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INTEGRATED USE OF BIOCHAR: A TOOL FOR IMPROVING SOIL AND WHEAT QUALITY OF DEGRADED SOIL UNDER WHEAT-MAIZE CROPPING PATTERN

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Abstract

Wheat quality, nutrient uptake and nutrient use efficiency are significantly influenced by nutrient sources and application rate. To investigate the integrative effect of biochar, farmyard manure (FYM) and nitrogen (organic and inorganic soil amendments) in a wheat-maize cropping system, a two year study was designed to assess the interactive outcome of biochar, FYM and nitrogenous fertilizer on wheat nitrogen (N) parameters and associated soil quality parameters. 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 nitrogen fertilizer (60 and 120 kg ha^{-1}) were used in the study. Biochar application displayed a significantly increased in wheat leaf, stem, straw and grain N content; grain and total N-uptake and grain protein content by 24, 20, 24, 56, 50, 17 and 20% respectively. Similarly, biochar application significantly increased soil total N (TN) and soil mineral N (SMN) by 63 and 40% respectively in second year. FYM application increased grain, leaf and straw N content by 20, 19.5 and 18% respectively, and increased total N-uptake and grain protein content by 49 and 19% respectively. FYM increased soil TN and SMN by 63 and 32% in both the years of the experiment. Mineral N application increased soil TN by over a half and SMN by a third, and grain protein content increased 16%. In contrast, nitrogen use efficiency (NUE) decreased for all amendments relative to the control. However, biochar treated plots improved NUE by 38% compared to plots without biochar. In conclusion, this field experiment has illustrated the potential of biochar to bring about short-term benefits in wheat and soil quality parameters in wheat-maize cropping systems. However, the long-term benefits remain to be quantified.

Key words: Wheat and soil quality, Organic amendments, Tissue analysis and grain protein.

Introduction

Nutrient physical absorption and crop quality in wheat are considerably influenced by the fertilization regime, including the sources of nitrogen (N) and the degree of input. The introduction and utilization of synthetic fertilizers greatly increased crop production during the Green Revolution in Pakistan (Islami *et al*., 2011; Abbas *et al*., 2013), indeed there was a ten-fold increase in fertilizer use between 1950 and 2000 (Ghorbani *et al*., 2010). However, currently only 30-50% of applied N is taken up by the crop (Smil 1999; Cassman *et al*., 2002). The demand for sustaining continuous cropping production systems whilst protecting the environment from further degradation is driving the demand for the improvement in the efficiency of nutrients use in the cropping system (Tilman *et al*., 2002; Mahmood *et al*., 2005; Munir *et al*., 2012). The most common definition of nutrient use efficiency is the yield of a given crop per unit available nutrient (N and P). One major way to improve NUE, is to apply N fertilizers so that it coincides more closely with crop demand (Khan *et al*., 2008; Dawson *et al*., 2008), with models indicating a potential NUE improvement of 12% by simply adjusting the date of N application (Semenov *et al*., 2007).

Adequate N levels in soil and the subsequent uptake of N by the crop is essential for productive wheat systems (Malhi *et al.,* 2006). Brown & Petrie (2006) demonstrated that available N has a positive influence on protein content and NUE of wheat (Kichey *et al.,* 2007). Nitrogen fertilization is recognized to boost soil total N (TN) whilst decreasing the C/N ratio in addition to the enhancement in crop quality (Habtegebrial *et al*., 2007; Yang *et al*., 2007; Jan *et al*., 2012). The application of N to wheat crops via inorganic sources (i.e. synthetic N) is instrumental in the increase of wheat protein content (López-Bellido *et al*., 2001). Li *et al*. (2003) illustrated that synthetic N could mineralize N between 4.0 and 9.4% more N compared to N from organic sources (e.g. farmyard manure; FYM), resulting in the increase in soil ammonium (NH_4-N) and nitrate (NO_3-N) (Malhi *et al.,* 2006; Mahmood *et al*., 2007; Mahmood *et al*., 2005). Despite synthetic fertilizers increasing the initial mineralization of N, they have been shown to lower soil quality; inducing soil deterioration, increasing soil bulk density, and acidification (Liu *et al*., 2010). The use of synthetic fertilizers together with organic materials for the eradication of these problems was advocated by Fageria & Baligar, (2005). FYM is an N-rich organic fertilizer, which can enhance wheat N uptake (i.e. N utilization), grain protein and improve soil fertility (Silva *et al*., 2006; Busra *et al*., 2005).

Whilst the benefits of FYM as an alternative fertilizer are well known, it must be used with consideration so to avoid N losses from the system. For the quantity of FYM to be used, the crop, the soil condition and season must be contemplated for nutrient balance.

Biochar is believed to withstand soil degradation under tropical conditions, and to increase NUE, N uptake and soil N status (Lehman *et al*., 2003). Successive experiments on the use of biochar have verified improvements in soil productivity, leaf and tissue N content, and N remobilization of some field crops (Islami *et al*., 2011); but little is known about its efficiency in wheat production.

In this study we have investigated the effects of agronomic practices (FYM, biochar, and synthetic N) on NUE and associated parameters in wheat grown for two years at the New Developmental Farm of the University of Agriculture, Peshawar, in order to assess fertilization management regimes for optimum wheat production.

Materials and Methods

Experimental site: The data presented were collected from a two year experiment conducted during the winter of 2012 and 2013 on the Research farm of the Agriculture University, Peshawar (34.1°’21”N, 71°28’5”E). The weather and climatic characteristics of the site consisted of warm to hot, semi-arid, sub-tropical, continental climate with mean annual rainfall of 360 mm (falling primarily in the winter). The summer (May–September) mean maximum temperature is 40°C and the mean minimum temperature is 25°C, whilst the winter (December to March) mean maximum temperature is 18.4°C, and the minimum temperature is 4°C, with temperatures dropping to 0°C in the month of January. The highest winter rainfall was recorded in March and April (2012 and 2013 respectively), while the highest summer rainfall was in August. The experimental site is deficient in N, P and Zn, whereas K content is adequate.

Experimental design: During the course of the study biochar was applied at three levels such as 0, 25 and 50 t ha^{-1}, farmyard manure was applied at two levels such as 5 and 10 t ha^{-1} while nitrogen (N) was applied at the rate of 60 and 120 kg ha^{-1} supplied as urea, together with a control treatment (no biochar, FYM or fertilizer-N). In total, there were 13 combinations of treatments applied for each replicated (n=3) plot (Table 1).

Table 1. Description of treatment combinations used for each replicated (*n* = 3) experimental plot.

Biochar (ton ha^{-1})	FYM (ton ha^{-1})	Ferilizer N (kg ha^{-1})	Abbreviation*
0	0	0	Control
0	5	60	B1-FYM1-N1
0	5	120	B1-FYM1-N2
0	10	60	B1-FYM2-N1
0	10	120	B1-FYM2-N1
25	5	60	B2-FYM1-N1
25	5	120	B2-FYM1-N2
25	10	60	B2-FYM2-N1
25	10	120	B2-FYM2-N1
50	5	60	B3-FYM1-N1
50	5	120	B3-FYM1-N2
50	10	60	B3-FYM2-N1
50	10	120	B3-FYM2-N1

*B1, no biochar; B2, Biochar at the rate of 25 ton ha^{-1}; B3, Biochar at the rate of ton ha^{-1}

*FYM1, FYM at the rate of 5 ton ha^{-1}; FYM2, FYM at the rate of 10 ton ha^{-1}

*N1, Nitrogen at the rate of 60 kg ha^{-1}; N2, Nitrogen at the rate of 120 kg ha^{-1}

Biochar was applied to the wheat crop in the first year of the experiment, while its residual effect was investigated in the second year. FYM was applied at the time of sowing, and fertilizer-N was applied in split doses (i.e., half was applied at sowing stage and the remaining half was applied at tillering stage). Single super phosphate (SSP) was applied at the rate of 90 kg ha^{-1}across all plots. The FYM was obtained from the University of Agriculture Peshawar dairy farm, and the biochar was produced from Acacia (e.g. *A. nilotica* (L.) Delile) using traditional methods employed in the region.

Table 2. Fresh biochar and FYM chemical properties before application to soil.

Parameters	Biochar	FYM
pH	7.01	8.65
EC (dS m^{-1})	1.57	2.44
C (%)	57.82	48.6
P (%)	1.14	3.52
N (%)	0.07	1.56
Ca (mg g^{-1})	2.68	1.86
Mg (µg g^{-1})	10.0	112.6

The experiment had three replicates per treatment and randomized complete block design (RCBD) was used for conduction of experiment. The treatment plots were 4.0 m x 4.5 m in size and ridges were made around each plot for delineation and to prevent biochar migration. Wheat seeds were sown in rows with 30 cm inter row-distance. Field was ploughed twice before sowing down to a depth of 30 cm with the help of cultivator followed by planking to break the clods and level the field taking care not to disturb the ridges and to facilitate biochar movement from one plot to another. Wheat (*Triticum aestivum* L. cv. Siran) was sown at a rate of 100 kg ha^{-1} on November 1st, 2012 in first year and November 7th 2013 in second year of the experiment. Flood method of irrigation was followed using river water for irrigation as and when needed. Puma super herbicide was used for the control of annual weeds.

Data collection: Soil samples from depth of 15 cm were collected from each experimental plot at physiological maturity of wheat crop and crushed, passed through a 2 mm sieve and stored for analysis in polythene bags after air drying. Total N and mineral N in soil samples were determined by the steam distillation method as described by Mulvaney (1996).

Whole plant at grain filling stage was collected and separated as leaves and stem in both years. Matured grains (12.7 ±_0.2% moisture content) and straw from harvested materials were also analyzed for N content and N-uptake. All components including stem, leaves, straw and grains were dried at 50ºC for 24 hours. The dried fractions (moisture <6 ± 0.3%) were weighed separately for determination of various growth parameters. The dried samples were ground by a tissue grinder and passed through a 0.2 mm sieve to obtain a fine powder for determination of N content.

Grain protein content is calculated as the percent N in the grain multiplied by 6.25 as described by the Kjeldahl method (Anon., 2005). Grain N uptake (kg N ha^{-1}) was determined by multiplying the grain biomass (kg ha^{-1}) by the grain N concentration (g N kg^{-1}), and the straw N uptake (kg N ha^{-1}) determined by multiplying the straw biomass (kg ha^{-1}) by the straw N concentration (g N kg^{-1}). Total N uptake (kg N ha^{-1}) was calculated as the sum of the straw and grain N uptake.

Nitrogen use efficiency (NUE; kg kg N^{-1}) was determined after harvesting of wheat as the wheat grain yield (Gy) per unit of N supply (N_s), and was calculated by the formula (G_w/N_s). Nitrogen supply was calculated as N applied as fertilizer plus total N uptake in control plots (Huggins & Pan, 1993). Nitrogen utilization efficiency (NUtE) was also calculated, by diving the grain biomass (kg ha^{-1}) by the total N uptake (kg N ha^{-1}) (Fiez *et al*., 1995).

Data analysis and presentation: After the harvesting of wheat crop the data collected were statistically analyzed using the procedure appropriate for RCB 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).

Results and Discussion

The experimental site displayed a neutral-alkaline pH of 7.6, and a low EC of 0.39 dS m^{-1}. The soil was low in OC (0.47%), P (3.87 mg kg^{-1}) and moderate in K (84.19 mg kg^{-1}) (Rizwan *et al*., 2012). The physico-chemical characteristics of the FYM and biochar are shown in Table 2. The biochar displayed an almost neutral pH of 7.01, and the FYM displaying amore alkaline pH of 8.65. Both biochar and FYM displayed a low electrical conductivity (<2.5 dS m^{-1}).

The presence of N, P and K in biochar and FYM showed that they could be sources of fertilizer for crop production, with biochar displaying higher N, P and K contents than FYM.

Biochar (BC), FYM and nitrogen (N) effect on crop and soil parameters: Relative to control and no biochar treated plots, wheat straw and grain nitrogen (N) was significantly affected by biochar application in both year of the experiment ($p < 0.05$; Table 3). Biochar application at the rate of 50 ton ha^{-1} resulted in higher straw and grain N % as compared to no biochar and control plots. Straw N % was higher in the first year of the experiment while grain N % was at par in both year of the experiment (Fig. 1a &1b). Likewise, FYM and mineral N application also significantly affected wheat straw and grain N content over control ($p < 0.05$; Table 3). Nitrogen application at the rate of 120 kg ha^{-1} and FYM at the rate of 10 ton ha^{-1} resulted in higher wheat straw and grain N content (Fig. 1a & b). Wheat leaf and stem nitrogen was significantly affected by BC, FYM and N application rate ($p < 0.05$; Table 3). Wheat stem N % was higher in second year of the experiment as compared to first year (Fig. 2a). Higher stem N % was investigated in plots treated with 50 ton ha^{-1} BC in combination with 5 ton FYM ha^{-1} and 120 kg N ha^{-1} (Fig. 2a). In contrast higher leaf N % was found in plots treated with 25 ton BC ha^{-1}, 10 ton FYM and 120 kg N ha^{-1} (Fig. 2b). Control plots resulted in lower stem and leaf N % in both years of the experiment as compared to treated plots (Fig. 2a & b).

Table 3. P values for two-way ANOVA comparing differences in tissue N content and grain protein in year 1 & 2.

Treatments	Straw N %		Grain N %		Stem N %		Leaf N %	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Biochar	**	**	**	**	**	*	**	**
FYM	*	**	*	*	**	*	*	*
N fertilizer	*	**	**	**	**	*	**	**
BC x FYM	ns	ns	*	**	*	ns	ns	ns
BC x N	ns	*	ns	*	**	**	ns	ns
FYM x N	ns	*	ns	ns	*	*	ns	ns
BC x FYM x N	ns	*	ns	ns	ns	*	ns	ns

Asterisks indicate a significant difference at the *P<0.05, **P<0.01 level; *ns*, not-significant

Table 4. P values for two-way ANOVA comparing differences in grain protein content and tissue N-uptake.

Treatments	Grain protein content		Grain N-Uptake		Straw N-Uptake		Total N-Uptake	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Biochar	**	**	**	**	*	ns	**	**
FYM	*	*	*	Ns	**	*	*	*
N fertilizer	**	**	**	*	*	*	*	*
BC x FYM	*	*	ns	Ns	ns	ns	ns	ns
BC x N	ns	ns	ns	Ns	ns	ns	ns	ns
FYM x N	ns	ns	ns	Ns	ns	ns	ns	ns
BC x FYM x N	ns	ns	ns	Ns	ns	ns	ns	ns

Asterisks indicate a significant difference at the *P<0.05, **P<0.01 level; *ns*, not-significant

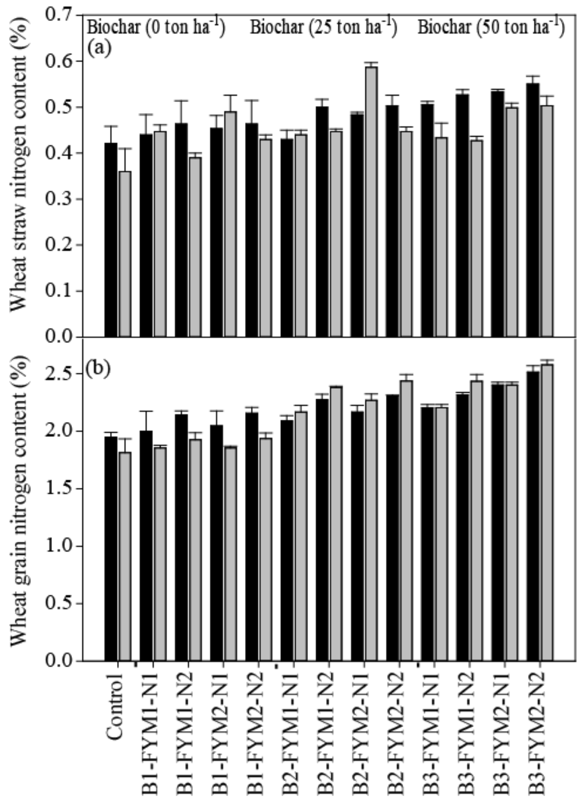

Fig. 1. Wheat straw and grain nitrogen % in year 1 (black bars) and year 2 (grey bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha^{-1} (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs.

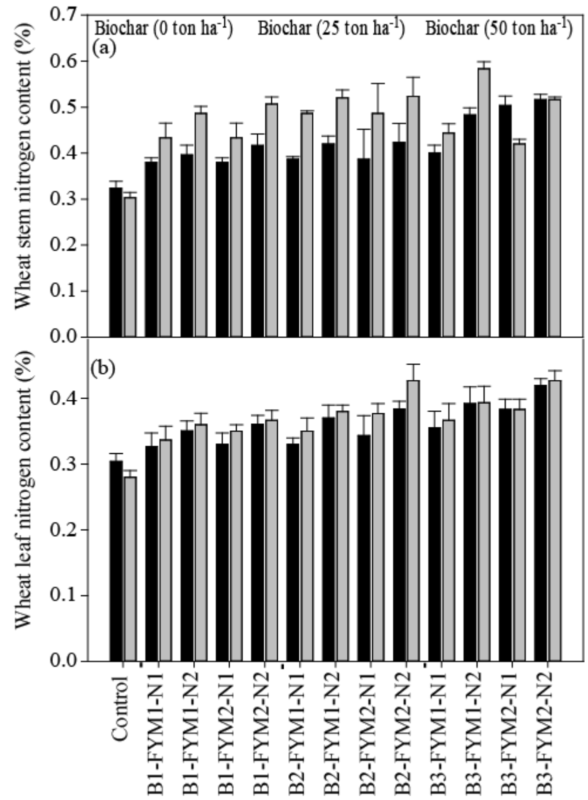

Fig. 2. Wheat stem and leaf nitrogen % in year 1 (black bars) and year 2 (gray bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha^{-1} (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs.

Wheat grain protein content and grain N-uptake was significantly affected by BC, FYM and N application rate ($p<0.05$; Table 4). Wheat grain protein content and grain N-uptake showed similar trend and increased as BC application rate increase from 0 to 50 ton ha^{-1} in both years of the experiment (Fig. 3a & b). Application of BC at the rate of 50 ton ha-1 resulted in higher grain protein content and grain N-Uptake as compared to no biochar treated plots (Fig. 3a & b). Likewise, application of N at the rate of 120 kg ha^{-1} and FYM at the rate of 10 ton ha^{-1} resulted in higher grain protein and N-Uptake as compared to 60 kg N ha^{-1} and 5 ton FYM ha^{-1} respectively (Fig. 3a-b). Control plots resulted in lower values of grain protein and N-uptake in both years (Fig. 3a-b). Wheat straw and total N-uptake was significantly affected by BC, FYM and N application rate ($p< 0.05$; Table 4). Wheat straw N-uptake increased as BC application rate increased from 0 to 25 ton ha^{-1} and further increasing BC application rate to 50 ton ha^{-1} reduced straw N content of wheat (Fig. 4a). In contrast, wheat total N-uptake increased in linear manner by increasing BC application rate form 0 to 50 ton ha^{-1} (Fig. 4b). Nitrogen application at the rate of 120 kg and FYM at the rate of 10 ton ha-1 resulted in higher wheat straw and total N-uptake over control (Fig. 4a-b).

Wheat nitrogen use efficiency (NUE) and soil mineral N was significantly affected by BC, FYM and N application rate in both years of the experiment ($p< 0.05$; Table 5). Wheat NUE decreased as N application rate increased from 60 to 120 kg ha^{-1} in both year of the experiment (Fig. 5a). Over all, control plots resulted in higher NUE while N and FYM application reduced NUE as compared to control (Fig. 5a). Biochar application at the rate of 25 ton ha^{-1} improved NUE as compared to 50 ton BC ha^{-1} and no BC treated plots (Fig. 5a). Moreover, BC application at the rate of 50 ton ha^{-1} significantly reduced soil mineral N content as compared to control and 25 ton BC application (Fig. 5b). Soil mineral N was improved by N application at the rate of 120 kg ha^{-1} and FYM application at the rate of 10 ton ha^{-1} as compared to control in both years (Fig. 5b). Soil total N was significantly affected by BC, FYM and N application in both years of the experiment ($p<0.05$; Table 5). Soil total N was reduced as BC application increased from 0 to 50 ton ha^{-1} in 1st year of the experiment, however, during second year of the experiment soil total N was increased as BC application rate increase (Fig. 6a). FYM and N application rate enhanced soil total N in both year of the experiment while control plots resulted in lower soil total N (Fig. 6a). Likewise, BC and FYM application significantly affected soil C % while the effect of N application was found non significant ($p<0.05$; Table 5). Soil C % increased in both years as biochar application rate increased form 0 to 50 ton ha^{-1} and BC application at the rate of 50 ton ha^{-1} resulted in higehr soil C % (Fig. 6b). Furthermore, FYM application at the rate of 10 ton ha^{-1} resulted in higher soil C as compared to FYM application of 5 ton ha^{-1} and control (Fig. 6b).

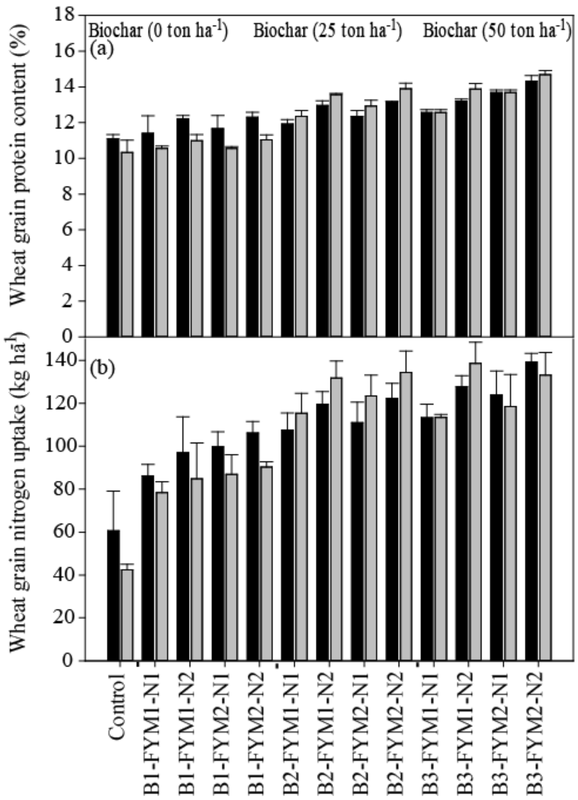

Fig. 3. Wheat grain protein content (%) and grain N-uptake in year 1 (black bars) and year 2 (grey bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha^{-1} (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs.

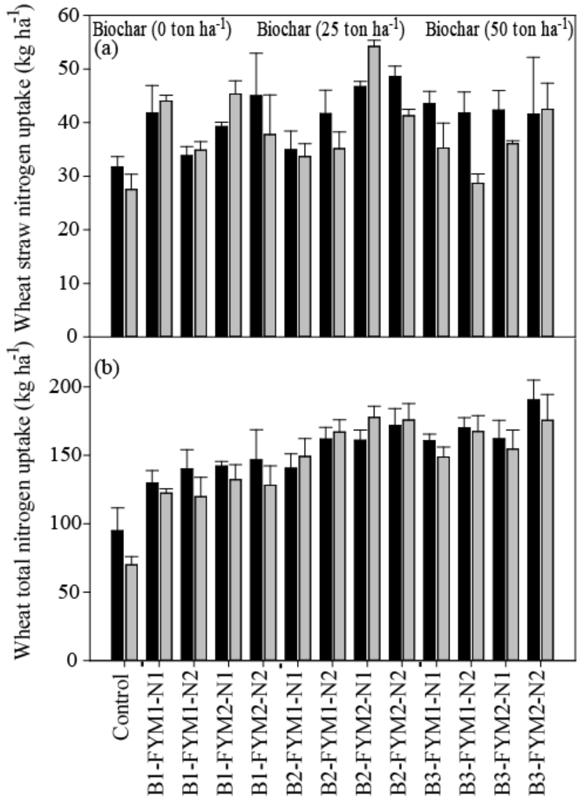

Fig. 4. Wheat straw and total N-uptake in year 1 (black bars) and year 2 (gray bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha^{-1} (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs.

Table 5. P values for two-way ANOVA comparing differences in NUE and soil N pool and carbon content after wheat harvest.

Treatments	NUE		Soil total N %		Soil mineral N %		Soil Carbon %	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Biochar	**	*	**	**	**	**	**	**
FYM	**	**	**	**	*	**	**	**
N fertilizer	**	**	**	**	*	**	ns	ns
BC x FYM	*	ns	**	**	ns	ns	**	**
BC x N	ns	ns	*	*	ns	*	ns	*
FYM x N	ns	ns	ns	ns	ns	*	**	*
BC x FYM x N	ns	ns	ns	ns	ns	*	ns	**

Asterisks indicate a significant difference at the *P<0.05, **P<0.01 level; *ns*, not-significant

Discussion

Integrated use of biochar and FYM as a soil amendments: Keeping in view the importance of wheat quality and soil N status, it is realized that wheat quality and soil nutrients capacity (especially N) must be improved on priority basis. In order to tackle the increasing food insecurity in semi-arid agro-ecosystems, there is an urgent need to make agricultural systems more productive, whilst simultaneously making them more sustainable. In Pakistan, current attempts at alleviating soil nutrient deficiencies through the increased application of inorganic fertilizer are both economically and agronomically unsustainable. However, using organic materials such as FYM as fertilizers is receiving increased attention for maintaining crop productivity (Ali *et al*., 2012). By decreasing the costs of input provisioning, integrated soil fertility management can offer a sustainable solution to nutrient input by supplementing smaller (and thus cheaper) quantities of synthetic fertilizers with locally available organic amendments.

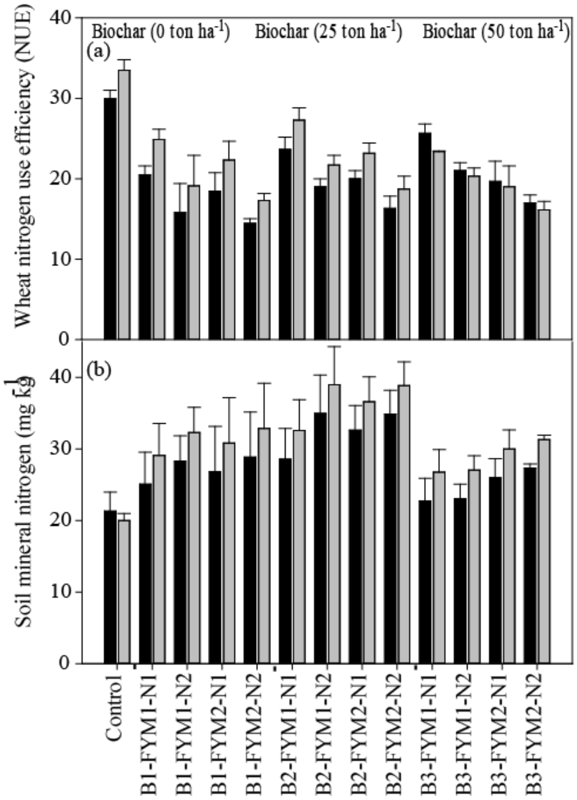

Fig. 5. Wheat nitrogen use efficiency in year 1 (black bars) and year 2 (grey bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha-1 (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs

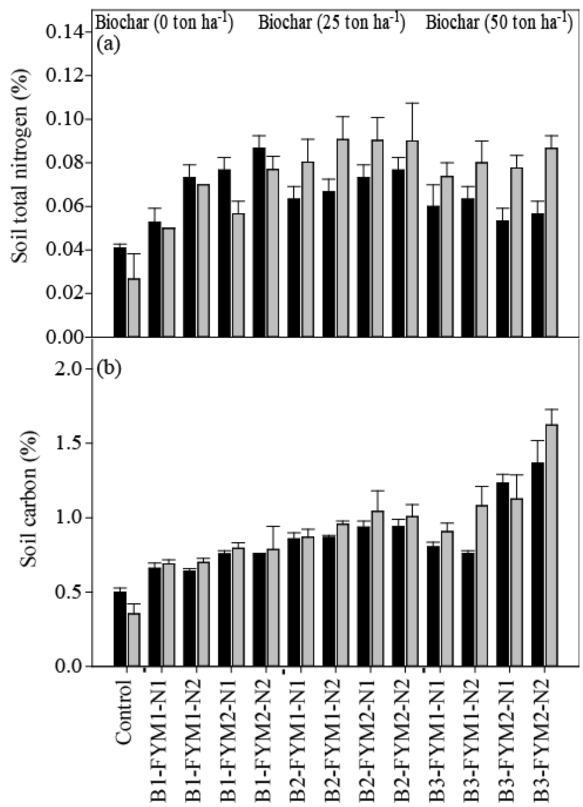

Fig. 6. Wheat nitrogen use efficiency in year 1 (black bars) and year 2 (grey bars). FYM was applied at the rate of 5 ton ha^{-1} (FYM1) and 10 ton ha^{-1} (FYM2), Nitrogen at the rate of 60 kg ha^{-1} (N1) and 120 kg ha^{-1} (N2) and biochar was applied at 0 ton ha^{-1} (B1), 25 ton ha^{-1} (B2) and 50 ton ha^{-1} (B3). Means of the three replicated along with SE are presented in graphs

Potential use of biochar for improving crop and soil quality: Application of biochar caused a reduction in soil TN and SMN content in year 1 relative to the plots under FYM and synthetic fertilizer only. Whilst in year 2, the soil TN and SMN was increased by the previous years' biochar application. Available N concentration in the soil largely depends on the C:N ratio of the applied organic matter (OM). OM with high C:N ratio is known to immobilize mineral N in soil (Blackwell *et al*., 2010). Because of the high C:N ratio, most of the biochar is expected to cause N immobilization and possibly induce N deficiency in soil (Lehman *et al*., 2013). Wheat leaf, stem, straw and grain N contents and uptake were significantly improved by the application of biochar. Highest N uptake was observed in soils amended with 50 t ha^{-1} biochar as compared to control. Van-Zwieten *et al*. (2010) reported similar effects of biochar on N uptake by crops. Nitrogen uptake and quality of radish plants were improved when grown in biochar amended soils (Chan *et al*., 2005). This increase in N uptake and quality of wheat under biochar (BC) amended plots indicates the beneficial effect of BC to improve fertilizer use efficiency especially in soils where nitrogen loss is a major environmental and agronomic concern. Application of mineral N enhanced N mineralization by decreasing C:N ratio and thus improved soil TN. Application of high amounts of FYM resulted in C, N and S accumulation in clay soils. This finding was supported by Yang *et al*. (2007). Application of FYM synergistically improved soil, leaf, stem, straw and grain N content and grain protein. It was observed that higher level of FYM resulted in higher concentration of all parameters under study. The increased uptake of N in leaf, stem, straw and grain in higher FYM incorporated plots might be associated with the mineralization of FYM throughout the growing season that ensured its availability to wheat crop (Shah & Ahmad, 2006). Moreover, the high concentration of N in wheat might be associated with the on-time mineralization of FYM, which was absorbed by wheat and thus might have lowered the N losses through de-nitrification or leaching, or even lower N immobilization in organic forms (Shah & Khan, 2003). Our results are confirmed by the findings of Silva *et al*. (2006) and Rao & Shaktawat (2002) who found increased concentration of N in wheat grain and straw when FYM in combination with N fertilizer was used as N source as compared to sole N fertilizer application. The major contributions of high levels of residual soil N over time due to organic source of N might have increased the N content in aerial components of wheat compared to control (Sowers *et al*., 1994). Other possible reasons might be the vigorous growth of plant components in response to the optimum nutrient availability in the plots incorporated with FYM that also received fertilizer N. Gibson *et al*. (2007) obtained more

N accumulation in the plant components in fertilized plots than unfertilized plots. Mineralization of organic manure by microbes might be another possible reason for greater N accumulation in fertilized plots compared to control (Shah *et al*., 2009). Accumulation of N in the aerial parts of the plant and their partition to the various plant vegetative components (i.e. leaf, stem and roots) had influenced the N-content (Shah & Ahmad, 2006). Application of urea fertilizer significantly increased N content and its uptake by various wheat component. Concentration of leaf, straw and grain N could be attributed to higher wheat nitrogen uptake under fertilized plots. Wheat dry matter and leaf area could be increased under N fertilization at optimum or higher level as compared to control (Olesen *et al*., 2002). Grain protein directly affected wheat grain quality (Souza *et al*., 2004). Our results of higher grain N content in N fertilized plots are confirmed by the findings of Zhu *et al*. (2006). Subedi *et al*. (2007) are of the view that proper amount of fertilizer-N directly influence wheat quality and yield. Similarly, Saeed *et al*. (2013) reported that increasing N application significantly increased wheat grain weight and protein content. As compared to control, wheat straw nitrogen percentage significantly improved in N-fertilized plots mainly because of a progressive crop growth and N-uptake over the time as compared to control that had poor growth as the crop grew (Tahir & Nakata, 2005).

Conclusion

Experiments were conducted to show individual effect of biochar, FYM and N fertilizer on soil N and N concentrations in wheat (test crop). The use of Biochar improved wheat leaf, stem, straw and grain N and protein content. N-uptake and use efficiency were also enhanced. The application of FYM at the rate of 10 t ha^{-1} led to higher wheat leaf, stem, straw and grain N content and grain, straw and total N-uptake in comparison to low level of FYM (5 t ha^{-1}). Urea fertilizer used at the rate of 120 kg ha^{-1} ameliorated wheat leaf, stem, straw and grain N concentration and grain protein content. Nitrogen use efficiency was severely affected by FYM and urea fertilizer. Biochar in combination with FYM and mineral N is recommended in cereal-cereal cropping pattern in Pakistan to preserve soil and prevent soil degradation and improve soil and crop quality.

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References

Abbas, G., J.Z.K. Khattak, G. Abbas, M. Ishaque, M. Aslam and Z. Abbasi. 2013. Profit aximizing level of potassium fertilizer in wheat production under arid environment. *Pak. J. Bot*., 45(3): 961-965.

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.

Anonymous. 2005. Official methods of analysis. 17th ed. Gaithersburg, Md.: AOAC International.

Blackwell, Paul, E. Krull, G. Butler, A. Herbert and Z. Solaiman. 2010. Effect of Banded Biochar on Dryland Wheat Production and Fertiliser Use in South-Western Australia: An Agronomic and Economic Perspective. *Aust. J. Soil. Res*., 48(7): 531-45.

Brown, B.D. and S. Petrie. 2006. Irrigated hard winter wheat response to fall, spring, and late season applied nitrogen. *Field Crop Res*., 96: 260-268.

Busra, M., A.M. Ranjha, M. Abid and M. Iqbal. 2005. Soil physical properties and wheat growth as affected by tillage and farm manure. *Pak. J. Agric*., 42: 56-58.

Cassman, K.G., A. Dobermann and D.T. Walters. 2002. Agroecosys- tems, nitrogen-use efficiency, and nitrogen management. *AMBIO*., 31(2): 132-140.

Chan, K.Y., V. Zwieten, B.L. Meszaros, I. Downie and D.S. Joseph. 2005. Using poultry litter biochars as soil amendments. *Australian J. Soil Res*., 46: 437- 444.

Dawson, J.C., D.R. Huggins and S.S. Jones. 2008. Characterizing nitrogen use efficiency in natural and agricultural ecosys- tems to improve the performance of cereal crops in low- input and organic agricultural systems. *Field Crops Res.*, 107: 89-101.

Fageria, N.K. and V.C. Baligar. 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy*, 88: 97-185.

Ghorbani, R., S. Wilcockson, A. Koocheki and C. Leifert. 2010. Soil management for sustainable crop disease control: a review. In: *Organic farming, pest control and remediation of soil pollutants*, (Ed.): Lichtfouse vol 1. Sustainable Agricul- ture Reviews. *Springer Netherlands*, 177-201.

Gibson, L.R., C.D. Nance and D.L. Karlen. 2007. Winter triticale response to nitrogen fertilization when grown after corn or soybean. *Agron. J*., 99: 49-58.

Habtegebrial, K., B.R. Singh and M. Haile. 2007. Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (Eragrostis tef (Zucc.) Trotter) and soil properties. *Soil and Tillage Res*., 94: 55-63.

Huggins, D. R. and W.L. Pan. 1993. Nitrogen efficiency component analysis: an evaluation of cropping system differences in productivity. *Agron. J*., 85: 898-905.

Islami, T., B. Guritno, Nurbasuki and A. Suryanto. 2011. Maize yield and associated soil quality changes in cassava + maize intercropping system after 3 years of biochar application. *J. Agri. and Food Tech.*, 1: 112-115.

Jan, M.T., M.J. Khan, F. Ullah, M. Arif, M.Z. Afridi, A. Khan and H. Akbar. 2012. Integrated management of crop residue and N fertilizer for wheat production. *Pak. J. Bot*., 44(6): 2015-2019.

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.

Khan, A., M.T. Jan, M. Arif, K.B. Marwat and A. Jan. 2008. Phenology and crop stand of wheat as affected by nitrogen sources and tillage practices. *Pak. J. Bot*., 40: 1103-1112.

Kichey, T., B. Hirel, E. Heumez, F. Dubois and J. Le-Gouis. 2007. In winter wheat, post-anthesis nitrogen uptake and remobilization to the grain correlates with agronomic traits and nitrogen physiological markers. *Field Crop Res*., 102: 22-32.

Lehman, J., J.P.Jr. da Silva, 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.

Li, H., Y. Han and Z. Cai. 2003. Nitrogen mineralization in paddy soils of the Taihu Region of China under anaerobic conditions: dynamics and model fitting. *Geoderma*., 115: 161-175.

Liu, E., Y. Changrong, M. Xurong, H. Wenqing, H. B. So, D. Linping, L. Qin, L. Shuang and F. Tinglu. 2010. Long term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in north-west China. *Geoderma*., 150: 173-180.

López-Bellido, L., R.J. López-Bellido, J.E. Castillo and F.J. López-Bellido. 2001. Effects of long-term tillage, crop rotation and nitrogen fertilization on bread-making quality of hard red spring wheat. *Field Crop Res*., 72: 197-210.

Mahmood, T., R. Ali, F. Hussain and G.R. Tahir. 2005. Seasonal changes in soil microbial biomass carbon under a wheat-maize cropping system receiving urea and farmyard manure in different combinations. *Pak. J. Bot*., 37: 105-117.

Mahmood, T., R. Ali, F. Hussain, K.A. Malik and G. Rasul. 2007. Seasonal changes in soil microbial biomass Nitrogen under an irrigated wheat-maize Cropping system. *Pak. J. Bot*., 39(5): 1751-1761.

Malhi, S.S., R. Lemke, Z.H. Wang and B.S. Chhabra. 2006. Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality, and greenhouse gas emissions. *Soil and Tillage Res*., 90: 171-183.

Mulvaney, R.L. 1996. Nitrogen—Inorganic forms. p. 1123-1184. In: *Methods of soil analysis*. (Eds.): D.L. Sparks *et al*. Part 3. SSSA Book Ser. 5. SSSA, Madison, WI.

Munir, A., Anwar-ul-Hassan, S. Nawaz and M.A. Bajwa. 2012. Farm manure improved soil fertility in mungbean-wheat cropping system and rectified the deleterious effects of brackish water. *Pak. J. Agri. Sci*., 49: 511-519.

Olesen, J.E., J. Berntsen, E.M. Hansen, B.M. Petersen and J. Petersen. 2002. Crop Nitrogen demand and canopy area expansion in winter wheat during vegetative growth. *Europ. J. Agron.*, 16: 279-294.

Rao, S.S. and M.S. Shaktawat. 2002. Residual effect of organic manure, phosphorus and gypsum application in preceding groundnut (Arachis hypogea) on soil fertility and productivity of Indian mustard (*Brassica juncea*). *Ind. J. Agron*., 47: 487-494.

Saeed, B., A.Z. Khan, S.K. Khalil, H.U. Rahman, F. Ullah, H. Gul and H. Akbar. 2013. Response of soil and foliar applied nitrogen and sulfur towards yield and yield attributes of wheat cultivars. *Pak. J. Bot*., 45(2): 435-442.

Semenov, M. A., P.D. Jamieson and P. Martre. 2007. Deconvoluting nitrogen use efficiency in wheat: a simulation study. *Eur. J. Agron.*, 26: 283-294.

Shah, S.A., S.M. Shahab, W. Mohammad, M. Shafid and H. Nawaz. 2009. N uptake and yield of wheat as influenced by integrated use of organic and mineral nitrogen. *Int. J. Plant. Production*, 3(3): 45-56.

Shah, Z. and A.A. Khan. 2003. Evaluation of crop residues for mineralizable nitrogen in soils. *Sarhad J. Agric*., 19(1): 81-92.

Shah, Z. and M.I. Ahmad. 2006. Effect of integrated use of farmyard manure and urea on yield and nitrogen uptake of wheat. *J. Agric. And Boil. Sci*., 1: 60-65.

Silva, P.S., L. Silvaj, F.H.T. Oliveira and D. Sousaakf. 2006. Residual effect of cattle manure application on green ear yield and corn grain yield. *Hort. Brasileria.*, 24: 166-169.

Smil, V. 1999. Nitrogen in crop production: an account of global flows. *Global Biogeochem Cycles.*, 13(2): 647-662.

Souza, E.J., J.M. Martin, M.J. Guttieri, K.M. O'Brien and D.K. Habernicht. 2004. Influence of genotype, environment, and nitrogen management on spring wheat quality. *Crop Sci.*, 44: 425-432.

Sowers, K.E., W.L. Pan, B.C. Miller and J.L. Smith. 1994. Nitrogen use efficiency of split nitrogen applications in soft white winter wheat. *Agron. J*., 86: 942-948.

Subedi, K.D., B. L. Ma and A.G. Xue. 2007. Planting date and nitrogen effects on grain yield and protein content of spring wheat. *Crop Sci. J*., 47:36-44.

Tahir, I.S.A. and N. Nakata. 2005. Remobilization of nitrogen and carbohydrate from stems of bread wheat in response to heat stress during grain filling. *Japan J. Agron & Crop Sci*., 191: 106-115.

Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor and S.Polasky. 2002. Agricultural sustainability and intensive production practices. *Nature*, 418 (6898): 671-677.

Van Zwieten, L., S. Kimber, S. Morris, K.Y. Chan, A. Downie, J. Rust, S. Joseph and A. Cowie. 2010. Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant and Soil*, 327: 235-246.

Yang, J.Y., E.C. Huffman, R.D. Jong, V. Kirkwood, K.B. MacDonald and C.F. Drury. 2007. Residual soil nitrogen in soil landscapes of Canada as affected by land use practices and Agricultural policy scenarios. *Land Use Policy*, 24: 89-99.

Zhu, G.X., D.J. Midmore, D.F. Yule and B.J. Radford. 2006. Effect of timing of defoliation on wheat (*Triticum aestivum*) in central Queensland 2. N uptake and relative N use efficiency. *Field Crops Res*., 96: 160-167.

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