

**CHANGES IN SOIL MOISTURE VALUES TWO YEARS
AFTER BIOCHAR REAPPLICATION**

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Biochar, as a carbon rich material, has properties which are similar to water repellent material. Its application into the soil changes these properties, but it takes a few years. Our research was focused on soil moisture values comparison at plots with aged biochar (applied into the soil in 2014) and fresh biochar (aged biochar applied in 2014 + reapplied biochar applied into soil in 2018). Results indicated that fresh biochar had water repellent properties in first year after its application into the silt loam soil, which were changed in second year after its application. Our measurements show positive effect of biochar on soil water regime in a longer time horizon.

KEY WORDS: biochar reapplication, soil moisture, barley, maize

Introduction

Biochar is a solid porous material with high carbon content. It is the product of thermal degradation of organic materials in the absence of air (pyrolysis). During pyrolysis, between 50% and 80% of biomass is converted into combustible liquids and vapours, which can be used to produce bioenergy (Laird et al., 2009). The remaining biomass is converted into biochar, which retains some residual feedstock properties but is essentially composed of amorphous carbon, turbostratic crystallites of polycondensed aromatic sheets, and interspersed voids (Keiluweit et al., 2010). Feedstock selection and pyrolysis conditions affect biochar properties (Rutherford et al., 2012). Functional surface groups of biochars create hydrophobic hot-spots thereby increasing spatial heterogeneity of the water repellency of the soil (Kinney et al., 2012). It has been reported that water repellency is linked to the abundance of non-polar aliphatic and aromatic groups of organic compounds (Ellerbrock et al., 2005).

The hydraulic system becomes more complex when biochars are added to soil. The impact of soil water repellency on hydraulic properties including infiltration capacity, surface runoff and erosion has been studied intensively during the last two decades (e.g., Bachmann et al., 2013). Water repellency depends on the initial moisture content and time. Biochars tend to decompose slowly in the environment and are thus considered temporal sinks for atmospheric CO₂ (Glaser et al., 2002). Water repellency and delayed wetting are commonly causing higher fractions of entrapped air and thus

decrease the fraction of saturated soil pores, which should reduce both, the available water capacity and hydraulic conductivity. Therefore, the development of chars with low water repellency has been proposed for optimizing the positive effects on soil hydraulic properties (Kinney et al., 2012).

Biochar produced at low temperature contains more aliphatic compounds in the biochar pores that increase the hydrophobicity (Chen et al., 2008; Gray et al., 2014), while high temperature pyrolysis allows a much smaller number of aliphatic compounds remaining in the pores (Chen et al., 2008). The addition of hydrophobic biochar can turn hydrophilic soil into water repellent. Addition of hydrophobic biochar to soil could change soil hydrophobicity that influences soil hydraulic properties (Jeffery et al., 2015). Therefore, biochar hydrophobicity should be considered for biochar application to soil amendment. The effects of biochar on soil hydrophobicity concerning physical structure change of soil have been discussed. However, regarding to chemical properties of soil and characteristics of biochar, the effects of biochar on soil hydrophobicity remain unclear (Mao et al., 2019).

In last year's began accrue number of articles aimed on impact of biochar on different research topics: soil moisture (Vitkova et al., 2017), grain yields (Horák et al., 2020), CO₂ production (Horák and Šimanský, 2017) or soil structure (Juriga and Šimanský, 2018) in Slovakia. Biochar hydrophobicity (or water repellency) is one of the topics, which has not been studied yet. Therefore, our article is focused on possible biochar's water repellency effect on soil moisture in field conditions.

Material and methods

Our measurements were conducted at the experimental site in Malanta (Fig. 1), which belongs to the Slovak University of Agriculture in Nitra, Slovakia. The research site is located approximately 5 km north-east of Nitra city (N 48°19'00"; E 18°09'00") 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 Haplic Luvisol with soil organic carbon content of 9.13 g.kg⁻¹, with pH of 5.71 and silt loam soil texture. The site is in the temperate region with the mean annual air temperature of 9.8°C and average precipitation amounting to 540 mm (30-year climate normal, 1961–1990) (Horák et al., 2019).

The biochar experiment was established in March, 2014 when whole area was separated at plots (6x4 m) separated by 0.5 m buffer zone. Certificated biochar (Table 1) in amount of 0, 10 and 20 t ha⁻¹ was applied on soil surface and incorporated into the depth of 0–10 cm. The biochar was produced from paper fiber sludge and grain husks in a ratio of 1:1 per weight, at a pyrolysis temperature of 550°C (Domanová et al., 2015). Research on various aspects of biochar application into the soil was studied at this area. In 2018, the original plots with former biochar

application were divided in halves (4x3 m) and the same biochar with the same dose (0, 10 and 20 t ha⁻¹) was reapplied to one of these halves (Toková et al., 2020).

In this paper we focused on impact of biochar application at the dose of 20 t ha⁻¹. Soil moisture was measured at plots with aged biochar – applied in 2014 (B20) and at plots with fresh biochar – consisting from aged biochar + new biochar applied in 2018 (B20 reap.). These measurements were compared with plots without biochar (Control).

Soil moisture was measured by 5TM dielectric sensors (Decagon Devices, USA) and data was collected in five-minute 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 plots with aged biochar and two plots with fresh biochar. Four sensors were installed to the depth of 5–10 cm below the soil surface at two Control plots. We present the average value for each variant. The measurements were carried out during the 2018 and 2019 growing seasons where cultivated crop was spring barley (*Hordeum vulgare* L.) and maize (*Zea mays* L.), respectively. The monitoring period lasted from June 22, 2018 to July 24, 2018 and from May 3, 2019 to October 23, 2019.

Significance was tested with a two-way analysis of variance. The significance limit was set to 0.05.

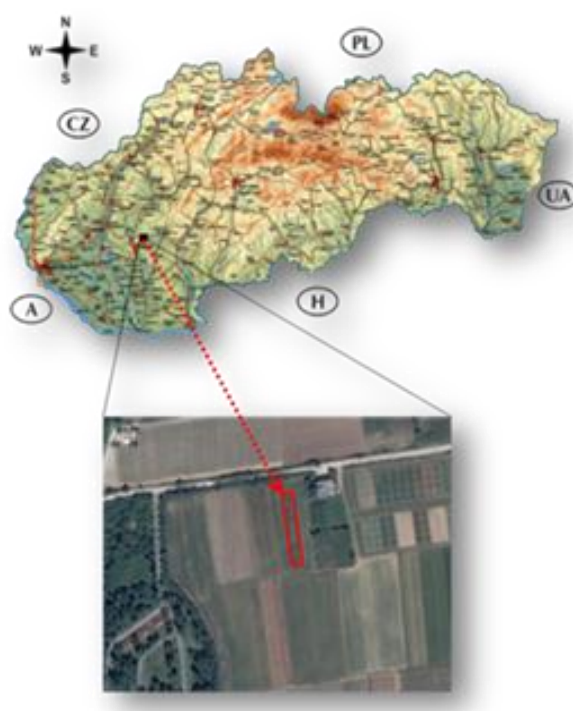


Fig. 1. Studied area at Malanta site (© Google maps 2019).

Table 1. Characteristics of used biochar

C	N	H	O	pH _(CaCl₂)	Ash	SSA
[%]	[%]	[%]	[%]	[-]	[%]	[m ² g ⁻¹]
53.1	1.4	1.84	5.3	8.8	38.3	21.7

Note: (C–carbon, N–nitrogen, H–hydrogen, O–oxygen, pH determined by CaCl₂, SSA–specific surface area)

Results and discussion

Meteorological characteristics are very important factors for soil moisture in top soil layer. The monitoring period (as well as the vegetation period) was very dry in 2018 and it was the warmest or equally warmest in the history of measurements in the meteorological station Nitra–Janíkovce according to SHMÚ (2019). According to SHMÚ (2020), the year 2019 was very warm especially in far east of Slovakia. Table 2 shows average monthly air temperatures and precipitation totals during monitoring days and their comparison to climatic normal 1961–1990 according to Šiška et al. (2005). Meteorological data from 2018 and 2019 were provided by Slovak Hydrometeorological Institute from Nitra–Janíkovce meteorological station, which is located approximately 6 km from studied area at Malanta site. In 2018, monitoring period starts on June, 22 and finished on July, 24, so only 9 days (9 values) were calculated as average value for air temperature or precipitation totals in VI./2018 and 24 values (24 days) were calculated for VII./2018 (Table 2). In 2019, monitoring period starts on May, 3 and finished on October, 23, so 29 values (29 days) were calculated for V./2019 and 23 values (23 days) were calculated for X./2019. The month June in Table 2 is not good to compare because of unequal number of values. Average value of air temperature and precipitation totals during other months was calculated from more than 23 days. Measured soil moisture was higher during monitoring period in 2019 because of higher amount of precipitation totals during spring months (Table 3).

Sensors 5TM reacted very well on precipitation in top soil layer. In 2018 (Fig. 2), soil moisture at B20 plots and B20 reap. plots was statistically insignificant during or in a short time after rain episodes (June, 28–30; July, 8; or July, 11–12). Larger differences (statistically significant) were occurred during longer time of non-precipitation days, when soil moisture at B20 reap. plots was lower in about 2–6% vol. in comparison to B20 plots. Soil moisture at Control plots was the lowest almost during the whole monitoring period except the end of monitoring period (July 16–22, 2018). In 2019 (Fig. 3), soil moisture values were completely different. The highest values were measured at B20 reap. plots. Soil moisture at B20 and Control plots was very similar (statistically insignificant) during non-precipitation days (June, 17–23; July, 3–6; or August, 2–6), but smaller at B20 plot in comparison to Control plot (statistically significant) during some rainy days (July, 7–August, 1; or September, 21–October, 2).

Our results showed differences in soil moisture values during monitoring period 2018 and 2019. While in 2018 soil moisture was lower at plots with fresh biochar than at plots with aged biochar, the situation was opposite in 2019. Soil moisture at Control plots was the lowest almost in all months during monitoring periods in 2018 and 2019. Similar results at the same experimental site in 2018 measured also Tarnik (2019) with different sensors. Few studies investigated the particular role of biochar water repellency on hydraulic properties of amended soils. In soil water infiltration experiments the observed reduction of the infiltration rate was attributed to hydrophobic properties of pyrochars (Githinji, 2014).

Table 2. Average monthly air temperature and precipitation totals at Nitra area during monitoring days in comparison to the climatic normal (CN) 1961–1990

	TEMPERATURE			PRECIPITATION		
		[°C]			[mm]	
	CN	2018	2019	CN	2018	2019
V.	9		13	135		116
VI.	19	18	23	29	26	63
VII.	22	21	22	52	42	41
VIII.	22		23	64		107
IX.	16		16	53		67
X.	12		13	18		16

Table 3. Average monthly soil moisture values at Malanta area during monitoring days

	2018			2019		
	[cm ³ .cm ⁻³]			[cm ³ .cm ⁻³]		
	Control	B20	B20 reap.	Control	B20	B20 reap.
V.				0.209	0.238	0.259
VI.	0.080	0.143	0.137	0.178	0.195	0.211
VII.	0.101	0.144	0.120	0.158	0.143	0.169
VIII.				0.166	0.173	0.194
IX.				0.187	0.192	0.208
X.				0.183	0.188	0.207

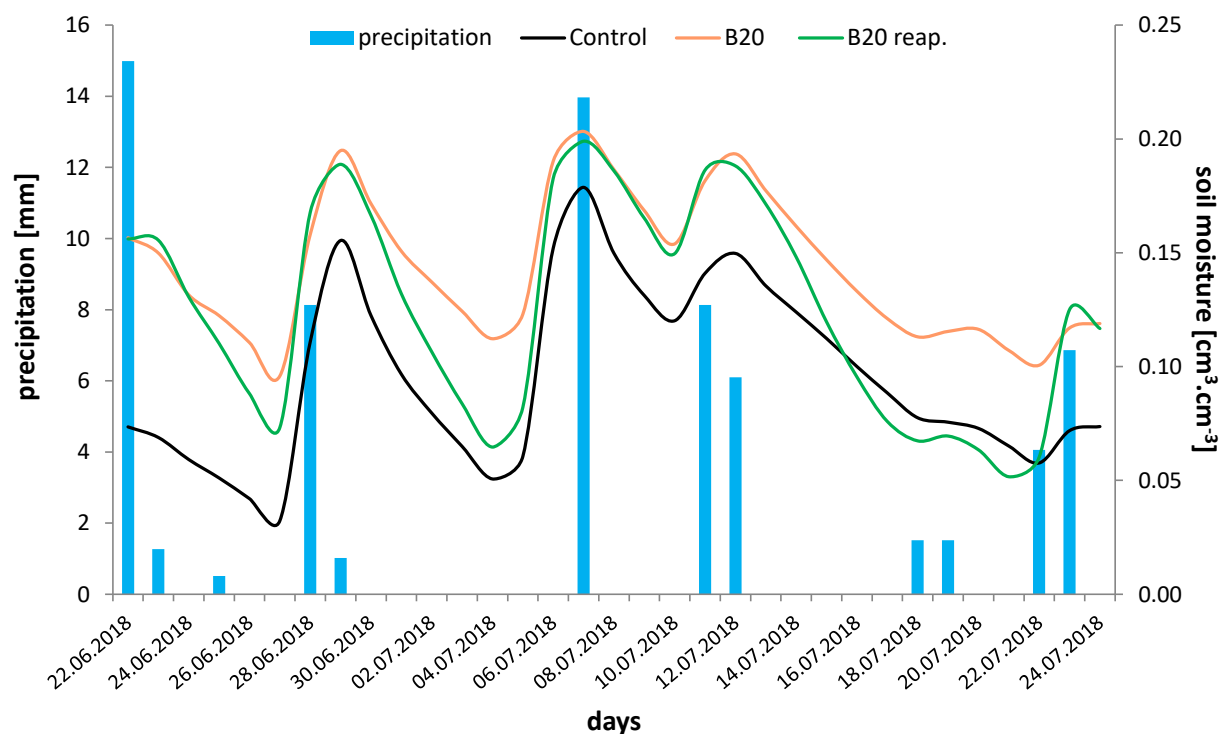


Fig. 2. Measured soil moisture at plots without biochar (Control) and plots with aged biochar (B20) and fresh biochar (B20 reap.) in comparison to daily precipitation totals during monitoring period 2018.

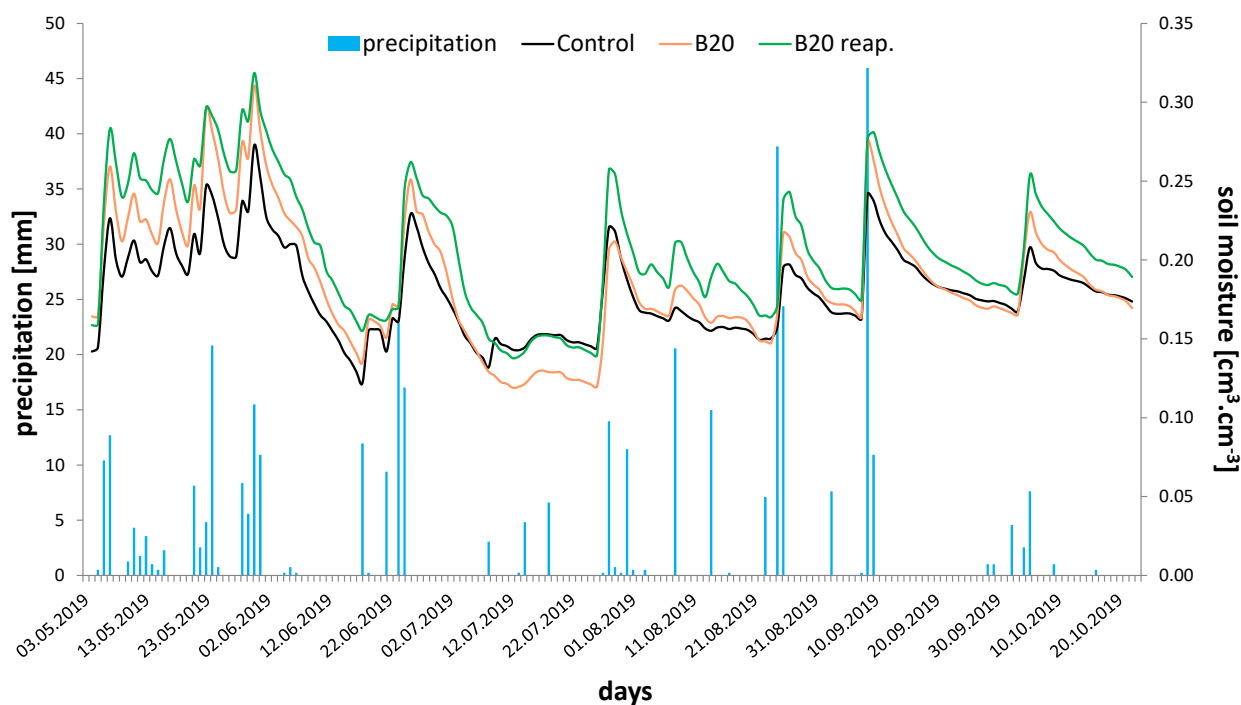


Fig. 3. Measured soil moisture at plots without biochar (Control) and plots with aged biochar (B20) and fresh biochar (B20 reap.) in comparison to daily precipitation totals during monitoring period 2019.

In another study, the water repellency of pyrochars decreased with increasing pyrolysis temperature resulting in higher field capacities (Kinney et al., 2012). In contrast, Baronti et al. (2014) did not find any effects on wettability in a two-year field experiment when sandy clay loam was amended with pyrochar. Our results showed that this type of fresh biochar reduced the soil moisture during non-precipitation days in comparison to plots with aged biochar and Control in 2018. But in 2019 soil moisture was the highest at plots with fresh biochar in comparison to Control and aged biochar. Fresh biochar becomes a part of soil aggregates gradually and its properties are changing by meteorological changes; root system of vegetation; soil animals etc. The results showed that biochar's water repellency properties were lower two years after its reapplication into the silt loam soil. Biochar degradation is a natural process and properties of aged biochar are now different than it was in 2014 and also properties of fresh biochar are different than it was in 2018. It may also be some reasons of our results.

Conclusion

In this paper we focused on biochar application and its reapplication into silt loam soil at Malanta site (Slovakia). We measured soil moisture in short time intervals to have a good overview of impact of precipitation totals and air temperature on soil moisture changes. Our results confirmed that biochar has water repellent properties and with soil moisture being lower at B20 reap. plots (with fresh biochar) than at B20 plots (with aged biochar, applied 5 years ago) first year of its reapplication (in 2018) into the soil. Soil moisture was still higher at B20 plots compared to Control plots (without biochar). It was caused by aged biochar particles (applied in 2014) which are situated at B20 reap. plots and in this time they are part of soil aggregates. The soil moisture was higher at B20 reap. plots two years after biochar reapplication (in 2019) almost the whole monitoring period. These results show positive effect of this type of biochar on soil water regime in a longer time horizon. Authors are aware of the fact that two years after biochar reapplication in field conditions is not long enough to make a strict conclusion, but the results indicate that biochar application into the soil has more benefits in a longer time horizon. Therefore, it is necessary to continue with this research.

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