INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 7, No. 4, p. 12-21, 2015

RESEARCH PAPER OPEN ACCESS

Impact of rice husk biochar and macronutrient fertilizer on fodder maize and soil properties

Allah Wadhayo Gandahi[1*], Shah Faisal Baloch[1], Mohamad Saleem Sarki[1], Rabail Gandahi[2], Muhammad Siddique Lashari[1]

[1]*Department of Soil Science, Sindh Agriculture University Tandojam, Sindh, Pakistan*

[2]*Department of Land Management, Universiti Putra Malaysia, Malaysia*

Key words: Rice husk biochar, Maize growth, Yield, NPK, Soil characteristics.

http://dx.doi.org/10.12692/ijb/7.4.12-21 Article published on October 10, 2015

Abstract

A greenhouse pot experiment was conducted with the objectives to assess the efficacy of rice husk biochar with and without fertilization application on the growth, fodder production of maize, NPK content in soil, plant and some soil properties. The treatments included: T1= Control (no macronutrient fertilizers or biochar), T_2= 100% recommended (130-80-40 NPK kg ha^{-1}), T_3= 2.5 t ha^{-1} Biochar (BC), T_4 = 5 t ha^{-1} BC, T_5= 10 t BC ha^{-1}, T_6= 25% less NPK+5 t ha^{-1} BC, T_7 = 25% less NPK+10 t ha^{-1} BC, T_8 = 50% less NPK+5 t ha^{-1} BC, and T_9 = 50% less NPK+10 t ha^{-1} BC. Results of study showed that combined application of macronutrient and rice husk biochar had positive impacts on maize growth nutrient content and soil organic matter. The application of T1 and T6 were at par with each other and significantly higher from other treatments. The soil properties like: organic matter %, pH and EC were positively affected by BC application at all levels. The above findings suggested that application of biochar alone was not good enough to improve the nutritional status and growth of the maize. Hence, combining biochar with NPK fertilizers was suitable strategy to get higher maize yields. It was also observed that although residual NPK status in soil increased but increase in soil pH and electrical conductivity was not good sign for calcareous soils and it was may be due to high alkali nature of rice husk biochar.

* **Corresponding Author:** Allah Wadhayo Gandahi ✉ gandahi@yahoo.com

Introduction

Biochar can increase soil fertility, increase agricultural productivity, and provide protection against some foliar and soil-borne diseases. Biochar being used as an alternative organic fertilizer additionally with chemical fertilizer for sustainable crop production in the agricultural sector have remarkable agronomic values and yield potential in poor degraded soils (Lashari *et al.,* 2013). There is a growing interest in the use of biochar as a soil amendment, with potential to increase nutrient availability. Biochar is reputed to improve the water holding capacity and the availability of nutrients in soil as well as the biomass of crops. Biochar combined with nitrogen fertilizer has been reported to have positive impacts for the soil and the plant (Nguyen *et al.*, 2012). The research field of biochar is expanding rapidly, mainly because of its potential for carbon sequestration (Lehmann, 2011), being a highly effective and promising technology for immobilizing pollutants (Beesley *et al.*, 2013), handling waste (Woolf *et al.*, 2010) and increasing soil fertility (Jeffery *et al.* 2011). Earlier research has attributed the impact of biochar on crop yield to increased CEC and associated nutrient retention (Lehmann *et al.*, 2003), increased available P (Hossain *et al.*, 2008), and increased plant-available water (Novak *et al.*, 2012). Soil biological parameters have also been demonstrated to be affected by the addition of biochar, Biochar could especially influence mycorrhizal abundance and/or functioning, allowing improved uptake of nutrients by plants (Warnock *et al.*, 2007).

Since green revolution the application of inorganic fertilizer is hardly avoided in increasing crop production even the application of chemical fertilizer is also not capable of maintaining yield increase consistently because larger portion of inorganic fertilizer become unavailable and lost from the root zone such as nitrogen volatilization and leaching (Islami *et al.*, 2011). The common technology for increasing fertilizer efficiency is integrated crop management, which includes the application of organic manure and other organic source of bio-waste materials to soil (Fageria & Baligar, 2005). A lot of works have shown that biochar has been considered as a prime source and able to improve soil properties, including soil pH, CEC, soil aggregation, water holding capacity and soil microbial population (Lu and Lashari *et al.,* 2015, Masulili *et al.*, 2010, Chan *et al.*, 2008). Steiner *et al.* (2007) observed that in the long term, application of biochar increases plant nutrient availability and soil productivity. The application of biochar significantly increased maize and soyabean crop yields (Islami *et al.*, 2011, Sukartono *et al.*, 2011). One major reason for higher crop yield with biochar application was the increased nitrogen utilization from the applied fertilizer due to decrease of nitrogen loss due the increase of soil CEC (Widowati *et al.*, 2011, Masulili *et al.*, 2010). Overall, the use of chemical fertilizer can be reduced with the supplement application of biochar; moreover biochar is effective to reduce the need of chemical fertilizer due to bio-fortification and increases soil microbial population and activity, resulting in more carbon storage in soil (Lashari *et al.,* 2013, Chen *et al.*, 2008).

In developed country biochar science has been considered a reliable source of energy as well as soil health promoter produced from bio-wastes but still unknown worldwide. Some literature showed clear evidence that biochar is highly effective for acidic and neutral soil, improve soil nutritional availability, plant growth and yield but not yet clearly know the effects of biochar amendment on alkaline tropical soils. Therefore, in this study we investigated the impact biochar with recommended dose of macronutrients on maize and soil organic matter content of alkaline tropical soil.

Materials and methods

Silty clay soil with EC 0.45 dS m^{-1}, pH 7.2, organic matter 0.9%, total N 0.03%, available P 0.10 mg kg^{-1} and Extractable K 35 mg kg^{-1} was collected from Latif Experimental Farm, Sindh Agriculture University Tandojam. Plastic pots (having a drainage hole at the bottom of each pot) were filled with air dried soil. The experiment was laid out with nine treatments and replicated thrice in a randomized complete design (CRD). The treatment were; T_1 = Control T_2 = 100%, recommended (130-80-4 kg ha^{-1}) NPK, T_3 = Biochar (BC) 2.5 t ha^{-1}, T_4 = BC 5 t ha^{-1}, T_5 = BC 10 t ha^{-1}, T_6 = 25% less NPK+5 t ha^{-1} BC, T_7 = 25% less NPK+10 t ha^{-1} BC, T_8 = 50% less NPK+5 t ha^{-1} BC, T_9 = 50% less NPK+10 t ha^{-1} BC.

Application of biochar and inorganic fertilizers

Biochar prepared from rice husk was obtained from the Department of Land Management, Faculty of Agriculture, University Putra Malaysia. The composition of rice husk biochar was pH 8.1, EC (µm/cm) 1100, TDS 450, N 1.0 (mg kg^{-1}), K 150 (mg kg^{-1}), S 0.17 mg, Ca 100 (mg kg^{-1}). The quantity of biochar required for each treatment was calculated as per treatment plan for seven kg soil. In each pot, biochar was thoroughly mixed with soil. Recommended (130-80-40 kg ha^{-1}) dose of nitrogen for maize was applied in the form of urea (46% N) in three split doses i.e. at the time of seed bed preparation, at first irrigation and at second irrigation. Recommended phosphorus in the form of single superphosphate (18% P_2O_5) and potassium from sulphate of potash (50% K_2O) was applied at the time of seed bed preparation.

Planting of maize and soil sample analysis

Ten seeds of maize (cv. Akbar) were planted in each pot. After germination, the seedlings were thinned to four per pot. The plants were irrigated as required and harvested at tasseling stage. The agronomic observations; plant height (cm), stem girth (cm), number of green leaves (plant^{-1}), number of dry leaves (plant^{-1}), green fodder yield (g pot^{-1}), biomass production (g pot^{-1}) were recorded. Before planting and after harvesting of crop, soil samples were collected from each pot and analysed for physico-chemical properties. Recognized analytical methods were followed for determination of Electrical conductivity, pH, soil texture, organic matter %, nitrogen %, available P and K. From each replication and treatment; the fully developed leaf, below whorl were collected and analysed for total nitrogen and phosphorus.

Statistical analysis

The data recorded on different parameters were subjected to the analysis of variance (ANOVA) to find out the difference between different treatments. In cases where differences were found significant, means were compared for differences using least significant difference (LSD) test at 5% level of significance. Statistical computer software SPSS was applied for computing both the ANOVA and LSD.

Results

Plant height

The plant height was positively affected by macronutrient and rice husk biochar application (Table 1).

Table 1. Impact of biochar and macronutrient fertilizer on plant height (cm) of maize.

Treatments	Plant height (cm)	Stem Girth (cm)	Number of Green Leaves	Green Fodder Yield(g/pot)	Biomass Production (g/pot)
Control	39.33 d	1.45 d	3.36 e	34.60 d	39.86 d
Recommended NPK (130-80-40 kg ha^{-1})	84.16 a	2.12 a	10.23 a	78.11 a	104.23 a
Biochar (BC) 2.5 t ha^{-1}	40.69 d	1.43 d	3.39 d	36.46 d	40.33 d
BC 5 t ha^{-1}	55.75 d	1.61 c	5.70 cd	46.92 c	59.50 c
BC 10 t ha^{-1}	55.197 d	1.61 c	5.66 d	50.73 c	59.40 c
25% less NPK+5 t ha^{-1} BC	70.60 bc	1.97 ab	9.94 abc	69.99 ab	86.83 ab
25% less NPK+10 t ha^{-1} BC	76.88 ab	2.11 a	11.30 a	78.35 a	104.67 a
50% less NPK+5 t ha^{-1} BC	66.55 c	1.85 b	8.28 bc	65.90 b	79.02 b
50% less NPK+10 t ha^{-1} BC	67.16 c	1.85 b	8.26 bc	65.90 b	78.83 b
S.E	9.72	0.074	1.34	4.46	9.7
LSD 0.05%	20.42	0.155	2.82	9.38	20.42

Means followed by same letter (s) do not differ significantly at 5% level of probability.

The average plant height was increased with the addition of BC as well as inorganic NPK fertilizers. The highest plant height (84.16 and 76.88cm) was obtained with the recommended NPK (130-80-40 kg ha^{-1}) and 25% less than recommended NPK+ 10t ha^{-1} BC. It was further observed that plant height was also enhanced in those treatments where 50% less NPK +5 and 10 t ha^{-1} BC was applied. The lowest height of maize plants was recorded in control pots which received no fertilizer as well as BC (Table 2).

Table 2. Impact of biochar and macronutrient fertilizer on maize leaf NPK % content.

Treatments	Total N (%)	Available P (%)	Available K (%)
Control	1.62 d	0.043 d	1.26 d
Recommended NPK (130-80-40 kg ha^{-1})	2.95 a	0.094 a	1.96 a
Biochar (BC) 2.5 t ha^{-1}	1.53 d	0.043 d	1.25 d
BC 5 t ha^{-1}	2.11 c	0.060 c	1.44 c
BC 10 t ha^{-1}	2.05 c	0.058 c	1.45 c
25% less NPK+5 t ha^{-1} BC	2.74 ab	0.084 ab	1.78 ab
25% less NPK+10 t ha^{-1} BC	2.94 a	0.094 a	1.93 a
50% less NPK+5 t ha^{-1} BC	2.52 b	0.074 b	1.68 b
50% less NPK+10 t ha^{-1} BC	2.53 b	0.073 b	1.70 b
S.E	0.191	5.44	0.082
LSD 0.05%	0.401	0.011	0.174

Means followed by same letter (s) do not differ significantly at 5% level of probability.

Stem girth

The NPK fertilizers and biochar improved the plant stem girth and the significant variation was observed (Table 1). The greater stem girth (2.12 cm) was observed in pots where recommended NPK at the rate of 130-80-40 kg ha^{-1} were applied. The results of this treatment were at par with incorporation of 25% less than recommended NPK+ 10 tons ha^{-1} BC. The plants with thinnest stems (1.45 cm) were observed in control plots.

Number of green leaves

The results of analyses of variance for the number of green leaves $plant^{-1}$ demonstrated that 25% less NPK+10 t ha^{-1} BC and 100% recommended (130-80-40 kg ha^{-1}) NPK resulted in significantly higher (11.30 and 10.23) number of green leaves $plant^{-1}$ in compare to other treatments (Table 1). Both these treatments were at par with each other. The pots where 25% less NPK+5 t ha^{-1} BC was also increased green leaves $plant^{-1}$ (9.94) as compare to other treatments. The lowest numbers of green leaves (3.36) were recorded with control pots.

Green fodder yield

Data regarding green fodder yield is presented in (Table 1). Statistical analysis of the data revealed that treatment had significant impact on green fodder yield. Pots treated with 25% less NPK+10 t ha^{-1} BC and those which received 100% recommended (130-80-40 kg ha^{-1}) NPK resulted in maximum green fodder yield (78.35 and 78.11 g pot^{-1} respectively). Application of 50% less NPK+ 5 and 10 tons ha^{-1} BC also produced higher green fodder yield as compared to other treatments than recommended (130-80-40 kg ha^{-1}) NPK as well as with 25% less NPK+10 t ha^{-1} BC. The lowest green fodder yield was recorded in pots which did not receive any macronutrient fertilizer or BC.

Biomass production

Results presented in Table 1, explaining that the average biomass production was increased with the application of BC as well as with inorganic fertilizer application (NPK). The highest biomass (104.67 and 104.23 g pot^{-1}) was obtained with the application of 25% less than recommended NPK+ 5 t ha^{-1} BC and recommended NPK at the rate of 130-80-40 kg ha^{-1}, respectively. The second highest biomass production (86.83 g pot^{-1}) was recorded in treatments where 25% less than recommended NPK+ 5 t ha^{-1} BC was applied. The lowest (39.86 g pot^{-1}) biomass production was calculated in control treatments.

Impact of macronutrient fertilizer and biochar on plant nutrient content

Plant N P K (%)

Table 2 shows that maize leaf N contents were significantly affected by macronutrient and biochar applications. The recommended NPK levels of 130-80-40 kg ha^{-1} as well as 25% less than recommended NPK+10 t ha^{-1} rice husk BC augmented N contents (2.95 and 2.94%) of maize plants, respectively. Ther was no significant difference between these treatments. The second highest total N (2.74%) contents were observed plants which received 25% less than recommended NPK + 5 t ha^{-1} BC. However, control pots showed least contents (1.62%) of total N.

Analysis of variance for maize P content showed significantly different results. Data shown in Table 2 revealed that maximum P (0.09 4%) was observed in plants treated with recommended NPK (130-80-40 kg ha^{-1}) as well as 25% less than recommended NPK+10 t ha^{-1} BC followed by plants which were applied 25% less than recommended NPK + 5 t ha^{-1} BC with 0.084 % available P. The plants in the pots which received no fertilizer and biochar had minimum P contents (0.043 %).

The highest plant K contents (1.96 and 1.93%) were noted in plants fertilized with recommended NPK (130-80-40 mg kg^{-1}) and 25% less than recommended NPK+10 t ha^{-1} BC (Table 2). Both treatments were at par with each other. The treatment with 25% less NPK+5 t ha^{-1} BC had the second highest plant K (1.78%) contents. Plants in the pots fertilized with 50% less NPK+5 or 10 t ha^{-1} BC have accumulated less K. Whereas, control pots showed minimum plant K contents.

Impact of macronutrient application and biochar on soil organic matter (%), EC (dS m^{-1}) and pH

The organic matter content of soil was positively affected by macronutrient fertilizers and biochar amendment (Table 3).

Table 3. Impact of biochar and macronutrient fertilizer on soil OM, EC and pH**.**

Treatments	Organic Matter (%)	E.C(dS m^{-1})	pH
Control	0.75 d	0.60 c	7.533 cd
Recommended NPK (130-80-40 kg ha^{-1})	0.83 d	0.61 c	7.533 cd
Biochar (BC) 2.5 t ha^{-1}	0.96 d	2.92 bc	7.400 d
BC 5 t ha^{-1}	1.29 c	4.1 ab	7.467 cd
BC 10 t ha^{-1}	1.47 bc	5.3 ab	7.667 bc
25% less NPK+5 t ha^{-1} BC	1.36 bc	4.1 ab	7.600 bcd
25% less NPK+10 t ha^{-1} BC	1.88 a	3.3 ab	7.700 abc
50% less NPK+5 t ha^{-1} BC	1.49 bc	3.69 ab	7.833 ab
50% less NPK+10 t ha^{-1} BC	1.59 b	5.43 a	7.933 a
S.E	0.133	1.182	0.1217
LSD 0.05%	0.281	2.489	0.2557

Means followed by same letter (s) do not differ significantly at 5% level of probability.

The highest OM (1.88%) content was observed in pots where 25% less NPK+ 10 t ha^{-1} BC was aphplied, whereas lowest OM contents (0.75, 0.83 and 0.96%) was with control pots, NPK alone and BC at the rate of 2.5 t ha^{-1} treatments, respectively.

Data for electrical conductivity (dS m^{-1}) of soil was affected by NPK fertilizer and BC amendment showed that soil amendment of BC raised EC of soil significantly (Table 3). The highest (5.43 dS m^{-1}) BC content was recorded in those pots where 50% less

NPK+10 t ha-1 BC was applied whereas; lowest EC (0.61 and 0.61 dS m-1) was recorded in control and NPK alone without BC amendments.

The results of experiment (Table 3) showed that soil pH was significantly affected by incorporation of biochar. The pH increased with increasing rate of biochar, values ranged from pH 7.5 to 7.9 for various treatments. Maximum soil pH (7.9) was observed in pots treated with 50% less NPK+10 t ha-1 BC followed by the treatment containing 50% less NPK+5 t ha-1 BC having pH of 7.8. Control and treatment having recommended NPK at the rate of 130-80-40 kg ha-1 had the lowest pH of soil.

Impact of macronutrient application and biochar amendment on macronutrient total soil N (%), available P (mg kg-1), extractable K (mg kg-1) content of soil

The laboratory analysis of soil samples showed significant impact of macronutrients and biochar on total N content of soil (Table 4). Results revealed that highest total N (0.089%) content was in pots which received 25% less NPK+10 t ha-1 BC and with recommended NPK (kg ha-1), whereas lowest N contents (0.30 %) was with control.

Data for available P (mg kg-1) content of soil was also significantly affected by macronutrient/inorganic fertilizers and BC application (Table 4).

Table 4. Impact of biochar and macronutrient fertilizer on Total N(%) in soil**.**

Treatments	Total N (%)	Available P (mg kg-1)	Extractable K (mg kg-1)
Control	0.03 d	1.06 d	0.026 d
Recommended NPK (130-80-40 kg ha-1)	0.089 a	1.96 a	0.070 a
Biochar (BC) 2.5 t ha-1	0.048 d	1.010 d	0.027 d
BC 5 t ha-1	0.060 c	1.323 c	0.041 c
BC 10 t ha-1	0.064 c	1.47 c	0.041 c
25% less NPK+5 t ha-1 BC	0.081 ab	1.80 ab	0.060 ab
25% less NPK+10 t ha-1 BC	0.089 a	1.96 a	0.069 a
50% less NPK+5 t ha-1 BC	0.078 b	1.67 b	0.054 b
50% less NPK+10 t ha-1 BC	0.078 b	1.68 b	0.054 b
S.E	4.26	0.08	6.15
LSD 0.05%	8.96	0.16	0.012

Means followed by same letter (s) do not differ significantly at 5% level of probability.

The NPK and BC significantly raised available P content in the soil. The treatment in which 25% less NPK+10 t ha-1 BC and those with recommended NPK at the rate of 130-80-40 kg ha-1 had highest (1.96 mg kg-1) available P in soil followed by 1.80 mg kg-1 P in pots treated with 25% less NPK+5 t ha-1 BC. However, lowest P content was in soil of control pots.

Extractable K in soil, showed significant difference among treatments (Table 4). Data revealed that 100% recommended (130-80-40 kg ha-1) NPK and 25% less NPK+10 t ha-1 BC had highest soil K content (0.070 and 0.069 mg kg-1) followed by 0.060 mg kg-1 in pots treated with 25% less NPK+5 t ha-1 BC. The lowest soil K content (0.026 mg kg-1) was in control pots.

Discussion

The important determinant that influences crop growth cycle and directly or indirectly affects crop productivity is the efficient nutrient management for a crop. In Pakistan, maize production mainly relies on commercial fertilizers. Application of biochar alters availability of nutrients in soils which could effect on plant growth.

According to the results of the study, macronutrient and rice husk biochar (BC) had significant effect on agronomic traits, plant and soil macronutrients status and properties of soil. The highest values of plant height, stem girth, number of green leaves plant^{-1}, less number of dry leaves plant^{-1}, greater green fodder and biomass production was obtained with the application of 25% less than recommended NPK+ 10 t ha^{-1} BC and recommended NPK at the rate of 130-80-40 kg ha^{-1}, respectively. This increase in plant height could be attributed to positive impact of NPK and BC on vigorous vegetative growth (Khan *et al.*, 2008). Our results are in agreement with the findings of Bocchi and Tano (1994) and Ali *et al.* (2011) that soil physio-chemical properties could be improved and yield can be increased by the application of different organic matters with combination of fertilizers. This increase of agronomic traits found in maize plant was mainly due to the improvement in the CEC of the soil, an increase in the carbon, nitrogen and phosphorus content of the soil and decrease in the hydraulic conductivity of the soil (Uzoma *et al.*, 2011). Liang *et al.* (2006) reported that biochar significantly effect on soil moisture and nutrient dynamics and yield (biomass and grain) of maize.

Possible explanation for increase in maize fodder and yield in biochar applied pots is be due to impact of biochar on soil physico-chemical properties like enhanced water holding capacity, increased cation exchange capacity, and providing a medium for adsorption of plant nutrients and for providing improved conditions to soil micro-organisms (Sohi *et al.,* 2010). The increased N content in soil may be due to the biochar efficiency to adsorbs ammonia (NH_3) and acts as a binder for ammonia in soil, therefore, having the potential to decrease ammonia volatilization losses from soil (Oya and Iu, 2002 and Iyobe *et al.*, 2004). The results of our experiment are in accordance with the observations of Singh *et al.,* (2010) and Ali *et al.,* (2011); according to them, that availability of N could be insured and maize plant productivity increased by combined use of mineral N and organic manures.

The another possibility for the better crop growth in NPK+biochar applications could be other mechanisms that improve crop growth and nutrient availability as biochar amendments increase the microbial population and their activity in soils and it could improve bioavailability of nutrient to the plant and stimulate the release of plant growth promoting hormones (Lehmann *et al.*, 2007).

In this study it was observed that soil as well as plant N, P and K contents were significantly affected by macronutrient and biochar applications. Fresh BC may contain significant amount of soluble P and K which contribute to plant- available pool upon incorporation in the soil (Kloss *et al.,* 2014; Lashari *et al.,* 2015). It was observed in experiment that for a better plant growth application of chemical fertilizers was mandatory, however soil and plant nutrient status in 25% less NPK + biochar treatments was significantly better. This may be due to the fact that biochar pushes to those mechanisms that are responsible improve crop growth and nutrient status. Nitrogen in biochar may not be available immediately to the plant as it is usually found in heterocyclic compounds that are part of the biochar matrix. The biochar in soil could significantly reduce leaching losses of N and P making them more available to the plant. (Laird *et al.,* 2010, Knicker, 2007). Therefore, N and P availability could be expected to increase with biochar application rate.

The biochar application significantly raised soil OM content and this was due to the increased biomass production of maize plant. Soil organic matter has an important role in soil fertility and agricultural productivity. Apart from enriched soil organic C, application of biochar improved other soil properties too. The soil pH and EC increased with increasing rate of biochar (Major *et al.,* 2010 and Kloss *et al.*, 2014), due to the alkaline nature of biochars. with a pH of 8.02 and this resulted in slight increase in pH of biochar treated pots. Naeem *et al.,* (2014) reported that pH, electrical conductivity (EC) and carbon content of biochars increased significantly with increasing temperature and maximum pH (10.4) and EC (3.35 dS m^{-1}) were observed in rice straw biochar at 500°C which may be due to an increase of high soluble and exchangeable base cations. Singh *et al.*,

(2010) also reported that EC values increased with increasing pyrolysis temperature.

The higher soil nutrient content of biochar pots showed the positive impacts of organic matter in increasing soil nutrient availability for plants. The application of biochar can maintain with these positive attributes of soil for a longer period of time (Islami *et al.*, 2011).

Conclusion

Application of biochar alone was not sufficient to improve the nutritional status and growth of the plant. Combining biochar with 25% of recommended NPK fertilizers resulted significantly highest growth and yield traits of maize fodder.

These results thus suggest that integrating BC with 25% of recommended NPK fertilizers are appropriate for sustainable crop production on a low fertility soil as integrated nutrient management is much better as compared to sole organic or inorganic fertilizer. It is concluded that biochar application at the rate of 10 tones ha^{-1} in combination with 25% less than recommended NPK improved growth and fodder of maize crop. However, increases in soil pH and electrical conductivity due to rice husk biochar application could be due to high alkali nature of biochar. Therefore more research is needed to find out alternate biochar feedstock with acid nature.

References

Ali K, Munsif F, Zubair M, Hussain Z, Shahid M, Din IU, Khan N. 2011. Management of organic and inorganic nitrogen for different maize (*Zea mayz* L) varieties. Sarhad Journal of Agriculture **27(4),** 525-529.

Bocchi S, Tano F. 1994. Effect of cattle manure and components of Pig slurry on maize growth and production. European Journal of Agronomy **3,** 235-241.
http://dx.doi.org/10.1016/S1161-0301(14)80088-9

Beesley L, Moreno-Jimenez E, Gomez-Eyles JL. 2013. Effects of biochar and green waste compost amendments on mobility, bioavailability and toxicity of inorganic and organic contaminants in a multi-element polluted soil. Environmental Pollution **158,** 2282-2287.
http://dx.doi.org/10.1016/j.envpol.2010.02.003

Chan KY, Van Zwieten BL, Meszaros I, Downie D, Joseph S. 2008. Using poultry litter biochars as soil amendments. Australian Journal of Soil Research **46,** 437- 444.
http://dx.doi.org/10.1071/SR08036

Fageria NK, Baligar VC. 2005. Enhancing nitrogen use efficiency in crop plants. Advances in Agronomy **88,** 97-185.
http://dx.doi.org/10.1016/S0065-2113(05)88004-6

Islami T, Guritno B, Basuki N, Suryanto A. 2011. Biochar for cassava based cropping system in the degraded lands of East Java, Indonesia. Journal of Tropical Agriculture **49,** 40- 46.

Islami T, Guritno B, Basuki N, Suryanto A. 2011. Maize yield and associated soil quality changes in cassava + maize intercropping system after 3 years of biochar application. Journal of Agriculture and Food. Technology **1,** 112-115.

Jeffery SF, Verheijen FGA, Van Der Velde M, Bastos AC. 2011. A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agriculture, Ecosystems and Environment **144,** 175-187.
http://dx.doi.org/10.1016/j.agee.2011.08.015

Knicker H. 2007. How does fire affect the nature and stability of soil organic nitrogen and carbon, a review. Biogeochemistry **85,** 91-118.
http://dx.doi.org/10.1007/s10533-007-9104-4

Khan HZ, Malik MA, Saleem MF. 2008. Effect of rate and source of organic material on the production potential of spring maize (*Zea mays* L.). Pakistan Journal of Agricultural Sciences, **45 (1),** 40-43.

Kloss S, Zehetner F, Oburger E, Buecker J., Kitzler B, Wenzel WW, Wimmer B, Soja G. 2014. Trace element concentrationsin leachates and mustard plant tissue (*Sinapis alba* L.) after biochar application to temperate soil. Science of the Total Environment **481,** 498–508. http://dx.doi.org/10.1016/j.scitotenv.2014.02.093

Lashari MS, Liu Y, Li L, Pan W, Fu J, Pan G, Zheng J, Zheng J, Zhang X, Yu X. 2013. Effects of amendment of biochar-manure compost in conjunction with pyroligneous solution on soil quality and wheat yield of a salt-stressed cropland from Central China Great Plain. Field Crops Research **144,** 113-118.

Lashari MS, Ye Y, Ji H, Li L, Grace WK, Lu H, Zheng J, Pan G. 2015. Biochar-manure compost in conjunction with pyroligneous solution alleviated maize salt stress and improved growth in a salt-affected soil from Central China: A two-year field experiment. Journal of the Science of Food and Agriculture **95,** 1321-1327. http://dx.doi.org/10.1002/jsfa.682

Lehmann J. 2007. Bio-energy in the black. Frontiers in Ecology and the Environment **5,** 381-387. http://dx.doi.org/10.1890/15409295(2007)5[381:BITB]2.0.CO;2

Lehmann J, Rillig MC, Thies J, Masiello CA, Hockaday WC, Crowley D. 2011. Biochar effects on soil biota-A review. Soil Biology and Biochemistry, **43,** 1812–1836. http://dx.doi.org/10.1016/j.soilbio.2011.04.022

Lehmann J, Silva JP, Steiner JC, Nehls T, Zech W, Glaser B. 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. http://dx.doi.org/10.1023/A:1022833116184

Lu H¶, Lashari MS¶, Liu X, Ji, H, Li L, Zheng J,

Grace WK, Joseph S, Pan G. 2015. Changes in soil microbial community structure and enzyme activity with amendment of biochar-manure compost and pyroligneous solution in a saline soil from Central China Plain. European Journal of Soil Biology. http://dx.doi.org/10.1016/j.ejsobi.2015.07.005.

Iyobe T, Asada T, Kawata K, Oikawa K. 2004. Comparison of removal efficiencies for ammonia and amine gases between woody charcoal and activated carbon. Journal of Health Science **50,** 148–153. http://dx.doi.org/10.1248/jhs.50.148

Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill, Skjemstad JO, Thies J, Luizao FJ, Petersen J, Neves EG. 2006. Black carbon increases cation exchange capacity in soils. Soil Science Society of America Journal **70,** 1719-1730. http://dx.doi.org/doi:10.2136/sssaj2005.0383

Laird DA, Fleming P, Davis DD, Horton R, Wang BQ, Karlen DL. 2010. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. Geoderma **158,** 443–449. http://dx.doi.org/10.1016/j.geoderma.2010.05.013

Major J, Rondon M, Molina D, Riha S, Lehmann J. 2010. Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. Plant and Soil **333,** 117–128. http://dx.doi.org/10.1007/s11104-010-0327-0

Masulili A, Utomo WH, Syekhfani. 2010. Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its Influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. Journal of Agricultural Science (Canada) **3,** 25-33. http://dx.doi.org/10.5539/jas.v2n1p39

Nguyen GJ, Rondon M. 2012. Biochar squesrtration in terrestrial ecosystems. A review. Mitigation and Adaptation Strategies for Global Change **11,** 403-427.

http://dx.doi.org/10.1007/s11027-005-9006-5

Novak DR, Colle BA. 2012. Diagnosing snowband predictability using a multimodel ensemble system. Weather Forecasting, **27,** 565–585. http://dx.doi.org/10.1175/WAF-D-11-00047.1

Naeem MA, Khalid M, Arshad M, Ahmed R. 2014. Yield and nutrient composition of biochar produced from different feed stocks at varying pyrolytic temperatures. Pakistan Journal of Agricultural Sciences **51(1),** 75-82.

Oya A, Iu WG. 2002. Deodorization performance of charcoal particles loaded with orthophosphoric acid against ammonia and trimethylamine. Journal of soil use and management **40(9),** 1391-1399. http://dx.doi.org/10.1016/S0008-6223(01)00273-1

Singh J, Gu S. 2010. Biomass conversion to energy in India- a critique. Renewable and Sustainable Energy Reviews **14,** 2596–2610. http://dx.doi.org/10.1016/j.rser.2010.01.013

Sohi, SP, Krull E, Lopez-Capel E, Bol R. 2010. A review of biochar and its use and function in soil. Advances in Agronomy **105,** 47-82. http://dx.doi.org/10.1016/S0065-2113(10)05002-9

Steiner C, Blum WEH, Zech W, de Macedo JLV, Teixeira WG, Lehmann J, Nehls T. 2007. Long term effect of manure, charcoal and mineral fertilization on crop production and fertility on highly weathered central Amazonian upland soil. Plant and Soil **291,** 275-290. http://dx.doi.org/10.1007/s11104-007-9193-9

Sukartono W, Utomo H, Kusuma Z, Nugroho WH. 2011. Soil fertility status, nutrient uptake, and maize (*Zea mays* L.) yield following biochar application on sandy soils of Lombok, Indonesia. Journal of Tropical Agriculture **49,** 47-52.

Uzoma KC, Inoue M, Andry H, Fujimaki H, Zahoor A, Nishhara E. 2011. Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use and Management **27(2),** 205–212. http://dx.doi.org/10.1111/j.1475-2743.2011.00340.x

Warnock DD, Lehmann J, Kuyper TW, Rillig M. 2007. Mycorrhizal responses to biochar in soil—Concepts and mechanisms. Plant and Soil. **300,** 9-20. http://dx.doi.org/10.1007/s11104-007-9391-5

Widowati, Utomo WHL, Soehono LA, Guritno B. 2011. Effect of biochar on the release and loss of nitrogen from urea fertilization. Journal of Agriculture and Food Technology **1,** 127-132.

Woolf D, James E, Amonette F, Street-Perrott A, Lehmann J. Joseph S. 2010. Sustainable biochar to mitigate global climate change. Nature Communications **1(5),** 1-9. http://dx.doi.org/10.1038/ncomms1053