Impact of Biochar on Soil Water Permeability Coefficient During 2 Year Field Experiment

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Abstract. Water is the most important substance which occurs in soils. As a soil solution it is a basis of life for plants, as well as a carrier of mineral salts collected by plants through roots. Ability to collect water by plants depends on the power of its binding with soil and thus on the quality of soil and amount of water. The objective of the article is to determine the water permeability coefficient in the superficial layer of soil in relation to the applied biochar dose. The research was provided in 2018 and 2019 year at agricultural field located in Krakow, Poland. The soil used for test was typical brown clay soil. The lowest value of water permeability was observed for soil where above 60 Mg∙ha⁻¹ of biochar was applied. Water permeability is strictly connected with general porosity and is often assumed as such in many papers. It was reported that the water permeability for control soil where no addition of biochar was used indicates up to two times lower permeability in comparison to the soil where biochar was added which indicates that biochar influences the amount of water available for plants which the investigated soils were able to store.

1. Introduction

Soil is a natural porous material which is gas- and water-permeable. Fluid flow is possible due to the presence of a network of channels and gaps between the mineral grains forming the soil structure. It is possible using an water energy gradient (from higher to lower). Knowledge of soil water permeability mainly has an engineering dimension, but is also very important for the proper growth of plants. Soil permeability depends on many factors such as density, porosity, porosity distribution, saturation level, mineral composition. The permeability coefficient is specific for each type of porous material, and its variability can be up to 10 orders of magnitude between the same type of soil [1-5].

The water permeability coefficient is the key information about soil hydrological properties that determine water transport, evapotranspiration, filtration and water flow direction [6-8]. Knowledge of the spatial distribution of the soil permeability coefficient allows an approximate determination of the impact of atmospheric factors (e.g. rainfall, wind speed and direction), topographic (e.g. slope of the terrain) and plant cover on water distribution processes in soil [9, 10]. Due to the layered structure of the soil, the most visible changes in humidity can be observed in the top layer of the profile (up to 30
cm b.g.l.). The water present in this layer is very sensitive to external factors such as rainfall, solar radiation and wind speed [11, 12].

The objective of the article is to determine the soil water permeability coefficient in the superficial layer of soil in relation to the applied biochar dose.

2. Material and methods
The studies presented in this article were made on the experimental field that belongs to the University of Agriculture in Krakow. Soil used for research is brown soil made of Jurassic limestone. 11 experimental fields with dimensions of 1.2x1.2 m were distributed on an experimental field. They were fertilised with biochar produced from sunflower husk in the amount of 0, 1, 5, 10, 20, 30, 40, 50, 60, 80 and 100 Mg∙ha$^{-1}$. Before measurements were initiated, probes were conditioned in an incubator. Read outs on experimental fields were made every 30 days from May to September 2018 and 2019. Water permeability coefficient was measured for every probe in accordance to ISO 17892-11:2004 “Geotechnical investigation and testing — Laboratory testing of soil — Part 11: Determination of permeability by constant and falling head”. The analysis of variance in the scheme of repeated measurements that constituted extension of the analysis of the t-Student test for dependent tests were used for statistical assessment of the results of measurements. In the t-Student test were compared only two measurements and in the analysis of variance were compared two or more measurements of the same group of fields depending on the biochar dose.

3. Results and discussions
Figures 1 and 2 show the results of soil permeability coefficient measurements in 2018 and 2019. In 2018, after using biochar, the water permeability coefficient was formed at 4 different levels. The dose of biochar in the amount of 1 Mg∙ha$^{-1}$ did not change the value of the coefficient relative to control plot. Doses of 5 and 10 Mg∙ha$^{-1}$ biochar resulted in a 10% increase in permeability relative to control plot. Dosage of biochar in the amount of 20-50 Mg∙ha$^{-1}$ caused a further increase in soil water permeability (about 20% in relation to control plot and 5% in relation to smaller doses). The largest variation in soil permeability coefficient was observed for doses of 60-100 Mg∙ha$^{-1}$ biochar, which achieved an increase in permeability at 3 times the permeability for control plot.

![Figure 1](image_url). Average value of soil permeability coefficient in relation to biochar dose (Mg∙ha$^{-1}$) and month of measurement in 2018.
Research carried out in 2019 showed stabilization of the permeability coefficient and its reduction compared to 2018. After 24 months from the application of biochar on plots with 1-10 Mg·ha⁻¹ doses, the permeability coefficient equaled the value of control plot. Doses of 20-50 Mg·ha⁻¹ biochar shaped the water permeability coefficient at 1.5 times the value of the coefficient for control plot. The remaining doses maintained high water permeability relative to the control plot, which decreased to twice the value of the control plot.

![Figure 2. Average value of soil permeability coefficient in relation to biochar dose (Mg·ha⁻¹) and month of measurement in 2019.](image)

![Figure 3. Average soil permeability coefficient difference between 2018 and 2019 in relation to biochar dose (Mg·ha⁻¹) and month of measurement.](image)
Figure 3 shows the variability of the soil water permeability coefficient in the scale of the 2 measuring years analyzed. The smallest variability of the coefficient was noted for biochar doses in the amount of 20-50 Mg·ha⁻¹, which was lower than the variability estimated for control plot. For the remaining doses, varied permeability coefficient variation was observed, which exceeded twice the value of the control plot value.

All analyzed changes of soil water permeability coefficient showed statistically significant differences when using biochar dose groups into 3 or 4 experimental groups.

4. Conclusions
Summing up the presented experimental results, it can be concluded that the optimal dose of biochar that should be used to improve soil water permeability is 20-50 Mg·ha⁻¹. This doses may be suitable for soil grains similar to the soil under test. In other cases, appropriateness of the biochar use as an improvement of field retention should be considered.

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