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Geophysics

Evaluation of Biochar Amendment Impact on Soil Water Content Changes in Field Conditions according to the Soil Hydrolimits

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ABSTRACT. **This paper is focused on quantification of soil water content and soil water retention capacity changes after biochar amendment in amount of 20 t ha-1 in the agriculturally used soil. The changes were analysed according to soil hydrolimits wilting point (θWP) and field capacity (θFC), which were determined for the research site. Presented results were obtained in the year 2015 when maize (Zea mays subsp. mays) was sown. Soil water content was measured with 5TM sensors. They were installed in 5-10 cm depth below the surface from August to October 2015. Based on the previous scientific studies we had expected higher values of soil water content and available soil water retention capacity at plot with biochar amendment. Achieved results were different. Measured values of soil water content were higher at Control plot and were dominantly affected by precipitation events. In addition, soil water content decreased below θWP at both plots during the almost whole monitoring period. One of the reasons is that spring and summer in 2015 were one of the hottest and the driest in the history of measurements in Slovakia.**

Key words: soil water retention capacity, soil hydrolimits, biochar, climate change

Nowadays, the interest of society is to mitigate the effects of climate change on soil, atmosphere, plants and water resources. One of the tools to reduce the negative impact of climate change on soils characteristics could be the application of biochar.

Biochar is the product of thermal degradation of organic materials in the absence of air (pyrolysis) and is distinguished from charcoal by its use as a soil amendment [1]. Biochar can be used in a large number of applications, ranging from heat and power production to soil amendment. The properties of carbonized biomass depend on the feedstock and the process conditions [2].

Soil amendment with biochar is currently one of the highlights in scientific community due to improved soil fertility and moderate climate change. Biochar can be a useful contribution to climate change mitigation by surface soil organic [3]. Biochar in soils augments carbon retention and substantially reduces greenhouse gas emissions [4, 5].

Biochar in soil reduces the production of CH_4 and N_2O, even when the conditions are suitable for emission. Due to the presence of numerous pores, biochars retain water and nutrients, and also have bacterial residence; these are properties that improve soil quality [3]. Wastewater with high levels of heavy metals, pesticides, and other organic pollutants are adsorbed on biochar, as it provides an excellent medium for the treatment of wastewater [6]. Amending agricultural soils with biochar is commonly reported to improve chemical properties of the soil (e.g. pH, cations) [7, 8].

Biochar has a positive improvement for the hydro-physical properties of soils [9, 10]. Biochar increased air space, water retention capacity, total porosity and has no impact on the wettability of soils [11]. It also stands out as a cheap, low-tech method, which can reach rural areas in developing countries.

In this paper, we focused on quantification of the changes in soil water content and available soil water retention capacity after biochar amendment according to the soil hydrolimits.

Materials and Methods

The research site Malanta belongs to Slovak University of Agriculture in Nitra, Slovakia (Fig. 1.). It is situated approximately 5 km north-east of the Nitra city in the west part of Slovakia (N 48°19'00"; E 18°09'00") at an altitude of 175 m a. s. l. [12]. The soil type is classified as silt loam with the content of sand 15.2%, silt 59.9% and clay 24.9% [13]. The whole site was divided into plots with the size 6×4 m separated by 0.5 m bands. Our field experiment began on March 2014 when a certificated biochar was applied to a 0-15 cm depth of soil profile. Biochar, used for the field experiment, was produced from paper fiber sludge and grain husks; 1:1 per weight (Sonnenerde Company, Austria) by pyrolysis at 550°C for 30 minutes in a Pyreg reactor. Basic biochar characteristics are given in Table 1. We have compared two plots in our analyses: the first plot with application of biochar in amount of 20 t ha^{-1} (B20), the second plot was without biochar amendment (Control). Monitoring period lasted from August 12 to October 22, 2015 and the research site was cultivated with the maize (*Zea mays subsp. mays*). Decagon Devices (USA) with 5TM dielectric sensors performed the measurements of soil water content. Decagon Devices, using the EM 50 data loggers collected and saved in 5-minute interval the soil water content data.

Soil water retention curves were determined from soil samples with volume of 100 cm^3 (collected from the depth of 10 cm in spring and autumn 2015) through the use of standard pressure plate apparatus (Soil Moisture Equipment Corp., USA). Sampling was provided in the same plots, where the sensors were installed. Spring soil sampling was carried out after agro-technical operation stubble ploughing, before the maize sowing. Autumn sampling was done after the maize harvesting. Values of hydrolimits θ_{FC} and θ_{WP} were estimated from soil water retention curves; θ_{FC} for pF = 2.5 and θ_{WP} for pF = 4.2.

Table 1. Biochar characteristics

	C (g kg^{-1})	**N** (g kg^{-1})	**H** (g kg^{-1})	**O** (g kg^{-1})	**pH** –
Biochar	531	14	18.4	53	8.8

Results and Discussion

The top soil layer was analysed in the time, when root system of maize was deep enough i.e. the monitoring period cancelled in the end of the maize vegetation period. Monitoring was finished when the maize was harvested. Based on previous scientific studies dealing with a biochar amendment in soils, we had expected that higher values of soil water content will be measured in B20 plot. The

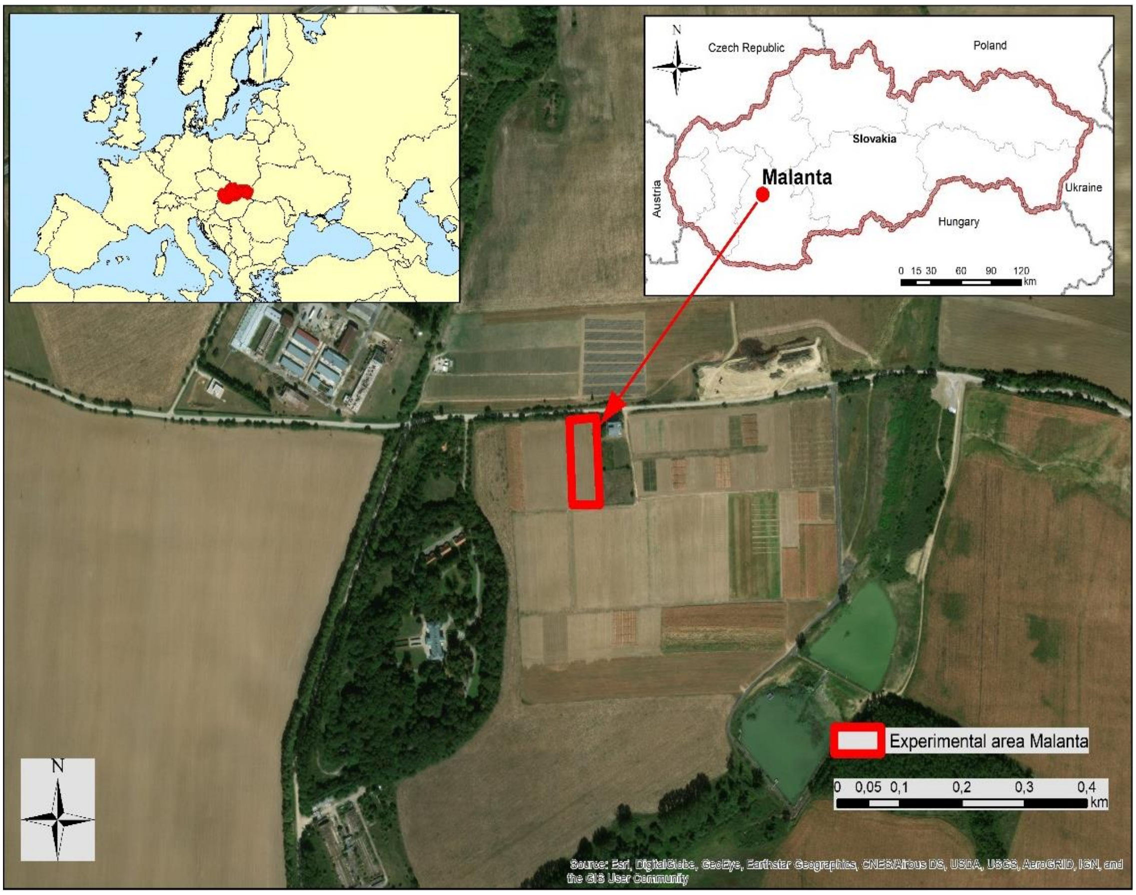

Fig. 1. Location of Malanta experimental area.

results obtained were the opposite. Soil water content was higher at Control plot during monitoring period regardless of whether there was dry or wet period (Fig. 2.). Soil water content during the most of the monitoring period decreased below the soil hydrolimit θ_{WP}. It was caused by low precipitation totals and extremely high air temperatures during summer, which was one of the hottest and the driest in the history of measurements in Slovakia.

Very dry vegetation period resulted in the deficit of soil water content in top soil layer. Optimal soil water content for plants (interval between θ_{FC} and θ_{WP}) was measured for only few days in the middle of October. Statistical analysis of measured soil water content is shown in Fig. 3. The longer duration of soil water deficit at B20 plot resulted in the smaller yield observed at B20 plot in comparison to Control plot [14]. Negative trend of available soil water storage in the whole Nitra river catchment in 2015 is confirmed in [15].

Absolute values of soil hydrolimits at both plots from spring sampling were higher than the soil hydrolimits from autumn sampling (Fig. 4). In the Control plot the difference in θ_{WP} was 4% vol. and in θ_{FC} it was 3% vol. The difference in θ_{WP} and θ_{FC} was 1% vol. in the B20 plot. Only small changes were observed in available soil water retention capacity in both plots. Differences were caused by agro-technical operation at field. In B20 plot, the higher values were measured before sowing (spring sampling) and lower values after harvesting (autumn sampling) (Table 2.). Changes in available soil water retention capacity in Control plot were observed in different order, i.e. higher values were measured during autumn sampling. In conditions of our experiment, the biochar amendment did not improve available soil water retention capacity.

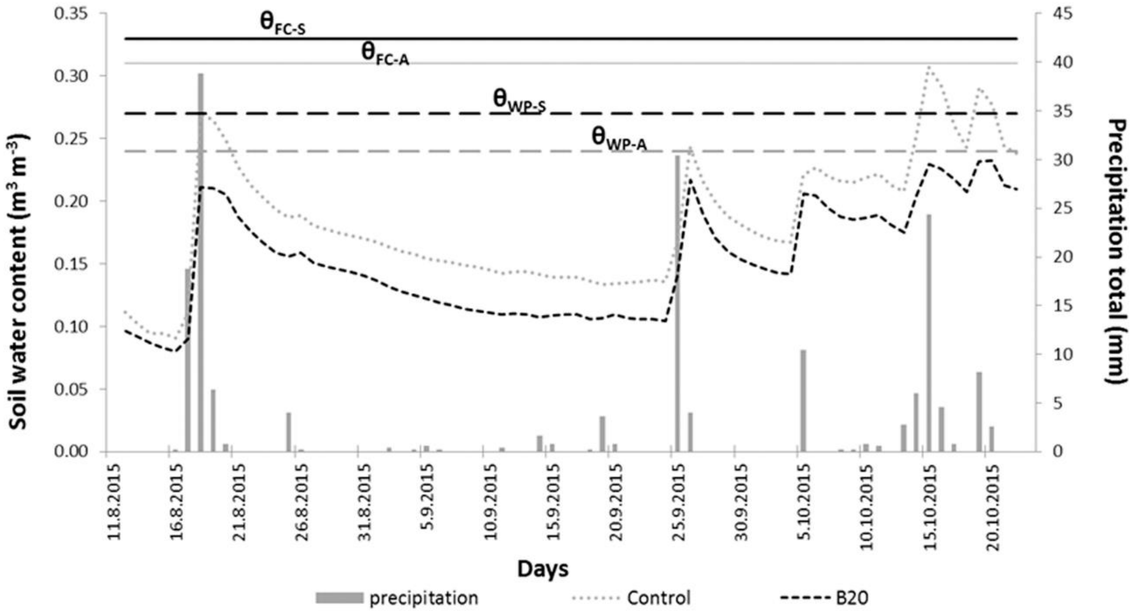

Fig. 2. Soil water content in Control and B20 plots in comparison to soil hydrolimits θ_{FC} and θ_{WP} during spring (S) and autumn (A) samplings at Malanta site.

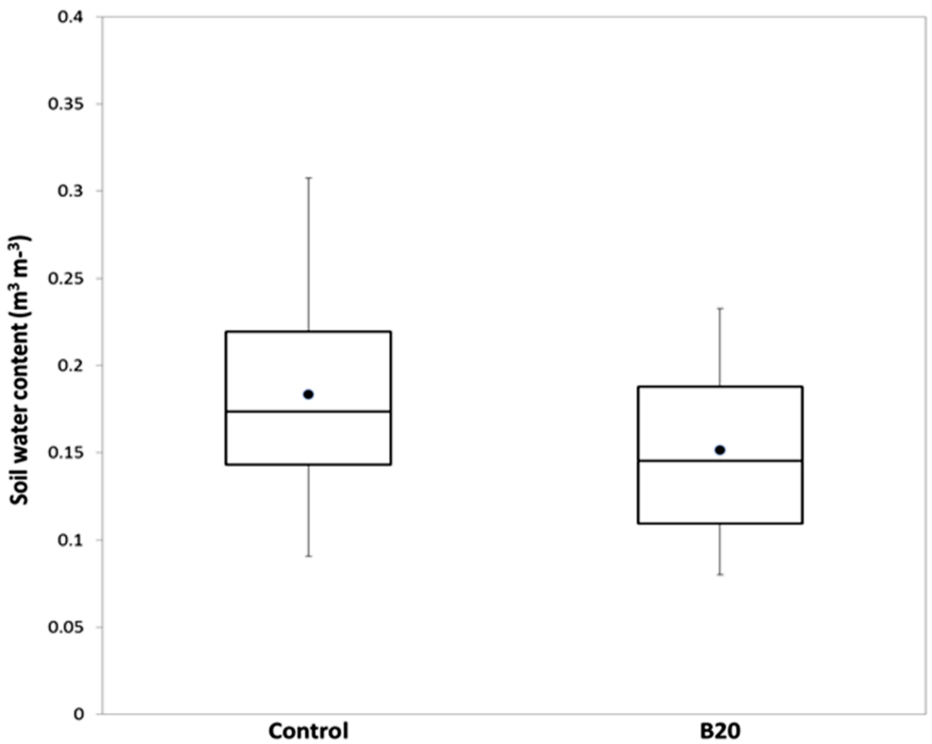

Fig. 3. Soil water content range in Control and B20 plots at Malanta site during monitoring period. Value range: minimum, the 25th percentile, median, the 75th percentile, maximum and circles represent average value.

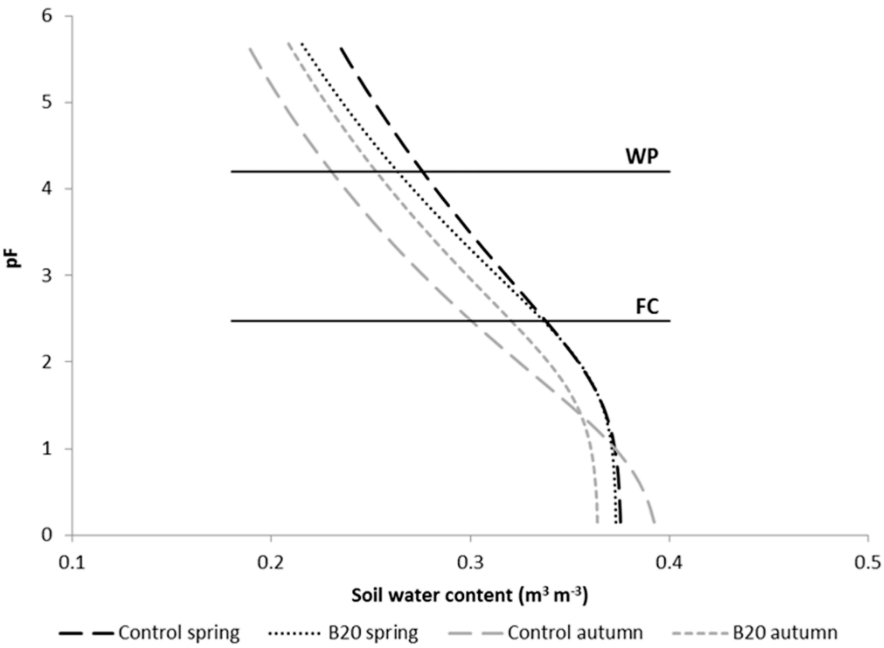

Fig. 4. Soil water retention curves determined from spring and autumn samplings at Malanta site and comparison to soil hydrolimits wilting point (WP) and field capacity (FC).

Table 2. Available soil water retention capacity in Control and B20 plots based on spring and autumn samplings

	Available soil water retention capacity	
	Spring ($m^3 m^{-3}$)	**Autumn** ($m^3 m^{-3}$)
Control	0.0618	0.0702
B20	0.0732	0.0678

Conclusions

Soil water content measured in Control plot was higher than soil water content at B20 plot during whole monitoring period and decreased below the soil hydrolimit θ_{WP} during the most part of monitoring period. It could be caused by high air temperatures and low precipitation totals during summer of 2015.

Absolute values of soil hydrolimits θ_{FC} and θ_{WP} were higher at the beginning of vegetation period, because soil sampling was done after agro-technical operation, which caused soil loosening – better physical condition of upper 15 cm soil profile. The soil hydrolimits were lower in the end of vegetation period due to soil compaction. Available soil water retention capacity did not change significantly, but it was 1.04 times higher in Control plot in autumn sampling in comparison to B20 plot. Agro-technical operation before spring sampling and biochar amendment had positive effect on available soil water retention capacity in B20 plot, but after continual increase of soil compaction during vegetation period (induced by meteorological factors) the impact of biochar was reduced.

Our hypothesis that biochar with the above-mentioned characteristics will increase soil water content and improve available soil water retention capacity was not confirmed in conditions of performed field experiment.

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გეოფიზიკა

საველე პირობებში ნიადაგის ჰიდროლიმიტების მიხედვით ნიადაგის წყლის შემცველობის ცვლილებებზე ბიოდანამატების ზემოქმედების შეფასება

ჯ. ვიტკოვა*, პ. რონჩაკი*, პ. სურდა*, გ. კორძახია**

**სლოვაკეთის მეცნიერებათა აკადემიის ჰიდროლოგიის ინსტიტუტი, ბრატისლავა, სლოვაკეთი*
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ნაშრომში ყურადღება გამახვილებულია ნიადაგის წყლის რაოდენობისა და ნიადაგის წყალშემცველობის რიცხობრივი ცვლილებების გაზომვაზე სასოფლო-სამეურნეოდ გამოყენებულ ნიადაგში 20 ტ/ჰა ოდენობით ბიოდანამატების შეტანის შემდეგ. ცვლილებები გაანალიზდა ნიადაგის ჰიდროლიმიტების ჭკნობის კოეფიციენტით (θ_{WP}) და საველე სიმძლავრის (θ_{FC}) მიხედვით, რომლებიც განისაზღვრა საკვლევი ნაკვეთისათვის. წარმოდგენილი შედეგები მიღებულია 2015 წ., როდესაც დაითესა სიმინდი (*Zea mays subsp. mays*). ნიადაგის წყლის შემცველობა იზომება 5TM სენსორებით, რომლებიც დამონტაჟებულ იქნა 5-10 სმ სიღრმეზე ზედაპირიდან, 2015 წლის აგვისტოდან ოქტომბრამდე. წინა სამეცნიერო კვლევების გათვალისწინებით, მოსალოდნელი იყო წყლის რაოდენობისა და ნიადაგის წყალშემცველობის უფრო მაღალი სიდიდეები საკვლევ ნაკვეთში, რომელშიც შეტანილი იყო ბიოდანამატები. მიღებული შედეგები განსხვავებული იყო. ნიადაგის წყლის რაოდენობის მაჩვენებლები უფრო მაღალი იყო საკონტროლო ნაკვეთზე და ნალექები ახდენდა დომინანტურ ზემოქმედებას. ამასთანავე, თითქმის მთლიანი მონიტორინგის პერიოდის განმავლობაში ნიადაგის წყლის რაოდენობა ორივე ნაკვეთში θ_{WP}-ზე დაბლა შემცირდა. ერთ-ერთი მიზეზი ისაა, რომ 2015 წლის გაზაფხული და ზაფხული ერთ-ერთი ყველაზე ცხელი და მშრალი იყო სლოვაკეთში დაკვირვებების წარმოების ისტორიაში.

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