Impact of Biochar on Water Permeability in Soil

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Abstract. Water is the most important substance which occurs in nature. As a soil solution it is a basis of life for plants, both as an indispensable element of plant tissues as well as a carrier of mineral salts collected by plants through root hair. 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 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 changes of soil granulometry were made with sunflower husk biochar. The biochar permeability was \(3.2 \times 10^{-5} \text{ m} \cdot \text{s}^{-1}\). The lowest value of water permeability \(3.3 \times 10^{-7} \text{ m} \cdot \text{s}^{-1}\) was observed for soil where 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

In the literature there are many papers discussing the impact of biochar on the hydraulic properties of soil and its water capacity. The possibilities of using biochar as a substance supporting water retention is determined by its physicochemical properties. Meteorological observations carried out by meteorological stations in Europe indicate the increasing occurrence of the phenomenon of hydrological drought, caused by a decrease in annual rainfall sums and increasingly milder, snowless winters. For this reason, it is important to determine the possibility of water retention in soil or the use of substances that support it [1,2]. Water content in soil is a function of porosity and soil-forming processes. Its value directly translates into water retention, which is defined as the ability to retain specific amounts of water under strict conditions [3]. There is a useful retention in it, which is defined as that part of the water accumulated in the soil that plants can use [4].

Biochar is a commonly used substance that increases the content of organic carbon in soil and clay fraction material. The authors of this publication in their previous studies [6-9] showed that biochar increases the water holding capacity in soil and improves its water retention possibilities. In the literature, there are also works in which there is a lack of positive impact of biochar to improve soil
water properties. Most often, the application of biochar to soil changes its properties physico-chemical properties (including porosity). These changes strongly affect the soil moisture characteristics and depend on the granulation of the biochar used. Their result depends on the type and dose of biochar, soil properties and local microclimate [10].

The purpose of the study is to determine the relationship between water retention in the topsoil depending on the applied dose of biochar expressed in water permeability coefficient.

2. Material and methods
The experiment was established on the experimental field belonging to the University of Agriculture in Krakow. The soil used for research is a brown soil made from Jurassic limestones. To determine the effect of biochar on soil grain composition, 10 experiments were established with biochar content in the range of 1÷100 Mg·ha\(^{-1}\) and 1 control plot (marked with the symbol 0 – grain size is presented on fig. 1). Biochar produced from sunflower husk was used for the research. The grain composition of biochar is shown on fig. 2. Water permeability coefficient of the material was measured below \(3.2 \cdot 10^{-5}\) m·s\(^{-1}\). Volume density of biochar was 2.65 Mg·m\(^{-3}\).

The particle size analysis and water permeability was tested in accordance to BS 1377: Part 2:1990, clauses 9.2 and 9.5 – “Methods of test for soils for civil engineering purposes. Classification tests”.

**Figure 1.** Soil blank probe grain size [%]

**Figure 2.** Biochar grain size [%]
3. Results and discussions
Calculations of water permeability of soil samples were based on grain size analysis (fig. 1, 2). The empiric measurements of water permeability coefficient is presented on fig. 3.

![Figure 3. Biochar and soil mixtures water permeability coefficient](image)

Analyzing the data presented on Fig. 3, it cannot be unequivocally indicated that the observed variability is due to the addition of biochar. The addition of biochar caused a reduction in the amount of water permeability coefficient (SD 6.52·10⁻⁸ m·s⁻¹). The largest coefficient increment was recorded for the dose of biochar in the amount of 80 Mg·ha⁻¹, and the lowest for the dose of 60 Mg·ha⁻¹. The addition of biochar into the soil caused the division of plots into three groups. The first one corresponds to doses of 20, 50 and 60 Mg·ha⁻¹, which caused a decrease in the water permeability coefficient. In the second group doses of biochar were used at levels 1 Mg·ha⁻¹ which didn’t changed water permeability of tested soil. The last group contains biochar doses which reduced water permeability coefficient. Similar reduction (about 23%) was observed for doses 5, 10, 30, 40 and 100 Mg·ha⁻¹. The biochar dose 80 Mg·ha⁻¹ decrease water permeability coefficient on 40%.

When analyzing the data presented on figures 1 and 2, it is not possible to clearly indicate the effect of the addition of biochar on the water retention coefficient of the cultivated soil. This is due to the application of a material with non-homogeneous grain composition, which decide about water retention in soils. The above-mentioned studies also indicate a problem in the selection of biochar dose, because in the case of soils with a high content of silt and clay, further reduction of water permeability will cause problems in the beginning of spring crop.
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 retention is 20, 50 and 60 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. The conducted experiment also indicates that in order to improve water properties, the underflow of the silt or clay fraction should be replenished in the soil, and consequently biochar with an appropriate grain size should be used.

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