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Effect of different levels of fertilizers, biochars and their feedstocks on nutrient content in mustard and properties of post-harvest soil

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Abstract
An investigation was undertaken in the net house of Department of Soil Science and Agricultural chemistry, Banaras Hindu University, Varanasi, during *Rabi* season of 2015-16 with a view to assess the effect of different levels of fertilizers, biochars and their feedstocks on nutrient content in mustard and post-harvest soil of red soil of Eastern Uttar Pradesh used for this experiment. This experiment was laid out in Randomized Complete Block design (RCBD) with twenty treatment combinations consisting of three levels of different types of biochars and its feedstocks i.e. 0, 2.25 g kg^{-1} and 4.5 g kg^{-1} of soil(corresponding to 5 t ha^{-1} and 10 t $ha^{-1,}$ respectively) along with 50 percent RDF and four levels of fertilizers 0 percent, 50 percent, 75 percent and 100 percent of recommended dose (100 per cent RDF means 45:30:20:20 mg kg^{-1} corresponding to 90: 60: 40: 40: kg ha^{-1} of N, P_2O_5, K_2O & S, respectively in case of mustard) replicated thrice. Required quantities of biochar for 10 kg soil were calculated and full doses were applied as soil application 15 days prior to sowing. Nutrient content in stover and seed, residual nutrient content in post-harvest soil were determined to assess the effect of treatments. The data collected during the course of investigation were subjected to statistical analysis to draw valid conclusions.

Keywords: Biochar, feedstocks, RDF, SOC, RCBD, DAS

Introduction

Biochar is a fine grained, highly porous charcoal substance that is distinguished from other charcoals in its intended use as a soil amendment. The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soils with very little biological decay (Lehmann *et al.*, 2006) [14]. While raw organic materials supply nutrients to plants and soil microorganisms, biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar enable it to adsorb or retain nutrients and water and also provide a habitat for beneficial microorganisms to flourish (Glaser *et al*., 2002, Lehmann *et al.*, 2006, and Warnock *et al.*, 2007) [10, 14, 21]. Addition of biochar to soils has attracted widespread attention as a method to sequester carbon in soil. Increased soil carbon sequestration can improve soil quality because of the vital role that carbon plays in chemical, biological, and physical soil processes and many interfacial interactions. The research conducted in different parts of world suggests the beneficial effect of biochar in crop production. However, effects of biochar application on soil properties or its potentiality as nutrient source deserve detailed investigation. The production conditions, along with nature of biomass feedstocks, determine the physical and chemical qualities of the produced biochar to be used as a soil amendment (Antal and Gronli, 2003) [2]. Application of biochar commonly influences soil bulk density, OC content, ash content, nutrient content, elemental composition, surface area, porosity, surface functional groups, cation exchange capacity (CEC), iodine number, and sorption properties (Gaskin *et al*., 2009). Upon pyrolysis of biomass feedstock, most biochars retain calcium (Ca), magnesium (Mg), potassium (K) and phosphorus (P) and plant micronutrients, and about half of the nitrogen (N) and sulphur (S) of the biomass feedstock that are partitioned into the biochar fraction (Laird *et al*., 2010) [11]. Therefore, application of biochar to a soil generally returns most of the nutrients back to the soil. Biochar also increases the capacity of soils to adsorb plant nutrients (Lehman *et al*., 2007; Cheng *et al*., 2008; Spokas *et al*., 2012) [13, 19], thereby potentially reducing leaching losses of nutrients.

Biochar has been shown to decrease soil bulk density, and increase CEC, improve nutrient cycling, and the ability of soils to retain plant available water. Therefore, the use of biochar as a soil amendment is expected to increase both nutrient and water use efficiency and thereby agronomic crop productivity (Liang *et al*., 2006) [15].

Materials and Methods

The present investigation involved a pot experiment conducted in net house followed by laboratory analysis of the stalks, seeds and soil samples in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India). Located on the western bank of river Ganges, Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between 25°19' North latitude and 85°10' East Longitude and falls in a semi-arid to sub humid climate. To conduct the pot experiment, bulk surface (0-15) soil were collected from the village of Saharanpur district Chandauli. The soil of chandauli district have predominace of kaolinite minerals. Cropping history of this pot experiment is given below. Previous season (2015) kharif baby corn was grown in net house. The fertility status of soil is classed as low to moderately acidic in reaction.10 kg of soils was filled in polythene lined experimental pots. Soil samples were taken from each pot after completion of the pot experiment for the determination of physico-chemical properties of the soils. The initial physico-chemical properties of experimental soils were analysed by following standard laboratory methods (table 1).

Table 1: Physico-chemical characteristics of the initial soil

Particulars	Contents	Method employed
A. Mechanical Separates		
Texture		
a) Sand	59.26	Bouyoucos Hydrometer (Bouyoucos, 1962)
b) Silt	25.22	
c) clay	15.52	
Textural class	Sandy Clay Loam	
B. Physico-chemical characteristics		
a) pH	5.5	Determination in 1:2.5 soil water suspension by using pH meter (Chopra and Kanwar, 1982)
b) Electrical Conductivity (dSm^{-1})	0.03	Determination in 1:2.5 soil water suspension by using EC meter (Jackson, 1973)
c) CEC ($Cmol(p+)kg^{-1}$)	8.83	Sodium acetate extraction method using centrifuge (Jackson, 1973)
d) Bulk density ($Mg\ m^{-3}$)		Using pycnometer
e) WHC (%)	31.54	Using keen box
f) Organic carbon (%)	0.50	Rapid Titration Method (Walkley and Black, 1934)
g) Available N ($kg\ ha^{-1}$)	147.21	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
h) Available P ($kg\ ha^{-1}$)	17.50	Bray and Kurtz method
i) Available K ($kg\ ha^{-1}$)	121.50	Neutral normal Ammonium acetate method (muhr *et al*. 1965)
j) Available S ($kg\ ha^{-1}$)	9.78	Turbidity method (Chesnin and Yien, 1950)

This experiment was laid out in Randomized Complete Block design (RCBD) with twenty treatment combinations consisting of three levels of different types of biochars and its feedstocks i.e. 0, 2.25 g kg^{-1} and 4.5 g kg^{-1} of soil(corresponding to 5 t ha^{-1} and 10 t $ha^{-1,}$ respectively) along with 50 % RDFand four levels of fertilizers 0 percent, 50 percent, 75 percent and 100 percent of recommended dose (100 per cent RDF means 45:30:20:20 mg kg^{-1} corresponding to 90: 60: 40: 40: kg ha^{-1} of N, P_2O_5, K_2O & S, respectively in case of mustard) replicated thrice. Required quantities of biochar for 10 kg soil were calculated and full doses were applied as soil application 15 days prior to sowing. Mustard variety PRO-4001 was sown in polythene lined earthen pots. The treatment combination used in the experiment is given in table 2. Nutrient content in stover and seed as well as residual nutrient content in post-harvest soil were also determined to assess the effect of treatments.

Table 2: Treatment combinations

Treatment	NPK	Biochar		Biochar/Feedstock
		Applied in pots (g kg^{-1} soil)	Equivalent to t ha^{-1}	
T_1	0%	0	0	No
T_2	50%	0	0	No
T_3	75%	0	0	No
T_4	100%	0	0	No
T_5	50%	2.25	5	Sugarcane bagasse biochar
T_6	50%	2.25	5	Rice husk biochar
T_7	50%	2.25	5	Parthenium Biochar
T_8	50%	2.25	5	Lantana biochar
T_9	50%	4.5	10	Sugarcane bagasse
T_{10}	50%	4.5	10	Rice husk biochar
T_{11}	50%	4.5	10	Parthenium Biochar
T_{12}	50%	4.5	10	Lantana biochar
T_{13}	50%	2.25	5	Sugarcane bagasse feedstock
T_{14}	50%	2.25	5	Rice husk feedstock
T_{15}	50%	2.25	5	Parthenium feedstock
T_{16}	50%	2.25	5	Lantana feedstock
T_{17}	50%	4.5	10	Sugarcane bagasse feedstock
T_{18}	50%	4.5	10	Rice husk feedstock
T_{19}	50%	4.5	10	Parthenium feedstock
T_{20}	50%	4.5	10	Lantana feedstock

100% NPKS = 45:30:20:20 mg kg^{-1} corresponding to 90: 60: 40: 40: kg ha^{-1} of N, P_2O_5, K_2O & S, respectively.

Types of biochar and feedstocks were prepared from sugarcane, rice husk, parthenium and lantana applied as such to various pot as per treatment. Required quantities of fertilizers for 10 kg soil were calculated and applied in soluiton form through urea, potassium dihydrogen phosphate and elemental S, respectively. Potassium will be applied through potassium chloride after adjusting the amount of potassium already added while adding phosphorus through potassium dihydrogen phosphate. Half dose of nitrogen and full dose of phosphorus and potassium will be applied at the time of sowing as basal dose in mustard crop. Full dose of sulphur will be applied before one week of sowing as a basal dose. Remaining half dose of nitrogen will be applied at the time of first irrigation. Four types of biochar viz. sugarcane baggase biochar, rice husk biochar, parthenium biochar and lantana biochar and their respective feedstocks were applied in two doses i.e. 2.25 g kg^{-1} soil and 4.50g kg^{-1} soil. Required quantities of biochar for 10 kg soil were calculated and full doses were applied as soil application before sowing. The data collected during the course of investigation were subjected to statistical analysis to draw valid conclusions.

Results and discussion

Major nutrients content of mustard seed and stover

In the present study, in general, application of biochar along with 50% RDF has resulted in similar growth and yield of mustard as with 75% RDF. The data presented in (Table 3) point out that addition of bio-char to soil has shown definite increases in the availability of major cations and phosphorus as well as in nitrogen concentrations (Glaser *et al.*, 2002 and Lehmann *et al.*, 2003) [10, 12]. Higher nutrient concentration of mustard due to biochar treatments might be due to favourable soil physical and chemical conditions that lead to increase the availability of nutrients. The increase in nutrient concentration may also be due to higher nutrient content coupled with better vegetative growth with these treatments. The ash content of biochar helps accelerate the release of the occluded mineral nutrients like Ca, K and N for crop use. An increase in N, P and K content of seed with fertilizers, biochars and their feedstocks may also be due to the fact that added biochar and feedstocks served as store house of several macro and micronutrients which are released during the process of mineralization. In addition to release of plant nutrients from the organic matter, the organic acids formed during the decomposition process also release the native nutrients in soil and increase the availability to plants. Other studies have shown that use of biochar stimulates plant growth and increases the fertilizer use efficiency, especially when biochar is combined with fertilizer which in turn lead to higher nutrient content (Alburquerque *et al.*, 2013; Steiner *et al.*, 2008) [20]. According to Steiner *et al.* (2008) [20], the total N recovery in crop residues and grains was considerably higher with compost (16.5%), biochar (18.1%), and biochar + compost treatments (17.4%) than with mineral fertilizer alone (10.9%). Lehmann *et al.* (2003) [12] also observed an increase in P concentration in plants with increasing biochar application.

Table 3: Effect of different levels of fertilizers, biochars and their feedstocks on major nutrients content of mustard seed and stover

Treatments	N content (%)		P content (%)		K content (%)		S content (%)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
T_1 0% RDF	1.64±0.047^{e}	0.309±0.027^{g}	0.249±0.017^{e}	0.038±0.005^{f}	0.446±0.018^{d}	0.731±0.025^{e}	0.253±0.012^{f}	0.080±0.007^{g}
T_2 50% RDF	1.97±0.016^{bcd}	0.492±0.045^{f}	0.304±0.005^{d}	0.083±0.005^{de}	0.506±0.003^{c}	0.821±0.028^{d}	0.298±0.009^{cde}	0.118±0.006^{def}
T_3 75% RDF	1.99±0.017^{abc}	0.541±0.020^{abc}	0.320±0.00^{abc}	0.095±0.004^{abc}	0.523±0.007^{ab}	0.861±0.005^{a}	0.316±0.005^{ab}	0.135±0.007^{ab}
T_4 100% RDF	2.02±0.012^{a}	0.566±0.009^{a}	0.329±0.006^{a}	0.102±0.007^{a}	0.538±0.010^{a}	0.876±0.011^{a}	0.323±0.001^{a}	0.144±0.004^{a}
T_5 SBB (2.25 g kg^{-1})+T_2	1.96±0.011^{cd}	0.497±0.010^{ef}	0.305±0.009^{cd}	0.082±0.006^{de}	0.506±0.010^{c}	0.826±0.009^{cd}	0.297±0.012^{cde}	0.116±0.008^{ef}
T_6 RHB (2.25 g kg^{-1}) +T_2	1.97±0.009^{bcd}	0.503±0.018^{ef}	0.306±0.005^{bcd}	0.083±0.006^{de}	0.508±0.017^{bc}	0.825±0.034^{cd}	0.300±0.007^{cde}	0.116±0.013^{ef}
T_7 PB(2.25 g kg^{-1}) +T_2	1.97±0.017^{bcd}	0.509±0.030^{cdef}	0.313±0.013^{abcd}	0.086±0.002^{cde}	0.508±0.012^{bc}	0.831±0.009^{bcd}	0.304±0.006^{bcde}	0.123±0.010^{def}
T_8 LB(2.25 g kg^{-1}) +T_2	1.98±0.017^{bcd}	0.515±0.021^{bcdef}	0.314±0.019^{abcd}	0.090±0.006^{bcde}	0.510±0.007^{bc}	0.833±0.009^{bcd}	0.306±0.010^{bcde}	0.122±0.008^{def}
T_9 SBB (4.50 g kg^{-1}) +T_2	1.98±0.020^{bcd}	0.521±0.018^{bcdef}	0.316±0.014^{abcd}	0.092±0.004^{bcd}	0.516±0.009^{bc}	0.849±0.008^{bc}	0.306±0.008^{bcde}	0.126±0.006^{bcd}
T_{10} RHB (4.50 g kg^{-1}) +T_2	1.98±0.018^{bcd}	0.53±0.021^{bcde}	0.317±0.016^{abcd}	0.093±0.002^{abc}	0.513±0.008^{bc}	0.850±0.008^{bc}	0.304±0.004^{bcde}	0.127±0.006^{bcd}
T_{11} PB (4.50 g kg^{-1}) +T_2	1.99±0.019^{abc}	0.54±0.018^{abcd}	0.320±0.013^{abc}	0.099±0.005^{ab}	0.515±0.012^{bc}	0.852±0.014^{ab}	0.309±0.002^{bcd}	0.135±0.006^{abc}
T_{12} LB (4.50 g kg^{-1}) +T_2	1.99±0.019^{ab}	0.55±0.010^{ab}	0.321±0.006^{ab}	0.098±0.009^{ab}	0.516±0.008^{bc}	0.853±0.008^{ab}	0.311±0.006^{abc}	0.134±0.006^{bc}
T_{13} SBF (2.25 g kg^{-1}) +T_2	1.96±0.017^{d}	0.49±0.010^{f}	0.306±0.008^{bcd}	0.081±0.005^{e}	0.506±0.008^{c}	0.824±0.012^{cd}	0.294±0.010^{e}	0.114±0.006^{f}
T_{14} RHF (2.25 g kg^{-1}) +T_2	1.96±0.010^{cd}	0.5±0.010^{ef}	0.307±0.013^{bcd}	0.082±0.010^{de}	0.505±0.007^{c}	0.825±0.006^{cd}	0.294±0.007^{e}	0.115±0.008^{ef}
T_{15} PF (2.25 g kg^{-1}) +T_2	1.96±0.009^{cd}	0.5±0.010^{ef}	0.307±0.012^{bcd}	0.082±0.005^{e}	0.509±0.006^{bc}	0.826±0.013^{cd}	0.294±0.011^{e}	0.115±0.004^{ef}
T_{16} LF (2.25 g kg^{-1}) +T_2	1.97±0.008^{bcd}	0.50±0.018^{ef}	0.311±0.011^{bcd}	0.083±0.006^{de}	0.508±0.006^{bc}	0.828±0.007^{cd}	0.297±0.002^{de}	0.118±0.007^{bef}
T_{17} SBF (4.50 g kg^{-1}) +T_2	1.98±0.010^{bcd}	0.51±0.010^{def}	0.315±0.009^{abcd}	0.087±0.005^{cde}	0.509±0.006^{bc}	0.834±0.011^{bcd}	0.296±0.014^{de}	0.120±0.008^{def}
T_{18} RHF (4.50 g kg^{-1}) +T_2	1.98±0.019^{bcd}	0.51±0.009^{def}	0.315±0.007^{abcd}	0.086±0.006^{cde}	0.508±0.007^{bc}	0.833±0.006^{bcd}	0.298±0.006^{cde}	0.120±0.010^{def}
T_{19} PF (4.50 g kg^{-1}) +T_2	1.97±0.025^{bcd}	0.51±0.010^{cdef}	0.314±0.006^{abcd}	0.086±0.005^{cde}	0.507±0.003^{bc}	0.833±0.003^{bcd}	0.300±0.002^{cde}	0.121±0.005^{def}
T_{20} LF (4.50 g kg^{-1}) +T_2	1.99±0.015^{abc}	0.53±0.010^{bcde}	0.317±0.006^{abcd}	0.094±0.005^{abc}	0.513±0.006^{bc}	0.838±0.004^{bcd}	0.305±0.011^{bcde}	0.124±0.005^{cde}

Values (mean ± standard deviation) in each column followed by dissimilar lower case letters are significant according to Duncan's Multiple Range Test at P = 0.05.

Properties of post-harvest soil

Nutrient concentrations in post-harvest soil were significantly influenced by biochar application (Table 4 & 5). Increasing doses of fertilizers from 0% RDF to 100% RDF significantly increased the availability of N, P and K in soil measured post-harvesting. However, available soil nitrogen and phosphorus did not vary significantly due to application of different types and doses of biochars as well as their respective feedstocks and were statistically similar to 50% RDF. The availability and rate of mineralization of organic N found in biochar applied to soil provides an indication of the ability of biochar as a slow release N fertilizer Chan and Xu (2009) [6] and Steiner *et al.* (2008) [20]. The increase in concentrations of available P found in the soil with the application of biochar obtained from crop biomass ashes can provide a P source similar to that of commercial P and K fertilizer (Luo *et al.* 2014). Chan *et al.* (2008) also reported the increase in available phosphorus in soil after the application of biochar. Whereas, LB (T_{12}) and PB (T_{11}) treated soils showed significantly higher value of available K as compared with 50% RDF (T_2) and were statistically similar in their effects with 75% RDF (T_3). This increase was due to the high concentration of K found in the biochar (Chan *et al.* 2007) [5]. The immediate beneficial effects of bio-char additions on nutrient availability are largely due to higher potassium (Lehmann *et al.* 2003) [12]. In case of soil pH, exchangeable Ca, exchangeable Mg and SOC, all the treatments showed statistically similar results. Biochar and their feedstocks did not showed any significant effect on available N, available P, exchangeable Ca, exchangeable Mg, soil pH and SOC over 50% RDF. This might be due to the fact that the initial pH of the soil was iso-neutral and no significant difference was noticed. Although several worker have found positive effects. When (Chan and Xu 2009) [6] reported that biochar has high concentrations of carbonates, it may have effective liming properties for overcoming soil acidity. Another reason for the increase in soil pH due to application of biochar could be because of high surface area and porous nature of biochar that increases the cation exchange capacity (CEC) of the soil. Most biochars have a small labile (easily decomposed) fraction in addition to a much larger stable fraction. This may be because of its high porosity and surface/volume ratio and can improve plant nutrients uptake and P, Ca, K availability (Chan *et al.*, 2007 and Yamato *et al.*, 2006) [5]. The cation retention of soils has been shown to increase after application of biochar, due to high surface charge density of biochar which enable the retention of ions (Liang *et al.* 2006, and Major *et al.* 2010) [15].

Effect on water holding capacity

The maximum water holding capacity and were significantly influenced by biochar application (Table 5). Application of biochar (T_5-T_{12}) which include biochar at higher dose (4.50 g kg^{-1} soil) as well as lower dose (2.25 g kg^{-1} soil) biochar showed significant increase in WHC over fertilizers treatments (T_1-T_4). higher water holding capacity of soil was observed in the treatment receiving ($T_{12)}$ lantana biochar at higher dose (4.50 g kg^{-1} soil) which was followed by the treatment (T_{11}) receiving parthenium biochar at higher dose (4.50 g kg^{-1} soil) compared to all other treatments. This could be due to application of organic carbon in the form of biochar. Biochar act as cementing materials in forming stable soil aggregates. In general, biochar particles have low density with high porosity compared to that of soils which aids soil to hold more air and water, thus decreasing the soil bulk density (Downie *et al.* 2009) [8]. Several workers had reported that the porous structure of biochar increases macroporosity and hydrophilicity; in turn enhances water adsorption rate (Atkinson *et al.* 2010) [3]. Obia *et al.* (2017) also reported the effect of incorporation of maize cob and rice husk biochar particle size experiments (0.5, 0.5–1 and 1–5 mm particle sizes) in loamy sand and sand. Total porosity and available water capacity (AWC) increased by 2 and 3% respectively per percent BC added under both crops, whereas BD decreased by 3–5% per percent BC added.

Table 4: Effect of different biochar and their feedstocks on physicochemical properties of post-harvest soil

Treatments	Soil pH	WHC (%)	SOC (%)
T_1 0% RDF	5.62±0.038	46.6±1.10^{e}	0.49±0.01
T_2 50% RDF	5.62±0.046	47.6±0.87^{de}	0.49±0.01
T_3 75% RDF	5.60±0.040	48.1±0.50^{de}	0.49±0.01
T_4 100% RDF	5.60±0.050	47.133±0.67^{e}	0.49±0.02
T_5 SBB (2.25 g kg^{-1})+T_2	5.64±0.045	50.000±1.23^{bc}	0.50±0.02
T_6 RHB (2.25 g kg^{-1}) +T_2	5.64±0.049	49.967±1.07^{bc}	0.50±0.02
T_7 PB(2.25 g kg^{-1}) +T_2	5.65±0.040	50.000±1.05^{bc}	0.50±0.01
T_8 LB(2.25 g kg^{-1}) +T_2	5.66±0.038	50.267±1.50^{bc}	0.51±0.01
T_9 SBB (4.50 g kg^{-1}) +T_2	5.66±0.040	51.200±1.39^{ab}	0.51±0.02
T_{10} RHB (4.50 g kg^{-1}) +T_2	5.67±0.040	51.200±0.66^{ab}	0.51±0.01
T_{11} PB (4.50 g kg^{-1}) +T_2	5.68±0.046	52.467±0.84^{a}	0.51±0.01
T_{12} LB (4.50 g kg^{-1}) +T_2	5.69±0.044	52.667±0.93^{a}	0.51±0.01
T_{13} SBF (2.25 g kg^{-1}) +T_2	5.63±0.046	47.933±1.03^{de}	0.50±0.01
T_{14} RHF (2.25 g kg^{-1}) +T_2	5.61±0.038	47.967±1.10^{de}	0.50±0.02
T_{15} PF (2.25 g kg^{-1}) +T_2	5.61±0.031	47.833±1.21^{de}	0.50±0.02
T_{16} LF (2.25 g kg^{-1}) +T_2	5.63±0.046	49.000±0.75^{cd}	0.50±0.01
T_{17} SBF (4.50 g kg^{-1}) +T_2	5.62±0.042	49.900±1.04^{bc}	0.51±0.02
T_{18} RHF (4.50 g kg^{-1}) +T_2	5.61±0.029	49.767±1.12^{bc}	0.51±0.01
T_{19} PF (4.50 g kg^{-1}) +T_2	5.60±0.047	50.267±1.16^{bc}	0.51±0.01
T_{20} LF (4.50 g kg^{-1}) +T_2	5.62±0.053	50.900±1.21^{b}	0.51±0.02

Values (mean ± standard deviation) in each column followed by dissimilar lower case letters are significant according to Duncan's Multiple Range Test at P = 0.05.

Table 5: Effect of different biochar and their feedstocks on nutrient content of post-harvest soil

Treatments	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Exchangeable Ca (meq $100g^{-1}$)	Exchangeable Mg (meq $100g^{-1}$)
T_1 0% RDF	38.4±0.96^{d}	2.3±0.34^{d}	45.7±0.67^{g}	9.4±0.85	7.5±0.75
T_2 50% RDF	55.8±1.59^{c}	5.2±0.48^{c}	54.3±0.59^{def}	9.5±0.98	7.3±0.71
T_3 75% RDF	59.9±1.30^{b}	6.9±0.39^{b}	56.7±0.51^{b}	9.5±0.76	7.2±0.53
T_4 100% RDF	61.9±1.69^{a}	7.7±0.31^{a}	58.6±0.45^{a}	9.4±0.91	7.3±0.75
T_5 SBB (2.25 g kg^{-1})+T_2	56.2±1.16^{c}	5.6±0.44^{c}	54.8±0.60^{cde}	9.5±0.91	7.7±0.81
T_6 RHB (2.25 g kg^{-1}) +T_2	56.5±1.22^{c}	5.6±0.39^{c}	54.8±0.79^{cde}	9.5±0.76	7.5±0.72
T_7 PB(2.25 g kg^{-1}) +T_2	56.6±1.28^{c}	5.7±0.59^{c}	54.8±0.51^{cde}	9.7±0.76	8.0±0.85
T_8 LB(2.25 g kg^{-1}) +T_2	56.6±1.05^{c}	5.7±0.44^{c}	55.1±0.76^{cd}	10.1±0.44	8.3±0.40
T_9 SBB (4.50 g kg^{-1}) +T_2	57.2±0.95^{c}	5.8±0.50^{c}	55.3±0.81^{cd}	10.2±0.90	8.5±0.46
T_{10} RHB (4.50 g kg^{-1}) +T_2	57.4±1.15^{c}	5.7±0.43^{c}	55.3±0.85^{cd}	10.2±0.36	8.4±0.60
T_{11} PB (4.50 g kg^{-1}) +T_2	57.6±1.10^{c}	5.9±0.70^{c}	55.8±0.54^{bc}	10.4±0.36	8.6±0.70
T_{12} LB (4.50 g kg^{-1}) +T_2	57.4±1.27^{c}	5.9±0.42^{c}	55.8±0.66^{bc}	10.6±0.58	8.7±0.55
T_{13} SBF (2.25 g kg^{-1}) +T_2	56.5±0.97^{c}	5.5±0.40^{c}	53.9±0.60^{ef}	9.4±0.46	7.3±0.60
T_{14} RHF (2.25 g kg^{-1}) +T_2	56.9±0.78^{c}	5.6±0.38^{c}	53.8±0.62^{f}	9.3±0.67	7.4±0.58
T_{15} PF (2.25 g kg^{-1}) +T_2	57.2±0.95^{c}	5.7±0.35^{c}	54.6±0.51^{def}	9.4±0.55	7.6±0.60
T_{16} LF (2.25 g kg^{-1}) +T_2	57.2±0.77^{c}	5.9±0.43^{c}	54.8±0.89^{def}	9.5±0.57	7.8±0.55
T_{17} SBF (4.50 g kg^{-1}) +T_2	57.4±1.39^{c}	5.8±0.37^{c}	54.9±0.58^{cde}	9.4±0.87	7.5±0.72
T_{18} RHF (4.50 g kg^{-1}) +T_2	57.5±1.34^{c}	5.7±0.46^{c}	54.7±0.45^{def}	9.3±0.72	7.5±0.58
T_{19} PF (4.50 g kg^{-1}) +T_2	57.6±1.23^{c}	5.9±0.47^{c}	55.1±0.42^{cd}	9.5±0.55	7.9±0.46
T_{20} LF (4.50 g kg^{-1}) +T_2	57.6±0.98^{c}	5.9±0.46^{c}	55.2±0.50^{cd}	9.9±0.75	8.3±0.56

Values (mean ± standard deviation) in each column followed by dissimilar lower case letters are significant according to Duncan's Multiple Range Test at P = 0.05.

Conclusion

The results from this pot experiment on red soil of Eastern Uttar Pradesh indicate a strong and positive response of mustard growth and yield to the application of the biochars and its respective feedstocks, with smaller differences evident between the different biochars. Thus, this study demonstrated the potential of biochar as an amendment. Thus above results indicates the necessity of combined application of fertilizer and biochar for higher yield, reflecting and confirming the improved nutrient availability to mustard. Understanding the characteristics of different biochars and feedstocks and evaluation of the effects of biochar on soils and crop yield is needed to better assess the utility of biochar as a soil amendment.

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