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Research Article

Residual effect of potassium fertilizer and biochar on growth and yield of maize in the second season

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Abstract : Application of biochar can increase availability of plant nutrients and yield. A field experiment was conducted on anInceptisol with aim to determineresidual potassium fertilizer and biochar application on growth and yield of maize in the second season. A randomized block design was used with three replication. The treaments were residual application of potassium and biochar that consisted of biochar only (30 t/ha), and biochar plus several levels of potassium apllication (0, 50, 100, 150 and 200 kg/ha), included application of 200 kg/ha potassium without biochar. Basal fertilizersapplied in the first season were 90 kg N/ha and 100 kg P_20_5, and in the second season was 90 kg N/ha. The results showed that residual biochar alone or combined with different levels of potassium application increased yield of maize. Residual biochar increased avalilabilty of N, P, K, Ca, and Na in the soil.

Keywords *: biochar, maize, potassium, residual, yield*

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Introduction

Farm intensification technology applied in the farm without addition oforganic matters will decrease C-organic content in the soil. Thiscondition will reduce efficiency of fertlizer application. Application of manure and organic fertilizer can increase soil fertility and fertilizer efficieny. In the hot tropical conditions, decomposation and mineralitation of organic matter run very fast and thiswill cause increasing CO_2emition and global warming (Bol et al, 2000), and releasing CO_2 in the atmosfir (Fearnside, 2000). Low organic matter content also causeslow cation exchange capacity (CEC) and low availability of plant nutrients. Efficiency of anorganic fertilizer is also low, especially in the tropic where leaching is important aspect for mobile nutrients (Brady and Well, 2008).

In Inceptisols, potassium is usually not available because it is fixed by soil minerals. Problems related to availability of plant nutrients become worse because farmer donot have capacity to buy organic fertilizers. Plant nutrient availability becomes one of constraint to increasing plant production. In general, soil plant nutrient content can be increased by addition of ferlitilizers, but nutrient content will be decrased by plant absortion, volatization, leaching and fixation of by soil colloid. One of possible strategies to increase fertilizer efficiency is by application of combined organic and organic fertilizers or biochar. Lehmann *et* al. (2003) reported that biochar can maintaine nutrient content in the fertilizer to prevent leaching. On the other hand, Widowati et al,. (2012) stated that biochar can reduce N fertilizer application up to 70%. This is because biochar can manage N release by Urea fertilizer in the form of NH_4 (Widowati et al., 2011). Similar results obtained from a greenhouse experiment also showed that the increase ofpotassium fertilizer did not increaseleaching of potassium in 30-60 days after sowing (Widowati et al., 2012).

Biochar is organic charcol product of pyrolysis (convertion of thermo condition without oxygen). Biochar can be used is an alternatif produced energy by returning carbon and nutrient to the soil (Laird, 2008). Biochar from pyrolysis is type of carbon amorf consisting of many carbon symbiosis and ash (Chun et al., 2004). During process of pyrolysis, condition of temperature and time will affect characteristics of biochar (Antal and Gronil, 2003). At low temperatures (<500°C), raw material composition has a major influence on biochar characteristics which affecting agriculture such as cation exchange capacity and nutrient content (Gaskin et al., 2008). Several research results showed that biochar increased growth and yield of maize (Major et al., 2010), soybean (Tagoe et al., 2008), cowpea (Glaser *et* al., 2002), and rice (Steiner et al., 2007). Concentrations of carbon at low temperatures range from 380 g/kg to poultry waste biochar (Chan et al., 2008), 692 g/kg for wheat stalk (Chun et al., 2004) and 790 g/kg for biochar Chip Pine (Gaskin et al., 2008). Nitrogen concentrations in biochar range from 1.4 g/kg (pine), 19 g/kg (groundnut), 40 g/ kg (poultry waste) (Chan et al., 2007). Low concentrations of P and K were found in biochar of pine of 0.089 and 0.659 g/kg respectively, and biochar of chicken manure of 33.6 and 45.6 g/kg (Gaskin et al., 2008). Concentrations of P and K in biochar of organic waste product were 0.72% and 0.93%, respectively (Widowati et al., 2011).

Several studies showed that biochar increased nutrient retention, especially Nitrogen content in tropical areas (Lehmann et al., 2003; Steiner et al., 2008). When the process of nutrient loss due to leaching can be reduced this means that there is still nutrient retention in the soil as a residue that can be utilized for the next crop. Nutrient residue in soil after harvest can reflect nutrient availability status in low, moderate, high, and very high category. Such conditions will determine whether to add nutrients through fertilization. The small amount or amount of added fertilizer will affect the amount of nutrients absorbed and left behind as nutrient residues available in the soil. Widowati et al. (2014) showed that the sole application of biochar increased maize production by 14% compared sole application of KCl fertilizer.

In contrast, application of biochar and 75% of dosage of KCl fertilizer increased maize production by 29%. Biochar residues and increased doses of potassium fertilizer will have the same effect on crop yields.This asumption is supported by Mayor et al. (2010) who reported that yield of maize did not increase in the first season, but it increased in the second season after applicationof biochar. Information on this aspect is vey limited, and therefore, the objective of this experiment was to determine the residual effect of potassium fertilizer and biochar on growth and yield of maize in the second season.

Materials and Methods

A field experiment was conducted from September 2012 to February 2013 on an Inceptisol of Tunggulwulung village, Lowokwaru sub district of Malang City. Biochar was made from organic waste by pyrolysis method. The Pertiwi-3 maize cultivar used in the second planting was planted in September 2012. All treatments were laid in a randomized block design with three replications. In the first planting, each treatment was supplied with urea fertlizer with a dosage of 90 kg N/ha.

The urea Fertilizer was applied twice (1/3 of dose at 6 days after planting and 2/3 of dose used at four weeks after planting). Phosphate fertilizer was applied at 6 days after planting. Potassium fertilizer that was applied at 1 and 4 weeks after planting consisted of B0K200 (200 kg KCl/ha), B30KO (biochar, without KCl), B30K50 (biochar + 50 kg KCl/ha), B30K100 (biochar + 100 kg KCl/ha), B30K150 (biochar + 150 kg KCl/ha), and B30K200 (biochar + 200 kg KCl/ha). Basal fertilizer supplied for the second season was 90 kg Urea/ha without P and K fertilizers. Total number of plots were 21 with each of 3 m x 4 m size. Maintenance of the experiment was done by weeding twice, and irigation twice per-week. Plant spacing was 80 x 25 cm, 1 seed per-hole and total number of plant population was 50.0000/ha. Soil samples were collected after harvest in the first and second seasons, and analyzed for organic content (Walkley and Balck), N (Kjedahl), availability of P (Bray 1), potassium availability (NH_40AC 1 N pH 7), total K (HCl 25%), Ca, Mg and Na. There were five plant samples obeserved for plant height, stem diameter, leaf area index, stem dry matter, leaf, plant dry matter, length and diameter of ear, seed dry weight, potassium content in the leaf (70 days), and in the seed after harvest (130 days), and K absorbtion. Plant dry matter was observed by drying the plant fresh material in an oven with tempereture of 70 ^oC for 48 hours. Uptake of N, P, and K by maize crop was calculated from plant dry weight and and N, P, and K contents. Data obtained were analyzed usingSPSS version 13.00.

Results and Discussion

Crop growth

Residual biochar of 30 t/ha with and without addition of pottasium fertilizer application produced the highest plant height. On the other hand, the residual biochar that was followed by the increase dosage of potassium application from 50 kg up to 200 kg/ha reduced plant height significantly (Table 1). Application of 200 kg KCl/ha decreased plant heightabout 28.40 cm compared with application of 50 kg KCl/ha. Residual biochar treatment alone increased plant height, stem diameter, and leaf size, although the stem diameter was not significantly different with that of residual biochar added with potassium application treatment. Biochar as a soil amandement caused better root development and higher drymatter production than without biochar and only 200 kg KCl/ha (Table 2) and as high as seed yield of maize (Table 4). Application of potassium fertilizer did not increase crop growth and grain yield of maize (Table 4).

Dry matter production showed similar trend with stem diameter. Residual biochar with or withiout addition of potassium fertilizer application showed higher dry matters of leaf, stem, and total biomass production compared with no biochar added 200 kg KCl/ha (Table 2). Total dry matter production is production of drymatter during plant growth. In the short period, fertilizer that isadded to biochar can increase plant growth (Lehmann *et al.*, 2003).

Table 1. Plant height, Stem diameter, and Leaf size at 70 days after planting

Treatment	**Plant height (cm)**	**Stem diameter (cm)**	**Leaf size (cm^2)**
200 kg KCl/ha	233.82 b	2.46 a	5493.22 a
Biochar	252.83 c	3.02 b	6712.51 b
Biochar + 50 kg KCl/ha	250.69 c	2.80 b	6397.63 b
Biochar + 100 kg KCl/ha	230.18 ab	2.93 b	6581.94 b
Biochar + 150 kg KCl/ha	227.67 ab	2.87 b	6601.77 b
Biochar + 200 kg KCl/ha	222.29 a	2.89 b	6310.49 b
LSD 0.05	10.99	0.20	487.68

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05.

Table 2. Drymatter of leaf, stem,and total biomass production of maize crop at 70 days after planting

Treatment	**Leaf dry matter (t/ha)**	**Stem dry matter (t/ha)**	**Total biomass production (t/ha)**
200 kg KCl/ha	1.90 a	2.81 a	4.71 a
Biochar	2.69 cd	4.06 b	6.75 b
Biochar + 50 kg KCl/ha	2.42 b	4.00 b	6.42 b
Biochar + 100 kg KCl/ha	2.78 d	3.92 b	6.70 b
Biochar + 150 kg KCl/ha	2.55 bcd	3.67 b	6.22 b
Biochar + 200 kg KCl/ha	2.47 bc	3.79 b	6.27 b
LSD 0.05	0.25	0.43	0.58

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05.

Nutrient content and uptake of N, P, K

Application of biochar supplied enough nutrients for the second crop especially P and K. It is showed that the crop did not experiencedefficiency of nutrients (Table 3). Total macronutrients of N (0.17-0.26%), P_2O_5 (60-185 mg/kg) and K_2O (0.5-0.9 me/100g) available in the soil after harvest the first season would beavailable for the second crop. Residual effect of K fertilizer and K fertilizer with biochar gave same affect on level of N and P in the leave or P in the grain (Table 3). Residual biochar increased P and K contents in grain (Figures 2 and 3). Nutrient uptake by crop depends upon the availability of the nutrient in the soil. It is showed that combination of residual biochar and K feritlizer decreased absorbtion of Potassium (Figure 3).

Table 3. Content of N, P, K in the leaf (70 days after sowing) and grain of maize (130 days after sowing)

Treatment	**Nitrogen content (%)**		**P content (%)**		**K content (%)**	
	Leaf	**Grain**	**Leaf**	**Grain**	**Leaf**	**Grain**
200 kg KCl/ha	3.22 a	1.43 a	0.29 a	0.16 a	0.08 a	0.13 ab
Biochar	3.37 a	1.77 b	0.31 a	0.16 a	0.14 bc	0.12 a
Biochar + 50 kg KCl/ha	3.24 a	2.04 b	0.28 a	0.20 a	0.13 b	0.16 bc
Biochar + 100 kg KCl/ha	3.24 a	2.01 b	0.28 a	0.18 a	0.13 bc	0.13 a
Biochar + 150 kg KCl/ha	3.26 a	2.00 b	0.29 a	0.16 a	0.13 b	0.13 a
Biochar + 200 kg KCl/ha	3.32 a	1.83 b	0.30 a	0.20 a	0.16 c	0.17 c
LSD 0.05	0.26	0.33	0.04	0.08	0.03	0.03

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05.

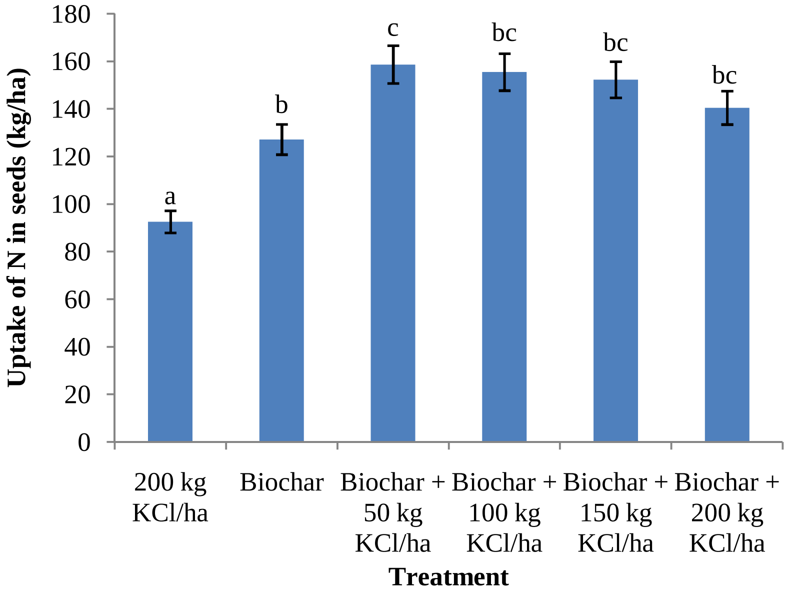

Figure 1. Nitrogen uptake in the grain of maize at harvest

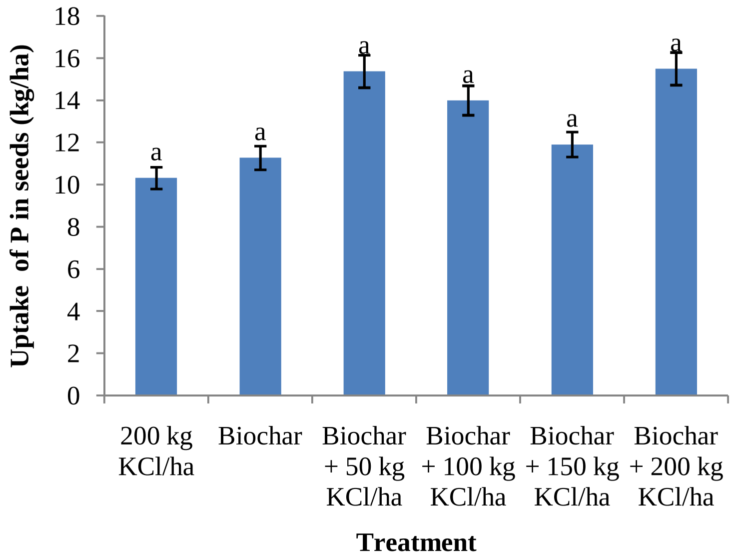

Figure 2. Phosphorus uptake in the grain of maize at harvest

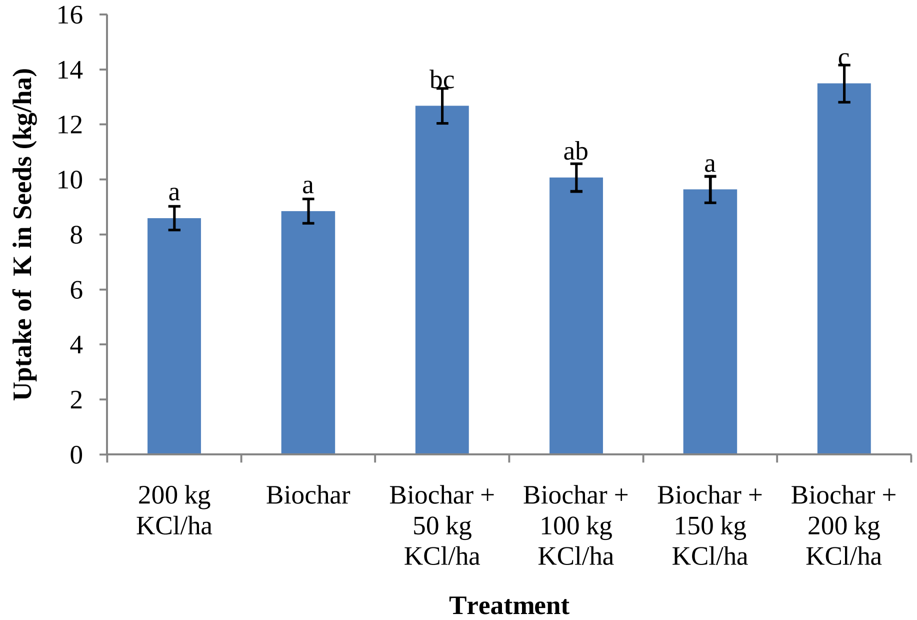

Figure 3. Potassium uptake in the grain of maize at harvest

Plant yield and carbohydrate content in maize grains

Even without the addition of P and K fertilizers, plant growth and yield were not affected by the availability of nutrients P and K from the first maize harvest residues.It is assumed that the available nutrients from the first season were still enough to support crop growth during the second season (Table 4). This results showed that residual biochar gave the good effect for availability of P and K nutrients, and for growth and yield. Residual biochar alone or combined with potassium increased ear size, earl length, grain size (1000 g), grain yield/plant, and grain yield (t/ha). The increase of grain yield from residual biochar alone was lower (11%) compared with that of residual biochar combined with Potassium fertilizer (18-20%). In the first season, biochar did not increase yield significantly. Residual biochar gave high signifantly effect to the crop by time to time as reported by by Steiner et al. (2007) and Major et al. (2010).

Residual biochar with potassium in different dosage gave the same effect to yield component and grain yield of maize (Table 5). Biochar applications independently showed the same maize yield when biochar was combined with potassium fertilizer at various doses. Phosphate and potassium combination with biochar gave the effect of residual for the second cop. This was due to the ability of biochar to maintain retention of nutrient in the soil. In fact, there is more than 90% of ash in biochar that that is available for the crop (Glaser et al., 2002). The data from this experiment showed that biochar did not only act as a soil conditioner but also increased cation exchange capacity. Similar results were also reported by Liang et al. (2008). Application of biochar that consists of ash increasescation K, Ca, Mg in the soil (Glaser *et al*., 2001a). Residual biochar increased soil organic content (Table 6). The increase of soil oganic matter in the soil is always related with active decomposition of organic matter (Wilhelm et al., 2004). In the degraded Oxisol in Kenya, Kimetu et al. (2008) reported that maize production increased twice after three repeated applications of biochar of 7 t/ha during two years.

After application of biochar in the first season, availability of N, P, K, Ca and Mg increased by 39-53%, 179-208%, 69-89%, 61-70%, and 1-22%, respectively (Widowati et al., 2014). This condition approved hypothesis that grain yield of maize increased during the second season although without addition of P and K fertilizers.Grain yield of maize in the first season was lower (5.46-7.02 t/ha) compared with that in the second season (Table 5). This indicated that biochar gave positif effect to the crop in the second season. Other data showed that total N and availabilty of phosphate were higher than without biochar. Widowati et al. (2012) pointed out that biochar reduced leaching process of potassium while application of biochar combined with KCl fertilizer did not increase K leaching. Effect of residual potassium fertilizer independently and potassium fertilizer with biochar highly significant in carbohydratecontent in the grain seed maize. Application of biochar alone resulted in the lowest carbohydrate content. The highest carbohydrate content was observed for application of biochar combined with 150 kg K/ha (Figure 4).

Table 4. Yield and yield component of maize crop in the second season

Treatment	Ear length (cm)	Diameter of ear (cm)	Weight of 1000 grains (g)	Ear dry weight (g)	Grain yield per-plant (g)	Grain yield (g)
200 kg KCl/ha	17.6 a	5.43 a	302.9 a	21.63 a	122.52 a	6.46 a
Biochar	20.3 b	5.77 b	338.9 b	32.22 b	141.38 b	7.18 b
Biochar + 50 kg KCl/ha	19.9 b	5.82 c	346.7 b	30.29 b	155.46 b	7.77 b
Biochar + 100 kg KCl/ha	19.7 b	5.78 c	348.4 b	32.50 b	154.47 b	7.72 b
Biochar + 150 kg KCl/ha	19.7 b	5.81 c	359.0 b	33.75 b	151.97 b	7.60 b
Biochar + 200 kg KCl/ha	19.2 b	5.97 c	325.2 b	30.01 b	154.26 b	7.71 b
LSD 0.05	1,16	0.20	44.89	6.78	19.49	0.82

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05.

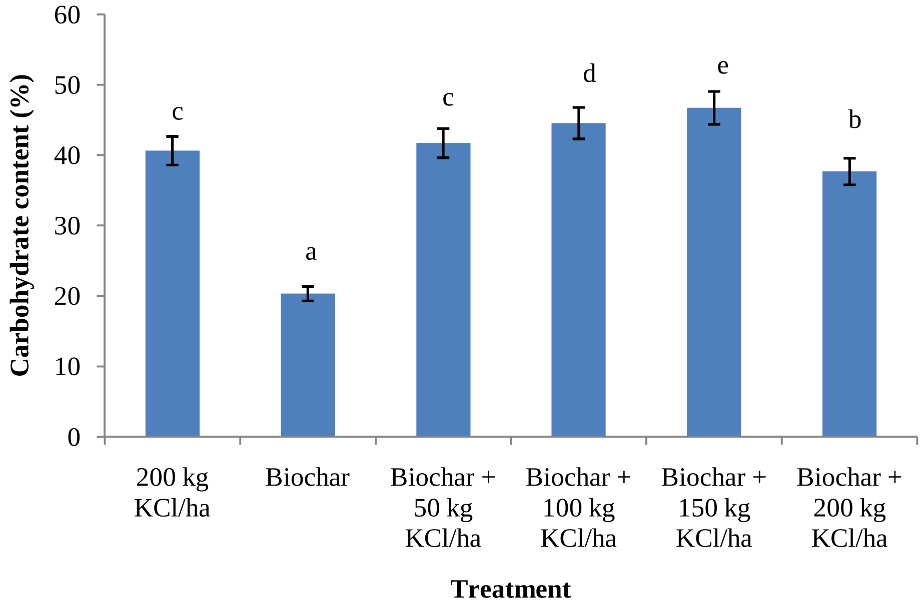

Figure 4. Carbohydrate content in the grain of maize on harvest

Availability of nutrients in the soil after harvest in the first and second seasons

Residual effect of potassium fertilizer combined with biochar increased K, Ca, Mg and Na cations in the soil because of the increase of organic content in the soil (Table 5). Similar results were also found by Major et al. (2010), Rondon et al. (2007), Steiner et al. (2007), and Topoliantz et al. (2005). Biochar could increse soil organic matter in the soil during the first and second seasons. Application of N, P and K fertilizers with biochar gave higher availability of nutrients compared with no biochar application. This was one of the reasons why grain yield in the second season (6.5-7.8 t/ha) was higher than that in the first season (5.5-7.0 t/ha).

Table 5.Nutrient availability in the soil before sowing, after first season and after second season

Treatment	**Total N (%)**			**P (mg/kg)**			**K^+ (me/ 100 g)**			**Total K (%)**			**Soil C organic (%)**		
	BT	**FS**	**SS**	**BT**	**FS**	**SS**	**BT**	**FS**	**SS**	**BT**	**FS**	**SS**	**BT**	**FS**	**SS**
200 kg KCl/ha	0.14 a	0.17 a	0.11 a	24.38 a	59.97 a	41.84 a	0.25 a	0.46 a	0.35 a	30.91 a	50.20 ab	284.01 b	1.46 a	1.35 a	1.93 a
Biochar	0.14 a	0.24 c	0.17 c	24.38 a	167.42 b	48.01 ab	0.25 a	0.88 c	1.03 c	30.91 a	122.86 c	234.57 a	1.46 a	1.86 b	2.30 b
Biochar + 50 kg KCl/ha	0.14 a	0.26 c	0.16 bc	24.38 a	173.25 b	91.87 e	0.25 a	0.82 c	0.87 b	30.91 a	142.36 c	526.12 d	1.46 a	1.88 b	2.27 b
Biochar + 100 kg KCl/ha	0.14 a	0.24 c	0.20 d	24.38 a	180.51 b	61.08 c	0.25 a	0.78 bc	1.25 d	30.91 a	63.25 b	891.81 e	1.46 a	1.87 b	2.28 b
Biochar + 150 kg KCl/ha	0.14 a	0.24 c	0.16 b	24.38 a	183.31 b	71.04 d	0.25 a	0.83 c	0.99 c	30.91 a	57.12 ab	355.85 c	1.46 a	1.87 b	2.26 b
Biochar + 200 kg KCl/ha	0.14 a	0.23 b	0.16 b	24.38 a	184.62 b	51.63 b	0.25 a	0.82 c	1.17 d	30.91 a	54.50 ab	334.35 c	1.46 a	1.88 b	2.27 b
LSD 0.05	ns	0.01	0.01	ns	27.23	8.99	ns	0.52	0.13	ns	40.76	27.99	ns	0.15	0.16

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05.
BT = before treatment, FS = first season, SS = second season

Table 6. Availability Ca and Mg in the soil after harvest first season and second season

Treatment	**Ca^{2+}(me/100 g)**			**Mg^{2+}(me/100 g)**			**Na^{+} (me/100 g)**
	BT	**FS**	**SS**	**BT**	**FS**	**SS**	**SS**
200 kg KCl/ha	4.49	17.08 a	15.94 a	3.81 a	1.27	3.26 c	0.82 a
Biochar	4.49 a	27.44 bc	22.36 cd	3.82 a	1.27	3.25 c	0.99 b
Biochar + 50 kg KCl/ha	4.50 a	29.08 c	21.82 bc	3.81 a	1.28	3.14 bc	1.19 cd
Biochar + 100 kg KCl/ha	4.50 a	29.06 c	23.29 d	3.81 a	1.55	2.77 b	1.25 d
Biochar + 150 kg KCl/ha	4.48 a	27.57 c	22.02 bc	3.82 a	1.52	4.43 d	1.36 e
Biochar + 200 kg KCl/ha	4.49 a	27.44 bc	21.18 b	3.81 a	1.5	1.99 a	1.15 c
LSD 0.05	ns	5.69	1.11	ns	1.00	0.41	0.06

Remarks: within each column, mean values followed by the same letters do not differ significantly at LSD 0.05. BT = before treatment, FS = first season, SS = second season

Conclusion

Residual effect of potassium fertilizer combined with biochar supported availability of nutrients for maize crop in the second season.The other side, residual effect of biochar increased availabilty of N, P, K, Ca and Na nutrients in the soil. Residual effect of biochar independently or combined with potassium fertilizer application increased yield of maize crop in the second season.

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