Short communication

Differences in soil properties and crop yields after application of biochar blended with farmyard manure in sandy and loamy soils

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In recent years, the importance of biochar application in world´s soils have increased tendency mainly due to its opposite effects. Therefore, the effort of many companies is based on the development of soil amendment which together improve properties and crop productivity in lot of soils. In this short study, we have verified the effectiveness of biochar blended with farmyard manure named *Effeco* on soil properties and crop yields in different textural soils (1. sandy soil in Dolná Streda and 2. loamy soil in Veľké Uľany). Our results showed that the *Effeco* increased soil pH in both soils. In sandy soil, the *Effeco* more significantly affected sorptive parameters and soil organic carbon content than in loamy soil. Water retention in capillary pores after *Effeco* application in sandy and loamy soils was higher by 22% and 4%, respectively compared to control. On the other hand, more significant effect of *Effeco* application on soil structure was observed in loamy soil. The total crop productions in sandy and loamy soils due to the *Effeco* application were higher by 82% and 16%, respectively, compared to control plots. All in all, we concluded that the effects of biochar blended with farmyard manure differ mainly on soil texture.

Keywords: *Effeco*, sorptive parameters, soil organic matter, water retention, soil structure, loamy soil, sandy soil

1 Introduction

Long-term and mainly intensive soil management practices have negative effects on soils properties and often results in their degradation include soil acidification, decrease of soil organic matter, soil structure stability, porosity, water retention etc. (Polláková et al., 2018; Kotorová et al., 2018). A fundamental factor which alter soil properties is soil organic matter (Szombathová, 2010) and therefore, the effective maintenance of soil organic matter in degraded soils can help preserve soil fertility.

In last time, biochar has becoming a great of interest as a mean for carbon sequestration, resulting from its high content of carbon and long-term persistence in soil (Dong et al., 2019). Biochar is the solid product of pyrolysis, designed to be used for environmental management (Lehmann et al., 2015). IBI (2013) defines biochar as: A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. Biochar can be used as a product itself or as an ingredient within a blended product, with range of applications as an agent for soil improvement, improved resource use efficiency, remediation and/or protection against particular environmental pollution and as an avenue for greenhouse gas mitigation. The biochar properties can be different in relation to type of feedstock source, temperature and time of pyrolysis, pressure and soil type where the biochar is applied (Jeffery et al., 2011; Wang et al., 2013; Ahmad et al., 2014). For example, biochar produced from grasses at temperatures 250–400 °C had higher mineralisation rate (Zimmerman et al., 2011) than biochar produced at high temperatures (525–650 °C) and from hard woods (Fischer and Glaser, 2012). Biochar produced from manure usually has smaller surface area, than biochar produced from wood. The higher temperature increases the content of carbon and the surface area in biochar while the content of oxygen and hydrogen decreases (Lopez-Capel et al., 2016).

Under above mentioned context is evident that biochar properties and its acts in different soil-climatic condition are different. For farmers is, however essential whether the application of biochar improves soil fertility, increases crop yields and brings economic profit. Manufacture of biochar that would improve all soil characteristics and also bring the economic effect is not an easy task.

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Scientific studies show that the efficiency of biochar can be improved by its combination with application with other organic fertilizers, composts, NPK fertilizers. For this reason, fertilizer manufacturers are working to create products that combine biochar with other soil fertility enhancers in one suitable for different soil-climatic conditions. For example, a scientific studies and own research activities of the company Zdroje Zeme a.s. helped to developed soil amendment for activation intensively used land named *Effeco* (combination biochar together with farmyard manure in volume 1 : 1) and within this short study, we have verified the effectiveness of *Effeco* on soil properties and crop yields in different textural soils.

2 Material and methods

Field experiments were performed at two sites with texturally different soils. Before established experiments, the soils in both localities were intensively used. The sites description is given in Table 1. For the purposes of this short study, soil samples were taken from two treatments: 1. Control (no fertilized) and 2. *Effeco* amendment (at rate of 20 t ha^{-1}) in the autumn 2018 in both study sites. In soil samples, soil pH, sorptive characteristics, soil organic carbon, physical and hydro-physical properties were evaluated by standard methods (Hrivňáková et al., 2011). Yields of crops were also evaluated.

3 Results and disscussion

El-Naggar et al. (2019) published that the role of biochar application in the enhancement of soil fertility and productivity can be categorized into aspects relating to nutrient cycling, crop productivity, soil pH, cation exchange capacity (CEC), nitrogen (N), microbial communities, water retention, and C sequestration and our results mentioned aspects also confirmed (Table 2). In sandy soil, original neutral soil pH increased to slightly alkaline due to *Effeco* application. The increase of soil pH by 0.26 pH unit was determined also in loamy soil. Ibrahim et al. (2013) also reported increases in pH in a biochar amended sandy and loamy soils. In our cases, a higher decrease of hydrolytic acidity after *Effeco* application in sandy soil than loamy soil was observed. Some differences between soils in values of sum of basic cation and CEC were as result of *Effeco* application. In sandy soil, the *Effeco* significantly increased sum of basic cations and on the other hand in loamy soil its effects were opposite. In sandy and loamy soils, the CEC values were very low and high, respectively. In sandy soil, the CEC values after *Effeco* increased by 30% compared to no fertilized plot. The main reason is related to particle size distribution (low sorption capacity of sand particles) and higher level of soil organic matter after *Effeco* application. Opposite situation in loamy soil was determined. The CEC values decreased. The decrease of CEC is related to negative charge in the *Effeco* surface and absorption of anions is preferred. These results confirmed the findings of Laghari et al. (2015) who reported increase of CEC due to potentially high surface functional group content of biochar mainly in sandy-textured soils.

Biochar addition has been shown to increase organic carbon in soils (Agegnehu et al. 2016). Soil minerals and organic matter associate with biochar tended to form aggregates in which the biochar turned occluded from

Table 1 Characteristics of studied sites

Site	Climatic	Soil	Soil management	Crop and previous crop	Establishment of experiment
	Conditions				
Dolná Streda	9–10 °C 520–600 mm	Haplic Arenosol (Arenic, Calcic) sandy soil	reduced soil management (disking to the depth 15 cm) – growing of market crops	sunflower hard wheat	autumn 2017
Veľké Ulany	10 °C 550 mm	Vermic Chernozem (Mollic, Loamic) loamy soil	intensive soil management, included drip irrigation (conventional tillage to the depth 20 cm) – vegetable growing	capsicum carrot	spring 2018

Table 2 Soil pH, sorptive parameters and soil organic carbon content

Sities	Treatment	pH	H	SBC	CEC	Bs	SOC
Dolná Streda (sandy soil)	control	7.24	4.02	36.0	40	90.0	0.90
	Effeco	7.43	3.21	48.8	52.0	93.8	1.13
Veľké Uľany (loamy soil)	control	7.63	2.53	492.3	494.8	99.5	1.85
	Effeco	7.89	2.19	488.5	490.6	99.6	1.88

H – hydrolytic acidity, SBC – sum of basic cations, CEC – cation exchange capacity, Bs – base saturation, SOC – soil organic carbon

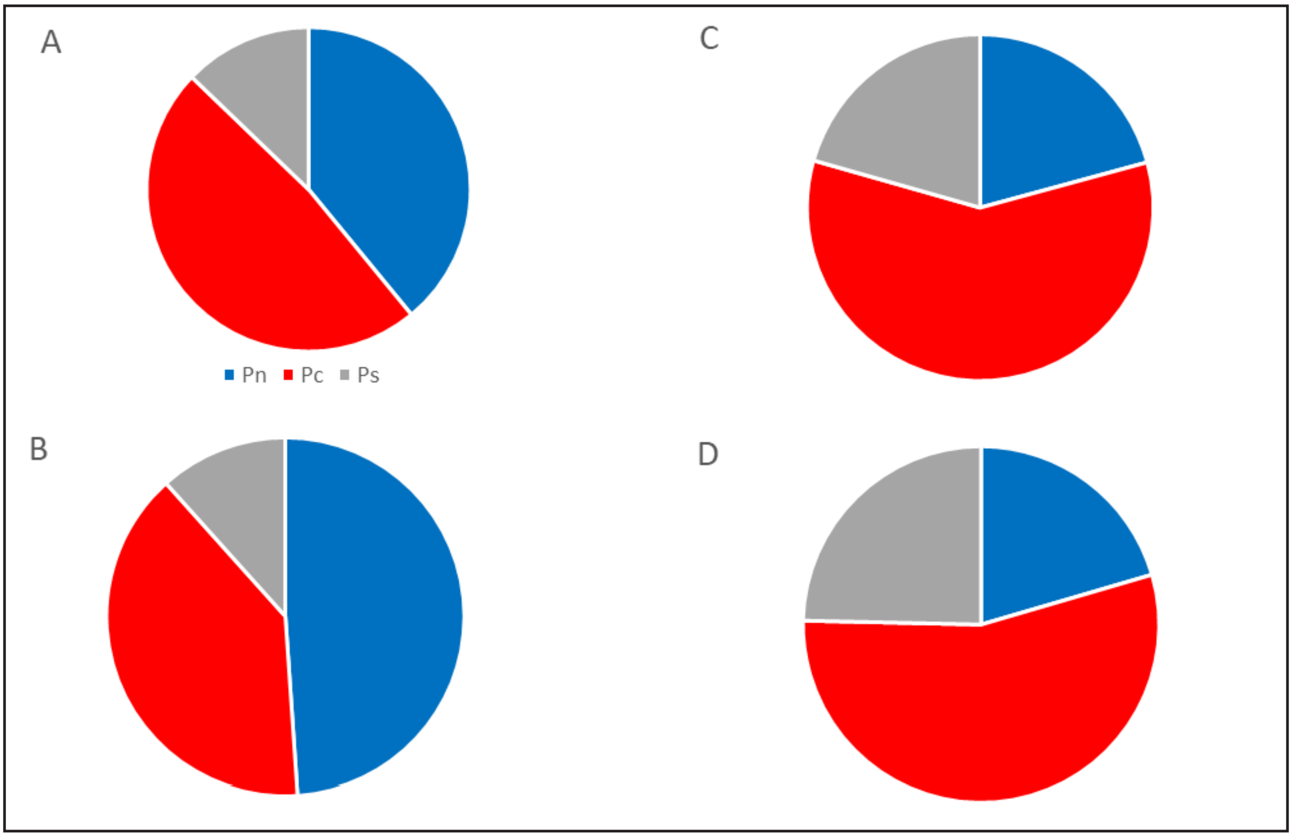

Figure 1 Volume of pores in sandy soil (A, B) and in loamy soil (C, D) after *Effeco* application (A, C) and in no fertilized treatments (B, D)
Pn – volume of non-capillary pores, Pc – volume of capillary pores, Ps – volume of semi-capillary pores

chemical degradation or transport (Brodowski et al., 2006), which could be the main reason of C increase in the aggregates and one of the most important mechanism of C sequestration in soils (Šimanský et al., 2017). In *Effeco* plot, the content of SOC was higher by 26% in comparison to control in sandy soil and the same trend but no significant was observed in loamy soil (Table 2).

In sandy soil, between treatments any significant differences were not determined for bulk density and total porosity, however, the volume of energetics pores differ on *Effeco* (Figure 1 A, B). In *Effeco* treatment, the volume of semi-capillary and capillary pores increased by 10 or 22% respectively on one hand, and decreased volume of non-capillary pores by 20% on the other. The volume of non-capillary, capillary and semi-capillary represented 39, 48 or 13% of the total porosity because of *Effeco* application, whereas in the case of control it was 49, 39 and 12% of the total porosity. In *Effeco* treatment values of capillary absorption, maximum capillary water capacity and retention water capacity were 32.6%, 27.4% and 24.4%, respectively, and in control these one was 27.8%, 23.2% and 20%, respectively. *Effeco* application almost one-time increased available water supply and also available water capacity compared to control. In loamy soil, the *Effeco* did not have any significant effects on energetics pore categories (Figure 1 C, D), capillary absorption, maximum capillary water capacity, retention water capacity and available water capacity (Table 3). On the other hand, *Effeco* applied to the loamy soil increased by 37% available water supply. Our results in both soils did not confirm positive biochar effect on decrease of bulk density on one hand and increase of total porosity on other (Ajayi and Horn, 2016; Obia et al., 2016), however, our results confirmed positive effects of biochar on water holding capacity (Haider et al., 2017; Omondi et al., 2016) mainly in sandy soil. Water retention in capillary pores after *Effeco* application in sandy and loamy soils was higher by 22% and 4%, respectively, compared to control. The potential of biochar addition for improving physical soil properties was mainly observed in coarse-textured and low fertility soils (Laghari et al., 2015; Omondi et al., 2016). From the soil structure point of view, these results were not obviously confirmed. As shown in Table 4, in sandy soil, the *Effeco* treatment had no significant effects on contents of water-stable aggregates in comparison to control. Despite this fact, the better soil structure (higher values of MWDw by 6% and K by 30%) after *Effeco* treatment than no fertilized (control) plot was determined. In case of loamy soil, after

Table 3 Physical and hydro-physical properties

Sities	Treatment	ρd	P	ΘKN	ΘMCWC	ΘRWC	ΘAWC	AWS
Dolná Streda (sandy soil)	control	1.26 0.16	50.7 ±6.08	27.8 ±2.33	23.2 ±3.18	20.0 ±2.76	13.7 ±3.11	5.01 ±2.59
	Effeco	1.26 0.13	50.7 ±4.88	32.6 ±0.57	27.4 ±1.34	24.4 ±1.56	17.4 ±1.84	9.07 ±3.15
Veľké Uľany (loamy soil)	control	1.36 ±0.08	46.0 ±3.54	38.3 ±2.55	34.6 ±1.48	31.6 ±0.21	24.5 ±0.99	11.6 ±0.21
	Effeco	1.36 ±0.02	47.4 ±1.20	38.7 ±0.85	34.6 ±0.99	33.0 ±1.06	25.6 ±2.19	15.9 ±1.77

Pd – bulk density, P – total porosity, ΘKN – capillary absorption, ΘMCWC – maximum capillary water capacity, ΘRWC – retention water capacity, ΘAWC – available water capacity, AWS – available water supply

Table 4 Soil structure parameters

Sities	Treatment	WSA_{mi}	WSA_{ma}	WSA_{ma} 0.5–3	MWDw	K
Dolná Streda (sandy soil)	control	18.2 ±2.04	81.8 ±2.04	43.7 ±1.86	0.53 ±0.04	0.82 ±0.01
	Effeco	19.5 ±4.67	80.5 ±4.67	40.0 ±4.06	0.56 ±0.09	1.07 ±0.06
Veľké Uľany (loamy soil)	control	41.2 ±6.83	58.8 ±6.83	15.1 ±0.49	0.42 ±0.05	0.70±0.07
	Effeco	21.6 ±4.95	78.4 ±4.95	36.8 ±10.8	0.92 ±0.12	1.22±0.04

WSA_{mi} – water-stable micro-aggergates, WSA_{ma} – water-stable macro-aggregates, MWDw – mean weight diameter for wet sieving, K – structure coefficient

Effeco application the situation was significantly better in all evaluated soil structure parameters compared to the sandy soil. The *Effeco* reduced the content of WSAmi on one hand, and increased content of WSAma and WSAma 0.5–3 on the other. In the *Effeco* treatment the values of MWDw and K were almost one times higher than control.

Biochar application to low fertility soils may also substantially enhance crop production (Laghari et al., 2015; Zhang et al., 2017) what confirmed our results (Figure 2). Application of *Effeco* (blended biochar with farmyard manure) at rate of 20 t ha^{-1} significantly increased grain yield of sunflower in comparison to no fertilized plots in sandy soil. The same effect was observed in case of loamy soil. The total yields of peppers were higher by 16% in *Effeco* treatment (20 t ha^{-1}) than control plot. During vegetation season of peppers, a total of three harvests of peppers have been done. The changes in yields between individual harvests are shown in Figure 2 B. In comparison to control, the *Effeco* application in 1st, 2nd and 3th harvests increased yield of peppers by 6, 15 and 20%, respectively. Differences between sandy and loamy soils in total yields of crops were observed too. The total crop productions in loamy and sandy soils due to the *Effeco* application were higher by 16% and 82%, respectively, as compared to control plots in both soils. As presented Laghari et al. (2015) but also Van Zwieten et al. (2010) the increase in crop productivity from biochar application is most commonly observed in nutrient-poor and degraded soils.

All in all, we concluded that the biochar blended with farmyard manure improved soil properties, but its effects differ mainly on soil texture. The results of this short study also indicate that the application of biochar in combination with farmyard manure can be useful

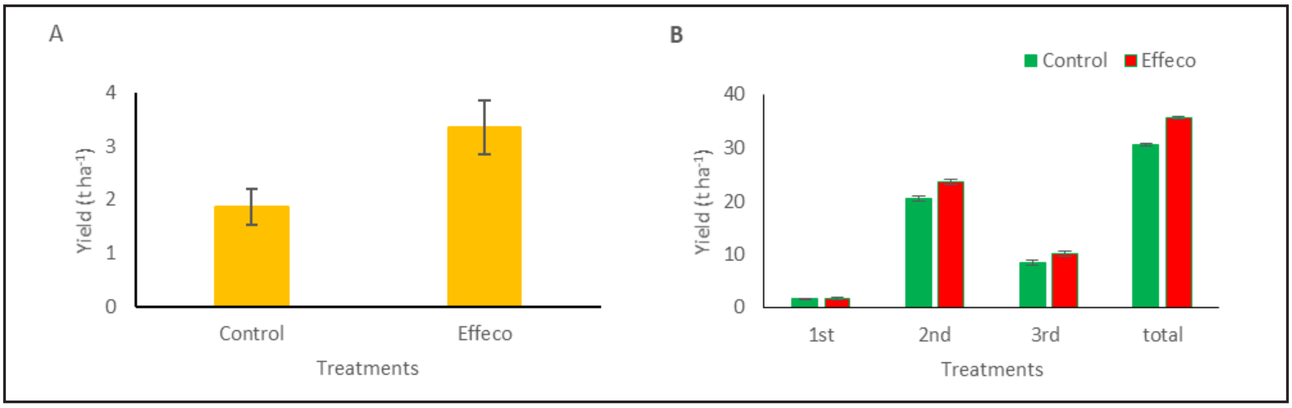

Figure 2 Yields of A) sunflower grains, and B) peppers fruits yield of pepper in 1st, 2nd, 3rd harvests

method for sustainable soil management in arable soils of Slovakia.

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