Impact of Biochar on Water Retention in Soil

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Abstract. The article presents analysis of retention properties of mineral soil formations enriched with biochar and an attempt was made to characterise the states of hydration. Due to a complex and time-consuming process of direct measurement of hydration and retention soil characteristics (the so-called pF curve). The paper investigates the relation between a biochar dose and the amount of water retained in soil at the set capillary potential (pF).

1. Introduction

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. Presence of water in soil determines all its essential functions. Thus, knowledge of water soil properties is a basic condition for understanding and description of its remaining functions [1]. Physical properties of cultivation soil are variable in the vegetation season because they depend not only on the textural group, mineral composition of soil and content of organic matter but also on agri-technical treatments, species of cultivation plants and meteorological conditions. Unfortunately, results of the research on physical properties are often difficult to compare due to a choice of various dates of the research, application of various research methods and various measurement units [2,3].

On account of a complex and time-consuming process of direct measurement of pF curve, various direct methods started to be used, that use a relation between the basic physical properties of soil and characteristic hydration states. In the research practice, they are known as “pedotransfer” function [4,5]. To parameters that are often taken into consideration we may include a textural group, compaction, mineral composition (colloidal fraction content and type of colloids), parameters of soil structure (aggregate distribution), organic substance content, etc. Basically, we may distinguish two types of models, the first one consisting in correlation of coefficients of a theoretical model that
describes the entire hydro physical characteristic with selected physical and structural parameters of soil and the second one that consists in the correlation of points on hydro physical characteristics for selected values of potential with selected parameters of the soil solid phase [1]. These, however, are estimate methods. Moreover, they require representative primary data for given types of soil.

Many authors pay attention to the fact that soil ability to retain water and its availability for the root system, along with the resourcefulness of nutrients and air content, are the most important elements in the soil-plant-atmosphere system [6,7]. Investigation of soil richness in water in its superficial layers has a special meaning. In the superficial layers of soil, there is the main mass of the root system, also this part constitutes a buffer between the bottom, deeper layers of the soil profile and the lower part of atmosphere. Simultaneously, due to a special impact of meteorological conditions in upper layers of soil profiles, here we observed the highest dynamics of changes in the relations of air and water and temperature. This, on the other hand affects the soil processes which take place in superficial layers [8]. Moreover, in the realised research project, application of varied doses of biochar is predicted in the superficial layer of soil, thus, in the studies that concern pF curves, collection of soil samples from the depth of 0-15 cm with the intact system is recommended, both for determination of soil density and the water retention size with the porous plates method in Richards pressure chambers.

Water retention, or water capacity of soil is an ability to retain specified amounts of water in the strictly determined conditions [9]. But it includes a utility retention, which is defined as a part of water that has accumulated in soil, which may be used by plants [10].

The objective of the article is to determine the relation of water retention 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 Kraków. 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 in the amount of 0, 1, 5, 10, 20, 30, 40, 50, 60, 80 and 100 Mg·ha⁻¹.

Measurements of characteristic hydration states within capillary potentials that do not exceed 100 cm of water head were made with the sand-box method. To obtain a water content of soil formations at capillary potentials pf 2.7-4.2 high and low-pressure chambers were used. Water retention curves have a nature of non-linear relations between capillary potential and water content. To develop intermediate models, it was necessary to express explanatory variables in the form of curvilinear relations.

3. Results and discussions

Characteristic indispensable for determination of water and soil constants is a curve of soil water retention – pF. The shape of the curve is determined by granulation, content of mineral and organic colloids and soil structure [11]. The obtained curves of soil retention pF with additions of varied doses of biochar from the initial experiment were presented in figure 1 and 2.

Soils on experimental fields with participation of biochar within 1-30 t·ha⁻¹ were characterised with varied course of pF curves. Big differences within low potentials from pF 0.0 to pF 1.2 were reported. Potential of soil water -0.1 kPa (pF 0.0) indicates full water capacity namely the maximum amount of water, which soil can contain [12]. pF curves for soils where biochar was applied within 1-30 t·ha⁻¹ differed with values of full water capacity. In natural conditions the water stock corresponding to the maximum water capacity, soils achieve very rarely, it takes place after long-term heavy rains or during spring melting. It is an undesired phenomenon when the state of full saturation of soil with water is
maintained for a longer time since it intensifies reduction processes and leads to reduction of crops [13].

**Figure 1.** Retention curve of soils with addition of biochar within 1-30 tonnes per hectare.

**Figure 2.** Retention curve of soils with addition of biochar within 40-100 tonnes per hectare.
Similarly, when biochar is used in the dose of 40-100 t ha\(^{-1}\), a varied course of pF curves is observed. In this case the biggest differences occurred within potential from pF 0.0 to pF 3 covering thus a field water capacity (pF 2.2). According to Walczak et al. [14,15] in cultivation soils of Poland, a field water capacity is within a wide range of 0.039 to 0.455 m\(^3\) m\(^{-3}\). For analysed soils where 1-100 t ha\(^{-1}\) of biochar was used this range was within 0.224 - 0.280 m\(^3\) m\(^{-3}\). It was noticed that the obtained pF curves had a steep course, which means that soil macropores empty water gradually, indicating an irregular distribution of their sizes. Generally, it is assumed that an irregular distribution of the size of soil macropores is more favourable from the point of view of farming since soils have a bigger ability to retain water. It was reported that pF curves where biochar was used in the lowest doses have a slightly milder course, which means that they contain slightly more soil macropores with a comparable size. Macropores with similar sizes dry at the same capillary potential of soil. It was also concluded that in the point with permanent plant withering, soils with addition of high doses of biochar achieve a lower water content in comparison to soil where no biochar was applied.

4. Conclusions
The highest value of full water capacity 0.49 m\(^3\) m\(^{-3}\) was observed for soil where 30 t ha\(^{-1}\) of biochar was applied. The full water capacity calculated to soil capacity (in m\(^3\) m\(^{-3}\)), theoretically is equal to general porosity and is often assumed as such in many papers [2]. One should remember that the range of potentials corresponding to pF 2.2 - pF 3 concerns the amount of water grouped in soil pores which is easily available for plants and within the range of pF 3 - pF 4.2 difficult to access by plants, while the value of pF 7 (corresponding to capillary potential -10 000 000 hPa or -10 000 bar) means water content 0. It was reported that the curve for control soil where no addition of biochar was used indicates a slightly lower water content at a field water capacity 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.

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