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IMPROVEMENT IN MAIZE (*ZEA MAYS* L) GROWTH AND QUALITY THROUGH INTEGRATED USE OF BIOCHAR

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Abstract

To evaluate the potential use of biochar in crop production, two years experiments were conducted in 2013 and 2014. The experiment 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 (75 and 150 kg ha^{-1}). A control treatment (no application of either treatment) was included in the experiment for comparison. All the treatments were replicated three time in RCB design at New Developmental Farm of the University of Agriculture Peshawar Pakistan. Experimental evidence indicated that BC, FYM and N significantly delayed all growth stages of maize such as days to taseling, silking and maturity. Biochar application significantly improved maize oil content by 12 and 29% over no BC plots (plots receiving other treatments) and control plots respectively. An increase of 27% and decrease of 11% was observed in maize protein and starch content in BC treated plots over control. FYM application of 10 ton ha^{-1} improved maize protein content by 12% but reduced oil content by 15% over 5 ton FYM ha^{-1}. Likewise, N application resulted in higher protein content and starch content but reduced oil content significantly. Overall, application of BC showed convincing results as sole application of N and FYM, however, problems associated with BC production in Pakistan are needed to be addressed in future research.

Key words: Biochar, C:N ratio, Carbon sequestration and crop production.

Introduction

Nitrogen is one the significant factor that affect growth, development, yield and quality of maize crop. The repeated use of inorganic N fertilizers as agent for enhancing yield is unavoidable since green revolution due to its great impact (Akbar *et al*., 1999; Khaliq *et al*., 2009, Ali *et al*., 2012; Habtegebrial *et al*., 2007). However, this increase had decline both the quality of soil health and grain produced (Lehmann *et al*., 2007). Furthermore, the complete reliance on in-organic fertilizers also increased the cost of production, the excessive use of the inorganic N fertilizer not only accelerate soil degradation but also created many environmental hazards (Ali *et al*., 2012; Liu *et al*., 2010). Thus the organic fertilizer use or the integration of both organic and inorganic application is the pre- requisite not only for enhancing the quality of crop production but can also ensure the soil sustainability and solution to the environmental hazardous. The organic and other form of nitrogen uptake from soil by the plants are reported by the recent studies (Jaliya *et al*., 2008; Lungu *et al*., 2008) encourage the organic application of nutrients to the soil (Khan *et al*., 2008; Arif *et al*., 2012). The greater fertilizer use efficiency is obtained under the combine use of both organic and inorganic materials to soil (Sharif *et al*., 2002). The rapid decomposition of organic material under wet tropical condition not only increase the dosage of material but also enhace cost on application of organic materials each year subsequently increases global warming (Lehmann *et al*., 2003; Sohi *et al*., 2008). To tackle such hazarods, the application of more resilient organic material like biochar can be applied to the soil along the other organic or inorganic material (Lehmann *et al*., 2007). It is reported from previous studies under different environments that application of biochar had enhanced soil physical chemical properties and microbial characteristics i.e., soil pH, soil aggregation, soil water holding capacity and soil biology population (Fageria & Baligar, 2005). Steiner *et al*. (2007) reported that plant nutrients uptake and soil productivity enhanced with long term biochar application. Improvement in maize yield under biochar application was also reported by Islami *et al*. (2011a) and Steiner *et al*. (2007) and Widowati *et al*. (2011) investigated that increase in yield was due to the lower nitrogen losses from mineral fertilizer under boichar application that also enhanced soil CEC (Chan *et al*., 2008; Masulili *et al*., 2010) or due to the inhibition of N-NH4 to N-NO_3 from mineral N fertilizer (Widowati *et al*., 2011). The study is initiated with the aim to determine whether the integration of biochar with inorganic and organic N can decrease the total nitrogen requirement for enhancing growth, yield and quality of maize crop. The hypothetical statement of the experiment is that "under no significant decline in nitrogen loss with application of biochar, more nitrogen will be needed for the same yield under no biochar application.

Material and Methods

In this experiment we have studied the integrated use of biochar, FYM and mineral nitrogen from improving maize growth and quality. These experiments was based on the hypothesis (1), Biochar could be used as tool for improving crop productivity and quality (2) Biochar did not effect maize growth and quality. Two level of FYM and N were used in the experiment to insure timely availability of all essential nutrients and mineralization of added biochar with the help of soil microbes.

Soil characteristics: Soil was collected from the top layer (0-10 cm depth) of the New Developmental Farm of the University of Agriculture, Peshawar located at 34.1°'21"N, 71°28'5"E. The soil has a clay loam texture. Immediately after collection, the soil was transferred to the laboratory in gas permeable bags where it was sieved to pass 2 mm to remove stones, plant roots and earthworms. The basic properties of the soil are presented in Table 1.

Experimental site: Experiments were carried out during winter 2012-13 ad 2013-14 at the Agronomy Farm of the University of Agriculture, Peshawar positioned at 34.1°'21"N, 71°28'5"E. The mean annual rainfall and mean maximum temperature of the experimental location is 360 mm and 40°C, respectively with very hot in summer in the months of May to August to harsh cold in winter in the months of December to February. More rainfall occurs in summer usually in the months of July-August than winter in the months March.

Nutrients analysis of biochar and FYM: The biochar 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 biochar 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 5g of sieved sample and 10ml 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 and Schwab, 1977). Phosphorus was read as Spectrophotometer after colour development and potash on Flame Photometer. For Ca and Mg, solution was directly read on Atomic Absorption Spectrophotometer (Perkin Elmer Model 2380, USA).

Experimental design: The study consisted of three levels of biochar (0, 25 & 50 t/ha), two levels of FYM (5 & 10 t/ha) and two levels of fertilizer-N (60 & 120 kg/ha) supplied as urea together with a control treatment (no biochar, FYM or fertilizer-N). Biochar was applied to wheat crop of the first year while its residual effect was investigated in the second year of the experiment. Detail of the treatments and their combination along with abbreviations are given in Table 2. Animal manure was applied at the time of sowing whereas 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 per ha as a basal dose. The FYM was obtained from the University of Agriculture Peshawar dairy farm and the biochar was produced from Acacia (e.g. A. nilotica (Linn.) Delile) using traditional methods employed in the region. Physico-chemical characteristics of the FYM and biochar are shown in Table 2.

Experimental layout: The experiment with three replications was carried out in randomize complete black design. The treatment plots were 4.0 m x 4.5 m in size with strong ridges placed around each plot for delineation and to prevent biochar migration. Row-to-row distance was 75 cm. The field was ploughed twice 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. Maize (*Zea mays*, cv. Azam) was sown at a rate of 40 kg ha^{-1} on June 21st, 2013 in first year and June 25th 2014 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.

Table 1. Physio-chemical properties of soil used in these experiments are given below. 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 μScm^{-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 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

Procedure for data recording and tissue analysis: To evaluate the effect of different organic and inorganic forms of nutrients on the growth of maize (*Zea mays*, Cv. Azam). The experiment consisted of 3 different nutrients sources namely: (1) Biochar, (2) FYM and (3) Urea (Nitrogen) (Table 2). After sowing of maize seed and complete application of experimental treatments, days to taseling, silking and maturity were counted from date of sowing to 50% completion of respective growth stage. Plant height was recorded by measuring the height of 5 plants from base to top of the plant in each experimental unit. Leaf area was calculated by measuring the length and width of the leaf and multiplying by correction factor. Maize grains were oven dried after harvest of the crop. The grains were analysed by a Near Infrared (NIR) spectrometer using the Infrared TM Foss 1241 Grain Analyzer (Eden Prairie, MN) Crude protein determination utilized the Kjeldahl method (GB-2905-82) and an automatic nitrogen analyzer (Foss Kjeltec TM 2300, N6.25). Crude starch was determined byacetic acid-calcium chloride and polarization (GB-5006-85) using samples in which sugar was removed (Li, 1991) and crude fat (oil content) utilized the Soxhlet method (GB-2906-82) and a fat analyser (Foss Soxtec Avanti 2050, Foss Analytical AB, Hoeganaes, Sweden). Chemical values were analysed (n¼3/sample) based on sample dry weight (%). The oil content was measured by NMR (Nuclear Magnetic Resonance, Minispec MQ20; Bruker, Ettlingen, Germany), and the spectra of intact samples were canned by NIRS (VECTOR 22/N Fourier Transform Near Infrared Spectrometer; Bruker).

Table 3. Effect of biochar application levels on phenological and qualitative parameters of maize in 2013 and 2014.

Parameters	2013			2014			Two years mean		
	Biochar levels (ton ha^{-1})			Biochar levels (ton ha^{-1})			Biochar levels (ton ha^{-1})		
	0	25	50	0	25	50	0	25	50
Days to taseling	47.8 c	49.0 b	50.9 a	49.4 b	52.0 a	52.8 a	48.6 c	50.5 b	51.8 a
L.S.D$_{(0.05)}$		**0.97**			**1.33**			**0.46**	
Days to silking	57.1 c	59.0 b	60.9 a	62.6 b	63.9 ab	64.5 a	59.8 c	61.4 b	62.7 a
L.S.D$_{(0.05)}$		**0.86**			**1.23**			**0.42**	
Days to maturity	87.5 b	91.6 a	92.8 a	99.2 c	100.8 b	103.0 a	93.3 c	96.2 b	97.9 a
L.S.D$_{(0.05)}$		**1.61**			**1.29**			**0.58**	
Plant height	190 c	199 b	217 a	203 c	216 b	234 a	197 c	207 b	226 b
L.S.D$_{(0.05)}$		**7.83**			**7.35**			**3.02**	
Leaf area	3160	3077	3735	3698	3683	3520	3429 a	3380 b	3160 b
L.S.D$_{(0.05)}$		**ns**			**Ns**			**63.56**	
1000 grain weight (g)	258 c	330 b	356 a	222	238	224	240 b	285 a	290 a
L.S.D$_{(0.05)}$		**15.48**			**Ns**			**6.9**	
Grain protein content	8.20 c	8.28 b	8.66 a	8.37 c	8.52 b	8.95 a	8.28 c	8.40 b	8.80 a
L.S.D$_{(0.05)}$		**0.08**			**0.10**			**0.04**	
Grain oil content	3.52 b	3.33 c	4.07 a	3.69 b	3.63 b	4.41 a	3.60 c	3.48 b	4.24 a
L.S.D$_{(0.05)}$		**0.14**			**0.22**			**0.07**	
Grain starch content	64.5 a	61.2 ab	58.0 b	81.3 a	75.5 b	77.9 b	72.9 a	68.4 b	67.9 b
L.S.D$_{(0.05)}$		**5.12**			**4.40**			**1.90**	

Means of the same category followed by different latter are significantly different from one another at 5% and 1% level of probability
*,** = Significant at 5 and 1% level of probability, respectively
ns = Non-significant

Results

Effect of Biochar on maize growth and quality: Data on growth and quality parameter of maize are given in Table 3. Biochar significantly affected growth and quality parameters of maize. Biochar application prolonged taseling, silking and maturity of maize in comparison with plots having no biochar. It extended taseling during both years with little difference between the 25 and 50 t BC ha^{-1} (Table 1). Likewise, biochar application also delayed silking and maturity over control. Silking and maturity were later in plots treated with 50 ton ha^{-1} BC followed by 25 ton ha^{-1} while they were faster in no BC plots. Plants were taller in biochar treated plots as compared to no biochar plots. Maize leaf area was inversely affected by BC application and plots with no BC amendments produced higher leaf area. Thousand grain weight showed positive response to BC addition. Maize grains attained more weight with application of 50 ton BC ha^{-1} followed by 25 ton BC ha^{-1} whereas no BC plots produced lighter grains. Furthermore, the addition of BC also significantly affected protein, starch and oil contents of maize grain. Biochar application improved protein and oil contents of maize grains as compared to no BC plots. Higher oil and protein contents were recorded in plots treated with 50 ton BC ha^{-1} followed by 25 ton BC ha^{-1}. Plots with no BC resulted in lower protein and oil contents. However, starch content decreased with increasing level of BC application. Plots with no biochar application recorded higher starch content as compared to plots amended with 25 or 50 t BC ha^{-1}.

Effect of FYM on maize growth and quality: FYM significantly affected days to taseling, silking and maturity of maize during both years of the experiments (Table 4). FYM application at the rate of 10 t ha^{-1} delayed taseling, silking and maturity as compared to 5 ton ha^{-1} during both years. The difference between two levels of FYM (5 and 10 ton ha^{-1}) was much evident for days to taseling and silking while it was minute for days to maturity. Plots amended with 10 ton FYM ha^{-1} extended taseling, silking and maturity than 5 ton FYM ha^{-1} during both years. Similarly, plants were taller with application of FYM at the rate of 10 ton ha^{-1} as compared to 5 ton FYM. Plots amended with 10 ton FYM ha^{-1} produced significantly higher leaf area, grain weight and protein content. However, maize oil content was not significantly affected by FYM and grain starch content showed decreasing trend with increasing level of FYM. Starch content decreased with increase in FYM rate from 5 to 10 t ha^{-1} during both years.

Effect of Nitrogen on maize growth and quality: Nitrogen levels caused significant variation in maize growth parameters such as taseling, silking and maturity (Table 5). Application of N at the rate of 150 kg ha^{-1} significantly delayed taseling, silking and maturity in comparison with 75 kg N ha^{-1} during both years. In addition, maize plants were taller in plots fertilized with 150 kg N ha^{-1} as compared to 75 kg N ha^{-1}. Leaf area was higher at higher level of nitrogen and more leaf area was measured in 150 kg N ha^{-1} treated plots as compared to 75 kg N ha^{-1}. Thousand grain weight improved with increasing level of N. Higher grain weight and protein content was recorded in 150 kg N ha^{-1} treated plots while application of 75 kg N ha^{-1} resulted in lower grain weight and protein content. In contrast, maize oil and starch content showed declining response to increasing level of nitrogen and were lower in plots treated with higher N fertiliser (150 kg N ha^{-1}) than lower N application (75 kg N ha^{-1}).

Table 4. Effect of FYM application levels on phenological and qualitative parameters of maize in 2013 and 2014.

Parameters	2013		2014		Two years mean	
	FYM levels (ton ha^{-1})		FYM levels (ton ha^{-1})		FYM levels (ton ha^{-1})	
	5	10	5	10	5	10
Days to taseling	48.17	50.33	50.67	52.17	49.42	51.25
Significance level	*		*		*	
Days to silking	57.67	60.33	62.89	64.56	60.28	62.44
Significance level	*		*		*	
Days to maturity	98.72	91.56	100.3	101.6	95.03	96.61
Significance level	*		*		*	
Plant height	197	208	213	222	205	215
Significance level	*		*		**	
Leaf area	3112	3228	3575	3835	3354	3532
Significance level	ns		ns		ns	
1000 grain weight (g)	301	328	230	226	265	277
Significance level	**		*		*	
Grain protein content	8.29	8.47	8.49	8.74	8.39	8.60
Significance level	*		*		*	
Grain oil content	3.58	3.70	3.90	3.92	3.74	3.81
Significance level	*		*		*	
Grain starch content	65.0	57.38	83.6	72.8	74.3	65.1
Significance level	**		*		**	

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

Table 5. Effect of nitrogen application levels on phenological and qualitative parameters of maize in 2013 and 2014.

Parameters	2013		2014		Two years mean	
	Nitrogen levels (kg ha^{-1})		Nitrogen levels (kg ha^{-1})		Nitrogen levels (kg ha^{-1})	
	75	150	75	150	75	150
Days to taseling	47.4	51.1	49.8	53.1	48.6	52.1
Significance level	*		*		*	
Days to silking	56.9	61.1	62.9	64.6	59.9	62.8
Significance level	*		*		*	
Days to maturity	88.3	92.9	100.1	101.9	94.2	97.4
Significance level	*		*		*	
Plant height	190	215	207	229	199	222
Significance level	*		*		*	
Leaf area	3031	3331	3649	3762	3340	3547
Significance level	*		ns		ns	
1000 grain weight (g)	314	315	229	227	272	271
Significance level	ns		ns		ns	
Grain protein content	8.33	8.63	8.60	8.83	8.46	8.92
Significance level	*		*		*	
Grain oil content	3.78	3.50	4.07	3.74	3.93	3.62
Significance level	*		*		*	
Grain starch content	63.8	58.7	79.0	77.5	71.4	68.1
Significance level	*		*		*	

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

Interactions: The BC x N, BC x FYM, FYM x N and BC x FYM x N interactions for all parameters are given in Table 6. The BC x FYM interaction is presented in figure 1a. Linear increase in days to taseling was observed by increasing BC application rate form 0 to 50 ton ha^{-1} in plots amended with 10 ton FYM ha^{-1}. Plots that received FYM at the rate of 5 ton ha- delayed taseling as BC application rate was increased from 0 to 25 ton ha^{-1} and no significant change occurred by further increasing BC application rate to 50 ton ha^{-1}. Taseling was delayed as BC application rate was increased from 0 to 25 ton ha^{-1} and further increase in BC did not induce significant change in taseling under 150 kg N ha^{-1} . Delay in taseling showed an increasing trend as BC application rate was increased from 0 to 50 ton ha^{-1} in plots fertilized with 60 kg N ha^{-1} (Fig. 1b). Taseling was delayed in as N application rate was increased from 75 to 150 kg ha^{-1} at both level of FYM and higher days to taseling were counted in plots treated with 10 ton FYM ha^{-1} along with 75 kg N ha^{-1} (Fig. 1c).

Table 6. The BC x FYM, BC x N, FYM x N and BC x FYM x N interactions for phenological and qualitative parameters of maize.

Parameters	BC x FYM	BC x N	FYM x N	BC x FYM x N
Days to taseling	Fig. 1a	Fig. 1b	Fig. 1c	ns
Days to silking	Fig. 1d	Fig. 2a	Fig. 2b	ns
Days to maturity	Fig. 2c	Fig. 2d	ns	ns
Plant height	Fig. 3a	Fig. 3b	ns	ns
Leaf area	ns	ns	ns	ns
1000 grain weight (g)	ns	ns	ns	ns
Grain protein content	Fig. 3c	3d	ns	ns
Grain oil content	Fig. 4a	Fig. 4b	Fig. 4c	ns
Grain starch content	Fig. 4d	ns	ns	ns

ns = Non-significant

Moreover, linear increase in days to silking was noted as BC application was raised from 0 to 50 ton ha^{-1} in plots that had received FYM at the rate of 10 ton ha^{-1}. In contrast, plots received 5 ton FYM ha^{-1} resulted in more days to silking as BC application rate increased from 0 to 25 ton ha^{-1} and further increase in BC application rate did not induce significant change in silking of maize (Fig. 1d). Application of N at the rate of 150 kg ha^{-1} resulted in more days to silking at all three level of BC as compared to 75 kg N ha^{-1} (Fig. 2a). Linear increase in days to silking was observed as BC application rate increased from 0 to 50 ton ha^{-1} in plots fertilized with 75 kg N ha^{-1}. The FYM x N interaction is shown in figure 2b. Days to silking were increased as N rate increased from 75 to 150 kg ha^{-1} under both level of FYM (5 and 10 ton ha^{-1}) and higher days to silking were counted in plots treated with 150 kg N ha^{-1} along with 10 ton FYM ha^{-1} (Fig. 2b). Maturity was delayed as N application rate was increased from 75 to 150 kg N ha^{-1} in plots treated with 10 ton FYM ha^{-1} (Fig. 2c). As BC application rate increased from 0 to 50 ton ha^{-1} maturity was delayed in plots treated with 150 kg N ha^{-1}. Plots fertilized with 75 kg N ha^{-1} delayed maturity when BC rate was raised up to 25 ton ha^{-1} and further increasing BC application rate did not delayed maturity significantly (Fig. 2d). Maize plant height did not change significantly by changing BC application rate from 0 to 25 ton ha^{-1} however, as BC rate was raised to 50 ton ha^{-1} maize plant height increased convincingly in plots treated with 5 ton FYM ha^{-1}. In contrast, Maize plant height increased as BC rate was increased to 25 ton ha^{-1} and further increasing BC rate to 50 ton ha^{-1} did not induce significant increase maize plant height in plots that received 10 ton FYM ha^{-1} (Fig. 3a). Maize plant height increased by increasing BC rate to 25 ton ha^{-1} and then decreased drastically when BC rate was increased to 50 ton ha^{-1} under 75 kg N ha^{-1} applied plots. In plots where N was applied at the rate of 150 Kg h^{-1} plant height increased as BC application rate was increased from 0 to 50 ton ha^{-1} (Fig. 3b). Maize grain protein content increased as BC application rate increased from 0 to 50 ton ha^{-1} in plots treated with 5 ton FYM ha^{-1}. In case of 10 ton FYM ha^{-1} application grain protein content decreased and then increased as BC application rate was changed from 0 to 25 ton and 35 to 50 ton ha^{-1} respectively (Fig. 3c). Increasing of BC application rate from 0 to 50 ton ha^{-1} in combination with 150 kg N ha^{-1} resulted in linear increase of grain protein content. Grain protein content initially increased and then remained un changed by changing BC application rate from 0 to 25 and 25 to 50 ton ha^{-1} in plots treated with 75 kg N ha^{-1} (Fig. 3d). Grain oil content increased in linear passion with BC level was raised from 0 to 50 ton ha^{-1} in plots that had received 5 ton FYM ha^{-1} in contrast grain oil % first decreased and then increase as BC rate was raised to 25 and 50 ton ha^{-1} respectively, in plots treated with 10 ton FYM ha^{-1} (Fig. 4a). The BC x N interaction for grain oil % is shown in figure 3b. Application of N at the rate of 150 kg ha^{-1} resulted in linear increased in grain oil by increasing rate of BC from 0 to 50 ton ha^{-1} while 75 kg N ha^{-1} decreased grain oil content by raising BC rate to 25 ton ha^{-1} however, further increasing BC rate to 50 ton ha^{-1} increased grain oil content.

Discussion

Ideally, the same soil (under replication) with different nutrients sources (organic and conventional) should have been used to allow separately for direct comparison of biochar effects on conventional and organic regimes. However, due to management problems and unavailability of resources, the integrated use of biochar (BC) FYM and nitrogen (N) was practiced in this experiment. The following discussion focuses on the effects of biochar, FYM and N on maize quality and growth under wheat-maize cropping pattern. Biochar application delayed all growth stages of maize and thus enhance active growing period of maize crop for production of maximum dry matter and improving quality. Biochar enhanced soil fertility and insure availability of all essential nutrients that resulted in increased vegetative growth duration (Soil analysis before and after crop harvest, Table 3). Nitrogen is important nutrient that play important role crop phenology. Application of biochar increased soil N (Post harvest soil analysis, Table 3) and delayed taseling, silking and maturity of maize. Similarly N and FYM application enhanced maize taseling, silking and maturity duration. Delayed tasseling in N amended plots may be attributed to vigorous vegetative growth and increased light use efficiency with increase in use of N (Frederick and Camberato 1995). Similar results are reported by Dolan *et al*. (2006) and Li (2003) who investigated that higher nutrients availability and favorable soil conditions due to organic source of N may cause vigorous crop growth and delay phenology. Incorporation of mineral N delayed leaf senescence, sustained leaf photosynthesis during active crop growth stage and extended the duration of vegetative growth (Frederick & Camberato, 1995).

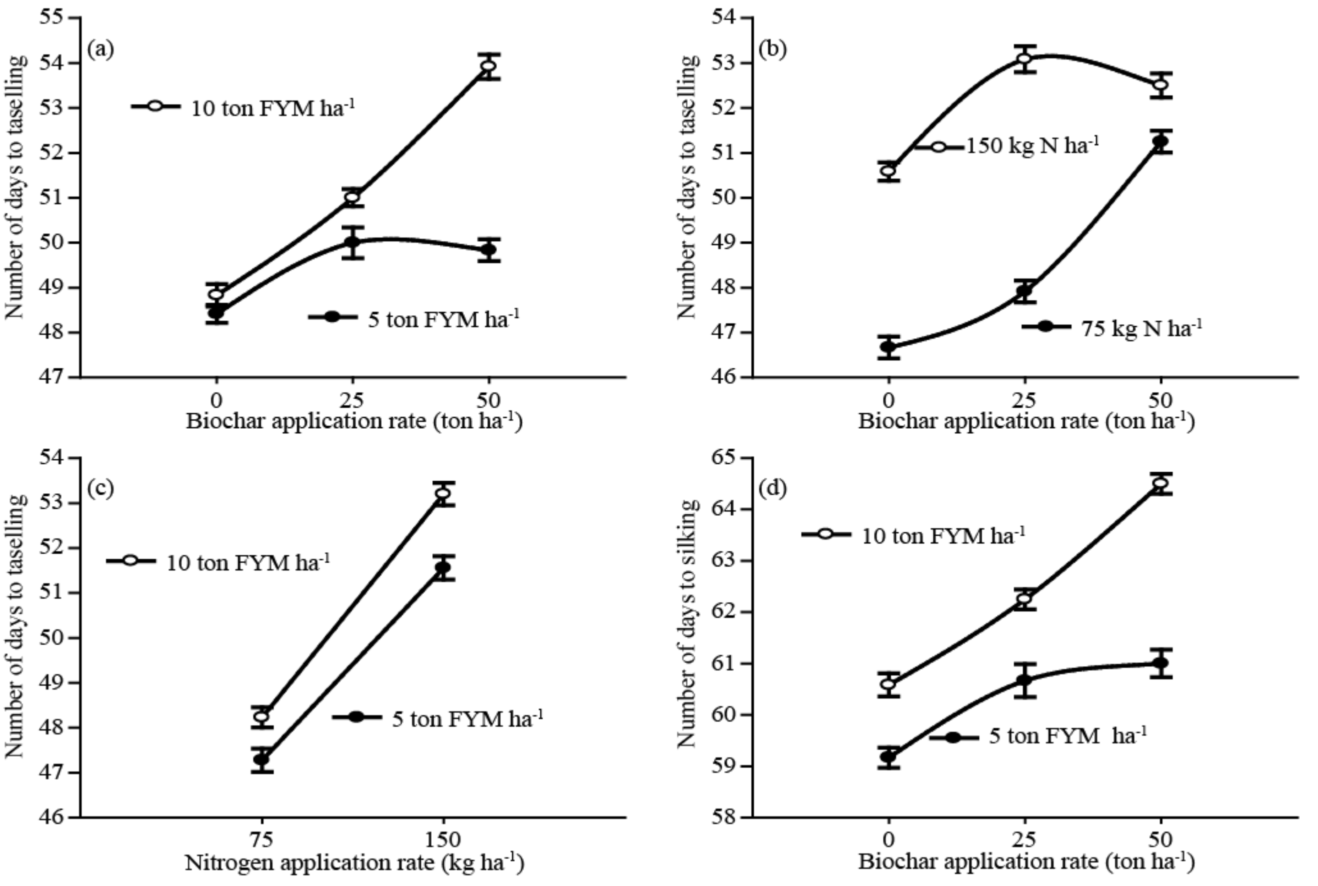

Fig. 1. (a). The BC x FYM interaction for number of days to taseling, (b). The BC x N interaction for number of days to taseling, (c). The FYM x N interaction number of days to taseling, (d). The BC x FYM interaction for number of days to silking, Error bars represent the standard error of three replications.

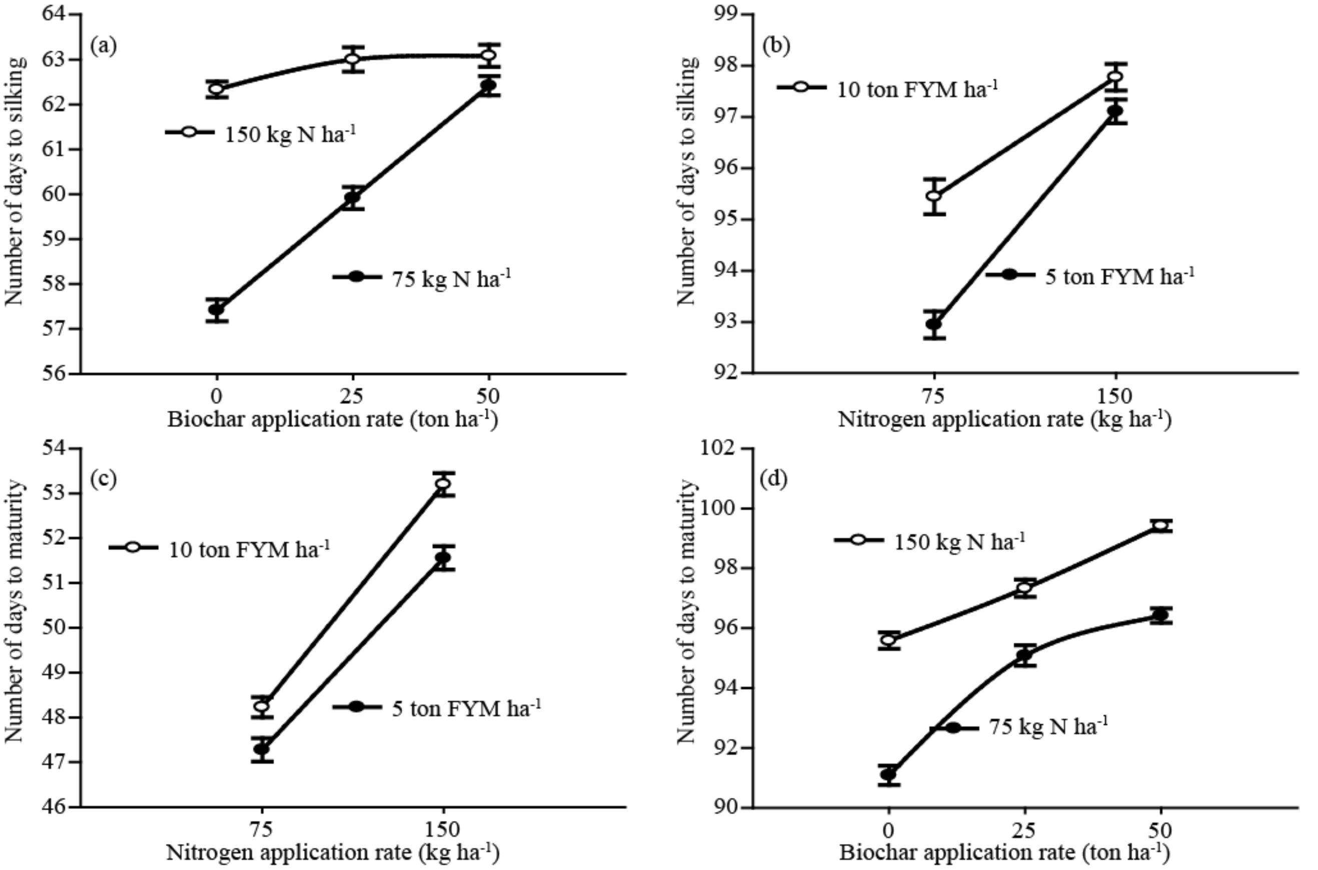

Fig. 2. (a). The BC x N interaction for number of days silking, (b). The FYM x N interaction for number of days to days to silking, (c). The FYM x N interaction for number of days to maturity, (d). The BC x N interaction for number of days to maturity. Error bars represent the standard error of three replications.

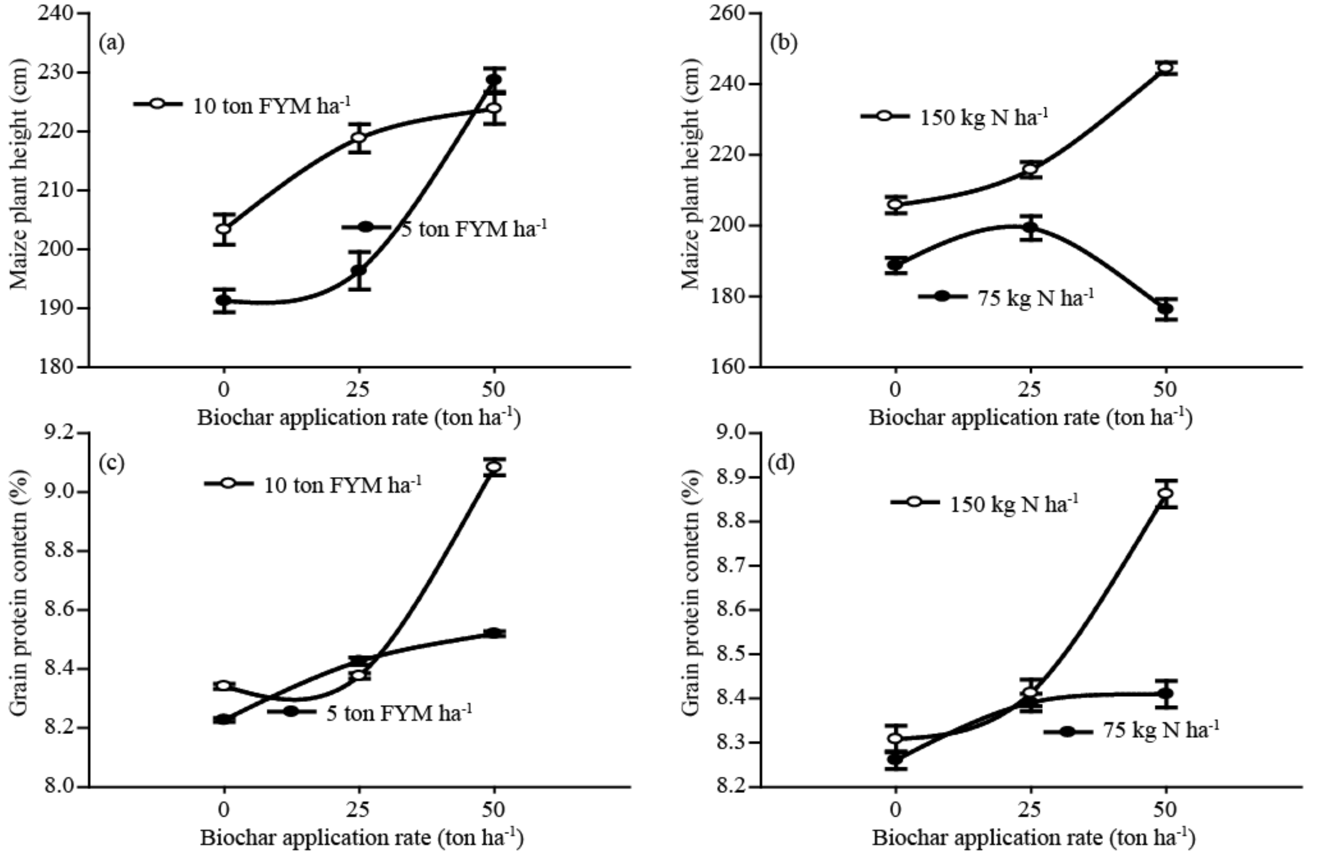

Fig. 3. (a). The BC x FYM interaction for maize plant height, (b). The BC x N interaction for maize plant height, (c). The BX x FYM interaction for grain protein content, (d). The BC x N interaction for grain protein content. Error bars represent the standard error of three replications.

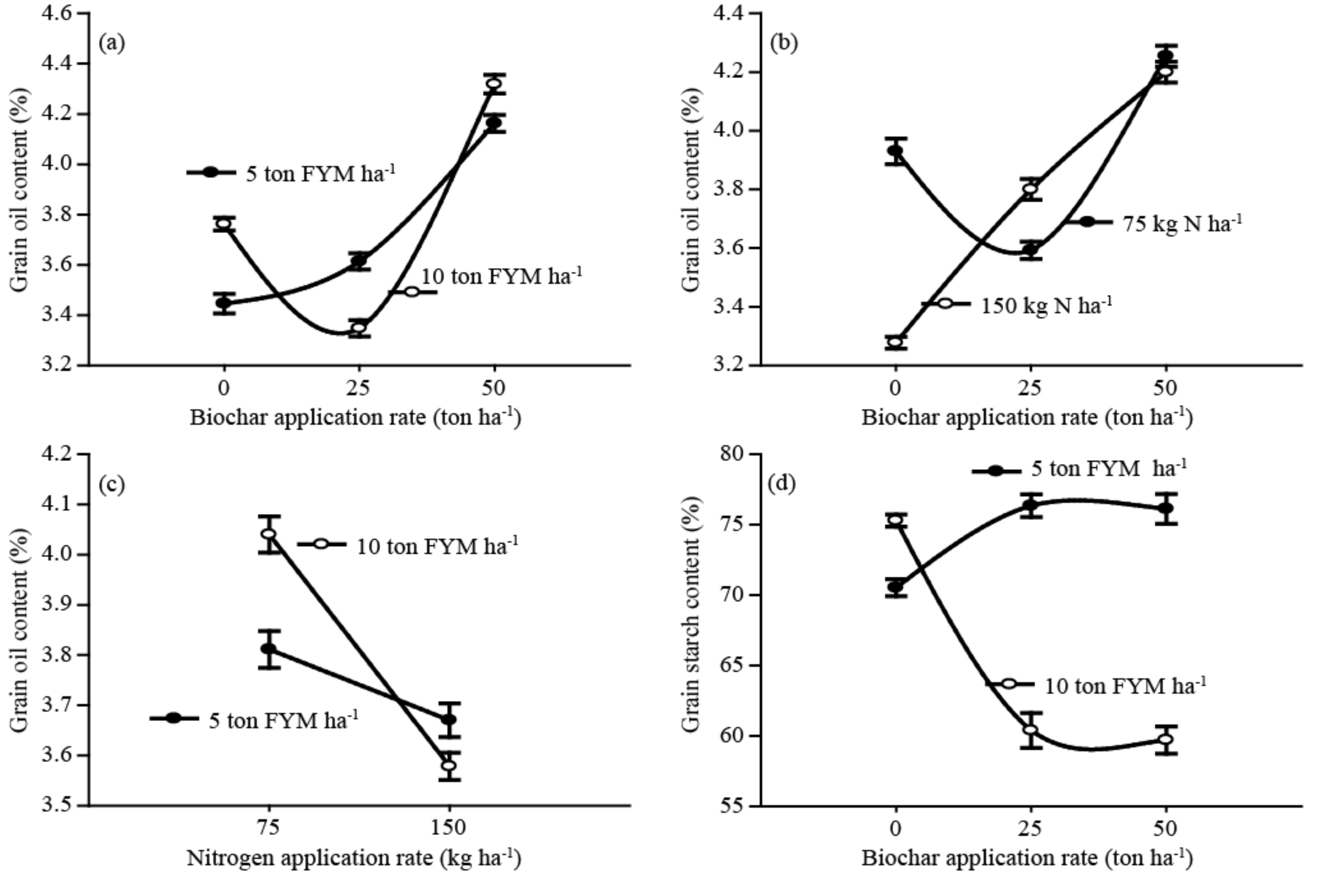

Fig. 4. (a). The BC x FYM interaction for grain protein content, (b). The BC x N interaction for grain oil content, (c). The FYM x N interaction for grain oil content, (d). The BC x FYM interaction for grain starch content. Error bars represent the standard error of three replications.

Our results are in agreement with the finding of Matsi *et al*. (2003) who reported that slow release of N from FYM could be possible reason for delayed phenology in N treated plots. Nitrogen application increased maize plant height by 37% over control. This increase in plant height could be attributed to positive effect of N on vigorous vegetative growth (Warren *et al*., 2006), more availability of N throughout the growing period and improvement in soil moisture content (Mitchell & Tu, 2005; Hossain *et al*., 2004), thus N amended plots had more taller plants as compared to control plots. Likewise maize grain oil and protein content was significantly improved by char application as compared to control. Biochar improved maize oil and grain protein content by 9% and 13% respectively as compared to no BC treated plots. Maize plant height and leaf area was increased by 23% and 17% respectively by biochar application. The effect of BC on the crop parameters varied under the given test conditions (Table 3). Biochar doses resulted in higher maize grain yield and leaf area relative to the control. Increases in plant height, biomass growth and grain quality under biochar amendments have been widely reported (Alburquerque *et al*., 2013; Baronti *et al*., 2010; Varela Milla *et al*., 2013). However, contrasting findings are also common (Mukherjee & Lal, 2014). It is well known that biochar improves soil fertility (Major *et al*., 2010; Schulz *et al*., 2013), acting as a good source of C, K and, to a lesser extent, of P for crop nutrition. The increase in grain quality can be related to these effects (Alburquerque *et al*., 2013). The pH, total exchangeable bases and EC increased with the treatments applied in this study. This increase might have increased the availability of nutrients (Atkinson *et al*., 2010; Laird *et al*., 2010; Major *et al*., 2010) and stimulated root activity (Khan & Shea, 2013). The increase in crude protein content and starch content in maize grain due N application might be the close relationship between N content and protein. Javed *et al*. (1985) and Hejjati & Maleki (1992) had reported the stimulating effect of N on protein content. Increase in seed starch was also reported by increasing N level (Hussain, 1998). Seed oil content was significantly reduced with increase in N levels during both the years. This might be due to the reciprocal relationship between crude protein and oil content. The increasing seed protein and starch content with increase in N might have caused reduction in seed oil content. This contrary relationship between seed oil and protein content had been reported by Singh *et al*. (1988); Zhao *et al*. (1993); Malik *et al*. (2002). , Khan *et al*. (1992) and Esechie *et al*. (1996). Several reasons have been given by different researchers for the reduction of oil content by increasing N, the increased seed yield and portent content under higher N reduced oil content due to the dilution effect (Kutcher *et al*. (2005). Jackson (2000) believed that delay in maturity due to N resulted in poor seed filling and greater proportion of green seed. Holmes (1980) also reported that a greater N application accelerate N containing protein precursors ultimately leading to the formation of protein for photosynthates; consequently reduction in fat synthesis from the latter available photosynthates. Likewise, Rathke *et al*. (2005) also correlated reduced availability of carbohydrates for oil synthesis with higher N. Significant reduction in oil content was also reported by several scientists with higher N levels (Jackson, 2000; Kutcher *et al*., 2005; Rathke *et al*., 2005; Cheema *et al*., 2001).

Conclusion

Incorporation of FYM and application of mineral N increased maize growth periods (Taseling, silking and maturity). Maize plant height, leaf area and grain protein content was also increased by FYM and N application. However, maize grain oil content and starch content was reduced by FYM and N application. Interestingly BC application improved maize growth parameters and enhanced quality of maize such as grain protein content, thousand grain weight and grain oil content. Though maize oil content was reduced by the individual effect of FYM or N however, when N was applied in integration with 25 ton ha^{-1} BC maize oil content and protein content significantly higher as compared to sole BC application.

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