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Effects of tomato harvest residue derived biochars obtained from different pyrolysis temperature on periodical available nutrient concentrations of soils

Domates hasat atıklarının farklı sıcaklıklarda prolizi ile elde edilen biyokömürün toprağın dönemsel besin elementi konsantrasyonlarına etkisi

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ABSTRACT

The aim of this study was to investigate the effects of biochars obtained by pyrolysis of the tomato harvest residues at different temperatures on some available nutrient concentrations of soil. For this purpose, biochars were obtained by pyrolysis of the tomato harvest residues at 500 and 700° C for 80 minutes. The biochars were applied to the parcels prepared in 50x50 cm dimensions under field conditions to 3 tons per decare and they were left to stand in natural conditions. 2 months after the application, soil samples were taken in 4 periods at one-month intervals. In these examples, plant available and/or extractable nutrients were determined. According to the results, it was observed that biochar applications did not affect the nutrient concentrations of the soil and had a negative effect on some nutrients. The pyrolysis temperatures had no effect on the efficiency of biochar on soil nutrient concentration.

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Besin elementi
Domates hasat kalıntısı
Toprak

ÖZ

Araştırmada farklı domates hasat kalıntılarından farklı sıcaklıklarda yakılmasıyla elde edilmiş biyokömürün, toprağın bazı yarayışlı besin elementi konsantrasyonlarına etkisini incelemek amaçlanmıştır. Bunun için domates sapları 500 ve 700 derecede 80 dakika süreyle yakılarak biyokömür elde edilmiştir. Elde edilen biyokömürler, arazi koşullarında 50x50 cm ölçülerinde hazırlanan parsellere dekara 3 ton olacak şekilde uygulanmış ve doğal koşullarda beklemeye bırakılmıştır. Uygulamadan 2 ay sonra, 1 er ay aralıklarla 4 dönemde toprak örnekleri alınmış ve bu örneklerde bitkiye yarayışlı ve/veya çözeltiye geçebilen besin elementleri analizleri yapılmıştır. Elde edilen sonuçlara göre biyokömür uygulamalarının toprakların besin elementi içeriklerini genelde etkilemediği, hatta bazı besin elementleri üzerinde olumsuz etki yaptığı görülmüştür. Yakma sıcaklıklarının biyokömürün etkinliği üzerine bir etkisi görülmemiştir.

1. Introduction

Preservation and sustainability soil fertility have an increasing importance especially in areas of intensive agriculture lands. Although, there are several ways to accomplish these goals, there are some materials having positive effects on conserving soil fertility. Manure, green fertilizers, composts, humic substances and algae are some of the well-known input material used for sustainable soil fertility. Biochar is another source used as a soil amender. Biochar is a carbon-rich and porous material produced from different kinds of biomass. Biochar is produced with a process called as pyrolysis. Pyrolysis is a carbonization process in which the content of carbon increases with temperature accompanied by a simultaneous decrease in oxygen and hydrogen contents. When used as a soil amendment, biochar can boost soil fertility and improve soil quality by increasing soil pH, increasing moisture-holding capacity, attracting more beneficial microorganism and improving cation exchange capacity (Schmidt and Noack 2000; Lehmann et al. 2006; Lehmann 2007; Herath et al. 2013). Biochar application to the soils increases soil cation exchange capacity as well (Nigussie et al. 2012). Incorporating carbon to the soil, biochar can increase soil fertility. Biochar helps nutrients to be held for a longer period of time within the root zone. This increases fertilizer use efficiency by the plants. Reduction in the quantity of agricultural waste is another advantage of biochar production. Tomato is one of the most important agricultural products in Turkey and quite amount of harvest residues exist at the production period. Burning of these residuals is a common application to be eliminated (Erdal et al. 2018).

In this study, we aimed to investigate the effect of biochar derived from tomato harvest residue at different combustion temperature on periodical soil nutrient changes under natural conditions.

2. Materials and Methods

2.1. Biochar material

In this study, tomato harvest residues were converted to biochar by slow pyrolysis method. A cylindrical batch prolyzer was used for the biochar production. The volume of the pyrolyser chamber is 50.24 l with the diameter of 40 cm and height of 40 cm. Biochar production was performed at temperatures of 500°C and 700°C for 80 min. The pH's of biochar produced at 500°C and 700°C were 9.10 and 9.70, respectively. The biochars were applied to the parcels prepared in 50x50 cm dimensions under field conditions to 3 tons per decare and they were left to stand in natural conditions. Soil samples were taken in 4 periods at one-month intervals after 2 months-application.

2.2. Some characteristics of experimental soils

Some characteristics of the soils at beginning of the experiment were given in Table 1. The soil was a clayey loamy, slightly alkaline, high in $CaCO_3$, low in organic matter. Soil nutrient concentrations were sufficient (Lindsay and Norwell 1969; FAO 1990).

Table 1. Some characteristics of the soil before biochar applications.

Characteristics	
Organic matter (%)	1.9
$CaCO_3$ (%)	17.6
Texture	CL
pH (1/2 soil/water)	7.9
Available P (mg kg^{-1})	35
Exchangeable Ca (cmol kg^{-1})	30.7
Exchangeable K (cmol kg^{-1})	4.0
Exchangeable Mg (cmol kg^{-1})	3.3
DPTA Extractable Fe (mg kg^{-1})	11
DPTA Extractable Mn (mg kg^{-1})	31.6
DPTA Extractable Zn (mg kg^{-1})	2.93
DPTA Extractable Cu (mg kg^{-1})	5.2

2.3. Soil analysis

Soil was extracted with $NaHCO_3$ (Olsen 1954) for P analysis. Potassium, Ca, and Mg extracted with NH_4AOC (Jackson 1967). In order to determine micronutrient concentrations soil was extracted with DTPA (Lindsay and Norvell 1969). Phosphorus measurement was made using spectrophotometer. All other nutrients were measured using atomic absorption spectrophotometer. Soil $CaCO_3$ content was determined with calcimeter (Allison and Moodie 1965), texture was measured as described by Bouyoucos (1951). pH was measured using a glass electrode (Peech 1965). Organic matter was determined according to Walkley and Black (1934).

3. Results

Individual effects of sampling time and pyrolysis temperatures or their interactions did not affect soil Ca, K and P concentrations (Table 2). Comparing to control, soil Mg concentrations decreased with biochar applications derived from both pyrolysis temperature. Looking at the periodical soil Mg concentration under both biochar applications, it can be said that Mg concentrations increased with the time (Table 2).

The effect of biochars on soil micronutrient concentrations can be seen in Table 3. Soil Cu concentration was affected negatively from the both biochar applications. Soil Cu concentrations measured at plots where biochars obtained at the 500 and 700°C were applied considerably were lower than that that of control plots. Additionally Cu concentration decreased with time. Soil Mn and Fe concentrations were significantly varied with pyrolysis temperature and sampling date interactions. Both nutrient concentrations in the soil significantly increased at the first sampling time, but then decreased with the time. While Fe and Mn concentrations under control conditions did not vary with the time, they decreased significantly with biochar applications. These decrements under biochar applied conditions increased with the progressing periods. Looking at the soil Zn concentrations, it was seen that it did not vary with biochar applications and sampling time.

4. Discussion

According to the result obtained, it was seen that whether both biochar applications did not affect soil nutrient concentrations such as K, P and Zn or led to decrease such as Mg and Cu. In most of the studies, it was implemented that biochar increased available soil nutrient concentrations and plant nutrient uptakes when fertilization was done. Most of the studies explained the positive effects of biochar on nutrients availability with the nutrient holding capacity of biochar preventing nutrient leaching especially under heavy rainy conditions (Lehmann et al. 2003). Additionally, some of the positive effect of biochars was observed on sandy soils with low cation exchange capacity (Tryon 1948). In our study, the soil used for experiment had favorable soil texture, so addition of biochar did not affect available soil nutrient concentrations by improving cation exchange capacity. Furthermore, not giving any fertilizer to the soil might be the reason for biochar's non effectiveness on the most of the nutrient availabilities. In most studies, it was remarked that effectiveness of biochar under fertilizer applied conditions were more obvious and there was little or no response to biochar in the absence of fertiliser (Van Zwieten at al. 2010; Sohi et al. 2010). Another explanation for this might be the fact that pure biochar does not directly enrich the soil with nutrients (Lehmann and Joseph 2015). Biochar applications led to decrease some nutrients such as Mg, Cu, and Fe. This may be due to increasing effect of biochar on soil pH leading nutrients, especially Cu and Fe, less available (Silber et al. 2010; Lehmann et al. 2015; Machado 2018). Additionally, the effect of biochar is closely related to soil fertility. It was indicated that the effect of biochar on soil amendment was higher on nutrient poor soils (Jiang et al. 2012). Our experimental soil is rich in terms of fertility. We also did not see any differences between pyrolysis temperatures on available soil nutrients. This may be due to the similar physical and chemical characteristics of both biochars. Also combustion duration may have an effect on soil nutrient supply. In a study, it was indicated that biochars, obtained from short duration had lower nutrient concentration than that obtained longer combustion duration (Peng et al. 2011).

As conclusion, biochar application did not have positive effect on available soil nutrients when fertilizers are not given. Moreover, it may be said that biochars do not increase soil nutrients if soils have sufficient nutrients and if the soils pH is high. Therefore, it is important to take care the soil characteristics before biochar's applications.

Table 2. Effect of biochar obtained from different pyrolysis temperatures on periodical Ca, K, Mg and P concentrations of soil.

Sampling time	Control (without biochar)	Combustion temperature (°C)		Mean
		500	700	
Ca (cmol kg^{-1})				
July	32.7	32.8	32.0	
August	31.2	30.6	30.0	
September	30.9	31.1	29.9	
October	30.0	30.9	31.6	
K (cmol kg^{-1})				
July	3.91	3.87	4.02	
August	4.01	3.98	4.17	
September	3.86	3.72	4.19	
October	4.11	3.80	3.92	
Mg (cmol kg^{-1})				
July	2.89	2.50	2.44	2.61B*
August	3.30	2.91	2.88	3.00A
September	2.96	2.74	2.85	2.85A
October	3.11	2.67	2.99	2.92A
Mean	3.07A*	2.71B	2.79 B	
P (mg kg^{-1})				
July	38	36	37	
August	36	38	40	
September	38	37	39	
October	39	39	38	

*Values followed by the same letters, within the columns are not significant ($p<0.05$).** Values followed by the same letters, within the rows are not significant ($p<0.05$).

Table 3. Effect of biochar obtained from different pyrolysis temperature on periodical Cu, Mn, Fe and Zn concentrations of soil.

Sampling time	Control (without biochar)	Combustion temperature (°C)		
		500	700	Mean
Cu (mg kg^{-1})				
July	5.43	4.12	4.28	4.61 A*
August	5.38	3.64	5.33	4.78 A
September	5.31	3.86	3.77	4.18 B
October	5.02	3.40	3.55	3.99 B
Mean	5.29A**	3.75B	4.23B	
Mn (mg kg^{-1})				
July	31.9 a***	32.1a	30.9a	
August	31.6 a	33.2a	32.4a	
September	30.6 a	31.4a	32.8bc	
October	32.3 a	25.8b	22.5b	
Fe (mg kg^{-1})				
July	11.0bc	16.9a	14.1ab	
August	10.2bc	11.3bc	10.9bc	
September	9.96 bc	11.1bc	11.8bc	
October	11.0bc	10.0c	9.22c	
Zn (mg kg^{-1})				
July	2.90	2.85	2.90	
August	2.83	2.69	2.83	
September	2.66	2.77	2.75	
October	2.93	2.69	2.74	

*Values followed by the same letters, within the columns are not significant ($p<0.05$). ** Values followed by the same letters, within the rows are not significant ($p<0.05$). ***Shows the interaction effects, letters sharing the same latter are not significantly different ($p<0.05$).

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