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Effects of Goat Manure, Biochar, and NPK Applications on Growth and Nutrient Concentrations of Lettuce

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ABSTRACT

During the last decades, biochar (BC) gained increasing importance amongst scholars. Though, only a few studies explored the effects of the combined application of BC with manure on plant growth and nutrient concentrations. This study investigates the effects of separate and joint applications of goat manure (GM) and its derived BC on the growth and mineral element concentrations in lettuce. A completely random design was used in the field experiment. Two factors consisted of GM, BC at 5 Mg ha^{-1} and 10 Mg ha^{-1} combined with inorganic fertilizers [nitrogen, phosphorus, and potassium (NPK)] at 100%, 50%, and 0% were applied to the soil before planting the lettuce and, ANOVA analysis and Duncan test (at α=5%) were conducted. The results showed that a joint application of inorganic and organic fertilizers affects significantly the yield and yield parameters of the lettuce whilst the separate application of organic fertilizer affects significantly the lettuce content in N, P, K, Ca and Mg. Compared to GM, the application of GM-derived BC increases significantly the lettuce content in Zn and decreases its content in Cu. In addition, the highest total yield of lettuce was obtained with a joint combination of GM, BC, and 100% NPK (100 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}). Consequently, this combination of organic and inorganic fertilizers is favorable fertilization in producing lettuce.

Keywords: Biochar, Goat manure, Lettuce, Inorganic fertilizer, Nutrients

1. Introduction

For long decades, inorganic fertilizers were used as one of the most essential inputs in agricultural systems. Though the resources consisting of the raw materials of some fertilizers such as phosphorus have declined (Gunes et al. 2006) and other inorganic fertilizers composed of heavy metals such as Hg, Cd, As and Pb accumulated in the different parts of the plants while they are applied at a high dose to the agricultural soil (Savci 2012). Besides, the pollution of soil and groundwater resources due to NO_3 constitutes serious issues (Pawar & Shaikh 1995) so that the increase of fertilizer efficient use becomes crucial. Accordingly, Palm et al. (1997) indicated that the combination of organic materials and inorganic fertilizers is a reliable method.

On the other hand, processed or unprocessed farmyard manures could be used in agricultural systems. Most studies focused on biochar (BC) obtained from wood materials (Lentz & Ippolito 2012; Borchard et al. 2012; Schomberg et al. 2012; Hansen et al. 2016). Besides, Sarmento et al. (2019) investigated the effects of goat manure (GM) application on the development and yield of lettuce plants in Brazil.

BC is a porous substance rich in carbon produced from organic materials such as; animal droppings, wood, green waste, sludge by a means of pyrolysis process under limited oxygen supply (Lehmann & Joseph 2009). Sohi et al. (2010) mentioned that the International Biochar Initiative (IBI) indicated that BC differs from charcoal due to it is especially used as a soil amendment. In addition, Lehmann et al. (2006) noted that BC is a material obtained from black fragments, light, porous, dry, and easy to transport. Zhao and Nartey (2014) defined BC as a porous, high specific surface area, negatively charged, containing functional groups (hydroxyl, carboxylic, phenolic) material.

Recently, BC has gained much importance from scholars due to it is considered a means to combat global climate change and to improve soil fertility. Besides Lehmann (2007) stated that BC is an inorganic and biological product that could remain active in the soil for more than 1000 years. Therefore, the application of BC in the soil offers opportunities for atmospheric carbon sequestration and increases the soil capacity in nutrient retention. This is due to that a high specific surface area coupled with the presence of numerous surface functional groups increase the cation exchange capacity (CEC) of the soil (Sohi et al. 2010; Verheijen et al. 2009). Krull et al. (2009) mentioned that the BC physico-chemical properties depend on the pyrolysis conditions and type of used raw material and Wang et al. (2012) noted that the BC effects on the availability of plant nutrients in soil depend on the type of raw material as well as the content of BC nutrients. Most studies focused on BC application, soil physico-chemical properties, and plant yield (Sohi et al. 2010; Jeffery et al. 2011) whilst only a few scholars explore the effects of BC and manure application jointly (Sarkhot et al. 2012; Lentz et al. 2014).

On the other hand, the application of BC could improve soil water retention, reduce the toxicity of certain pollutants and stimulate soil biodiversity (macro and micro-fauna) (Rees et al. 2014). Biederman and Harpole (2013) mentioned that the presence of BC in the soil increases crop productivity is usually observed in the presence of BC whilst Jeffery et al. (2011) stated that BC has potential negative effects such as; increasing soil salinity and fortifying soil contaminants. The use of BC in agriculture and the environment gained increasing importance due to it improving plant growth, sequestering carbon, and capturing the soil contaminants (Verheijen et al. 2009). Allaire and Lange (2013), highlight that this interest in BC comes from its ability to improve soil fertility, water content, and soil microbiology and therefore BC contributes to increasing plant productivity both in agricultural soils, artificial soils, or degraded soils.

In addition, the importance of BC depends on its properties, type of soil, plant species, and climate (Mounirou et al. 2020). Accordingly, the BC properties depend on the used raw material and the type of pyrolysis method used for its production. The advantages of the pyrolysis technique include easy liberation of nutrients to the soil and the BC can be lonely used or combined with organic or mineral fertilizers to improve soil fertility (Mounirou et al. 2020). In addition, BC can be applied to soils polluted by heavy metals to restore them. Besides, BC contains a high proportion of P, K, Ca, Mg, Fe, Zn, Cu, and Mn twice than manure, and can sequester carbon for millennia due to its high carbon content. BC improves soil pH, CEC, soil water retention capacity, biological activity, and structure so that it could significantly improve the physico-chemical and biological soil parameters (Kaya et al. 2019).

Many techniques are used in producing BC but they can be ranged into modern or artisanal techniques. Modern techniques, relatively affordable are developed in India, Canada, Japan, China, Turkey, France and Rwanda, which are countries are where there is increasing interest in BC. However, previously it was shown that BC can increase crop yields by 100-300% according to its raw materials, the temperature of pyrolysis techniques and the type of soil and the plant. This study aims to evaluate the efficiency of BC, manure, and inorganic fertilizers and their combination on lettuce cultivation.

2. Materials and Methods

2.1. Materials

2.1.1. Manure and biochar

The GM used in this study was procured at Ankara University hovel and it was sieved at 2 mm and then it was weighted before application. In addition, this sieved GM was used for obtaining BC. For this, the GM was pyrolyzed in a stainless-steel skip under limited O_2 conditions. First, the GM was filled into the skip and tilted horizontally on 2 bricks. Wood was fired perpetually under skip for 3 hours and rotated every 30 minutes and then after 3 hours, it was waited to cool room temperature and weighted for application. The BC yield was determined as described by Sadaka et al. (2014) and the physicochemical properties of the GM and BC were shown in Table 1.

Table 1- Physicochemical property of GM and BC

Characteristics	*GM*	*BC*
pH, (1:10 w/v)	9.22	12.2
EC, mS cm^{-1} (1:10 w/v)	16.3	26.0
Organic matter, %	65.9	41.3
Ash, %	34.1	58.7
C, g kg^{-1} (elemental analyzer)	273	281
N, g kg^{-1} (Kjeldahl)	26.8	17.8
P, g kg^{-1} (wet digestion)	8.46	15.9
K, g kg^{-1} (wet digestion)	34.5	69.4
Ca, g kg^{-1} (wet digestion)	41.7	64.7
Mg, g kg^{-1} (wet digestion)	9.25	12.6
S, g kg^{-1} (elemental analyzer)	6.60	7.85
Fe, g kg^{-1} (wet digestion)	5103	7860
Zn, g kg^{-1} (wet digestion)	220	410
Cu, g kg^{-1} (wet digestion)	50.0	92.0
Mn,g kg^{-1} (wet digestion)	341	609

GM: goat manure, BC: biochar

2.1.2. Site of study

This study was conducted at the Research Farm of Ankara University. The soil of the site of the experiment consists of clay loam and contains about 4.4 g kg^{-1} organic matter (wet digestion), 0.83 g kg^{-1} total N (Kjeldahl), 5.90 mg kg^{-1} available P ($NaHCO_3$ extraction), 743 mg kg^{-1} K, 5653 mg kg^{-1} Ca, 2387 mg kg^{-1} Mg (NH_4OAc extraction). Moreover, the soil of the site of the experiment had a pH value of 8.22, contained lime at 153.2 g kg^{-1} and its EC was 358 µS cm^{-1}. The available Fe, Zn, Cu, and Mn (DTPA extraction) were 3.22, 0.55, 1.43, and 11.6 mg kg^{-1}, respectively. Furthermore, the average temperatures were 18.8 °C maximum and 11.8 °C minimum whilst the average of rainfalls recorded in September was 26.8 mm and 19.5 in October.

2.1.3. Experimental design

This study was conducted in September and October 2017 at the Ayaş Horticultural Research and Application Station of Ankara University. A completely random experiment design consisting of 2 factors (organic and inorganic fertilizers) was used. GM and BC were applied separately and together at 5 Mg ha^{-1} and 10 Mg ha^{-1}, respectively, 2 days before planting the lettuce. In addition, inorganic fertilizers 100% [nitrogen, phosphorus, and potassium (NPK)] composed of 100 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1} was applied at the same date with inorganic fertilizer. Other NPK doses 50% NPK and 0% NPK (control) were used. Accordingly, soil and fertilizers were mixed with grabber and 30-day-old lettuce (*Lactuca sativa* L. var. Crispa) seedlings were planted spaced 30x30 cm between the rows and each plot was distant 1.5x1.5 m width and separated by a 0.5 m buffer. Then, the experiment area was watered with a drip irrigation system.

2.2. Methods

2.2.1. Measurements

Sixty days after planting, the plants were harvested, the total yield, the weight and diameter of the head, the weight of fresh and dry leaves and the total concentrations of the nutrient (N, P, K, Ca, Mg, Fe, Zn, Cu, Mn) were determined. A total of 10 mature plants randomly chosen from experiment plot, the weight of the plant, (g $plant^{-1}$) was determined by weighing on the balance. In addition, the head diameter was determined by selecting randomly 10 plants from each experiment plots as suggested by Sarmento et al. (2019). Accordingly, this head diameter was the average value obtained by measuring with a ruler by turning the heads upside down. Three leaves of lettuce were pulled off and 4th and 5th healthy leaves to determine the leafs fresh and dry weight. For this, the leaf samples were dried at 65 °C until to have a constant weight whilst the concentration of the leaves N and P were determined according to Kjeldahl procedure and spectrophotometrically, respectively and other parameters determined by AAS (Analytik Jena Vario 6) in a solution prepared form wet digested (4:1-HNO_3:$HClO_4$) plant subsamples (Isaac and Kerber 1971).

2.2.2. Statistical analysis

MINITAB 17 was used for data analysis, and the ANOVA test and Duncan test (at α=5%) were used to compare the study variables.

3. Results

3.1. Effects of NPK and organics manures applications on head weight and diameter of the lettuce

The combination between organic manures and NPK effects significantly the head weight and diameter of the plants of lettuce ($p<0.01$). The highest head weight was observed with the combination of 100% NPK + GM + BC (Table 2). Compared to 50% NPK + organic manure, 100% NPK didn't affect the head weight, but there were some similarities between head weight and diameter of lettuce. All the combinations increased head diameter as well as 100% NPK, and 50% NPK + organic manure combination.

Table 2- Effects of NPK and organic manure applications on head weight and diameter of the lettuce

Head weight (g plant⁻¹)			
Applications	100% NPK	50% NPK	0% NPK
Control	96.8 ± 1.64^{bc}	73.5 ± 0.44^{d}	32.7 ± 4.05^{e}
BC	114.3 ± 1.49^{b}	96.2 ± 7.21^{bc}	78.2 ± 3.95^{d}
GM	103.4 ± 11.2^{bc}	109.7 ± 11.1^{b}	86.2 ± 4.65^{cd}
BC + GM	133.6 ± 2.33^{a}	109.5 ± 3.83^{b}	74.0 ± 5.57^{d}
	NPK	57.85^{***}	
F value	OM	24.45^{***}	
	NPK x OM	3.76^{**}	
Head diameter (cm)			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	17.9 ± 0.43^{bcde}	16.2 ± 0.18^{e}	12.3 ± 1.14^{f}
BC	19.7 ± 0.35^{abc}	18.5 ± 0.59^{bcd}	17.8 ± 0.49^{cde}
GM	18.8 ± 0.45^{bcd}	19.2 ± 0.87^{abcd}	18.0 ± 0.09^{bcde}
BC + GM	20.9 ± 0.25^{a}	19.8 ± 0.61^{ab}	17.5 ± 0.67^{de}
	NPK	26.65^{***}	
F value	OM	27.19^{***}	
	NPK x OM	3.51^{**}	

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures
Values are the average of 4 replicates
**$p<0.01$, ***$p<0.001$
The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

3.2. Effect of NPK and organics manures applications on wet weight and dry weight of lettuce

Table 3 showed the effect of NPK and organic manure applications on wet weight and dry weight of lettuce. Accordingly, the application of both NPK, organic manure applications, and NPK x organic manures increased significantly the leaf fresh and dry weights and the interaction was significant at 5% ($p<0.05$).

Table 3- Effect of NPK and organic manure applications on wet weight and dry weight of lettuce

Wet weight (g leaf^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	7.95±0.15^{cde}	6.35±0.15^{f}	3.25±0.39^{g}
BC	9.50±0.24^{ab}	8.10±0.31^{cd}	6.75±0.39^{ef}
GM	8.90±0.82^{bc}	9.15±0.79^{abc}	7.20±0.18^{def}
BC + GM	10.30±0.37^{a}	9.05±0.33^{abc}	6.55±0.34^{f}
	NPK		59.53***
F value	OM		27.14***
	NPK x OM		2.68*
Dry weight (g leaf^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	0.43±0.01^{bcd}	0.36±0.01^{e}	0.21±0.02^{f}
BC	0.49±0.01^{ab}	0.44±0.01^{bc}	0.37±0.01^{de}
GM	0.48±0.04^{ab}	0.49±0.03^{ab}	0.41±0.01^{cde}
BC+GM	0.54±0.02^{a}	0.48±0.01^{ab}	0.37±0.02^{e}
	NPK		59.66***
F value	OM		29.47***
	NPK x OM		3.27*

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures
Values are the average of 4 replicates
$^{*}p<0.05$, $^{***}p<0.001$
The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

3.3. Effect of NPK and organics manures applications on the total yield of lettuce

The application of organic manures and NPK dosages affected significantly the total yield (p<0.01). The application of the organic manures and inorganic fertilizers affected the yield and the highest yield was obtained with the combination of 100% NPK + GM + BC (Figure 1). Furthermore, compared to the combination of 50% NPK + organic manure, the combination of 100% NPK did not affect the total yield.

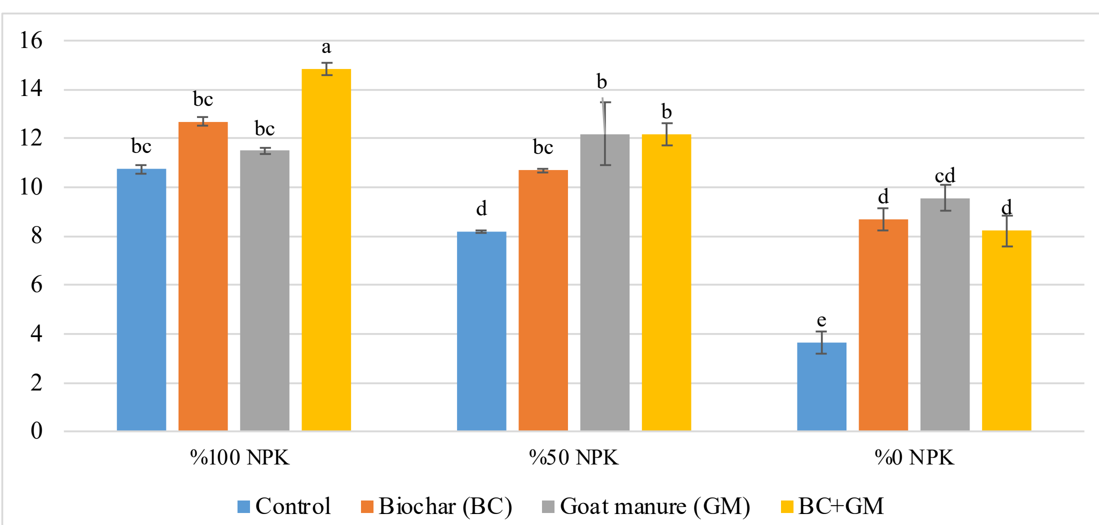

Figure 1- Effect of NPK and organics manures applications on total lettuce yield
Column showed mean of three repeats and bars showed standard error (p<0.05)

3.4. Effect of NPK and organics manures applications on total NPK of lettuce

Table 4 showed that the applications of inorganic and organic fertilizer on the total N content of the plant lettuce were statistically significant. With regards to the control treatment, the application of inorganic and organic fertilizers increased significantly the plant total N content. Likewise, the application of organic fertilizers increased the total N content compared to the control, the applications of 100% and 50% inorganic fertilizer did not show the effect on the plant total N.

On the other hand, the applications of inorganic and organic fertilizer affected significantly the total P content. Compared to the control treatment, the application of both inorganic, and organic fertilizers increased the total P content of the plant of lettuce. Besides, the application of organic fertilizers has increased significantly the lettuce content in P whilst the applications of inorganic and organic fertilizer and their interactions have affected significantly on the total K content in the trial area. Compared to the control, the total K content of lettuce plants increased significantly in all the treatments. For the combinations; 100% and 50% inorganic fertilizer, the total K content was statistically the same due to the applications of organic fertilizer Compared to the control, the total K content of lettuce plants receiving the organic fertilizers increased significantly.

Table 4- Effect of NPK and organics manures applications on total NPK of lettuce

Total N (g kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	36.0±0.54^{abc}	34.9±1.00^{abc}	29.6±0.93^{d}
BC	35.6±0.41^{abc}	35.5±0.43^{abc}	34.0±0.94^{c}
GM	36.9±0.50^{a}	36.4±0.74^{ab}	34.6±0.43^{bc}
BC + GM	36.1±0.55^{abc}	36.4±0.71^{ab}	35.1±0.47^{abc}
	NPK	20.52***	
F value	OM	8.59***	
	NPK x OM	3.64*	
Total P (g kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	3.50±0.32^{b}	2.81±0.16^{c}	2.03±0.06^{d}
BC	4.89±0.16^{a}	4.82±0.18^{a}	4.43±0.23^{a}
GM	4.40±0.16^{a}	3.82±0.12^{b}	3.27±0.12^{bc}
BC + GM	5.02±0.07^{a}	4.75±0.33^{a}	4.84±0.15^{a}
	NPK	18.22***	
F value	OM	77.55***	
	NPK x OM	2.64*	
Total K (g kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	87.8±1.45^{a}	85.5±1.93^{ab}	66.7±1.80^{c}
BC	86.8±0.77^{ab}	88.3±1.92^{a}	84.5±1.37^{ab}
GM	83.3±0.94^{ab}	88.2±4.34^{a}	83.6±3.13^{ab}
BC + GM	86.2±2.11^{ab}	89.2±3.92^{a}	79.5±2.46^{b}
	NPK	16.48***	
F value	OM	4.16*	
	NPK x OM	4.21**	

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures

Values are the average of 4 replicates

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

3.5. Effect of NPK and organics manures applications on total Ca and Mg of lettuce

The interaction effect between inorganic and organic fertilizer applications on lettuce total Ca content in the trial area was statistically significant. In all applications, the lettuce plant total Ca content increased significantly compared to the control. Application of 50% inorganic fertilizer only in plants treated with BC increased plant Ca content compared to 100% inorganic fertilization. In plants that do not apply inorganic fertilizers, all organic fertilizers applied significantly increased the total Ca content compared to control (Table 5). It showed that the effect of inorganic and organic fertilizer interaction on the total Mg content of the lettuce plant was statistically significant. In 100% to 50% inorganic fertilizer applications, organic fertilizer applications significantly reduced total Mg compared to their Controls. In plants without inorganic fertilizer application, total Mg content increased significantly with the application of BC and goat fertilizer.

Table 5- Effect of NPK and organic manure applications on total Ca and Mg of lettuce

Total Ca (g kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	32.4 ± 1.78^{bc}	34.7 ± 0.08^{abc}	24.9 ± 2.20^{d}
BC	29.9 ± 0.53^{c}	38.6 ± 1.86^{a}	33.4 ± 1.83^{bc}
GM	32.3 ± 2.10^{bc}	35.3 ± 1.46^{ab}	36.4 ± 0.61^{ab}
BC + GM	31.6 ± 1.83^{bc}	35.1 ± 0.65^{abc}	31.3 ± 2.11^{bc}
	NPK	10.2^{***}	
F value	OM	3.70^{*}	
	NPK x OM	3.74^{**}	
Total Mg (g kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	8.52 ± 0.22^{b}	9.47 ± 0.09^{a}	6.33 ± 0.20^{ef}
BC	7.18 ± 0.13^{cd}	7.50 ± 0.33^{c}	6.56 ± 0.15^{ef}
GM	5.51 ± 0.13^{h}	6.17 ± 0.14^{fg}	6.74 ± 0.07^{de}
BC + GM	5.73 ± 0.08^{gh}	6.12 ± 0.06^{fg}	8.64 ± 0.14^{b}
	NPK	12.9^{***}	
F value	OM	77.7^{***}	
	NPK x OM	68.5^{***}	

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures
Values are the average of 4 replicates
$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$
The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

3.6. Effect of NPK and organic manure applications on total Fe and Zn of lettuce

The effect of inorganic fertilizer and organic fertilizer applications on the total iron content of the lettuce plant in the trial area was statistically significant, but the effect of the interaction was insignificant. Total iron increased significantly with 50% inorganic fertilizer application. With regards to the application of organic fertilizer, there was not any statistically significant difference between the different treatments. However, the content in Fe was low in the plant receiving the goat fertilizer compared to plants with BC (Table 6). It showed that the effect of inorganic and organic fertilizer applications interaction on the total zinc content of the lettuce plant was significant. Through, the application of 50% inorganic fertilizer, only the BC plant increased the Zn content.

3.7 Effect of NPK and organic manure applications on total Cu and Mn of lettuce

The interaction of inorganic fertilizer applications to the total Cu content of the lettuce plant in the trial area was insignificant, but the effect of organic fertilizer applications was statistically significant. With the application of BC alone, the total Cu content of the lettuce plant decreased compared to the control (Table 7). Additionally, Table 7 showed that the application of only inorganic fertilizer on the total Mn content of the lettuce plant in the trial area was statistically significant and all inorganic fertilizer applications performed increased compared to the control.

Table 6- Effect of NPK and organic manure applications on total Fe and Zn of lettuce

Total Fe (mg kg^{-1})				
Applications	*100% NPK*	*50% NPK*	*0% NPK*	*Mean*
Control	122.6±10.5	126.6±3.52	138.6±18.7	129.3±6.85^{ab}
BC	134.1±15.1	153.1±4.12	127.4±9.55	138.2±6.44^{a}
GM	101.4±3.84	125.6±15.0	107.6±5.12	111.5±5.81^{b}
BC + GM	118.6±12.2	141.4±7.88	107.4±8.83	122.4±6.67^{ab}
Mean	119.2±5.85^{b}	136.7±4.94^{a}	120.2±6.26^{b}	
F value	NPK		3.39*	
	OM		3.39*	
	NPK x OM		0.94^{NS}	

Total Zn (mg kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	16.85±0.57^{bcd}	16.33±0.70^{cd}	19.65±0.35^{bc}
BC	14.18±0.24^{d}	20.35±1.23^{b}	17.48±0.75^{bcd}
GM	16.60±0.56^{cd}	15.08±1.15^{d}	24.37±3.24^{a}
BC + GM	16.15±0.59^{cd}	15.43±0.25^{d}	16.78±0.12^{bcd}
F value	NPK		10.99***
	OM		2.54^{NS}
	NPK x OM		6.04***

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures

Values are the average of 4 replicates

^{NS}Non-significant, *p<0.05, ***p<0.001

The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

Table 7- Effect of NPK and organic manure applications on total Cu and Mn of lettuce

Total Cu (mg kg^{-1})				
Applications	*100% NPK*	*50% NPK*	*0% NPK*	*Mean*
Control	18.15±0.67	17.93±0.66	18.33±0.80	18.14±0.38^{a}
BC	17.23±0.25	17.83±0.76	15.50±0.65	16.85±0.43^{b}
GM	20.20±0.40	18.08±0.73	18.90±0.53	19.06±0.40^{a}
BC + GM	19.88±0.41	18.65±0.75	19.00±1.02	19.18±0.43^{a}
F value	NPK			
	OM	7.81***		
	NPK x OM	1.55^{NS}	2.18^{NS}	

Total Mn (mg kg^{-1})			
Applications	*100% NPK*	*50% NPK*	*0% NPK*
Control	53.83±0.97	54.35±0.57	48.15±2.81
BC	54.10±1.62	53.35±1.41	51.18±1.84
GM	56.40±1.65	57.15±1.41	53.78±2.20
BC + GM	56.88±2.78	57.75±0.66	51.13±2.93
Mean	55.30±1.22^{a}	55.65±0.68^{a}	51.06±0.91^{b}
F value	NPK		
	OM	2.64^{NS}	
	NPK x OM	0.37^{NS}	7.23**

GM: goat manure, BC: biochar, NPK: inorganic fertilizer, OM: organic manures

Values are the average of 4 replicates

^{NS}Non-significant, **p<0.01, ***p<0.001

The difference between the means indicated with the same letter in the same column is not significant ANOVA test and Duncan test (at α=5%)

4. Discussion

The application of organic manure applications increases the efficient use of inorganic fertilizer. In addition, the application of organic amendments has improved the nutrient supplements, the capacity of soil water retention, bulk density and CEC. These results are consistent with Yadav et al. (2019) who indicated that the application of BC with inorganic fertilizers increased the biomass, whilst the application of farmyard manure combined with inorganic fertilizers reduced this biomass.

The application of alkaline BC and GM in calcareous soil increased significantly the lettuce total yield Similarly Gunes et al. (2014), Inal et al. (2015), Sahin et al. (2017) and Najafi-Ghiri et al. (2019) indicated that the application of BC increased barley yield. Besides, Kammann et al. (2011) found that the application of the BC on sandy soil at 0, 100 and 200 t ha^{-1} increase the plant development and the leaves content in N content under greenhouse conditions.

Table 4 showed that the applications of inorganic and organic fertilizer lettuce increase significantly the total N and P content of the plant and the applications of inorganic and organic fertilizer and their interactions have affected significantly on the total K content. Previously, Spokas et al. (2012) mentioned that BC acts as an N-trap in the soil so that it increased the rate of nitrogen utilization of plants. Clearly, Jones et al (2012) emphasized that the application of BC increased significantly the N content of the meadow and Deluca et al. (2009) explained that the conversion of organic matter to BC presents high soluble P content that increased significantly the plant phosphorus concentration. Furthermore, Wang et al. (2018) note that the application of bamboo BC prepared at 450 °C at 0.5, 10, and 25 g kg^{-1} increases the plant concentration in potassium.

Gunes et al (2014 and 2015) state that the application of BC and phosphorus improves the concentrations of N, P, K in the plant of lettuce plant and the application of chicken manure BC obtained under different temperatures increases P and K concentrations and total yield of lettuce and corn.

Compared to the control, the application of the organic fertilizers increases the total Ca content with the 100% to 50% inorganic fertilizer applications reduce significantly reduced total Mg in the plant. Major et al. (2010) found that the application of BC (0.8 and 20 tons ha^{-1}) increases the calcium intake of the plant and Lehmann et al. (2006) mentioned that the use of BC in tropical areas increases the P, K Ca uptake by the plants.

On the other hand, Rees et al. (2014) and Zhou et al. (2017), and Gunes et al. (2014) indicated that the intake of microelements decreased with the application of BC in the soils slightly alkaline and Mielki et al. (2016) stated that the application of the BC increases soil pH by decreasing the beneficial Fe concentration which decreases the iron concentration in the plant. Gunes et al. (2015) found that application BC caused a decrease in iron concentration in lettuce plants and Salmani et al. (2014) noted that the application of BC reduces the copper uptake of the plant because it adsorbs the amount of useful copper in the soil. Karami et al. (2011) found the application of BC reduces the copper concentration on the plant of meadow grass. Likewise, Park et al. (2011) reported that application of BC on the plant cabbage reduces copper intake and Guneş et al. (2015) mentioned that the development of chicken manure BC obtained at different temperatures on the plant of lettuce plant increases the concentration of the plant in Zn with the BC obtained at 300 °C and 350 °C. Previously, Mandal et al. (1988) stated that the application of BC increases soil organic matter.

Lentz and Ippolito (2012) highlight that the application of organic fertilizer at 42.4 ha^{-1} and BC obtained from hardwood pyrolysis at 22.4 t ha^{-1} increased the content of the soil in Mn 1.5 times, while the application of organic fertilizer increases 1.2-1.7 times other plant nutrients except Fe. Peng et al. (2011) and Dong et al. (2011) noted that the application of BC decreases the usefulness of some microelements by increasing soil pH according to the material used to produce this BC and Chirenje and Ma (2002) indicate that the increase in soil pH after BC application is thought to be related to the ash content and pH of the BC.

5. Conclusions

This study investigates the effects of separate and joint application of GM and BC on the growth, mineral concentrations and efficient use of inorganic fertilizer on the lettuce. The findings showed that the application of whether GM or BC alone improved significantly the parameters of the growth of the plants and the content of the nutrient of the plants in N, P, K and Ca. Though the application of inorganic fertilizers reduced significantly the content of plants in Mg, Fe, Zn, Cu, and Mn according to the applied doses of and partially decreased with the applications of BC. This study revealed that a joint application of 100% of inorganic fertilizer, BC and GM had the highest yield. Also, a joint application of 50% inorganic fertilizer combined whether with BC or the GM affected similarly the plant yield than 100% of inorganic fertilizer, BC and GM. Additionally, these doses affected the growth of the plants and the nutrients content of leaves. An application of BC or GM combined with a low dose of inorganic fertilizers, especially in the soil with low organic matter improves the physical, chemical, and biological of the soil. Therefore, it increases the productivity of the plants as well the content in nutrient of the plants.

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References

Allaire S E & Lange S F (2013). Le biochar dans les milieux poreux : une solution miracle en environnement ? *Vecteur Environnement* 46(4): 58-67.

Biederman L A & Harpole W S (2013). Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. *GCB Bioenergy* 5(2): 202-214. doi.org/10.1111/gcbb.12037.

Borchard N, Wolf A, Laabs V, Aeckersberg R, Scherer H W, Moeller A & Amelung W (2012). Physical activation of biochar and its meaning for soil fertility and nutrient leaching - a greenhouse experiment. *Soil Use and Management* 28(2): 177-184. doi.org/10.1111/j.1475-2743.2012.00407.x.

Chirenje T & Ma L Q (2002). Impact of high-volume wood-fired boiler ash amendment on soil properties and nutrients. *Communications in Soil Science and Plant Analysis* 33(1-2): 1-17. doi.org/10.1081/CSS-120002373.

DeLuca T H, Derek MacKenzie M & Gundale M J (2009). Biochar effects on soil nutrient transformation. In: J Lehmann, S Joseph (Eds.) *Biochar for environmental management: science and technology.* Routledge, London, pp. 251-270.

Dong X, Ma L Q & Li Y (2011). Characteristics and mechanisms of hexavalent chromium removal by biochar from sugar beet tailing. *Journal of Hazardous Materials* 190(1-3): 909-915. doi.org/10.1016/j.jhazmat.2011.04.008.

Gunes A, Inal A, Alpaslan M & Cakmak I (2006). Genotypic variation in phosphorus efficiency between wheat cultivars grown under greenhouse and field conditions. *Soil Science & Plant Nutrition* 52(4): 470-478. doi.org/10.1111/j.1747-0765.2006.00068.x.

Gunes A, Inal A, Sahin O, Taskin M B, Atakol O & Yilmaz N (2015). Variations in mineral element concentrations of poultry manure biochar obtained at different pyrolysis temperatures, and their effects on crop growth and mineral nutrition. *Soil Use and Management* 31(4): 429-437. doi.org/10.1111/sum.12205.

Gunes A, Inal A, Taskin M B, Sahin O, Kaya E C & Atakol A (2014). Effect of phosphorus-enriched biochar and poultry manure on growth and mineral composition of lettuce (L actuca sativa L. cv.) grown in alkaline soil. *Soil Use and Management,* 30(2): 182-188. doi.org/10.1111/sum.12114.

Hansen V, Hauggaard-Nielsen H, Petersen C T, Mikkelsen T N & Müller-Stöver D (2016). Effects of gasification biochar on plant-available water capacity and plant growth in two contrasting soil types. *Soil and Tillage Research* 161: 1-9. doi.org/10.1016/j.still.2016.03.002.

Inal A, Gunes A, Sahin O, Taskin M B & Kaya E C (2015). Impacts of biochar and processed poultry manure, applied to a calcareous soil, on the growth of bean and maize. *Soil Use and Management*, 31(1): 106-113. doi.org/10.1111/sum.12162.

Isaac R A & Kerber J D (1971). Atomic absorption and flame photometry: Techniques and uses in soil, plant, and water analysis. *Instrumental methods for analysis of soils and plant tissue* 17-37. doi.org/10.2136/1971.instrumentalmethods.c2.

Jeffery S, Verheijen F G, van der Velde M & Bastos A C (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. *Agriculture, Ecosystems & Environment,* 144(1): 175-187. doi.org/10.1016/j.agee.2011.08.015.

Jones D L, Rousk J, Edwards-Jones G, DeLuca T H & Murphy D V (2012). Biochar-mediated changes in soil quality and plant growth in a three-year field trial. *Soil Biology and Biochemistry* 45: 113-124. doi.org/10.1016/j.soilbio.2011.10.012.

Kammann C I, Linsel S, Gößling J W & Koyro H W (2011). Influence of biochar on drought tolerance of Chenopodium quinoa Willd and on soil–plant relations. *Plant and Soil* 345(1): 195-210. doi.org/10.1007/s11104-011-0771-5.

Karami N, Clemente R, Moreno-Jiménez E, Lepp N W & Beesley L (2011). Efficiency of green waste compost and biochar soil amendments for reducing lead and copper mobility and uptake to ryegrass. *Journal of Hazardous Materials,* 191(1-3): 41-48. doi.org/10.1016/j.jhazmat.2011.04.025.

KAYA E C, Hanife A, TAŞKIN M B, MOUNIROU M M & Tuğba K (2019). Effects of Biochar and Phosphorus Applications on Growth and Mineral Element Concentrations of Maize and Rice Plants. *Toprak Su Dergisi 8(1)*: 46-54. doi.org/10.21657/topraksu.544679.

Krull E S, Baldock J A, Skjemstad J O & Smernik R J (2009). Characteristics of Biochar: Organo-chemical Properties. In: Biochar for environmental management. Routledge, London, pp. 85-98.

Lehmann J (2007). Bio-energy in the black. *Frontiers in Ecology and the Environment* 5(7): 381-387. doi.org/10.1890/1540-9295(2007)5[381:BITB]2.0.CO;2

Lehmann J & Joseph S (2009). Biochar for environmental management: an introduction. Biochar for Environmental Management-Science and Technology. Routledge, London.

Lehmann J, Gaunt J & Rondon M (2006). Bio-char sequestration in terrestrial ecosystems–a review. *Mitigation and adaptation strategies for global change* 11(2): 403-427. doi.org/10.1007/s11027-005-9006-5.

Lentz R D & Ippolito J A (2012). Biochar and manure affect calcareous soil and corn silage nutrient concentrations and uptake. *Journal of Environmental Quality* 41(4): 1033-1043. doi.org/10.2134/jeq2011.0126

Lentz R D, Ippolito J A & Spokas, K A (2014). Biochar and manure effects on net nitrogen mineralization and greenhouse gas emissions from calcareous soil under corn. *Soil Science Society of America Journal* 78: 1641-1655. doi.org/10.2136/sssaj2014.05.0198

Majeed A J (2014). Toprak verimliliğini arttırmak için bir toprak düzenleyici olarak biochar. Yüksek Lisans Tezi, Kahramanmaraş Sütçü İmam Ün., Fen Bil. Ens, Biyomühendislik ve Bilimleri Anabilim Dalı, Kahramanmaraş.

Major J, Rondon M, Molina D, Riha S J & Lehmann J (2010). Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. *Plant and Soil* 333(1): 117-128. doi.org/10.1007/s11104-010-0327-0.

Mandal B, Hazra G C & Pal A K (1988). Transformation of zinc in soils under submerged condition and its relation with zinc nutrition of rice. *Plant and Soil* 106(1): 121-126. doi.org/10.1007/BF02371203.

Mielki G F, Novais R F, Ker J C, Vergütz L & de Castro G F (2016). Iron availability in tropical soils and iron uptake by plants. *Rev Bras Cienc* solo 40. doi.org/10.1590/18069657rbcs20150174.

Mounirou M M, Kaya E C, Ouedraogo A R, Demir K, Güneş A & İnal A (2020). Effects of biochar and organic fertilizer applications on the growth and inorganic fertilizer use efficiency of onion plant. *Toprak Bilimi ve Bitki Besleme Dergisi,* 8(1): 36-45. doi.org/10.33409/tbbbd.757008.

Najafi-Ghiri M, Razeghizadeh T, Taghizadeh M S & Boostani H R (2019). Effect of sheep manure and its produced vermicompost and biochar on the properties of a calcareous soil after barley harvest. *Communications in Soil Science and Plant Analysis* 50(20): 2610-2625. doi.org/10.1080/00103624.2019.1671444.

Palm C A, Myers R J & Nandwa S M (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. *Replenishing soil fertility in Africa 51*: 193-217. doi.org/10.2136/sssaspecpub51.c8.

Pandit N R, Mulder J, Hale S E, Martinsen V, Schmidt H P & Cornelissen G (2018). Biochar improves maize growth by alleviation of nutrient stress in a moderately acidic low-input Nepalese soil. *Science of the Total Environment* 625: 1380-1389. doi.org/10.1016/j.scitotenv.2018.01.022.

Park J H, Choppala G K, Bolan N S, Chung J W & Chuasavathi T (2011). Biochar reduces the bioavailability and phytotoxicity of heavy metals. *Plant and Soil* 348(1): 439-451. doi.org/10.1007/s11104-011-0948-y.

Pawar N A & Shaikh I J (1995). Nitrate pollution of ground waters from shallow basaltic aquifers, Deccan Trap Hydrologic Province*, India. Environmental Geology* 25(3): 197-204. doi.org/10.1007/BF00768549.

Peng X, Ye L L, Wang C H, Zhou H & Sun B (2011). Temperature-and duration-dependent rice straw-derived biochar: Characteristics and its effects on soil properties of an Ultisol in southern China. *Soil and Tillage Research* 112(2): 159-166. doi.org/10.1016/j.still.2011.01.002.

Rees F, Simonnot M O & Morel J L (2014). Short-term effects of biochar on soil heavy metal mobility are controlled by intra-particle diffusion and soil pH increase. *European Journal of Soil Science,* 65(1): 149-161. doi.org/10.1111/ejss.12107.

Sadaka S, Sharara M A, Ashworth A, Keyser P, Allen F & Wright A (2014). Characterization of biochar from switchgrass carbonization. *Energies,* 7(2): 548-567. doi.org/10.3390/en7020548.

Sahin O, Taskin M B, Kaya E C, Atakol O, Emir E, Inal A & Gunes A (2017). Effect of acid modification of biochar on nutrient availability and maize growth in a calcareous soil. *Soil Use and Management,* 33(3): 447-456. doi.org/10.1111/sum.12360.

Salmani M S, Khorsandi F, Yasrebi J & Karimian N (2014). Biochar effects on copper availability and uptake by sunflower in a copper contaminated calcareous soil. *International Journal of Plant, Animal and Environmental Sciences* 4(3): 389-394.

Sarkhot D V, Berhe A A & Ghezzehei T A (2012). Impact of biochar enriched with dairy manure effluent on carbon and nitrogen dynamics. *Journal of Environmental Qualit* 41(4): 1107-1114. doi.org/10.2134/jeq2011.0123.

Sarmento J J A, Costa C C, Dantas M V, Lopes K P, de Macedo I C, Bomfim S M P & Barbosa Da W S (2019). Productivity of lettuce under organic fertilization. *Journal of Agricultural Science* 11(1): 333-343. doi.org/10.5539/jas.v11n1p335.

Savci S (2012). An agricultural pollutant: inorganic fertilizer. *International Journal of Environmental Science and Development* 3(1): 73.

Schomberg H H, Gaskin J W, Harris K, Das K C, Novak J M, Busscher W J, Watts D W, Woodroof R H, Lima I M, Ahmedna M, Rehrah D & Xing B. (2012). Influence of biochar on nitrogen fractions in a coastal plain soil. *Journal of Environmental Quality* 41(4): 1087-1095. doi.org/10.2134/jeq2011.0133.

Sohi S P, 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. doi.org/10.1016/S0065-2113(10)05002-9.

Spokas K A, Novak J M & Venterea R T (2012). Biochar's role as an alternative N-fertilizer: ammonia capture. Plant and *Soil* 350(1): 35-42. doi.org/10.1007/s11104-011-0930-8.

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

Verheijen F, Jeffery S, Bastos A, Van Der Velde M, Diafas I (2009). Biochar application to soils: a critical scientific review of effects on soil properties, processes and functions. EUR 24099 EN. Luxembourg (Luxembourg): European Commission; 2010.

Wang L, Xue C, Nie X, Liu Y & Chen F (2018). Effects of biochar application on soil potassium dynamics and crop uptake. *Journal of Plant Nutrition and Soil Science* 181(5): 635-643. doi.org/10.1002/jpln.201700528.

Wang T, Camps-Arbestain M, Hedley M & Bishop P (2012). Predicting phosphorus bioavailability from high-ash biochars. *Plant and Soil* 357(1): 173-187. doi.org/10.1007/s11104-012-1131-9.

Yadav V, Karak T, Singh S, Singh A K & Khare P (2019). Benefits of biochar over other organic amendments: Responses for plant productivity (Pelargonium graveolens L.) and nitrogen and phosphorus losses. *Industrial Crops and Products* 131: 96-105. doi.org/10.1016/j.indcrop.2019.01.045.

Zhao B & Nartey O D (2014). Characterization and evaluation of biochars derived from agricultural waste biomasses from Gansu, China. Proceedings of the World Congress on Advances in Civil, Environmental, and Materials Research, Busan, Republic of Korea.

Zhou D, Liu D, Gao F, Li M & Luo X (2017). Effects of biochar-derived sewage sludge on heavy metal adsorption and immobilization in soils. *International Journal of Environmental Research and Public Health* 14(7): 681. doi.org/10.3390/ijerph14070681.