IMPACT OF BIOCHAR AMENDMENT ON SOIL PH OF ORTHIC LUVISOL AT THE RESEARCH SITE LOCATED IN WESTERN SLOVAKIA

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Abstract

One year field experiment of spring barley (Hordeum vulgare L.) was carried out to evaluate the effect of biochar amendment on the pH of Orthic Luvisol at the research site located in western Slovakia (lat. 48°19´00´´; lon. 18°09´00´´). Biochar with higher pH (8.8) was applied to the slightly acidic soils with the initial pH at 5.6. The field experiment consisted of control, 10 and 20 tha^{-1} of biochar application to soils where all treatments were equally fertilized with 80 kg N ha^{-1}. The soil pH (KCl) at depth 0-10 cm was measured once a month (March-October, 2014). Amendment of 10 tha^{-1} biochar increased pH (in all months) by 0.49-0.67 but the difference wasn't significant (P < 0.05) compared to control plots. Higher application rate of biochar (20 tha^{-1}) increased pH (in all months) by 0.62-1.09 with the significant difference in 5 of 8 measurements events compared to control.

Key words: *biochar, soil ph, orthic luvisol, agro-ecosystem*

1. INTRODUCTION

Driven by climate change and population growth, increasing human pressure on land forces conversion of natural landscape to agricultural fields and pastures while simultaneously depleting land currently under agricultural use further increasing climate change and so on (Lal, 2009). Consequently, a vicious circle develops; further aggravating climate change, soil degradation, erosion, los of soil organic matter (SOM) and leaching of nutrients. Therefore, sustainable concepts for increased food production are urgently needed to lower pressure on soil, in order to reduce or prevent the negative environmental impact of intensive agriculture.

Copying the ancient technique of terra preta de Indio formation is a potential tool for both mitigating climate change and sustainably increasing agricultural productivity (Glaser, 2007). Modern analogues of this Amazonian phenomenon, where aboriginal cultures boosted soil productivity of highly weathered tropical soils mainly through the incorporation of biochar and nutrients into the soil, are referred to as biochar management systems (Lehmann et al., 2003; Özçimen and Karaosmanoğlu, 2004; Glaser, 2007; Novotny et al., 2009). Soil OM of terra preta is composed of up to 35% of BC (Glaser et al., 2001). Terra preta sites exhibit mean biochar contents of 50 Mg ha^{-1} at 1 m soil depth, which is 70 times the amount of surrounding soils (Glaser et al., 2001).

Biochar (black carbon) refers to the aromatic carbon materials produced by pyrolysis of biomass (heating in an oxygen-limited environment at temperatures 400-900°C). Biochar production is considered to be a more effective way for long-term carbon storage in soil compared with the direct soil applicaton of the precusrosy materials.

The Terra Preta soil concept (Glaser et al., 2001) is responsible for the recent increased interest in biochar research which is driven by major global issues: climate change and a need to develop more sustainable agricultural systems. There have been reported a lot of positive impacts of biochar as a soil amendment such as mitigating climate change (Lehmann, 2007) through increasing soil carbon storage (Fowles, 2007) while decreasing direct GHG emission and improving soil fertility and crop productivity (Glaser et al., 2001; Major et al., 2010a; Lehmann, 2007; 2008).

In balance to this, biochar application has been shown to have barriers, as well. The barriers are the availability of biochar to farmers (no biochar producers in Slovakia up to now) and, a very important

one the legislative barrier that prevents biochar being applied to land (e.g. in Europe). The lack of biochar inclusion in current agricultural policy is due to the major uncertainty surrounding the long term behavior of biochar, its potential negative impacts on soil quality, and the fact that it cannot realistically be removed from soil after application.

One of the very important soil chemical properties is soil pH. The pH of the soil affects the solubility of the substances in the soil, thus their availability for living organisms. The potential liming effect of agricultural residues and other plant meterials has been reported (Noble et al., 1996; Tang & Yu, 1999). Decarboxylation of organic anions (as indicated by excess cations or ash alkalinity) of added plant residues consumes protons and thus increases the soil pH (Yan et al., 1996; Tang & Yu, 1999). Besides this carbon (C) transformation process, nitrogen (N) transformation is thought to be the other main process that has effect on the soil pH fluctuation (Xu & Coventry, 2003; Xu et al., 2006). Ammonification of residue organic N consumes protons and causes soil pH to increase, whereas nitrification of mineralized residue nitrogen releases protons and causes soil pH to decrease. Small increases in soil pH following crop residue addition to soil may act to stimulate nitrification and counteract the alkalinity produced. Hence, addition of offsite liming materials, such as biochar, may offer a possible solution to manage acidity of the agricultural soils.

Biochar application to soils may have agronomic benefits such as neutralizing soil pH and or providing nutrients (Jeffery et al., 2011, Yuan et al., 2011). The pyrolytic process of biochar production converts biomass acids into the bio-oil component and the alkalinity is inherited by the solid biochar (Laird et al., 2010). Producing biochar at different temperature causes the increases of their alkalinity with increasing charring temperature (Yuan et al., 2011c). The pH of biochar is influenced by the type of feedstock used, production temperature and production duration. The effectiveness of liming materials is determined by the pH buffer capacity of the soil and neutralizing values of the amendments. The effect of biochar on increase of pH in highly weathered tropical soils had been confirmed (Glaser et al., 2001; 2002). Other studies also showed that the alkalinity of biochars was a key factor affecting their liming potential (Yuan et al., 2011b) and also showing an increase of pH when biochar with higher pH value was applied to the acidic soil (Yuan et al., 2011c) with clear increase of soil pH with increasing biochar application rates (Yuan et al., 2011a). The effect of biochar on soil pH change and mode of action need to be studied thoroughly using various biochars (different in type of feedstock used, production temperature and production duration) in various soils of different agro-ecosystems.

The objective of this study was to evaluate the effect of biochar amendment on the pH of slightly acidic Orthic Luvisol at the research site located in western Slovakia. We hypothesized that the biochar with higher pH (8.8) has a strong ability to increase the soil pH of the studied soil with the initial pH at 5.6.

2. MATERIAL AND METHODS

2.1. Experimental site and experimental design

This field trial was conducted at the experimental site of SAU-Nitra (Nitra-Malanta), in Nitra region of Slovakia (lat. 48°19´00´´; lon. 18°09´00´´) during March-October, 2014. The soil type is classified as Orthic Luvisol (FAO, 1998). The average annual air temperature was 10.3°C and annual precipitation was 640mm during the studied year (Tab.1).

Soil samples (0-10cm) from 10 random locations (experimental field trial) were taken on 4th of March to get an initial value of soil pH (in KCl) before lying out of experiment (7th of March), applying biochar (10th of March) and sowing the crop (11th of March). The replicated (n=3) trial plots (4m x 6m) were laid out in a randomized block design and planted with spring barley (*Hordeum vulgare L.*) in the experimental field that has been used for crop production over the last several years. The treatments (3 replicates) consisted of control, 10 and 20 tha^{-1} of biochar application (control, BC10 and BC20) to soils with all treatments equally fertilized with 80 kg of mineral nitrogen per hectare. The plots were separated by a protection row 0.5 m in width (Fig 1).

Table 1 30-year mean and actual (2014) monthly climate data for the nearby automatic weather station (50 m from the field site)

Month	30 - year mean (1961-1990)		2014	
	Precip. (mm)	Mean temp. (°C)	Precip. (mm)	Mean temp. (°C)
January	31.0	-1.7	34.2	1.0
February	32.0	0.7	35.2	2.9
March	30.0	5.0	19.4	8.2
April	39.0	10.4	32.8	10.8
May	58.0	15.1	57.4	13.3
June	66.0	18.0	52.0	17.3
July	52.0	19.8	113.2	19.9
August	61.0	19.3	74.4	17.1
September	40.0	15.6	109.0	15.1
October	36.0	10.4	45.6	10.4
November	55.0	4.5	24.6	6.3
December	40.0	0.1	43.0	1.5
Annual (total/average)	539.0	9.8	640.8	10.3

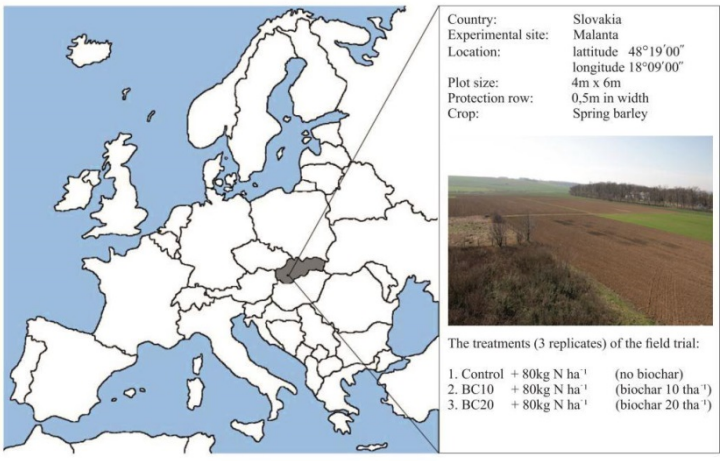

Fig. 1 Experimental site, treatments description and the picture of the field plots

2.2. Biochar characterization and pH measurements

Biochar used for the field experiment was produced from paper fiber sludge and grain husks (1:1 w/w) (company Sonnenerde, Austria) by pyrolysis at 550°C for 30 minutes in a Pyreg reactor (Pyreg GmbH, Dörth, Germany) (tab. 2).

The soil pH (KCl) at depth 0-10 cm was measured once a month (March-October, 2014) in a soil: 1 M KCl solution (1:2.5) following shaking suspension for 30 minutes using a pH meter (HI 2211, HANNA Instruments, RI, USA).

Table 2 Basic chemical and physical properties of the biochar (biochar certificate Nr.1013069001 provided by company Sonnenerde, Austria)

		Biochar
pH	(KCl)	8.8
Ca	g kg^{-1}	57
Mg	g kg^{-1}	3,9
K	g kg^{-1}	15
Na	g kg^{-1}	0,7
Total C	g kg^{-1}	53,1
Total N	g kg^{-1}	14
C/N		37,9
SSA	m^2g^{-1}	21.7
Ash	%	38,3

2.3. Statistical analysis

The statistical processing of the data included the determination of means, standard deviations. One-way analysis of variance (ANNOVA) at $p<0.05$ was performed to examine the effect of biochar at different application rates on soil pH. Significant differences between means of three replications were identified using a least significant difference (LSD at $p<0.05$) test using STATGRAPHICS Centurion statistical software.

3. RESULTS AND DISCUSSION

Fig. 1 and Table 3 presents soil pH change of all treatments during the 8 month field experiment at the experimental site of SAU-Nitra (Nitra-Malanta) in Nitra region of Slovakia. The average initial soil pH before applying biochar was 5.6. Biochar with higher pH (8.8) applied at 10 and 20 t ha^{-1} (BC10 and BC20) immediately increased soil pH (March measurements) by 0.66 and 0.93 unit for BC10 and BC20, respectively compared to control. This trend continued to the end of the experiment for both biochar treatments with the magnitude of soil pH increase in the order: control > BC10 > BC20.

Application of 10 tha^{-1} of biochar increased soil pH by 0.49-0.67 with no significant increase ($p < 0.05$) found compared to control plots during the whole period. However, the magnitude of the increase was larger for the higher biochar application rate (20 tha^{-1}) where the soil pH increased by 0.62-1.09 during all months with a significant increase ($p < 0.05$) from April to September except of May (5 of 8 measurement events).

The control soil pH in October was higher by 0.05 unit compared to control value of soil pH at the beginning of experiment (March). Opposite was found in case of both biochar treatments. The soil pH in October was lower by 0.11 and 0.25 unit for BC10 and BC20, respectively compared to pH values at the beginning of experiment.

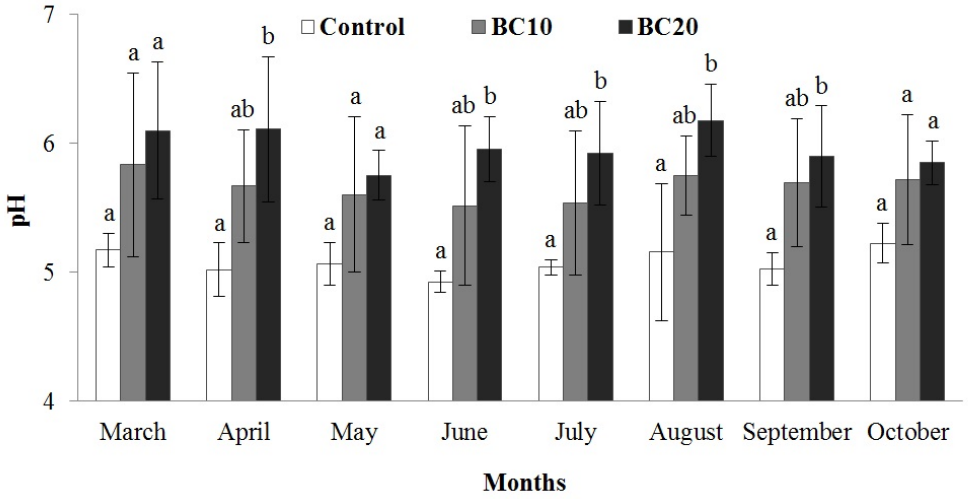

Fig. 2 Soil pH during the field experiment (March-October, 2014) on Orthic Luvisol planted with spring barley amended with biochar in 2014 (± standard deviation, n=3). Different letters indicate significant difference between treatments means by the LSD test ($p < 0.05$).

Other scientific studies also showed an increase of pH when biochar with higher pH value was applied to the acidic soil (Yuan et al., 2011c) with clear increase of soil pH with increasing biochar application rates (Yuan et al., 2011a). In prevoious studies, the increase in soil pH caused by organic material amendment was mainly attributed to organic anions present in the materials, and this was indicated by the concentration of excess cations over inorganic anions, that is, ash alkalinity (Yan et al., 1996). Hence, after biochar addition into soil, organic anions can undergo decarboxylation and consume protons. Additionally, organic anions and other negatively charged functional groups present in organic matter can undergo association reactions with H^+ ions (Tang & Yu, 1999; Xu et al., 2006). Therefore, it is expected that in this study, both of these processes are likely to contribute to the increases in soil pH after biochar application

Table 3 Soil pH during the field experiment (March-October, 2014) on Orthic Luvisol planted with spring barley amended with biochar in 2014 (± standard deviation, n=3). Different letters indicate significant difference between treatments means by the LSD test ($p < 0.05$).

Months	**Treatments**		
	control	BC10	BC20
March	5,17 ± 0,13a	5,83 ± 0,71a	6,10 ± 0,53a
April	5,02 ± 0,21a	5,67 ± 0,44ab	6,11 ± 0,56b
May	5,06 ± 0,17a	5,60 ± 0,60a	5,75 ± 0,19a
June	4,92 ± 0,08a	5,51 ± 0,62ab	5,95 ± 0,25b
July	5,04 ± 0,06a	5,53 ± 0,56ab	5,92 ± 0,40b
August	5,15 ± 0,53a	5,75 ± 0,31ab	6,17 ± 0,28b
September	5,02 ± 0,13a	5,69 ± 0,50ab	5,90 ± 0,39b
October	5,22 ± 0,15a	5,72 ± 0,51a	5,85 ± 0,17a

Treatment means and standard deviations with the different letter are significantly different (n=3) by the LSD test ($p<0.05$)

4. CONCLUSIONS

According to evaluation of the data can be concluded that incorporation of biochar to the slightly acidic soils was an effective way to increase soil pH up to at least 8 months after application. So our hypothesis that the biochar with higher pH (8.8) has a strong ability to increase the soil pH of the studied soil with the initial pH at 5.6 was confirmed. This indicates that a single biochar application may provide benefits at least over one year cropping season, however long-term field studies are still lacking and needed to determine when a steady state is reached or if and when a decline start to occur. The results also indicate that magnitude of soil pH would be increased by increasing biochar application rates. Therefore biochar could be a valuable tool for the management of agro-ecosystems and a plausible way to ameliorate slightly acidic soils and may be effective in increasing soil pH.

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