Pak. J. Bot., 51(4): 1255-1261, 2019. DOI: http://dx.doi.org/10.30848/PJB2019-4(7)

BIOCHAR: AN ECO-FRIENDLY APPROACH TO IMPROVE WHEAT YIELD AND ASSOCIATED SOIL PROPERTIES ON SUSTAINABLE BASIS

KAWSAR ALI[1*], XUECHUN WANG[2], MUHAMMAD RIAZ[3], BADSHA ISLAM[1], ZAFAR HAYAT KHAN[1], FAROOQ SHAH[1], FAZAL MUNSIF[4] AND SYED IJAZ UL HAQ[1]

[1]*Agriculture Department, Abdul Wali Khan University Mardan*
[2]*School of life science and technology, South West University of Science and Technology, Sichuan (621010), China*
[3]*Department of Environmental Sciences & Engineering, Govt. College University Faisalabad, Pakistan*
[4]*Agronomy Department, the University of Agriculture, Peshawar*
[*]*Corresponding author's email: kawsar@awkum.edu.pk*

Abstract

Despite making great progress in agriculture since after green revolution, Pakistan still needs to increase agricultural production to feed its growing population with its increasing expectations while overcoming the considerable environmental and soil related problems that industrial and agricultural development has brought with it such as air and water pollution and soil acidification. Incorporation of biochar in agriculture field has the potential to be a major factor in maintaining soil fertility and productivity. The present experiments were designed to evaluate the effect of varied organic (biochar and FYM) and inorganic amendments (nitrogen, urea) on the growth and yield of wheat and associated soil properties. Incorporation of biochar in agriculture field has the potential to be a major factor in maintaining soil fertility and productivity. The experiments consisted of three factors namely: (1) Biochar (0, 25 and 50 ton ha^{-1}), (2) FYM (5 and 10 ton ha^{-1}) and (3) nitrogen (60 and 120 kg ha^{-1}). A controlled treatment was included in the experiments. All the treatments were replicated three times in RCB design at New Developmental Farm of the University of Agriculture Peshawar Pakistan during winter 2012-13 and 2013-14. It was found that the use of BC increased wheat grain yield and biological yield by 23% and 17% respectively over non BC plots, while 49% and 31% increase in wheat leaf chlorophyll content and relative water content was measured as a result of BC application in integration with 60 kg N ha^{-1} as compared to control and sole application of biochar at the rate of 25 ton ha^{-1}. Moreover, application of FYM resulted 16% and 33% increase in wheat grain yield and biological yield over control. Likewise, wheat relative water content, leaf chlorophyll content, thousand grain weight , soil N and soil P content was increase by 17%, 11%, 15%, 8%, 13 and 24% as a result of 10 ton FYM ha^{-1} over 5 ton FYM ha^{-1}. Similarly, N application at the rate of 120 ton ha^{-1} improved wheat yield and yield components over control. Soil total N was increased by 8% and 4% over controlled by use of N at the rate of 60 and 120 kg ha^{-1} in combination with 25 ton BC ha^{-1} respectively. On the whole, the use of biochar in cereal crop production had shown positive effects on crop growth, yield and soil properties. However, more research is needed to evaluate the effect of lower biochar application rate on soil and crop performance.

Key words: Wheat, Biochar, FYM, Leaf chlorophyll content and grain yield.

Introduction

Agriculture is one of the most important sectors in Pakistan acting as the back bone of its economy (c. 21% of GDP and 43% of labor force) (Pak-EPA, 2005). It provides food, feed, fibers, fuel and shelter. It supplies raw materials to many of the largest industries of Pakistan, in particular textile and food processing (Ali *et al*., 2015). Major crops include cotton, rice, wheat, maize and sugarcane. Although wheat is the most important food crops after rice, however the average yield is very low below the potential yield of about (Arif *et al*., 2012; Ali *et al*., 2011). One of the reason for this low yield because mostly maize is planted on upland soil with low soil fertility status due to low soil organic matter content. As a consequence of this low soil organic matter, the soil usually has a low nitrogen and phosphor content (Ali *et al*., 2012; Patrick *et al*., 2013). The common treatment to increase the fertility and productivity of these soils is to increase soil organic matter by adding organic manure, such as compost or farm yard manure. However, it is now understood that this practice possess some limitations, one of them is that under wet tropical condition, these organic manure are undergo a rapid decomposition so that the organic manure should be added every year (Brunn *et al*., 2010). Rapid decomposition of organic manure has also attributed as one as the major contributor of global warming gas (Ciais *et al*., 2013). To overcome this problems, some workers, e.g. Lehman *et al*., (2013) suggested to use the more recalcitrance organic matter resources such as Biochar. Also the rapid increase in the human population has created pressure on food, water and energy supplies. Challenges in the agricultural sector are multifold and widespread, including low per hectare yield, low soil organic matter resulting in reduced soil fertility, salinity, lack of irrigation facilities, and inadequate supply of agricultural inputs, plant diseases, natural calamities and the endurance of old (less productive) methods of production. These challenges can be overcome by, amongst other approaches, adopting better soil nutrient management, conservation agriculture, use of remote sensing and other information technology in agriculture, soil erosion management and climate smart irrigation. Soil fertility related to application of organic soil amendments is the main focus of this paper, with a particular focus on biochar. Biochar is a black-carbon solid produced by the pyrolysis of organic materials (Lehmann *et al*., 2006) that is often distinguished from charcoal by its intended use as a specific soil amendment (Sohi *et al*., 2009). Due to severe climatic conditions of Pakistan, N fertilizer application to agricultural soils is not as productive as in more temperate climatic zones. After nitrogenous fertilizer application, a major portion of N is lost due to ammonia volatilization, denitrification and nitrate leaching. The efficiency of urea application (the most commonly applied N fertilizer in Pakistan) is just 30-50% (Ladha *et al*., 2005), due to its losses during and after soil application. Biochar application to these soils may help to combat this problem directly by nutrient addition or indirectly by improving soil CEC (more ammonium adsorption on biochar surfaces), N fixing microbial activity (itself a source of some elements essentially required by the N-fixing microbes) and by improving soil water holding capacity. One of the reasons for increasing crop yield with biochar application is the increasing of nitrogen utilization from the applied fertilizer (Steiner *et al*., 2007; Widowati *et al*., 2011). This is as the result from the decrease of nitrogen lost due the increase of soil CEC with biochar application (Chan *et al*., 2008) or because of the biochar ability to inhibit N-NO3 transformation from N-NH4 released by fertilizer (Widowati *et al*., 2011). The experiment reported here is aimed to know the possibility of decreasing nitrogen fertilizer requirement of maize with biochar application. The hypothesis behind this study is "if there is decrease in nitrogen loss due biochar application, then there is less nitrogen requirement to produce the same yield with that of obtained by the soil with no biochar application".

Material and Methods

Field experiments for two growing seasons and laboratory experiment were conducted to evaluate the individual and combined effect of biochar, FYM and N on wheat yield and associated soil properties. These experiments have been hypothesized on the following premise: (1), the use of biochar could be proved to be a useful tool in precipitating maximum crop productivity and soil fertility, (2), wheat production and soil properties are not affected by the use of biochar. In this experiment two layers of FYM and nitrogen were applied to make certain the judicious readiness of all vital nutrients and mineralization of applied biochar in conjunction with soil microbes.

Site description, experimental design and treatment combination for the field experiments: The experimental site is located at the New Developmental Farms of the Khyber Pakhtunkhwa University of Agriculture, Peshawar (34°1'21"N, 71°28'5"E) and the experiments have been conducted during the winter of 2013 and 2014. The climate of the experimental site is hot, semi-arid, sub-tropical and continental with an average annual rainfall of 360 milli metres. The average maximum temperature in the summer (from May to September) is 40°C and the average minimum temperature is 25°C. The average minimum temperature in the winter (from December to March) is 4°C and the maximum average temperature is 18.4°C. Normally, average rainfall is higher in the winter than in the summer. Maximum winter rainfall is recorded in the month of March, whereas the maximum summer rainfall is in the month of August. Before the conduction of field experiments soil was taken from the upper layer (0-15 cm depth) and soon after collection, the soil was instantly shifted to the laboratory in gas porous containers where it was filtered with the help of a sieve to pass 2 mm in order to eliminate stones, sand particles, plant roots and earthworms.

Field experiments were based on three levels of biochar (0, 25 and 50 t ha^{-1}), two levels of FYM (5 and 10 t ha^{-1}) and two levels of fertilizer-N (urea) (60 and 120 kg ha^{-1}) coupled with control treatment (zero biochar, FYM or fertilizer-N). Biochar and FYM were applied at the time of sowing. Biochar was applied in the first season of the experiment and later on its residual effect was studied. Half of the fertilizer-N (60 kg ha^{-1}) was applied at the time of sowing and the remaining half at the tillering stage. Single super phosphate (SSP) was used and source of P fertilizers and was utilized at the rate of 90 kg ha^{-1} as a basal dose at the time of sowing. Chemical/nutritional properties of biochar and FYM are given in 2. Randomize complete block design was used for the experiment with total 13 treatments and each treatment was replicated three time. The size of the experimental unit was 4.0 m x 4.5 m with durable and robust ridges placed around each plot for delineation and to preclude biochar's and FYM movement.

Field was ploughed twice to a depth of 30 cm with the help of cultivator and was followed by planking in order to level the field. Wheat (*Triticum Asitivum* L. cv. Siran-2010) was sown at the rate of 100 kg ha^{-1} on November 5th, 2012 and 7th November 2013. Irrigation schedule as locally recommended were followed with changes consistent with the existing weather condition on need basis. Weeds were rooted out and controlled manually with the help of a hoe.

Data collection and measurements: Grains spike^{-1} was noted by taking five randomly selected spikes in each experimental unit and average was recorded. Five central rows were harvested and dried for biological yield of wheat in each subplot. The harvested bundles were then weighed and converted to kg ha^{-1}. Grain yield was recorded by threshing five central rows in each experimental unit and the obtained grains were weighed and converted to kg ha^{-1}. Leaf chlorophyll content was measured weekly using aSPAD chlorophyll meter (SPAD-502Plus; Konica Minolta, Chiyoda, Tokyo, Japan). Relative water content was calculated by the following formula:

$$RWC = \frac{(TFW - BW) - DW}{TW - DW} \times 100$$

Statistical analysis: After the harvesting of wheat crop and amino acid mineralisation the data collected were statistically analyzed using the procedure appropriate for CR design suing Excel software. Standard error mean were calculated and Sigma Plot (12.5) were used for creating graphs for comparing mean (Jan *et al*., 2009). For measuring soil respiration repeated measure 2 way ANOVA was used. The SPSS v 20.0 (SPSS Inc., Chicago, IL) was used for calculating repeated measure ANOVA.

Results and Discussion

Number of grains spike^{-1}: The individual and interactive effect of biochar, FYM and nitrogen application rate on wheat number of grains spike^{-1} averaged over 2 growing seasons are shown in figure 1. Biochar, FYM and N application rate significantly affected grains spike^{-1} ($p<0.05$). More grains spike^{-1} were counted in plots treated with 25 t BC ha^{-1}, 10 t FYM and 120 kg N ha^{-1} as compared to no BC, 5 t FYM and 60 kg N ha^{-1} respectively (Fig. 1). Overall, BC application at the rate of 50 t ha^{-1} resulted in higher grains spike^{-1} irrespective of FYM and N application rate (Fig. 1). Though no BC treated plots resulted in fewer grains spike^{-1} relative to BC treated plots, however, the performance of no BC plots were superior to control plots at all level of FYM and N (Fig. 1).

Thousand grain weight (g): The effect of organic and inorganic amendments on thousand grain weight of wheat are shown figure 2 averaged over two field seasons. The effect of BC and FYM was non significant ($p>0.05$) on thousand grain weight while N application rate significantly affected thousand grain weight of wheat. Changing N rate from 60 to 120 kg ha^{-1} resulted 17% increase in thousand grain weight of wheat. Moreover, figure 2 indicated that 25 ton BC resulted in higher grain weight as compared to no BC and 50 t BC application ha^{-1} irrespective of FYM and N application rate. Interestingly, the behavior of BC application was totally changed under different FYM application rate (5 and 10 t ha^{-1}) irrespective of N application rate. At 5 t FYM no significant difference in thousand grain weight was noted between 50 t BC application and no BC treated plots, however under 10 t FYM application the application of BC at the rate of 50 t ha-1 drastically reduced thousand grain weight of wheat regardless of N application rate. Lower grain weight was measured in control plots (Fig. 2).

Wheat grain yield: Wheat grain yield, averaged over two years, as affected by BC, FYM and N application rate are reported in figure 3 (main and combined effect). As expected, the addition of N fertilizer and FYM significantly increased grain yield of wheat ($p<0.001$). Grain yield was also significantly affected by BC application. Application of BC at the rate of 25 t ha^{-1} resulted in higher grain yield followed by 50 t BC application while no BC plots resulted in lower grain yield (Fig. 3). The figure 3 narrated that overall, BC application at the rate of 25 t ha^{-1} increased grain yield regardless of N and FYM rates. The performance of BC at either rate were much superior at 5 t FYM in comparison with 10 FYM irrespective of N application rate (Fig. 3). Moreover, at 5 t FYM application of N at the rate of 120 kg ha^{-1} resulted in higher grain yield as compared to 60 kg N ha^{-1}, however, no dominant changes in N rates were observed when applied at 10 t FYM.

Biological yield: The effect of BC, FYM and N on biological yield of wheat (two years average) are shown in figure 4 (individual and combined effect). Biological yield was significantly affected by biochar and N while the effect of FYM was not significant. Application of BC at the rate of 25 t ha^{-1} and N at the rate of 25 t ha-1 and 120 kg N ha^{-1} resulted in higher biological yield as compared to no BC and 60 kg N ha^{-1} treated plots. The combined effect of all treatments are shown in figure 4. In comparison with no BC treatments, both level of BC (25 and 50 ton ha^{-1}) increased wheat biological yield. Generally, both levels of BC responded differently to FYM application rate (5 and 10 t ha^{-1}) and 25 ton BC performed better than 50 ton BC at 120 kg N ha^{-1} regardless of FYM rates. However, increasing N application rate to 120 kg ha^{-1} both level of BC were statistically at par at 10 t FYM while at 5 t FYM both level were different significantly (Fig. 4). Biochar application at the rate of 25 and 50 ton increased biological yield by 24 and 27% respectively, over zero BC treatment.

Relative water content (%): Relative water content is one of the important physiological property and is directly affected by soil moisture content and nutrients management. The effects of BC, FYM and N on relative water content were shown in in figure 5 (mean + interactive effect). The data bars present averaged of two cropping seasons. Incorporation of FYM and application of N significantly affected wheat relative water content over control ($p<0.05$). Relative water content (RWC) showed increasing trend by increasing BC rate from 0 to 50 t ha^{-1}. Overall, RWC was increased by 27% and 52% in BC treatments over no BC and control treatments respectively. The effect of 50 t BC was much visible than 25 t BC treatments regardless of FYM and N levels (Fig. 5). Overall, application of BC at the rate of 50 t ha^{-1} resulted in higher RWC after wheat harvest regardless of FYM and N application rate. Control plots (all treatments at nil level) resulted in lower RWC (Fig. 5).

Leaf chlorophyll content: The effect of BC, FYM and N on leaf chlorophyll content of wheat (two years average) are shown figure 4. Leaf chlorophyll content was significantly affected by biochar and N while the effect of FYM was not significant. Application of BC at the rate of 25 t ha^{-1} and N at the rate of 120 kg N ha^{-1} resulted in higher leaf chlorophyll content as compared to no BC and 60 kg N ha^{-1} treated plots (Fig. 6). Moreover, the combined effect of all treatments are shown in figure 4. In comparison with no BC treatments, both level of BC (25 and 50 ton ha^{-1}) increased wheat leaf chlorophyll content. Generally, both levels of BC responded differently to FYM application rate (5 and 10 t ha^{-1}) and 25 ton BC performed better than 50 ton BC at 120 kg N ha^{-1} regardless of FYM rates. However, increasing N application rate to 120 kg ha^{-1} both level of BC were statistically at par at 10 t FYM while at 5 t FYM both level were different significantly (Fig. 6). Biochar application at the rate of 25 and 50 ton increased leaf chlorophyll content by 24 and 27% respectively, over zero BC treatment.

Soil total N after wheat harvest: Soil nitrogen content is important macro nutrient that directly affects crop growth and development. Soil N content as affected by BC, FYM and N are reported in figure 7 (main and combined effect). All values are the average of two field seasons. Unexpectedly, the effect of FYM and N on soil total N was non significant ($p>0.05$) while BC significantly affected soil total N content ($p<0.05$). Soil TN increased by increasing BC rate from 0 to 25 t ha-1 and further increasing BC rate to 50 t ha-1 reduced soil TN. Figure 6 illustrated that generally soil TN was higher in all treated plots in relation to control. Overall, application of 25 t BC resulted in higher soil TN irrespective of FYM and N application rate, however, the performance of 25 t BC was much impressive when applied with 10 t FYM than 5 t FYM regardless of N application rate (Fig. 7). In contrast, under 5 t FYM application 50 t BC resulted in at par soil TN with 25 t BC however, 50 t BC adversely reduced soil TN when applied with 10 t FYM at both levels of N.

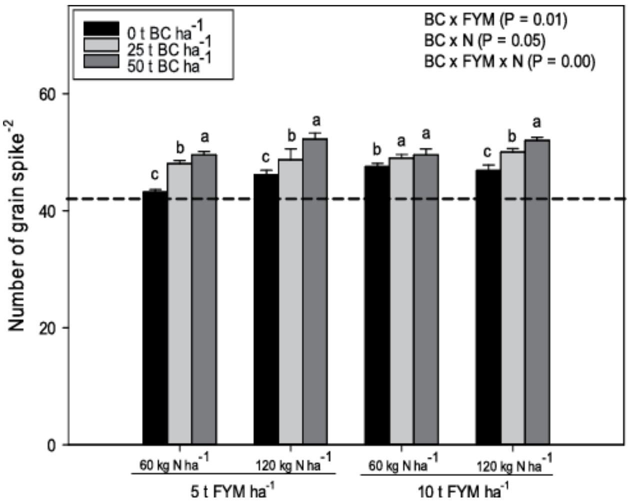

Fig. 1. Wheat number of grain spike^{-1} averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

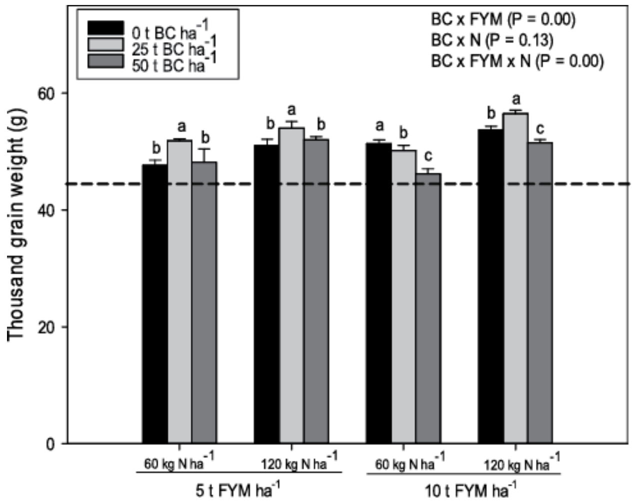

Fig. 2. Wheat thousand grain weight[1] averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

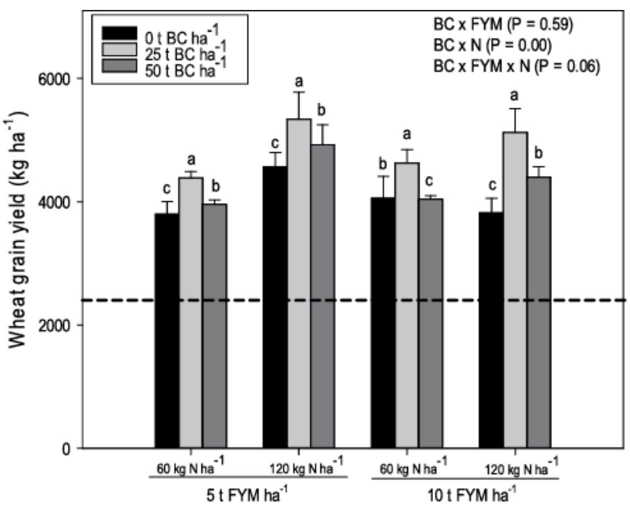

Fig. 3. Wheat grain yield (kg ha^{-1}) averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

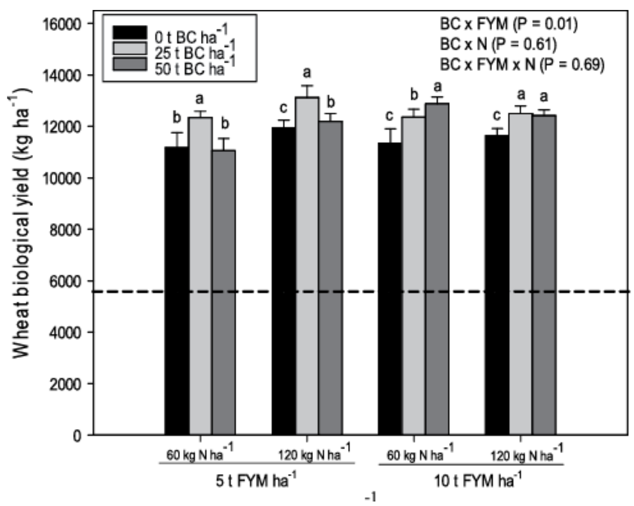

Fig. 4. Wheat biological yield (kg ha^{-1}) averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

Soil potassium content: Soil potassium (K) is an important macro nutrient that directly growth and yield of cereals. The individual and combined effect of BC, FYM and N on soil K after wheat harvest are reported figure 8 Two years average). As per hypothesis, application of FYM significantly (p<0.05) affected soil K content while the effect of N fertilization was found non significant (p>0.05). Soil was higher in plots treated with 10 t FYM as compared to 5 t FYM. Similarly, BC application at 50 t ha^{-1} improved soil K content by 120% than no BC plots. Figure 8 indicated that BC application at the rate of 50 t ha^{-1} resulted in higher soil K irrespective of FYM and N application rate however, at 10 t FYM the application of 25 t BC proved superior to the same rate of BC at 5 t FYM regardless of N application rate. There was much visible difference between the two rates of BC (25 and 50 t ha^{-1}) at 5 t FYM while under 10 t FYM the difference was minimized.

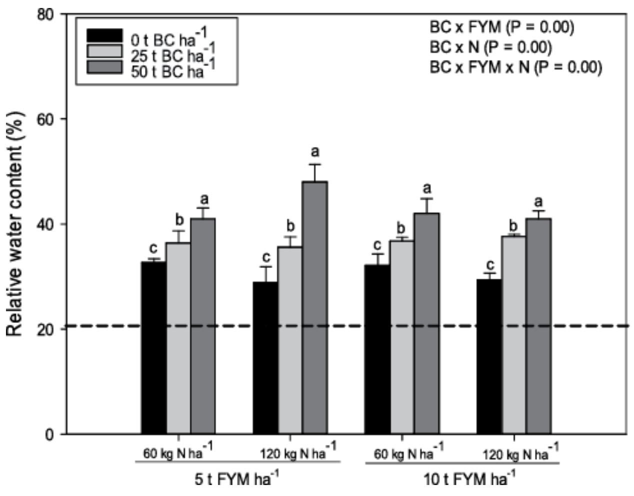

Fig. 5. Wheat relative water content (%[1]) averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

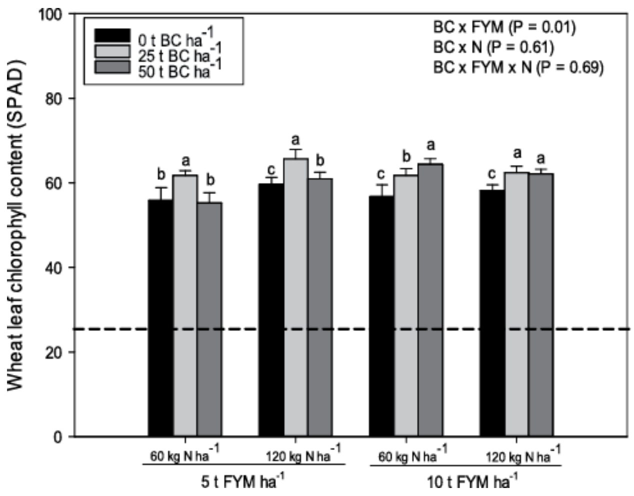

Fig. 6. Wheat leaf chlorophyll content (SPAD[1]) averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

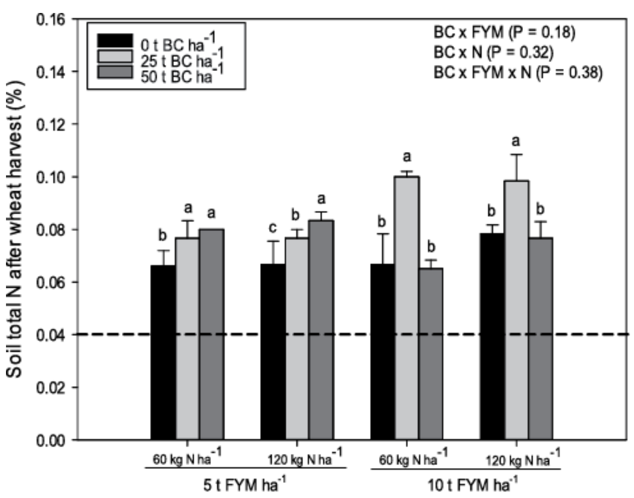

Fig. 7. Soil total N after wheat harvest averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

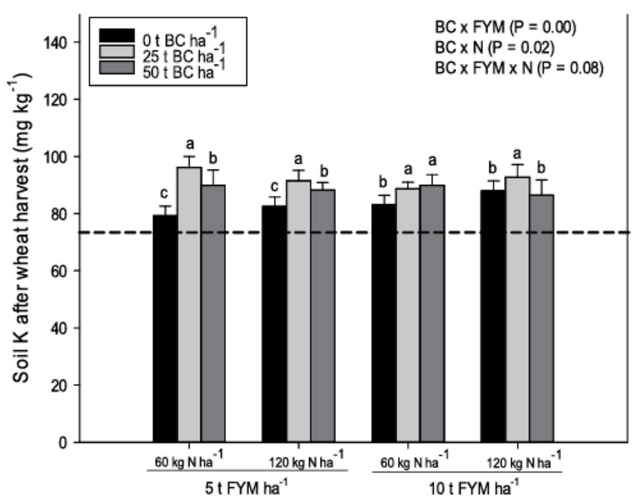

Fig. 8. Soil potassium content after wheat harvest averaged over two years (growing seasons) in response to the application of three different sources of nutrients (conventional inorganic N fertilizers, FYM and Biochar). Dotted line represents control plots where no treatment was added. Values represent means ± SEM (n = 3). Different capital letters above the represent significant differences between treatments at the p<0.05 level, while lowercase letters represent differences within an individual treatment at the p<0.05 level.

Discussion

Incorporation of biochar (BC) increased grain spike^{-1} by 23 and 37% over no BC and control plots while 8 and 15 % increase in wheat thousand grain weight were observed by BC application over no BC and control plots respectively. Likewise, BC application improved whet grain yield by 21 and 32% as compared to no BC treated and control plots. Moreover, 21 and 37% increase in wheat biological yield was noted by BC application of 25 t ha^{-1} over no BC and control plots respectively. Furthermore, BC application rate strongly improved wheat leaf chlorophyll content and relative water content. Beside this, soil properties such as soil N and P after wheat harvest were significantly improved by BC and FYM application irrespective of its application rate. Application of nutrients in combination with BC materials can increase crop yield on short-term basis (Lehmann *et al.*, 2003a). However, Liang *et al.*, (2008) are of the view that sustainable effects of BC on soil nutrient content and its availability crop is due to positive effect of BC on soil surface oxidation and cation exchange capacity (CEC) that intensifies over time (Cheng *et al*., 2006) and can boost crop yield components due to greater nutrient retention in soil and root zone. Sohi *et al*., (2009) further explained that increase in number of grains ear^{-1} in BC treated plots could be due to the effect of biochar on soil physio-chemical properties such as creating favorable environment for soil microbes, act as medium for plant nutrients absorption, improve water holding capicity and CEC.

The positive effect of biochar on wheat biological yield could be attributed to either nutrients saving (in terms of fertilizer) or improved fertilizer use efficiency and can therefore be regarded as an indirect nutrient value of biochar (Lehman *et al.*, 2003a). Also, biochar has the ability to remove soil constraints that are limiting plant growth and production such as the use of lime to overcome soil acidity, with resulting improvement in fertilizer use efficiency and increased in plant biomass (Glaser *et al.*, 2001). Biochar application to soil have been reported to increase N availability in soil and transport in crop as a result more photosynthates are formed and total biomass increased (Steiner *et al.*, 2007). Arif *et al*., (2012) recorded that biochar application at the rate of 30 t ha^{-1} in combination with mineral nitrogen increased maize biological yield, relative to sole biochar or mineral N application.

Other reasons for the increase in grain yield due to Biochar application could be its ability to enhance organic matter mineralization and improved crop yield and growth (Chan *et al.,* 2007). Biochar may reduce the activity of the compound that may be either inhibitory to nutrient transformation specialists such as nitrifying bacteria, (Park *et al.,* 2005), or reduce the concentration of phenolic compounds in the soil solution that would in other ways augment the immobilization of inorganic N which badly affect crop yield. Technically, Biochar acts as a buffer and contains some essential plant nutrients which significantly increase crop yield. Consequently, wheat yields were appreciably increased with higher rates of biochar. Being a comprehensive and multifunctional entity biochar increases soil fertility, organic matter, porosity, and improves nutrients availability and nutrients use efficiency in crops. Uzoma *et al*., (2011) achieved similar results and stated that biochar incorporation in soil at the rate of 30 and 20 t ha^{-1} appreciably increased maize grain yields by 150% and 98% as compared with the control, respectively. Encouraging plant response in terms of yield and growth due to biochar application was also noticed by Hossain *et al*., (2010). Higher grain yield in biochar applied plots might be due to its convincing effect on wheat N uptake which improves N fertilizer use efficiency especially in soils where N losses are more (Uzoma *et al.*, 2011).

Nitrogen application rate radically increased thousand grain weight of wheat as compared to control. In the first year thousand grain weights was increased by 23% while in the second year it was increased by 29% over control. As Nitrogen application promotes vigorous growth and formation of more photosynthates which are transported to grain at maturity, and healthy grains are formed. Moreover, comparable results are recorded by Akmal *et al*., (2010) who found significant increase in the 100 grain weight of maize when the crop growth was supplemented with higher rates of N fertilizer as compared to low N application rate. The results of Hussain & Shah (2002) also corroborate our results, they argued that nitrogen application convincingly enhanced wheat grain yield. Besides, our findings are in consonance with Bazitov (2000) and Bhagat *et al.*, (2001) who reported higher tillers plant^{-1}, spike length, spikelets spike^{-1} and higher thousand grain weight due to N fertilization and all these components collectively resulted in higher grain yield per unit area of wheat. Higher biological yield in mineral N applied plots could be ascribed to positive influence of N on vigorous crop growth. Integrated N management plots enhanced biological yield of maize as compared to control. This greater biological yield of maize in integrated N applied plots might be due the slow release and timely availability of N from organic sources which were less subjected to losses as compared to mineral N which is lost from soil more rapidly.

Conclusion and Recommendation

Currently the three main cereal crops (wheat, maize and rice) use only 33% of the nitrogen fertilizer applied, and less than 40% of the nutrients in recyclable organic 'wastes' such as livestock manure are returned to agriculture. Huge environmental and financial benefits can be achieved by the integration of biochar with synthetic N fertilizers. Incorporation of biochar will not only increase the output of the agriculture land in Pakistan, but it will also decrease our reliance on fossil fuels. Biochar application will tremendously improve soil fertility and crop productivity. Thus, integration of biochar with N fertilizers will have direct impact on the improvement of income and livelihood of the farmers' community. It will also help in retention of nutrients added to the soil through mineral fertilizers and will thus reduce their rate of chemical fertilizers application and will reduce cost of production. Thus, the profitability and productivity of cereal based cropping systems will improve along with decreasing reliance on chemical fertilizers by enhancing soil fertility through biochar application. This eco-friendly technology will decrease environmental hazards due to increased use of nitrogenous fertilizers by reducing N losses. It will ensure a sustainable crop production in Pakistan. It will also improve the fertility of the currently degraded soil on sustainable basis and can help in boosting the charcoal industry in Pakistan by its use as a soil conditioner. Therefore, it is important to adopt integrated use of biochar with FYM and mineral nitrogen to increase production, decrease production cost and improve soil fertility on sustainable basis.

References

Akmal, M., H. Ur-Rehman, Farhatulah, M. Asim and H. Akbar. 2010. Response of maize varieties to nitrogen application for leaf area profile, crop growth, yield and yield components. *Pak. J. Bot*., 42(3): 1941-1947.

Ali, K., F. Munsif, M. Zubair, Z. Hussain, M. Shahid, I. U. Din and N. Khan. 2011. Management of organic and inorganic nitrogen for different maize varieties. *Sarhad J. Agric*., 27(4): 525-529.

Ali, K., M. Arif, S. Shah, Z.Husain, A.Ali, S.Munir and H.Sher. 2015. Effect of organic and inorganic nutrients sources on phenology and growth of wheat. *Pak. J. Bot*., 47(6): 2215-2222.

Ali, K., S.K. Khalil, F. Munsif, A. Rab, K. Nawab, A.Z. Khan, A. Kamal and Z.H. Khan. 2012. Response of Maize (*Zea Mays* L.) to various nitrogen sources and tillage practices. *Sarhad J. Agric*., 28(1): 9-14

Arif, M., A. Ali, M. Umair, F. Munsif, K. Ali, Inamullah, M. Saleem and G. Ayub. 2012. Effect of biochar FYM and mineral nitrogen alone and in combination on yield and yield components of maize. *Sarhad. J. Agri*., 28(2): 191-195.

Bazitov, V. 2000. Production potential of wheat under different systems of soil tillage and fertilization. Rasteniev"dni Nauki. 37(10): 888-891.

Bhagat, R. K., R. P. Singh, B.M. Choudhary and R.K. Singh. 2001. Profitability of late sown wheat under small production system. *J. Res. Birsa Agri. Uni*., 13(2): 141-143.

Bruun, T.B., B. Elberling and B.T. Christensen. 2010. Lability of soil organic carbon in tropical soils with different clay minerals. *Soil Biol. Biochem*., 42: 888-895.

Chan, K.Y., L. Van-Zwieten, I. Meszaros, A. Downie and S. Joseph. 2007. Agronomic values of green waste biochar as a soil amendment. *Aus. J. Soil Res*., 45: 629-634.

Cheng, C.H., J. Lehmann, J.E. Thies, S.D. Burton and M.H. Engelhard. 2006. Oxidation of black carbon by biotic and abiotic processes. *Org. Geochem*., 37: 1477-1488.

Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, R. DeFries, J. Galloway, M. Heimann, C. Jones, C. Le Quéré, R.B. Myneni, S. Piao and P. Thornton. 2013. Carbon and Other Biogeochemical Cycles. In: Climate Change 2013: The Physical Science Basis.

Glaser, B., L. Haumaier, G. Guggenberger and W. Zech. 2001. The ‘terra preta’ phenomenon: A model for sustainable agriculture in the humid tropics. *Nature Wissen Schaften*, 88: 37-41.

Hossain, M.K., V. Strezov, K.Y. Chan and P.F. Nelson. 2010. Agronomic properties of waste water sludge biochar and bio availability of metalsin production of cherry tomato (*Lycopersicon esculentum*). *Chemosphere*, 78: 1167-1171.

Hussain, M.I. and S.H. Shah. 2002. Growth, yield and quality response of three wheat (*Triticum aestivum* L.) varieties to different levels of N, P and K. Inter. *J. Agri. & Bio*., 4(3): 362-364.

Jan, M.T., P. Shah, P.A. Hollington, M.J. Khan and Q. Sohail. 2009. Agriculture research: design and analysis, a monograph. NWFP. Agric. Univ. Pesh. Pak.

Lehman, J., J.P. da Silva Jr, C. Steiner, T. Nehls, W. Zech and B. Glaser. 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant Soil*, 249: 343-357.

Lehmann, J., D. Silva, C. Steiner, P. Nehls, T. Zech and W. Glaser. 2003a. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant Soil*, 249: 343-357.

Liang, B., J. Lehmann, D. Solomon, S. Sohi, J.E. Thies, J.O. Skjemstad, F.J. Luizão, M. H. Engelhard, E.G. Neves and S. Wirick. 2008. Stability of biomass-derived black carbon in soils. *Geochimica et Cosmochimica Acta*, 72: 6069-6078.

Park, B.B., R.D. Yanai, J.M. Sahm, D.K. Lee and L.P. Abrahamson. 2005. Wood ash effects on plant and soil in a willow bioenergy plantation. *Biomas. & Bioenergy*, 28: 355-365.

Patrick, M., J. Stephen, T.P. Ebanyat, M.M. Tenywa, D.N. Mubiru, T.A. Basamba and A. Leip. 2013. Soil organic carbon thresholds and nitrogen management in ropical agroecosystems: Concepts and Prospects. *J. Sus Devlop*., 12(6): 31-45.

Sohi, S., E. Lopez-Capel, E. Krull and R. Bol. 2009. Biochar, climatechange and soil: A review to guide future research. CSIRO Land and Water Science Report.

Steiner, C., W. Teixeira, J. Lehmann, T. Nehls, J. Vasconcelos de Macedo, W. Blum and W. Zech. 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant & Soil*, 291: 1-2.

Uzoma, K.C., M. Inoue, H. Andry, H. Fujimaki, A. Zahoor and E. Nihihara. 2011. Effect of cow manure biochar onmaize productivity under sandy soil condition. *Soil Use and Mgt*., 27: 205-212.

Widowati, W., H. Utomo, L.A. Soehono and B. Guritno. 2011. Effect of biochar on the release and loss ofnitrogen from urea fertilization. *J. Agri. & Food Tech*., 1: 127-132.

(Received for publication 23 February 2018)