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Statistical analysis of soil water content differences after biochar application and its repeated application during 2020 growing season

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Soil water content is an important factor influencing crop yield quantity and quality. Extreme meteorological events are more frequent in our geographical conditions in last years and they affect soil water storage. Biochar is an organic material and one of its properties is soil water holding for a longer time. This is one of great benefits during non-precipitation days. Our study is focused on soil water content changes with biochar amendment in comparison to soil without biochar. In addition, we analyzed biochar repeated application as well. It means addition another biochar dose into the soil where the biochar had been applied previously. Our results confirmed positive effect of biochar application and repeated application on soil water content. The soil water regime with biochar repeated application was the most stable in 2020 in comparison to other variants of experiment.

KEY WORDS: biochar, repeated application, soil moisture, statistical analysis

Introduction

In current times of increasing weather extremes and climate change, is difficult to ensure good-quality and safe agricultural products. It is challenge not only for big farmers, but also for individual persons who tried to grow their own vegetables in good (bio) quality. Soil fertilization is one of possibilities how to improve soil physical and chemical properties and increase an agricultural production. To improve soil properties are used various organic materials, and biochar is one of them. Biochar is carbon-rich porous material produced from biomass by pyrolysis process, what means thermochemical decomposition of organic material at temperatures from 300°C to 1000°C with reduced access of oxygen. The interest of researchers began to focus on applications of burned organic waste into soil in the 80's of the 20th century. They were inspired by Amazon area (Lehmann and Joseph; 2015) where the soils called Terra Preta were made by massive input of wood burnt (similar to biochar). These soils have a high content of organic material and retain a higher production potential than the surrounding soils (Glaser et al., 2003). The soils throughout the world contain specific amounts of biochar as a result of natural events such as natural fires, paleo fires (Kuzyakov et al., 2018) and land use history – deforestation, pre-industrial charcoal kilns and anthropogenic oven mounds (Kuzyakov et al., 2018; Hardy et al., 2017). Biochar may alter the physical properties of the soil, including increasing aeration and water holding capacity of certain soils (Sohi, 2010). High amounts of biochar added to soil affected soil wettability that influenced soil water retention (Ojeda et al., 2015). Biochar addition has been shown to improve plant growth (Graber et al., 2010), but also stimulate soil microbial activity (Smith et al., 2010). The agronomic value of biochar mainly resides in its value as a fertilizer and its ability to improve soil properties and increase crop production (Subedi et al., 2017; Yu et al., 2019).
In Slovakia, we started with biochar experiment in field condition in March of the 2014 and in the 2018 was the same biochar repeatedly applied. The aim of this paper was to evaluate the impact of the biochar application and its repeated application on soil water content of silt loam soil in surface layer during the monitoring time period of the year 2020.

Material and methods

Our measurements were conducted at the experimental area at Malanta site (Fig. 1). This area belongs to the Slovak University of Agriculture in Nitra, Slovakia. The research site is located 5 km north-east of Nitra city in the Nitra river basin where there is a deficit of soil water available to plants due to dry years (Tarnik and Leitmanova, 2017). The locality is 175 MASL and the soil is classified as a silt loam with content of sand 15.2%, silt 59.9% and clay 24.9% (Simansky and Klimaj, 2017). Our measurements began in March 2014 when certificated biochar was applied to the 0–15 cm soil depth. Basic biochar characteristics of used biochar are shown in Table 1. A more detailed specification of the experiment foundation was described by Vitkova and Surda (2016) and partial results were published by e.g. Brezianská and Hlaváčiková (2017), Hlaváčiková et al. (2016) or Domanová et al. (2015). The biochar was produced from paper fibre sludge and grain husks in a ratio of 1:1 per weight, at a pyrolysis temperature of 550°C (Vitkova and Surda, 2016). In 2018, the original plots with former biochar application were divided in halves and the same biochar with the same dose was repeatedly applied to one of these halves (Toková et al., 2020). In this paper, we focused on three variants: plots with biochar dose of 20 t ha^{-1} applied in 2014 (B20 old), plots with biochar dose of 20 t/ha repeatedly applied in 2018 (B20 new) and plots without biochar (Control).

Soil water content was measured by 5TM dielectric sensors (Decagon Devices, USA); data was collected in five minutes interval and stored using the EM 50 data loggers. Two sensors were installed to the depth of 5–10 cm below the soil surface at two B20 old plots, two sensors were installed in the same depth at two B20 new plots and two sensors at two Control plots (four sensors at each variant). We present an average value from all sensors for each variant. The measurements were carried out during the 2020 growing season and the cultivated crop was pea (Pisum sativum L.). It was sown on March 20th, but our measurements began later. The monitoring period lasted from April 24th to July 16th.

To better evaluate the effect of biochar application in various soil moisture conditions, we have selected (based on the measured daily precipitation totals) a so-called dry (4.7.2020–10.7.2020) and wet period (5.6.2020–1.6.2020). Differences in group means of soil water content during these periods at all variants of experiment were then compared with each other and tested for statistical significance.

Statistical analysis

Differences between the measured values of volumetric water content (θ) estimated at different variants of experiment were evaluated using single factor ANOVA with Tukey's Honest Significant Difference (HSD) post-hoc test. The Tukey-Kramer method (also known as Tukey's HSD method) uses the Studentized Range distribution to compute the adjustment to the critical value. The Tukey-Kramer method achieves the exact alpha level (and simultaneous confidence level $(1 - \alpha)$) if the group sample sizes are equal and is conservative if the sample sizes are unequal. The statistical significance in the analysis was defined at $P < 0.05$.

Results and discussion

Growing season in 2020 was well balanced with respect to precipitation, and during the monitoring period was observed dry period and also wet period. Average courses of soil water content values in 5–10 cm depth at plots Control, B20 old and B20 new in comparison to daily precipitation totals are shown at Fig. 2. The lowest values were measured at Control variant, but during

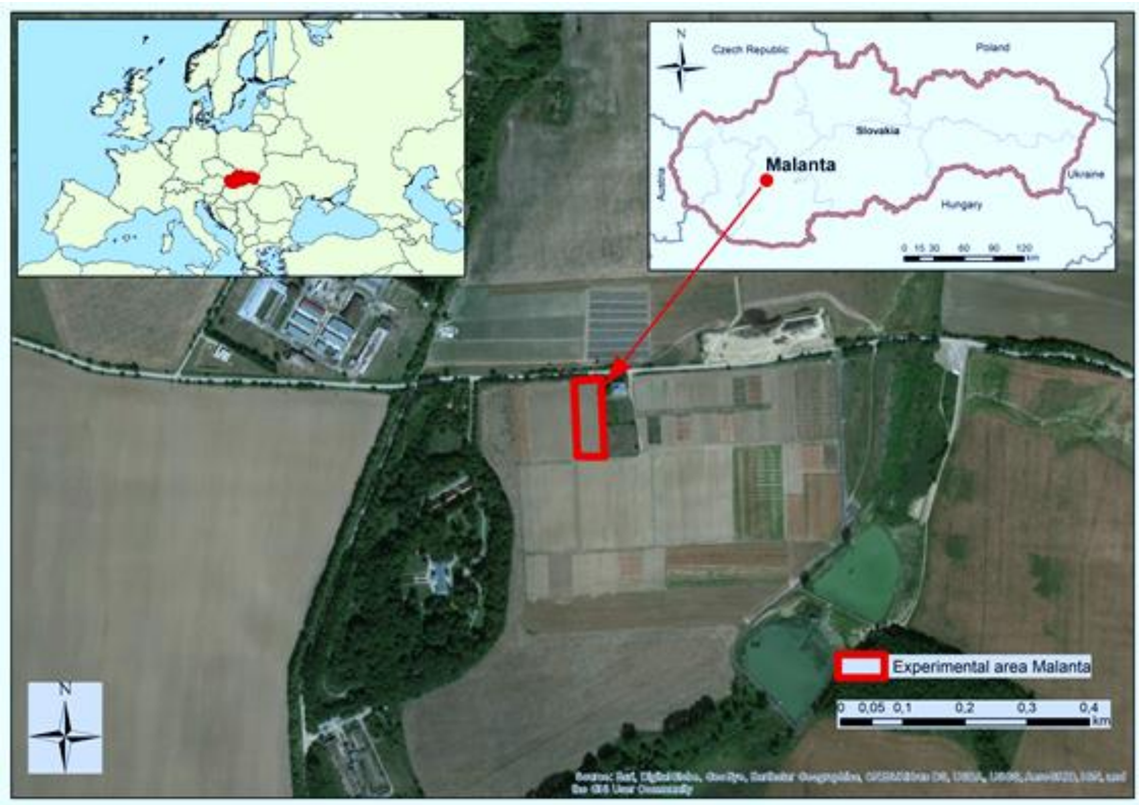

Fig. 1. Experimental area at Malanta site.

Table 1. **Biochar characteristics**

	C [%]	N [%]	H [%]	O [%]	$pH_{(CaCl_2)}$ [–]	Ash [%]	SSA [$m^2\ g^{-1}$]
Biochar	53.1	1.4	1.84	5.3	8.8	38.3	21.7

(C – carbon, N – nitrogen, H – hydrogen, O – oxygen, pH determined by $CaCl_2$, SSA – specific surface area)

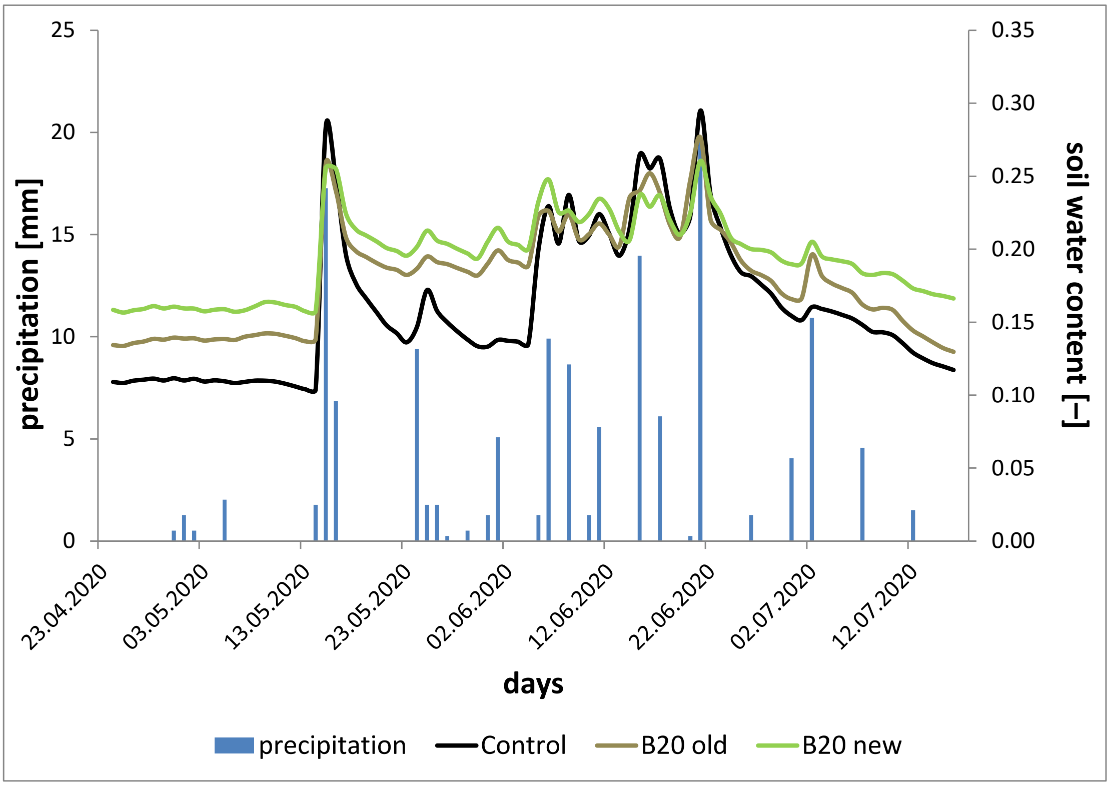

Fig. 2. Courses of measured soil moisture values at plots with old biochar, new biochar and without biochar (Control) during monitoring period.

the wet days were these values the highest. Opposite situation was measured at B20 new variant, where during days without precipitation were measured the highest values of soil water content. Based on these results it can be seen, that soil water content at B20 new variant was the most stabile during the monitoring period. For plants (globally, but also for pea grown in 2020) is not important higher amount of soil moisture during wet days, but higher amount of soil moisture during days without precipitations. Soil water content was higher at plots with biochar during dry days of monitoring period, so we can conclude that biochar application had a positive effect on soil water content. Aydin et al. (2020) observed the positive effect of biochar on the alternation of crop yields in the third and fourth year after biochar application into Haplic Luvisol soil, but it also depended significantly on the climatic conditions in the individual year. Higher positive effect of biochar repeated application (B20 new) on crop yield could be also observed during our monitoring period, but our study was not focused on it.

According to values of θ at B20 old, B20 new and Control variants of experiment measured during the whole monitoring period, we can state that both minimal (0.101) and maximal (0.427) value of θ were measured at Control plot. As a positive effect of the biochar application we can indicate that at B20 old, resp. B20 new the value of $\theta min.$ did not decrease below 0.124 resp. 0.153. Group means of θ for whole monitoring period increased in order Control < B20 old < B20 new (Fig. 3a) with statistically significant differences between all variants of experiment (Table 2). During dry period, we found statistically significant differences between all variants of experiment (Table 2) and group means of θ increased in the same order as during the whole monitoring period (Fig. 3b). During the wet period we did not found significant difference between the Control and B20 old variant (Fig. 3c); significantly different were B20 new and the remaining two variants. Slightly higher mean value of θ was measured on B20 new variant, than on the B20 old and Control.

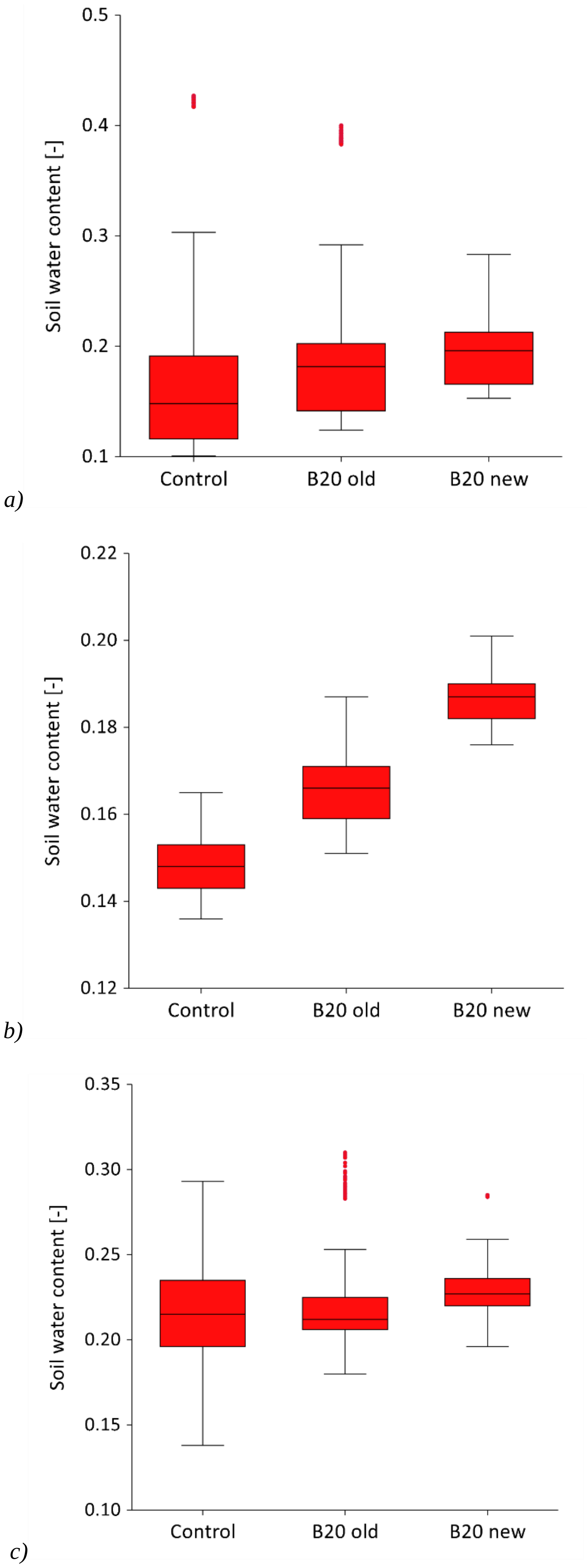

Fig. 3. Box plots with measured values of θ during a) whole monitoring period, b) dry period and c) wet period at Control, B20 old and B20 new variants.

Table 2. Measured values of volumetric soil water content, *θmin*. – minimal value of *θ*, *θmax*. – maximal value of *θ*, *θmean* (± their standard deviation) – arithmetic mean of *θ* values measured during monitoring period, *θdry* (± their standard deviation) arithmetic mean of *θ* values measured during dry period 4.7.2020–10.7.2020 and during wet period 5.6.2020–11.6.2020 (*θwet*); Arithmetic means with the same letter are not significantly different from each other (Tukey's HSD test, P < 0.05).

Plot	*θmin.* [–] (N=24023)	*θmax.* [–] (N=24023)	*θmean* [–] (N=24023)	*θdry* [–] (N=2016)	*θwet* [–] (N=2016)
Control	0.101	0.427	0.161 ± 0.0519^{a}	0.149 ± 0.0070^{a}	0.216 ± 0.0354^{a}
B20 old	0.124	0.400	0.180 ± 0.0398^{b}	0.166 ± 0.0090^{b}	0.217 ± 0.0206^{a}
B20 new	0.153	0.342	0.195 ± 0.0297^{c}	0.187 ± 0.0060^{c}	0.230 ± 0.0183^{b}

Conclusion

The application of organic material into the soil has been used for several centuries. In last decades, the interest of scientists has been focused on biochar. Its application into soil can improve its structure and quality thereby also having a positive effect on the crop quantity and quality. Statistically significant differences between all variants of experiment were measured especially during dry period. Repeated application of biochar (B20 new) increased the soil water content at 4% vol. in comparison to Control variant. During the wet period was the different between B20 new and Control variants only 1% vol. It was statistically confirmed that soil water regime was the most stable at B20 new variant (range of values 18.9% vol.) in comparison to B20 old (range of values 27.6% vol.) or Control (range of values 32.6% vol.), respectively. The results of our research at field conditions show that the application of biochar in the soil is very important, especially during dry days.

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