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# EFFECT OF ORGANIC AND INORGANIC NUTRIENTS SOURCES ON PHENOLOGY AND GROWTH OF WHEAT

**KAWSAR ALI[1*], MUHAMMAD ARIF[2], SHAHEN SHAH[2], ZAHID HUSSAIN[3], ASAD ALI[1], SAID MUNIR[4] AND HASSAN SHER[5]**

*[1]Department of Agriculture, Abdul Wali Khan University, Mardan*
*[2]Department of Agronomy; [3]Department of weeds Sciences, The University of Agriculture, Peshawar, Pakistan*
*[4]Institute of Hajj and Umrah Research, Umm-Al-Qura University, Makkah, Saudia Arabia*
*[5]Center for Plant Sciences and Biodiversity, University of Swat, Pakistan*
*[*]Corresponding author e-mail: kawsar@awkum.edu.pk*

**Abstract**

Incorporation of biochar to agriculture field has the potential to be a primary factor in maintaining soil fertility and productivity particularly in nitrogen and organic matter limiting environments however, clear experimental evidence to support this views still lacking. The current experiments were carried out to evaluate the effect of different organic (biochar and FYM) and inorganic amendments (nitrogen as urea) on the growth and phenology of wheat. The experiment with three factors such as biochar at three levels (0, 25 and 50 t $ha^{-1}$), FYM at two levels (5 and 10 t $ha^{-1}$) and N at two levels (60 and 120 kg $ha^{-1}$) were conducted for 2 years in winter 2012-13 and 2013-14. FYM and N significantly delayed booting, anthesis, milking and maturity in wheat and resulted in higher leaf area, plant height, tillers and spike $m^{-2}$ in comparison with control. Biochar application at the rate 25 t $ha^{-1}$ took more days to booting, anthesis, milking and maturity as compared to no BC and 50 t BC $ha^{-1}$, respectively. Taller plants and improved leaf area were measured in plots where BC was applied at the rate of 50 t $ha^{-1}$. It is concluded that biochar application at the rate of 25 t $ha^{-1}$ in combination with 60 kg N $ha^{-1}$ and 5 t FYM $ha^{-1}$ can be used for promoting vigorous wheat growth and development.

**Key words:** Wheat, Phenology, Leaf area, Growth, Physiology and biochar.

## Introduction

Wheat is an annual plant of Poaceae family. It belongs to genus Triticum. It is considered as a key crop to overcome food shortage in the country as increasing food is the cry of day. It is a staple food crop and is cultivated on large area and almost throughout the country (Rehman *et al*., 2010). It occupies major position in the (Gross Domestic Product) GDP and contributes 3.0% to GDP and 14.4% to the value added in agriculture (Anon., 2010). Keeping in view the importance of wheat crop, it is a challenge for agriculture scientist of the country to enhance the productivity of wheat either through best management practices or genetic modification. Phenology of a crop plays an important role in final yield of the crop. The equilibrium between vegetative and reproductive growth is crucial to overall crop performance and final yield (Ali *et al*., 2012; Khan *et al*., 2008). A carbon source in the leaves, root and other organs is established during vegetative growth which is used by reproductive sinks. This equilibrium is mainly achieved by developmental partitioning, especially in determinate plants such as wheat (Khan *et al*., 2008; Melaj *et al*., 2003). Growth and developmental phases correspond to phenological events, and consequently the timing of photo assimilate partitioning is largely determined by phenology (Jan *et al*., 2010; Rehman *et al*., 2010). In order to ensure this state of equilibrium and crop proceeds its growth smoothly, there is an immense need of judicious nutrient management (Hossain *et al*., 2002; Shah & Ahmad, 2006). Nitrogen is an essential nutrient for among essential plant nutrients, nitrogen play key role in plant growth, development and reproduction. Though nitrogen is one of the most abundant elements on earth, still nitrogen deficiency is probably the most common nutritional problem affecting plants worldwide. Like other crops, wheat growth and development is also largely influenced by N fertilization. Wheat number of tillers $m^{-2}$ increased when N were increased (Mossedaq & Smith 1994; Iqtidar *et al*., 2006). Days to50% heading and days to maturity delayed with the increase in N levels in combination with P and K (Ayoub *et al*., 1994). Plant height of wheat crop increased with the increase in NPK combination (Lloveras *et al*., 2001; Hossain *et al*., 2002).

Since 1970, productivity of wheat and other cereal had largely increased due to the great success of synthetic fertilizers, combined with intensive agronomic practices (Iqtidar *et al*., 2006; Khan *et al*., 2009). Though the importance of synthetic fertilizer could not be ignored however, synthetic fertilizer role have been much smaller in term of soil health maintenance (Hammad *et al*., 2010; Dong *et al*., 2006; Hussain & Khan, 2000). Therefore the need for organic fertilizer (biochar & FYM) was much explored in the current scenario in order to get higher yield without disturbing soil health (Arif *et al*., 2012a).

To cope this situation and compensate loses due to synthetic N fertilizations, the inclusion of organic sources of nutrients are considered the best possible solution. Application of farmyard manure (FYM) to soil have been practiced for many centuries and its application to soil have increased crop yield, improved soil fertility, increased soil organic matter, increased microbiological activities and improved soil structure for sustainable agriculture (Blair *et al*., 2006; Kundu *et al*., 2007). Combination of both organic and inorganic fertilizers delayed days to 50% heading, plant height, yield and yield components and leaf area index of wheat compared with sole organic or inorganic fertilizer (Hossain *et al*., 2002; Manna *et al*., 2005). Biochar is a fine grained charcoal high in organic carbon and largely resistant to decomposition. It is produced from pyrolysis of plants and waste feed stocks. Biochar application has received a growing interest as a sustainable technology to improve highly weathered or degraded soils (Lehmann & Rondon, 2006). Biochar contains number of important plant nutrients which significantly affect crop growth and phenology (Lehman *et al*., 2003; Arif *et al*., 2012b). Maize yield and nutrient uptake were significantly improved with increasing biochar application rate in combination with other commercial fertilizers (Randon *et al*., 2007). Yield characteristics and water use efficiency of maize was increased from 50 to 100% when biochar application rate was increased from 15 to 20 t ha-1 (Uzoma *et al*., 2011). Nutrient uptake and crop growth rate was increased with higher biochar applications (Ali *et al*., 2015). Maize yield and yield components showed positive response when biochar was used as soil amendment because it improves the field-saturated hydraulic conductivity of the sandy soil, as a result net WUE also increased and more moisture and nutrients became available to the crop throughout the growing season (Major *et al*., 2010).

Keeping in view the fundamental value of wheat phenology and its main share in the final yield of the crop as well as its response to different nutrient sources of organic and inorganic origin, the present project was designed It focused on looking for the best source and its optimum doze alone and (or) in combination in relation to impinge on the phenology of the wheat crop and consequently its role and impact on the final yield of the crop in question without disturbing or very less apprehension on the soil fertility status/health.

## Materials and Methods

**Experimental site:** Experiments were laid out during Fall 2012-13 ad 2013-14 at Agriculture Research Farm of the University of Agriculture, Peshawar situated at 34.1°'21"N and 71°28'5"E. The average precipitation and maximum temperature was 360 mm and 40°C, respectively. The texture of soil was clay loam and its basic properties are given in Table 1.

**Nutrients analysis of biochar and FYM:** The biochar (BC) and FYM samples were ground to a fine powder for subsequent C and N determination using a TruSpec® CN Analyzer (Leco Corp., St Joseph MI, USA). Water content was measured by sub sampling 10 g of BC and FYM, dried over night at 105°C and calculated on the basis of weight loss. Samples pH and EC were measured by sub sampling 5 g of sieved sample and 10 ml of deionised water (1:2 w/v) was added, followed by shaking for 1 hour using orbital shaker (250 rev $min^{-1}$). The available P and K were determined in the AB-DTPA extract (Soltanpour & Schwab, 1977). Phosphorus was read as Spectrophotometer after color development and potash on Flame Photometer. For Ca and Mg, solution was directly read on Atomic Absorption Spectrophotometer (Perkin Elmer Model 2380, USA). Chemical analysis of FYM and BC are given in Table 2.

**Experimental details:** The experiment was conducted at the agriculture research farm of the University of Agriculture, Peshawar during winter 2012. The study was consisted of three levels of BC (0, 25 and 50 t $ha^{-1}$), two levels of farmyard manure (FYM) (5 and 10 t $ha^{-1}$) and two levels of fertilizer-N (60 and 120 kg $ha^{-1}$) along with a control treatment. Biochar and FYM were applied at the time of sowing. Biochar was applied in first year only while FYM was applied in both years. Half of the fertilizer-N was applied at sowing and remaining half at tillering stage. Phosphorus (P) was applied at the rate of 90 kg $ha^{-1}$ as a basal dose. Urea and single super phosphate (SSP) were used as sources of N and P. The experiment with three replications was laid out in randomized complete block design. The plot size of 4 x 4.5 m with strong ridges around each plot was used. Row to row distance was 30. The field was ploughed twice up to the depth of 15-20 cm with the help of cultivator followed by planking to break the clods and level the field assuring not to disturb the ridges and move the biochar from one plot to another. Wheat cultivar 'Siran' was sown at the seed rate of 100 kg $ha^{-1}$ on November 4$^{th}$, 2012 and 5$^{th}$ November 2013. The field was irrigated according to the need of crop. All other agronomic practices were applied uniformly to all experimental units.

Data were recorded on days to emergence, plant height, days to boot, heading, anthesis, physiological maturity, plant height, leaf area and leaf area index.

**Table 1. Physico-chemical properties of soil of the experimental site. Values represent means ± Standard error mean (n = 3).**

| Soil character | Measured quantity |
|---|---|
| Water content (%) | 20.48 ± 0.29 |
| pH (1:2 $H_2O$) | 7.21 ± 0.01 |
| EC (1:2 $H_2O$ $\mu Scm^{-1}$) | 15.93 ± 0.53 |
| Available $NO_3^-$ (mg N $l^{-1}$ soil solution) | 4.51 ± 0.07 |
| Available $NH_4^+$ (mg N $l^{-1}$ soil solution) | 0.1 ± 0.01 |
| Organic matter (%) | 0.65 ± 0.03 |

**Table 2. Chemical characteristics of biochar and FYM used in the experiments.**

| Parameters | Biochar | FYM |
|---|---|---|
| Total N (%) | 0.08 ± 0.002 | 0.7 ± 0.003 |
| Total C (%) | 57 ± 0.08 | 13 ± 0.02 |
| Ca (mg $l^{-1}$) | 15 ± 0.04 | 19 ± 0.04 |
| K (mg $l^{-1}$) | 27 ± 0.01 | 15 ± 0.03 |
| P (mg $l^{-1}$) | 1.2 ± 0.07 | 2.4 ± 0.04 |
| Na (mg $l^{-1}$) | 12 ± 0.02 | 07 ± 0.01 |
| Mg (mg $l^{-1}$) | 09 ± 0.05 | 04 ± 0.02 |
| EC (mS) | 0.02 ± 0.001 | 0.05 ± 0.01 |
| pH | 7.2 ± 0.06 | 4.5 ± 0.02 |

**Statistical analysis:** The data were statistically analyzed using the procedure appropriate for randomized complete block (RCB) design. Means were compared using least significant difference (LSD) test at 5% level of probability when F values were significant (Jan *et al*., 2009).

## Results

Data on various growth and phenological parameters of wheat as affected by biochar application are given in Table 3. Booting delayed with increasing level of biochar from 0 to 25 t $ha^{-1}$ but further increasing BC application rate (50 t $ha^{-1}$) reduced days to booting. More days to booting (79.1) were recorded for 25 t BC $ha^{-1}$ followed by no BC treated plots (76.38) while fewer days were counted in plots treated with 50 t $ha^{-1}$ BC (76.4). Anthesis delayed with BC applied at 25 t $ha^{-1}$ followed by no biochar plots whereas 50 t BC $ha^{-1}$ had earlier anthesis.

Biochar application at the rate of 25 t ha$^{-1}$ delayed milk stage in wheat and took more days to milk stage (108) as compared to 50 t BC (104) and no biochar treated plots (107). Physiological maturity was late (170) in 25 t BC ha$^{-1}$ as compared to 50 BC t ha$^{-1}$ (166) and no BC treated plots (164). Tillers m$^{-2}$ increased with increase in BC application from 0 to 25 t ha$^{-1}$ and further increase reduced number of tillers m$^{-2}$. Higher number of tillers m$^{-2}$ were recorded 25 t BC ha$^{-1}$ followed by 50 t BC ha$^{-1}$ that were statistically similar with no biochar application. Plant height increased by increasing BC application rate from 0 to 25 t ha$^{-1}$ and then increased rapidly when BC application rate was further increased to 50 t ha$^{-1}$ in combination with 10 t FYM ha$^{-1}$.

Data on phenological and growth parameters of wheat as affected by FYM application are shown in Table 4. Incorporation of FYM at the rate of 10 t ha$^{-1}$ was superior as compared to 5 t FYM ha$^{-1}$ on all growth and phenological parameters. Higher rate of FYM delayed booting, anthesis and milk stage in wheat and higher days to booting, anthesis and milk stage were observed in plots treated with 10 t FYM ha$^{-1}$ as compared to 5 t FYM. Likewise, maturity was delayed by the application of 10 t FYM ha$^{-1}$ as compared to 5 t FYM ha$^{1}$. Incorporation of FYM increased wheat spike and tillers m$^{-2}$ in linear manner. Moreover, FYM application at the rate of 10 t ha$^{-1}$ resulted in higher plant height and wheat leaf area as compared to 5 t FYM.

Data regarding growth and phenology parameters as affected by nitrogen application are shown in Table 5. Nitrogen fertilization delayed booting and higher days to booting were counted in plots treated with 120 kg N ha$^{-1}$ as compared to 60 kg N ha$^{-1}$ and control plots. Higher rate of N (120 kg ha$^{-1}$) delayed anthesis and milk stage than lower rate of N (60 kg ha$^{-1}$). Days to maturity increased as N application rate was increased from 60 to 120 kg ha$^{-1}$. Likewise, increase in tillers m$^{-2}$ were recorded as N increased from 60 to 120 kg ha$^{-1}$ and more tillers were produced when N was applied at the rate of 120 kg ha$^{-1}$ (465) than 60 kg N ha$^{-1}$ (438). Furthermore, higher number of spikes was recorded from 120 kg N ha$^{-1}$ (459) than 60 kg N ha$^{-1}$ (438). Application of N increased plant height and leaf area. Plots that received N at the rate of 120 kg ha$^{-1}$ produced taller plants and higher leaf area than plots that received no or 60 kg ha$^{-1}$ N.

The interactions for BC X FYM, BC x N, FYM x N and BC x FYM x N were significant for (Table 6). Booting and anthesis delayed by BC application from 0 to 25 t ha$^{-1}$ under both N levels (60 or 120 kg ha$^{-1}$) however the delay in booting was more in plots treated with 25 t BC ha$^{-1}$ and 60 kg N ha$^{-1}$ (Fig. 1a). whereas anthesis was hastened when BC application increased up to 50 t ha$^{-1}$ along with 120 kg N ha$^{-1}$ compared to same level of biochar under half of N (Fig. 1b). Regarding the FYM x N interaction for days to anthesis, delay in anthesis was noted with increase in N from 60 to 120 kg ha$^{-1}$ and FYM from 5 t ha$^{-1}$ to 10 t ha$^{-1}$(Fig. 1c). Number of days to milk stage delayed by increasing BC from 0 to 25 t ha$^{-1}$ with 10 t FYM ha$^{-1}$and further increase in BC (50 t ha$^{-1}$) hastened milk stage whereas it was not influenced with incorporation of BC at 5 t FYM ha$^{-1}$ (Fig. 1d). Nitrogen and FYM interaction for milk stage indicated that delay in milk stage was more with increase in N under 5 t FYM ha$^{-1}$ as compared to 10 t FYM ha$^{-1}$(Fig. 2a). Furthermore, days to maturity prolonged as BC application increased from 0 to 50 t ha$^{-1}$ in combination with 5 t FYM ha$^{-1}$ whereas FYM incorporation at 10 t ha$^{-1}$ with increase in BC from 25 to 50 t ha$^{-1}$ resulted in quicker maturity (Fig. 2b). Maturity delayed with increasing BC application from 0 to 50 t ha$^{-1}$ along with 120 kg N ha$^{-1}$ whereas in case of 60 kg N ha$^{-1}$, the application of BC from 25 to 50 t ha$^{-1}$ hastened maturity (Fig. 2c). The interaction of BC x N for number of tillers (Fig. 2d) indicated that number of tillers enhanced linearly with increase in BC under 120 kg N ha$^{-1}$ unlike to decline in tillers under 50 t BC ha$^{-1}$ with 60 kg N ha$^{-1}$. Plant height increased with increase in BC under 10 t FYM ha$^{-1}$ whereas an initial decline in plant height was observed with 25 t BC ha$^{-1}$ and further increase in BC (50 t ha$^{-1}$) enhanced plant height under 5 t FYM ha$^{-1}$ (Fig. 3c). The significant BC x N interaction for plant height indicated that increasing BC from 0 to 25 t ha$^{-1}$ in combination with 120 kg N ha$^{-1}$ resulted in taller plants however, further increase in BC (from 25 to 50 t ha$^{-1}$) along with 60 kg N ha$^{-1}$ reduced plant height (Fig. 3d).

**Table 3. Effect of biochar levels on phonological and growth parameters of wheat.**

| Parameters | 2012 – 2013 | | | 2013 - 2014 | | | Two years mean | | |
|---|---|---|---|---|---|---|---|---|---|
| | Biochar levels (t ha$^{-1}$) | | | Biochar levels (t ha$^{-1}$) | | | Biochar levels (t ha$^{-1}$) | | |
| | 0 | 25 | 50 | 0 | 25 | 50 | 0 | 25 | 50 |
| Days to booting | 75.3 b | 77.9a | 70.2 c | 77.5 b | 80.3 a | 74.3 c | 76.3 b | 79.1 a | 72.3 c |
| L.S.D$_{(0.05)}$ | | 1.33 | | | 1.83 | | | 0.64 | |
| Days to anthesis | 95.9 a | 96.5 a | 93.7 b | 96.7 a | 100.2 a | 97.9 b | 96.3 b | 98.3 a | 95.7 c |
| L.S.D$_{(0.05)}$ | | 0.98 | | | 0.83 | | | 0.36 | |
| Days to milk stage | 106 b | 108 a | 102 c | 107 | 108 | 107 | 107 b | 108 a | 105 c |
| L.S.D$_{(0.05)}$ | | 1.09 | | | Ns | | | 0.49 | |
| Days to maturity | 163 c | 166 b | 163 a | 167 c | 174 b | 169 a | 165 c | 170 b | 166 a |
| L.S.D$_{(0.05)}$ | | 1.09 | | | 1.86 | | | 0.61 | |
| No. of tiller (m$^{-2}$) | 456 a | 440 b | 424 c | 433 c | 487 a | 469 b | 445 b | 464 a | 446 b |
| L.S.D$_{(0.05)}$ | | 11.31 | | | 18.71 | | | 6.68 | |
| No. of Spike (m$^{-2}$) | 445 a | 444 a | 431 b | 424 c | 474 a | 455 b | 434 c | 456 b | 442 a |
| L.S.D$_{(0.05)}$ | | 11 | | | 20 | | | 7.4 | |
| Leaf area | 31 | 31 | 30 | 34 | 34 | 33 | 33 | 33 | 32 |
| L.S.D$_{(0.05)}$ | | Ns | | | Ns | | | ns | |
| Plant height (g) | 112 c | 111 b | 119 a | 117 | 118 | 118 | 115 b | 114 b | 118 a |
| L.S.D$_{(0.05)}$ | | 3.82 | | | Ns | | | 1.17 | |

Means of the same category followed by different letter are significantly different from one another at 5% and 1% level of probability
ns = Non significant

**Table 4. Effect of FYM levels on phonological and growth parameters of wheat.**

| Parameters | 2013 | | 2014 | | Two years mean | |
|---|---|---|---|---|---|---|
| | FYM levels (t ha$^{-1}$) | | FYM levels (t ha$^{-1}$) | | FYM levels (t ha$^{-1}$) | |
| | 5 | 10 | 5 | 10 | 5 | 10 |
| Days to booting | 73.4 | 75.4 | 75.2 | 79.4 | 74.3 | 77.4 |
| Significance level | * | | * | | * | |
| Days to anthesis | 94.5 | 96.3 | 96.5 | 99.8 | 95.5 | 98.1 |
| Significance level | * | | * | | * | |
| Days to milk stage | 105.6 | 106.7 | 107.2 | 107.7 | 106.4 | 107.2 |
| Significance level | * | | * | | * | |
| Days to maturity | 163 | 165 | 169 | 171 | 166 | 168 |
| Significance level | * | | * | | * | |
| No. of tiller (m$^{-2}$) | 436 | 444 | 449 | 478 | 443 | 461 |
| Significance level | ** | | ** | | ** | |
| No. of Spike (m$^{-2}$) | 436 | 444 | 443 | 471 | 439 | 458 |
| Significance level | Ns | | ** | | * | |
| Leaf area | 30 | 31 | 33 | 34 | 32 | 33 |
| Significance level | * | | * | | * | |
| Plant height (g) | 112 | 116 | 117 | 118 | 115 | 117 |
| Significance level | * | | * | | * | |

*** = Significant at 5 and 1% level of probability, respectively. ns = Non significant

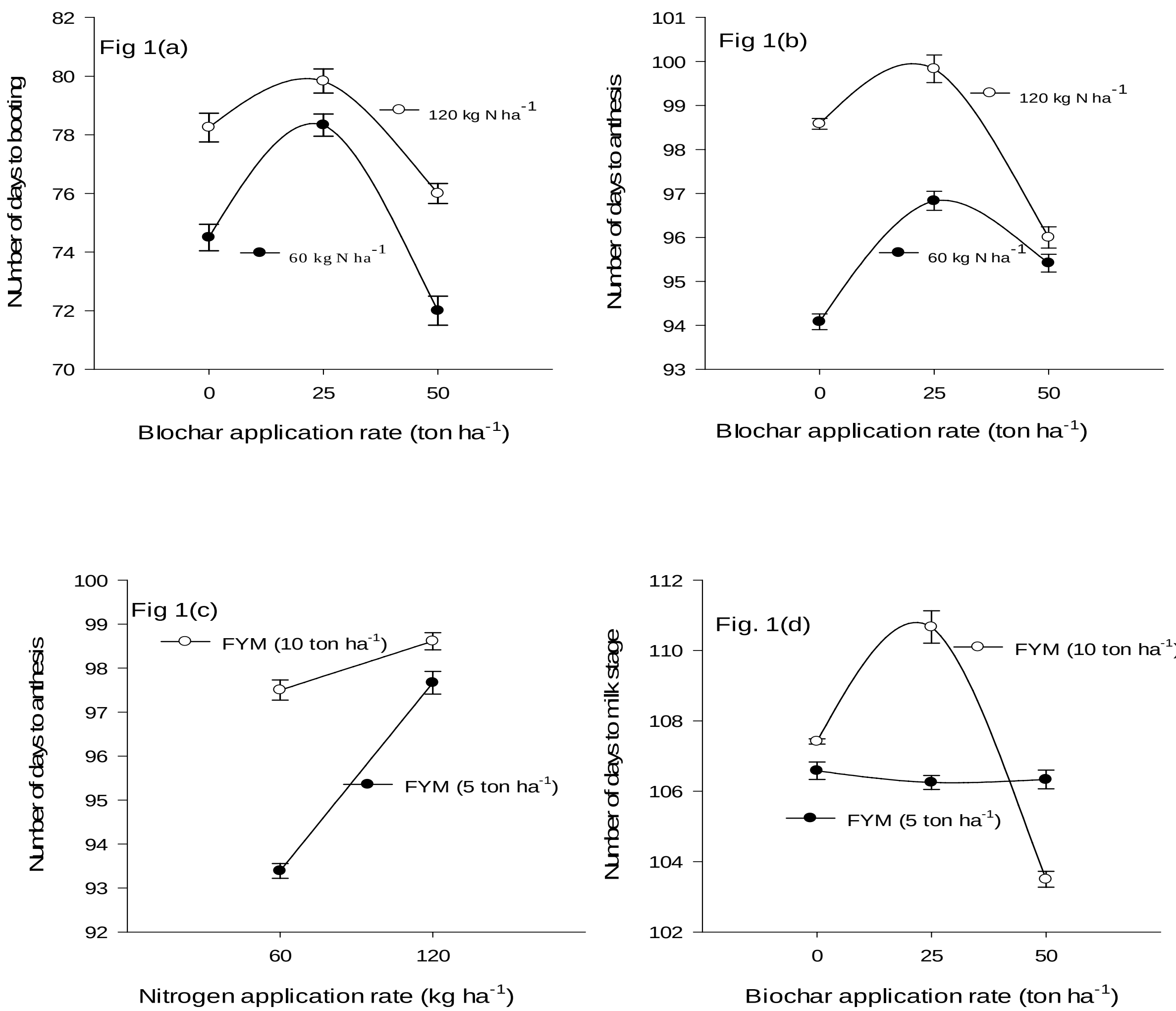


Fig. 1. (a) The BC x N interaction for number of days to wheat booting stage; (b) The BC x N interaction for number of days to wheat anthesis stage; (c) The FYM x N interaction for number of days to wheat anthesis stage; (d) The BC x FYM interaction for number of days to wheat milk stage. Note: Error bars represent the standard error of three replications.

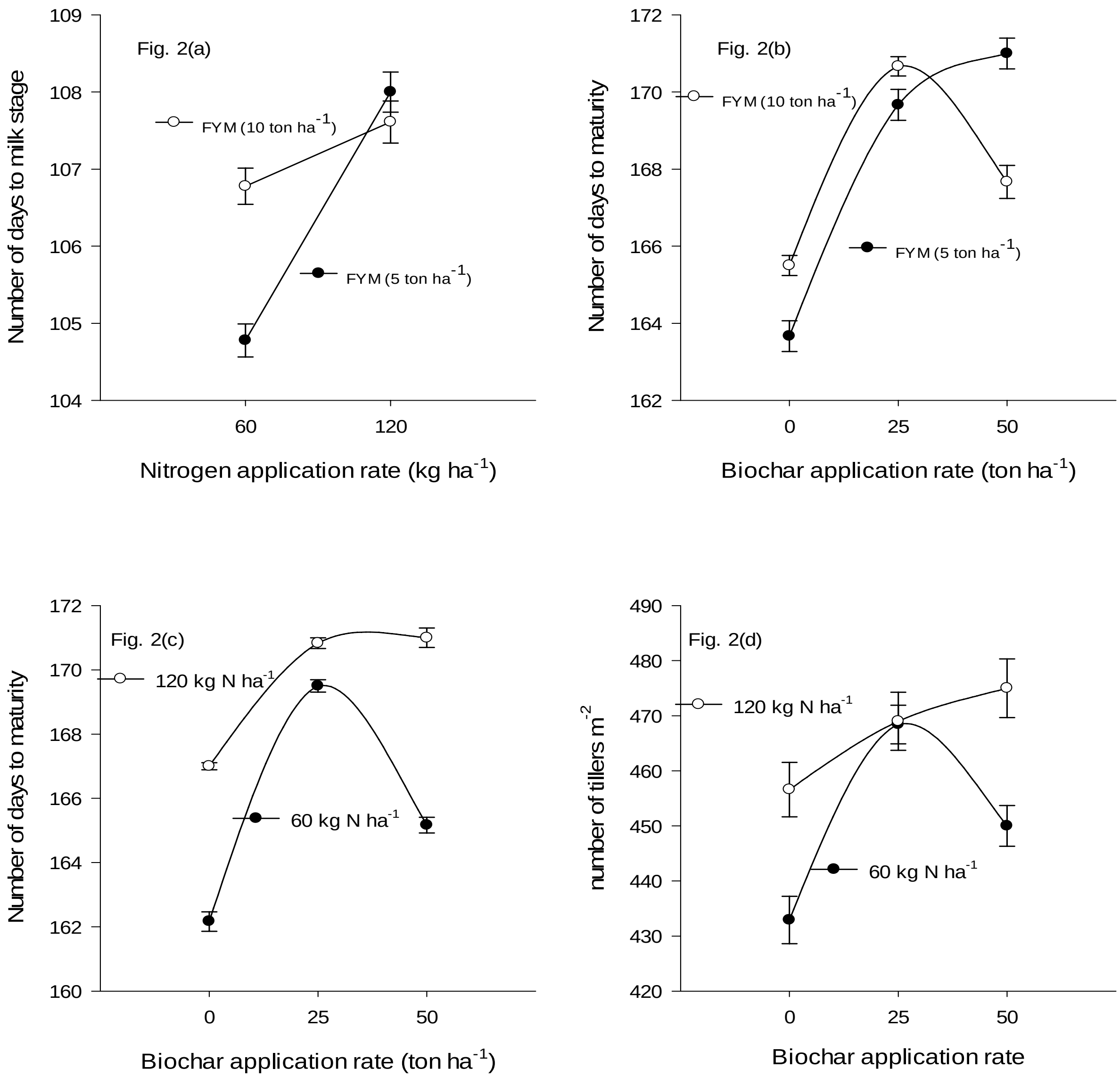


Fig. 2. (a) The FYM x N interaction for number of days to milk stage; (b) the BC x FYM interaction for number of days to maturity; (c) the BC x N interaction for number of days to maturity; (d) the BC x N interaction for tillers $m^{-2}$.
Note: Error bars represent the standard error of three replications.

**Discussion**

Biochar application delayed occurrence of various growth stages of wheat. Soil application of biochar improves nutrient use efficiency and crop growth. Slow release of nutrients by BC and higher cation exchange capacity of biochar delay plant senescence (Lehman *et al*., 2003; Uzoma *et al*., 2011; Vaccari *et al*., 2011) which may have resulted in delayed booting, anthesis and maturity. Likewise, FYM and N application plots took more days to booting, milking, anthesis and maturity of wheat. Possible reason for delay in various growth stages due to FYM application might be the availability of nutrients throughout the growth periods that resulted in delay maturity and increased growth period. Delay in maturity could be attributed to vigorous growth because more nutrients were supplied and available in FYM amended plots (Sharif *et al*., 2004). Increasing availability of more nutrients such as N improved WUE and increased duration of growth stages (Deng *et al*., 2004). Early boot stage in control plots could be attributed to nutrient deficiency in these plots due to which plants faced stress and were forced to complete life cycle early. Similar results were reported by Ali *et al*. (2011) who found early maturity and other growth stages in wheat samples collected from untreated plots. More days to 50% heading, anthesis and maturity might be due to higher leaf area duration, vegetative growth and light use efficiency with the use of nitrogenous fertilizer (Deldon, 2001; Badaruddin *et al*., 1999). Our results are supported by the finding of Badaruddin *et al*. (1999) who reported significant increase in days to 50% heading of wheat at 10 t FYM compared with control Leaf senescence could be delayed by increasing level of N which sustained leaf photosynthesis during grain filling period and extended grain filling duration (Ayoub *et al*., 1994) and thus directly affect wheat phenology. Improved nutrient availability and water holding capacity due to FYM might have extended growing period as consequences of vigorous and enhanced crop growth (Li, 2003), and thus have delayed booting, anthesis and maturity. Slow release of nutrients from FYM (Matsi *et al.*, 2003) might be an possible explanation for delayed phenology in fertilized plots. Ayoub *et al*. (1994) and Badaruddin *et al*. (1999) also reported delay in heading and maturity in fertilized plots. Increase in plant height may be due to favorable effect of N on promoting vigorous plant growth (Lloveras *et al*., 2001 and Iqtidar *et al*., 2006). Application of high rates of mineral N resulted in taller plants as compared to other treatments. This increase in plant height could be attributed to the fact that higher amounts of nitrogen trigger vigorous vegetative growth of crops (Blackshaw, 2005). Incorporation of animal manure (FYM) enhances soil mineral N status and affect chlorophyll content in wheat through better N absorption (Houles *et al*., 2007) and thus might had improved wheat leaf area. N-fertilization significantly stimulates growth of leaf, assimilation capacity due to higher photosynthetic surface area and thus leaf area (Khan *et al*., 2008). Our results are confirmed by the finding of Deldon (2001) who observed reduction in leaf area due to poor N-fertilization. Accordingly, Kibe *et al*. (2006) also recorded the higher leaf area and leaf area index in N-fertilized plots over control.

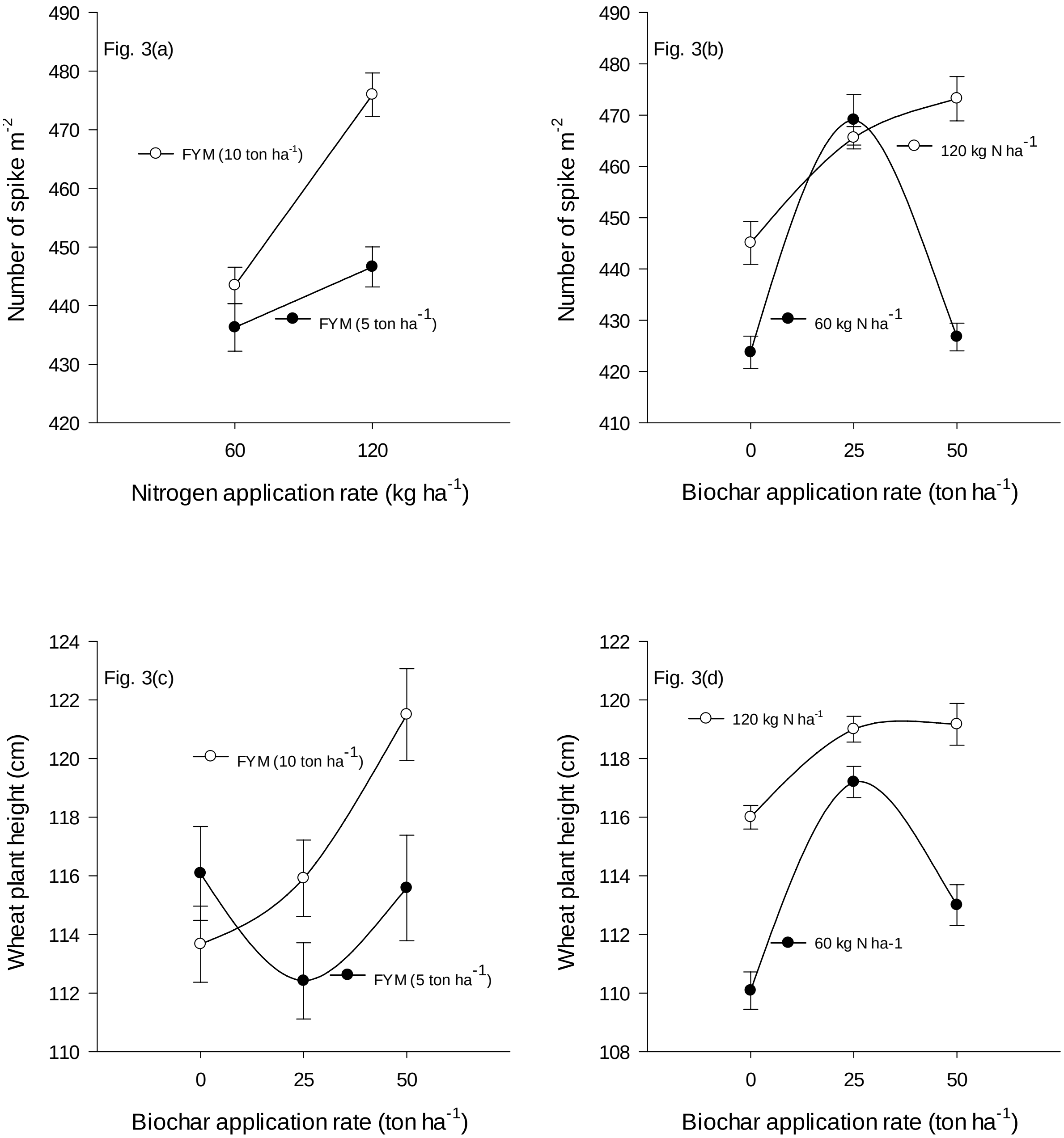


Fig. 3. (a) The FYM x N interaction for number of spike $m^{-2}$; (b) The BC x N interaction for number of spike $m^{-2}$; (c) The BC x FYM interaction for wheat plant height ; (d) The BC x N interaction for wheat plant height.

Note: Error bars represent the standard error of three replications.

**Table 5. Effect of N levels on phonological and growth parameters of wheat.**

| Parameters | 2012-2013 Nitrogen levels (kg ha$^{-1}$) | | 2013-2014 Nitrogen levels (kg ha$^{-1}$) | | Two years mean Nitrogen levels (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | 60 | 120 | 60 | 120 | 60 | 120 |
| Days to booting | 73.3 | 75.5 | 76.7 | 78.0 | 75.0 | 76.8 |
| Significance level | * | | * | | * | |
| Days to anthesis | 94.2 | 96.5 | 96.6 | 99.7 | 95.4 | 98.1 |
| Significance level | * | | * | | * | |
| Days to milk stage | 105.0 | 107.3 | 106.5 | 108.3 | 105.7 | 107.8 |
| Significance level | * | | * | | * | |
| Days to maturity | 163 | 165 | 169 | 171 | 166 | 168 |
| Significance level | * | | * | | * | |
| No. of tiller (m$^{-2}$) | 425 | 455 | 451 | 475 | 438 | 465 |
| Significance level | ** | | * | | ** | |
| No. of Spike (m$^{-2}$) | 425 | 455 | 450 | 463 | 438 | 459 |
| Significance level | * | | * | | * | |
| Leaf area | 30 | 32 | 33 | 34 | 32 | 33 |
| Significance level | * | | * | | * | |
| Plant height (g) | 110 | 118 | 117 | 119 | 113 | 118 |
| Significance level | * | | * | | * | |

*** = Significant at 5 and 1% level of probability, respectively. ns = Non significant

**Table 6. Interactive effects of biochar, FYM and nitrogen on phonological and growth parameters of wheat.**

| Parameters | BC x FYM | BC x N | FYM x N | BC x FYM x N |
|---|---|---|---|---|
| Days to booting | Ns | Figure 1a | ns | ns |
| Days to anthesis | Ns | Figure 1b | Figure 1c | ns |
| Days to milk stage | Figure 1d | Ns | Figure 2a | ns |
| Days to maturity | Figure 2b | Figure 2c | ns | ns |
| No. of tiller (m$^{-2}$) | Ns | Figure 2d | ns | ns |
| No. of spike (m$^{-2}$) | Ns | Figure 3b | Figure 3a | ns |
| Leaf area | Ns | ns | ns | ns |
| Plant height (g) | Figure 3c | Figure 3d | ns | ns |

ns = Non significant

## Conclusion

Biochar application convincingly improved wheat growth in comparison to no BC plots. Biochar application in Pakistan does offer some opportunities in agriculture but interpretation of pilot field scale trials needs to be carefully considered before more extensive trials are considered. There is also a need for more awareness and education of farmers in order to manage the application of biochar in an integrated manner. Application of biochar in agricultural land in Pakistan is still in its infancy. There is great potential in production of biochar in Pakistan due to the large amounts of organic agricultural waste that is being generated. Suitable feedstock for biochar includes rice straw, rice husk, residue from sugarcane industry, livestock manure and poultry litter. Whilst other sources of organic waste such as wheat straw, maize stalks and cotton stalks could be useful as feedstock for biochar, at the present time there is much competition for use of such feedstock as animal feed or as source of bio-energy.

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## References

Ali, K., F. Munsif, I. Uddin, A. Khan and N. Khan. 2012. Maize penology as affected by tillage practices and nitrogen sources. *Agric. Sci. Res. J.*, 2(8): 453-458.

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, M.T. Jan, M. J. Khan and D. L. Jones. 2015. Integrated use of biochar: a tool for improving soil and wheat quality of degraded soil under wheat-maize cropping pattern. *Pak. J Bot*., 47(2): In print.

Alvarez, R.H., S. Steinbach, S.M. Grigera, E. Cartier, G. Obregon, S. Torri and R. Garcia. 2004. The balance sheet method as a conceptual framework for nitrogen fertilization of wheat in Pampean agroecosystem. *Agron. J*., 96: 1050-1 057.

Anonymous. 2011. Agriculture Statistics of Pakistan. Govt. of Pakistan, Ministry of Food, Agriculture and Livestock, Economic Wing, Islamabad.

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

Arif, M., K. Ali, F. Munsif, W. Ahmad, A. Ahmad and K. Naveed. 2012b. Effect of biochar, FYM and nitrogen on weeds and maize phenology. *Pak. J. Weed Sci. Res*., 18(4): 475-484.

Ayoub, M., S. Guertin, S. Lussier and D.L. Smith. 1994. Timing and level of nitrogen fertilizer effects on spring wheat yield in eastern Canada. *Crop Sci*., 34: 748-756.

Ayoub, M., S. Guertin, S. Lussier and D.L. Smith. 1994. Timing and level of nitrogen fertilizer effects on spring wheat yield in eastern Canada. *Crop Sci*., 34: 748-756.

Badruddin, M., M.P. Reynolds and O.A.A. Ageeb. 1999. Wheat management in warm environments: Effect of organic and inorganic fertilizers, irrigation frequency and mulching. *Agron. J*., 91: 975-983.

Blackshaw, R.E. 2005. Nitrogen fertilizer, manure and compost effects on weed growth and competition with spring wheat. *Agron. J*., 97: 1612-1621.

Blair, N.R., D. Faulkner, A.R. Till and P.R. Poult. 2006. Long-term management impacts on soil C, N and physical fertility. *Soil and Tillage Res*., 91: 30-38.

Delden, A.V. 2001. Yield and growth components of potato and wheat under organic nitrogen management. *Agron. J*., 93: 1370-1385.

Deng, X.P., L. Shan, H. Zhang and N.C. Turner. 2004. New directions for a diverse planet. In: Proceeding of the 4th International Crop Science Congress, Sep. 26-1st Oct., 2004, *Brisbane, Australia*.

Dong, J., H. Hengsdijk, D. Ting-Bo, W. Boer, J. Qi and C.W. Xing. 2006. Long-term effects of manure and inorganic fertilizers on yield and soil fertility for a winter wheat-maize system in jiangsu, China. *Pedosphere*., 16: 25-32.

Gajri, P.R., V.K. Arora and M.R. Chaudhary. 1994. Maize growth responses to deep tillage straw mulching and farmyard manure in a coarse textured Soils of NW India. *Soil Use and Management*, 10: 15-20.

Hammad., H.M., A. Khaliq, A. Ahmad, M. Aslam, T. Khaliq, S.A. Wajid, A. Hussain, M. Usman, W. Nasim, W. Farhad and R. Sultana. 2010. Influence of organic manures on weed dynamics and wheat productivity under low rainfed area. *J. Crop and Environ.,* 1(1): 13-17.

Hossain, S.M.A., A.M.A. Kamal, M.R. Islam and M.A. Mannan. 2002. Effects of different levels of chemical and organic fertilizers on growth, yield and protein content of wheat. *J. Biol. Sci*., 2: 304-306.

Hussain, N. and M.B. Khan. 2000. Effect of Farmyard manure on growth and yield of wheat (*Triticum aestivum*) on saline soil. *J. Res. Sci*., 11: 31-4

Iqtidar, H., K.M. Ayyaz and K.E. Ahmad. 2006. Bread wheat varieties as influenced by different nitrogen levels. *J Zhejiang Univ. Sci*., 7: 70-78.

Jan, M.T., M.J. Khan, A. Khan, M. Arif, M. Shafi and Farmanullah. 2010. Wheat nitrogen indices response to nitrogen source and application time. *Pak. J. Bot*., 42(6): 4267-4279.

Khan, A., M.T. Jan, K.B. Marwat and M. Arif. 2009. Organic and inorganic nitrogen treatments effects of plant and yield attributes of maize in a different tillage system. *Pak. J. Bot*., 41: 99- 108.

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

Kibe, A.M., S. Singh and N. Kalra. 2006. Water–nitrogen relationships for wheat growth and productivity in late sown conditions. Agric. *Water Manage*., 84: 221-228.

Kundu, S., R. Bhattacharyya, V. Parkash, B. N. Ghosh and H.S. Gupta. 2007. Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the India Himalayas. *Soil and Tillage Res*., 92: 87-95.

Lehmann. J., J.P.J. de 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 and 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.

Lloveras, J., A. Lopez, J. Ferran, S. Espachs and J. Solsona. 2001. Breadmaking wheat and soil nitrate as affected by nitrogen fertilization in irrigated Mediterranean conditions. *Agron. J*., 93: 1183-1190.

Major, J., M. Rondon, D. Molina, S.J. Riha and J. Lehmann. 2010. Maize yield and nutrition after 4 years of doing biochar application to a *Colombian savanna* oxisol. *Plant and Soil*, 333: 117-128.

Manna, M.C., A. Swarup, R.H. Wanjari, H.N. Ravankar, B. Mishra, M.N. Saha, Y.V. Singh, D.K. Sahi and P.A. Sarap. 2005. Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops Res*., 93: 264-280.

Matsi, T.A., S. Lithourgidis and A.A. Gagianas. 2003. Effect of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. *Agron. J*., 95: 592-596.

Melaj, M.A., H.E. Echeverria, S.C. Lopez, G. Studdert, F. Andrade and N.O. Barbaro. 2003. Timing of nitrogen fertilization in wheat under conventional and no-tillage system. *Agron. J*., 95: 1525-1531.

Mossedaq. F. and D.H. Smith. 1994. Timing nitrogen application to enhance spring wheat yields in a Mediterranean climates. *Agron. J*., 86: 221-226.

Rehman, S., S.K. Khalil, F. Muhammad, A. Rehman, A. Z. Khan, Amanullah1, A.R. Saljoki, M. Zubair and I.H. Khalil. 2010. Phenology, leaf area index and grain yield of rainfed wheat influenced by organic and inorganic fertilizer. *Pak. J. Bot.,* 42(5): 3671-3685.

Rondon, M.A., J. Lehmann, J. Ramirez and M. Hurtado. 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with biochar additions. *Bio and Fertility Soils*, 43: 699-708.

Shah, Z. and M.I. Ahmad. 2006. Effect of integrated use of farm yard manure and urea on yield and nitrogen uptake of wheat. *J. Agric. and Bio. Sci.*, 1(1): 60-65.

Sharif, M., M. Ahmed, M.S. Sharir and R.A. Khattak. 2004. Effect of organic and inorganic fertilizers on the yield and yield components of maize. *Pak. J. Agri. Engg. Vet. Sci*., 20(1): 11-15.

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

Vaccari, F. P., S. Baronti, E. Lugata, L. Genesio, S. Castaldi, S. Fornasier and F. Miglietta. 2011. Biochar as a strategy to sequester carbon and increase yield in durum wheat. *Eur. J. Agron.,* 34: 231-238.

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