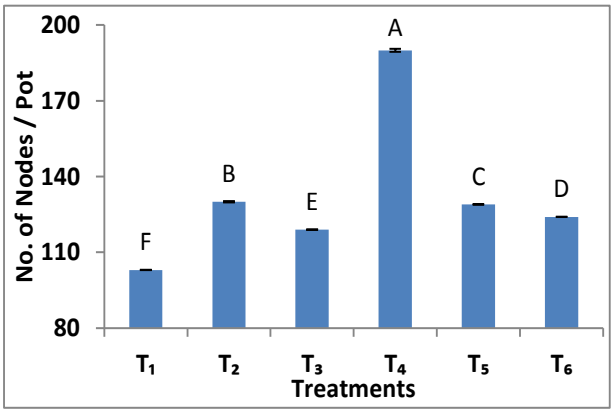


Fig. 3. Impact of biochar and micronutrients on nodes per pot in wheat

Table 1: Impact of Bichar and Micronutrient Treatments on pH, ECe and Organic Matter Percentage of Soil

Treatments	pH	ECe (dSm^{-1})	O.M (%)
1-Control	8.1	3.0	0.66
2-NPK + Micronutrient (Recommended)	8.1	2.0	0.62
3-NPK + Biochar (1%)	8.2	2.4	0.78
4-NPK + Micronutrient (Recommended) + Biochar (1%)	8.2	2.4	1.11
5-NPK + Biochar (2%)	8.2	2.5	1.25
6-NPK + Micronutrient (Recommended) + Biochar (2%)	8.1	3.6	1.11

While considering number of leaves, it was observed that 1% biochar (T4) along with all necessary macro and micronutrients had a significant increase in number of leaves over control but showed non significance among other treatments of biochar application (Fig. 4). It is also evident from the data that biochar at 2% alongwith all the macro and micronutrients had the lowest yield except control.

As far as tillering is concerned, biochar application had a significant impact over other treatments when used in combination with macro and micronutrients. The highest tiller number was observed on T6, 2% biochar application (Fig. 5).

Highest tillering being a result of biochar application was the trend that was followed for the attribute of fertile tillers. It was observed that application of nutrients had no impact as number of fertile tillers was the same in treatment 5 & 6, i.e., T5= 2% Biochar without micronutrients and T6= 2% Biochar with recommended doses of micronutrients (Fig. 6). A significant impact of micronutrients application was found among 1% biochar application treatments, where micronutrients application raised the yield of fertile tillers considerably over non application of micronutrients.

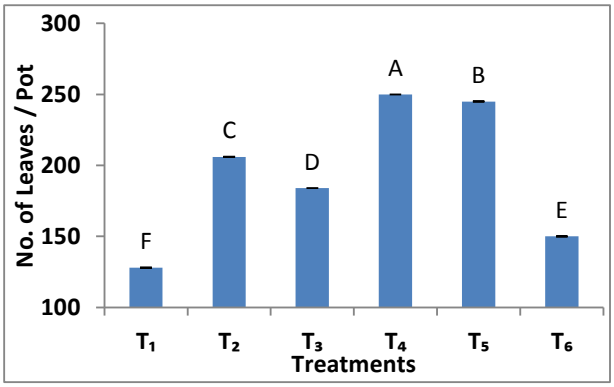


Fig. 4. Impact of biochar and micronutrients on number of leaves in wheat.

The highest grain yield was achieved with T4, a treatment with 1% biochar, applied with recommended doses of macro and micronutrients. This treatment had a significant difference over control and no biochar application treatment, while remained insignificant with 2% biochar application treatment (Figure 7).

4. Discusion

Biochar application resulted in an improvement in the number of nodes per plant. Treatment 4, with 1% biochar with recommended dose of micronutrients proved the best regarding this attribute. This treatment had significant increase over control, but non-significant as compared to other biochar treatments. Villar et al. (2013) also found similar results when they applied biochar alone and in combination with mineral nutrition. Similar trends are seen in number of leaves.

Biochar at 1% with mineral nutrition had the best results, but these had been non-significant with 2% biochar application with micronutrient application. It is quite clear that biochar application had a positive effect on this attribute when comparing with control and micronutrient treatment without bio char. These results were similar to those of Arif et al. (2012).

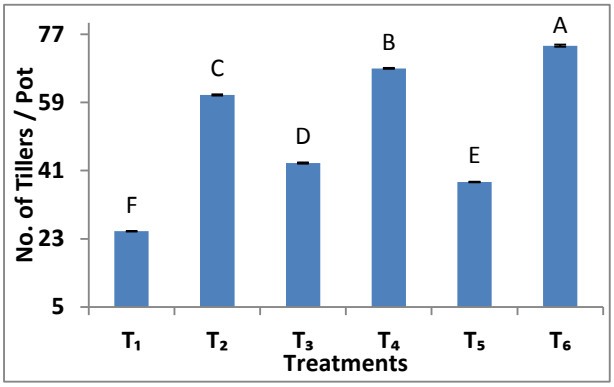


Fig. 5. Impact of biochar and micronutrients on no. of total tillers per pot in wheat.

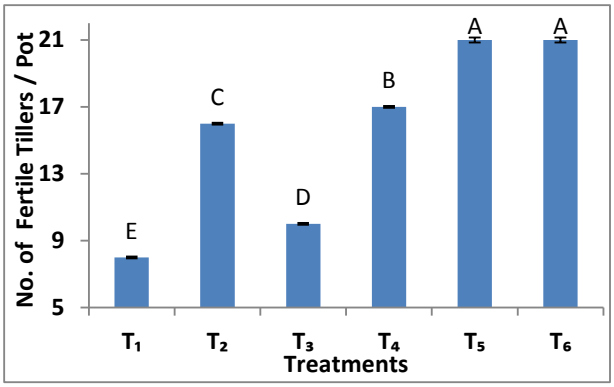


Fig. 6. Impact of biochar and micronutrients on fertile tillers per pot in wheat

Tillers and fertile tillers contribute directly to the yield of crop. Biochar application, irrespective of application rate, had a positive impact on it. It is probably due to land reclamation properties of biochar, which increases fertility and nutrient use efficiency (Negussie et al., 2012). The clearest impact of biochar was seen on yield of the crop. Biochar application had resulted in a significant increase over control and T_2. Wang et al. (2012) and Zhang et al. (2012) also found in their studies that an enhanced application of bio char enhanced the yield of cereals. They concluded that this may be due to improvement in texture and structure of the soil caused by rich in C and N organic source. Biochar improves soil physical properties, such as porosity, bulk density and water holding capacity.

There was positive effect of biochar application on yield and agronomic yield attributes of wheat. They found that biochar was more efficient when supplemented with recommended dose of chemical fertilizer and micronutrients. These results confirmed the results of this study, which reveals that biochar yields highest impact when used along with recommended dose of N, P, K and micronutrients (Arif et al., 2012).

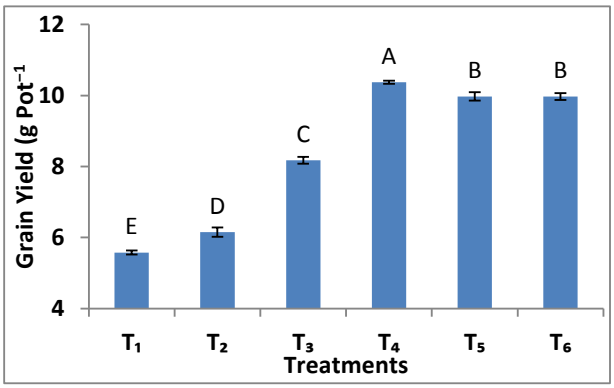


Fig. 7. Impact of biochar and micronutrients (x-axis) on yield (g pot^{-1}) of wheat

On the other hand Cornellisen et al (2013) found biochar to be effective on increasing yield and other yield attributes. Unger (2008) also found the results that biochar alone had no significant effect on yield, but when it was supplemented with N-Source fertilizers, it responded significantly. Our results are partially in contrast to this study where biochar application raised the yield, and partially in accordance to it as fertilizer supplement in this experiment raised the yield of crop significantly.

5. Conclusion

The yield of wheat crop improved through application of biochar and various combinations of inorganic fertilizers. Moreover, biochar and supplementation of recommended doses of macro and micronutrients not only enhanced the yield significantly, but also improved the soil characteristics. This study is a base for recommending the use of biochar on large scale spectrum as policy matter and as a novel approach to improve wheat production and soil properties.

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Competing Interests: The authors declare that there is no potential conflict of interest.

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