Impact of Biochar Reapplication on Physical Soil Properties

Andrej Tarnik 1

1 Department of Biometeorology and Hydrology, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Hospodarska 7, 949 76, Nitra, Slovakia

andrej.tarnik@uniag.sk

Abstract. The Biochar is getting attention of agronomist worldwide due to its positive effect on physical soil properties in last years. The influence of biochar on physical soil properties has been studied, but only few results was obtained from the field experiments. The main objective of this paper was to study the effect of repeated dose of the biochar on physical soil properties (water content, temperature). The biochar used for the field experiment was produced from paper fiber sludge and grain husks (1:1 w/w) by pyrolysis at 550 degrees C for 30 minutes. In this study, the soil water content (SWC) and temperature was measured in 0.05-0.10 m depth at experimental plots which received dose 20 t/ha 1 (in 2014); repeated dose 20 t/ha 1 (in 2018) and 0 t/ha (control) of biochar amendment at the Malanta area, Slovakia (48°19'23"N 18°09'01"E) in the year 2018. Our field measurements show the positive effect of biochar on SWC. SWC was higher (statistically significant difference) at plots with older dose of the biochar compared to plots with repeated dose and control plots. No statistically significant difference was between plots after reapplication of the biochar and control plots. It could be caused by short time period between biochar reapplication and SWC measurements which means that biochar incorporation to soil was limited. There was no significant difference between average daily temperatures on plots with variant dose of the biochar. Soil warming up offset could be observed during sunrise. It could be caused by darker colour of biochar.

1. Introduction

Global climate has been changing dramatically in last years. There exist proofs that the global warming, which is happening since the industrial revolution, is the consequence of the greenhouse emissions increase caused by the human activity [1]. Slovakia’s landscape significantly changed particularly since the 50’s of the 20th century [2]. Physical properties of soils plays important role in water retention and water availability in soil and landscape. Content of soil water is also very important indicator of climate change and sustainability of life. It is also important to know about soil water content due to extreme consequences of soil drought [3]. Biochar, as a product of thermal modification of organic matter by pyrolysis, is a solid porous material with high carbon content [4, 5, 6]. Several research studies were focused on biochar influence on soil properties. Carbon sequestration and reduction of greenhouse gas emissions were objectives of these studies [7]. Various studies have also shown that biochar has the potential to influence the physical soil properties [8].

The incorporation of biochar into agricultural soil changes the soil’s physical properties, which leads to changes in the soil’s hydraulic properties, such as water retention and permeability, and alters
the soil moisture environment in agricultural fields [9]. The biochar in soil also changes the soil’s porosity, pore size distribution and bulk density due to biochar’s structure [10]. Biochar amendment can also increase crop yields, improve soil quality and nutrient cycling, reduce the leaching of nutrients from soil and stimulate soil microbial activity [11, 12]. Biochar application to soil can be considered as a means to improve soil quality, thereby optimizing irrigation management and reducing irrigation needs, especially in dryland regions [13]. The ability of soil to retain water under drought and other extreme hydrological events is critical to the sustainability of food production systems and preserving soil ecosystem services [14]. Soil hydrology should be one of the highest future research priorities regarding biochar’s effects in soils [15].

2. Materials and methods

2.1. Field site
Field experiment started in the spring of 2014 at the Slovak University of Agriculture experimental site (Fig. 1). The site is situated in Malanta (48°19′23″N 18°09′01″E), in the Danubian Upland with altitude 175 m.

The Malanta experimental site is locality with warm lowland climate with long, warm and dry summers, and short dry winters and only a very short duration of snow cover (14-30 days). The average annual temperature varied in the range of 9 to 10 degrees C and the average annual precipitation varied from 500 up to 600 mm in this area [4].

The soil in this locality is classified as a Haplic Luvisol. The topsoil contains 249 g.kg\(^{-1}\) of clay, 599 g.kg\(^{-1}\) of silt and 152 g.kg\(^{-1}\) of sand, so it expresses silt loam texture. There is low in organic carbon content (9.13 g.kg\(^{-1}\)) and lightly acidic (pH 5.71) soil.

2.2. Biochar type
The biochar used for the field experiment was produced from paper fiber sludge and grain husks (1:1 w/w) by pyrolysis at 550 degrees C for 30 minutes. The biochar was produced by Sonnenerde, in Austria using pyrolysis in a Pyreg reactor (Pyreg GmbH, Dörhe, Germany). On average the biochar contained 57 g.kg\(^{-1}\) of Ca, 3.9 g.kg\(^{-1}\) of Mg, 15 g.kg\(^{-1}\) of K and 0.77 g.kg\(^{-1}\) of Na (DIN EN ISO 11885). Total C content of biochar was 53.1% while total N content was 1.4% (DIN 51732). The specific surface area was 21.7 m\(^2\).g\(^{-1}\) (DIN66132/ISO9277).

First single dose of the biochar (20 t.ha\(^{-1}\)) was applied in March 2014. The biochar was applied on trial plots (4 m x 6 m) by hand and incorporated into the soil to a depth of 0-10 cm with a cultivator. Experimental plots were cultivated continuously using technology without deep processing. There was grown spring barley (Hordeum vulgare) in 2014, corn crop (Zea mays L.) in 2015, spring wheat (Triticum aestivum L.) in 2016, corn crop (Zea mays L.) in 2017 and spring barley (Hordeum vulgare) in 2018. In spring 2018 was the biochar reapplication in the same dose (20 t.ha\(^{-1}\)). The original plots were divided and new dose of the biochar was applied only on a half of plot (4 m x 3 m). Incorporation of the biochar was done the same way as in 2014.
2.3. Measurements

Measurements were done from May 7th to July 25th 2018. Three treatments of the experiment were established in 3 replicates. The treatments were as follows: control B0 (biochar 0 t.ha⁻¹), B20A (biochar 20 t.ha⁻¹, application in 2014) and B20B (biochar 20 t.ha⁻¹, application in 2014 and reapplication in 2018).

Soil volumetric water content and soil temperature were measured in the soil horizon 0.05- 0.10 m. Time step of the measurements was set up to 30 minutes. SMT 100 soil moisture sensors and datalogger TrueLog100 by Truebner GmbH were used. These sensors can measure soil volumetric...
water content with accuracy ± 3 % vol. and temperature with accuracy ± 0.2 degree C [16]. The SMT100 [16] sensors combine the advantages of the FDR sensor systems with the accuracy of a TDR system. Like a TDR, it measures the travel time of a signal to determine the dielectric constant of the soil. And like a FDR, it converts this dielectric constant into an easy to measure frequency. But unlike an FDR it isn’t based on a capacitor, but utilizes a ring oscillator to transform the signal’s travel time into the measure frequency.

3. Results and discussions
The main aim of this paper was to observe differences between water content and temperature in soil with different addition of the biochar. We wanted to quantify effect of the biochar with various age to soil water content and temperature. The first dose of the biochar was incorporated in spring 2014, the second dose was applied in spring 2018.

![Figure 3.](image)

Figure 3. The trend in the soil water content [% vol.] at the depth 0.05 - 0.10 m

On basis of our field measurements at experimental site Malanta we could say that the addition of biochar influenced SWC. The trend of soil water content is presented in Fig. 3. SWC was higher with statistical significance (T-test, alpha = 0.05) at plots with dose B20A compared to control plots B0. There was no difference with statistical significance (T-test, alpha = 0.05) between plots B20B and B0. When we compared plots B20A and B20B we could observe differences with statistical significance (T-test, alpha = 0.05).

These results show the positive effect of biochar on SWC clearly. There was higher soil moisture at plots with older dose of the biochar. New dose of the biochar did not influence soil moisture significantly in any way, positively or negatively. No influence of new dose of the biochar could be caused by short time period between biochar reapplication and SWC measurements which means that biochar incorporation to soil was limited.

Long Term and continuous research of biochar impact is very important to find definitive results, because results of other researchers [17] show that the biochar did not increase SWC in all times. Another measurements showed that the positive effect of biochar amendment on SWC is strongly related to the type of the crop grown and not straightforward [18].
Figure 4. The trend in the soil temperature [degrees C] at the depth 0.05 - 0.10 m
There was no significant difference between average daily temperatures on plots with variant dose of the biochar (B0; B20A; B20B). Quicker growth of soil temperature (Fig. 4) during sunrise was observed at plots with dose B20A and B20B compared to plots with dose B0. There was also observed slower cooling of soil after sunset at plots with dose B20A and B20B compared with B0 plots. These differences could be caused by darker colour of biochar and soil with biochar addition.

4. Conclusions
Using of the biochar has many advantages. The biochar is a way how to dispose of organic waste, how to fight against global climate change and emission of greenhouse gases and also how to improve many of soil properties. This paper shows how could be biochar used for improve soil water regime. Our results showed that biochar is an option to increase soil water storage. Main problems of agricultural areas have been identified as water management and ecological aspects [19]. The biochar could help to solve right these problems. The biochar and biochar application to soil should be subject of next researchers in future. Only clearly demonstrated positive effect of biochar could be base of wider biochar use.

Acknowledgment(s)
This study was supported by projects KEGA 019SPU-4/2017 “Upgrade of education process in the field of hydropedology with implementation of centre of excellence in the learning process” and GA SPU 03-GASPU-2018 “Analysis of land use potential with respect to humidity regime in climate change conditions”.

References
[1] V. Barek, et al. “The Influence of Climate Change on Water Demands for Irrigation of Special Plants and Vegetables in Slovakia” Bioclimatology and Natural Hazards. Springer, Dordrecht, pp. 271-282, ISBN 978-1-4020-8875-9, 2009.
[2] Z. Muchova, et al. “Land cover change and its influence on the assessment of the ecological stability” Applied ecology and environmental research, vol. 16(3), pp. 2169-2182, 2018.
[3] L. Jurik, et al. “Soil water content evaluation and modelling in small catchment with agricultural use” Acta scientiarum polonorum-formatio circumiectus, vol. 12, pp. 53-62, 2013.
[4] D. Igaz, et al. “Can a single dose of biochar affect selected soil physical and chemical characteristics?” Journal of hydrology and hydromechanics, vol. 66, 4, pp. 421-428, 2018.
[5] J. Domanová et al. “The effect of application biochar on properties of soil” 2014 9th International Scientific Conference Veda mladých (Science of Youth), ISBN 978-80-552-1189-3, ISSN 2585-7398, pp. 82-87, 2014.
[6] J. Horak, et al. “Biochar and biochar with N-fertilizer affect soil N2O emission in Haplic Luvisol” Biologia, vol. 72, pp. 995-1001, 2017.
[7] J. Lehmann, el al. “Biochar effects on soil biota - a review. Soil Biol. Biochem., vol. 43, 9, pp. 1812-1836, 2011.
[8] N.P. Buchkina, et al. “Changes in biological and physical parameters of soils with different texture after biochar application. Selskokhozyaistvennaya Biologiya (Agricultural Biology), vol. 52, 3, pp. 471-477, 2017.
[9] K. Kameyama, et al. “Influence of biochar incorporation on TDR-based soil water content measurements” European Journal of Soil Science, vol. 65, pp. 105-112, 2014.
[10] J. Lehmann et al. “Biochar for Environmental Management - Science and Technology” Earthscan, London, ISBN: 978-1-84407-658-1, 2009.
[11] R. S. Quilliam et al. “Nutrient dynamics, microbial growth and weed emergence in biochar amended soil are influenced by time since application and reapplication rate” Agriculture, Ecosystems and Environment, vol. 158, pp. 192-199, 2012.
[12] L. Meng et al. “Soil-applied biochar increases microbial diversity and wheat plant performance
under herbicide fomesafen stress” Ecotoxicology and Environmental Safety, vol. 171, pp. 75-83, 2019.

[13] G. Baiamonte et al. “Effect of biochar on the physical and structural properties of a sandy soil” Catena, vol. 175, pp. 294-303, 2019.

[14] D. Wang et al. “Impact of biochar on water retention of two agricultural soils - A multi-scale analysis” Geoderma, vol. 340, pp. 185-191, 2019.

[15] P. Tammeorg et al. “Biochars in soils: Towards the required level of scientific understanding” Journal of Environmental Engineering and Landscape Management, vol. 25, pp. 192-207, 2017.

[16] Truebner BmbH “SMT 100 product description” available at: <http://www.truebner.de/en/smt100>, 2019.

[17] J. Vitkova, et al. “Soil Water Regime Evaluation after Biochar Amendment” WMESS 2018 - IOP Conf. Series: Earth and Environmental Science, vol. 221, 2019.

[18] J. Vitkova, et al. “Analysis of soil water content and crop yield after biochar application in field conditions” Plant, Soil and Environment, vol. 63, pp. 569-573, 2017.

[19] Z. Muchova, et al. “Elimination of the fragmentation of land ownership as an initiative for positive changes in a country, specific (implemented) example - Velke Vozokany (Slovakia) project area” Geoinformatics on Informatics, Geoinformatics and Remote Sensing, vol. 2, pp. 239-246, 2014.