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Effects of a hydrogel on the cambic chernozem soil's hydrophysic indicators and plant morphophysiological parameters

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ABSTRACT

Aquasorb is claimed to ensure the controlled release of water under drought condition, which could significantly reduce the hydric stress of agricultural crops. The aim of the study was to evaluate the interaction between cambic chernozem soil and a hydrophilic polymer (Aquasorb) derived from polyacrylamide and potassium acrylate. The laboratory experiment investigated the interactions between soil and hydrogel by macro- and microscopical investigation. The main surface characteristics of Aquasorb were determined by scanning electron microscopy. In the field experiment, the soil hydro-physical indicators (moisture, soil water reserve, soil total porosity and bulk density) and some plant morphological parameters (height, grains per cob, pods per plant, chlorophyll content) were studied, for maize and soybean crops. The experimental data were analysed using the ANOVA test, and a strong correlation between soil moisture and agricultural yields was established ($r = 0.9796$ for maize and $r = 0.9720$ for soybean crop). The hydrogel administration improved the cambic chernozem hydro-physical indicators and plant morphological parameters. These results sustain the existence of a direct relationship between the applied doses, the values of the studied parameters and the agricultural yields. Our study suggested that Aquasorb is able to ensure a normal growth for plants during dryness periods, fact that can often be decisive for saving crops.

1. Introduction

The global warming increases the frequency and intensity of severe phenomena, especially droughts, extreme temperatures, and floods. In Romania, the agricultural yield is diminished periodically, with at least 30–50% depending on the extent of extreme climate events. Thus, 64% of agricultural soil area is influenced to a more noteworthy or less degree by consecutive long periods of droughts, which reduces the efficiency of the agricultural sector (Hurduzeu et al., 2014; Mateescu and Alexandru, 2010).

The most vulnerable species are annual crops of wheat, maize, soybean, where the water deficiency in the summer season (which coincides with the water maximum requirements) caused significant decreases of production.

In our region, the alternating of dry periods with heavy rain periods may cause agro-technical issues related to water balance in the soil, so that adapting the agricultural technologies to a better water resource conservation in soil is of high importance (Bates et al., 2008). One of the solutions which may assure optimal capitalization and recovery of water from any source in the soil, is represented by the usage of superabsorbent hydrogels. In Romania, research regarding the hydrogel administration in agricultural soils is insufficient to implement this technology in crop production, this fact being the driving motive for conducting this study.

On international level, the studies showed that hydrogels provide a range of environmental benefits on soil erosion control by reducing sediment and nutrient losses (Assaf et al., 2015; Kang et al., 2015, Santos et al., 2003; Sepaskhah and Shahabizad, 2010; Sojka et al., 2007). Also, the hydrogels can absorb water and nutrients in order to gradually release them afterwards (Hany, 2007; An et al., 2005; Farrell et al., 2013; Sepaskhah and Bazrafshan-Jahromi, 2006). Hydrogel promotes soil colonization with bacteria and mycorrhiza (Sojka et al., 2006). The influence of hydrogels depends on the soil structure, concentration of salts and fertilizers (Yang-Ren et al., 2007), and on the specific plant cultivated.

Aquasorb is a polymer derived from polyacrylamide and potassium acrylate, able to work in water/nutrients absorption–desorption cycles, depending on the plant requirements. In arid or semiarid areas, Aquasorb proved to be efficient in increasing the soil water retention capacity, and decreasing the infiltration rate and cumulative evaporation (Hayat and Ali, 2004). The plants cultivated on soils treated with

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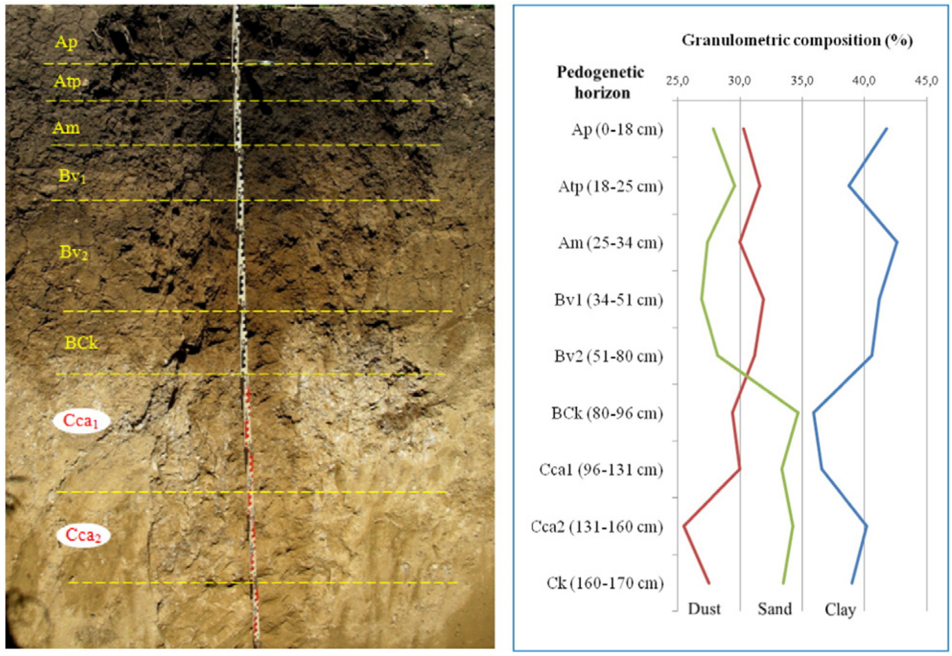

Fig. 1. Morphology profile and granulometric composition of chambic chernozem soil. Ap — ploughing layer; Atp — under arable layer; Am — A mollic horizon; Bv — B cambic horizon, BCk — intermediate BC horizon, with residual carbonate; Cca — C carbonate accumulative horizon; Ck — C horizon, with residual carbonate.

Aquasorb had more available water for longer periods of time, which led to lower irrigation frequency (Agaba et al., 2011). Generally, its efficiency is decreasing in time, as proved by the significant reduction of water retention capacity after 18 months from its administration on soil (Holliman et al., 2005). However, in normal climatic conditions, the acrylamide which resulted from polyacrylamide degradation does not exceed the legal concentrations (WHO, 2003).

Currently, many of the scientific researches reported controversial data regarding the efficacy of hydrogel administration on other (non-sandy) types of soils (Nevenka et al., 2012). Hence, the understanding and the evaluation of a hydrogel's effectiveness must involve its characterisation in relation to the specific soil type (Kim et al., 2010).

The aim of this study was to evaluate the interaction's results between Aquasorb and cambic chernozem soil (which is predominant in the NE part of Romania), accomplished through both laboratory and field experiments. Based on the conclusions of a laboratory dehydration experiment, a field assessment of the soil amended with hydrogel (Aquasorb) was made in order to highlight its efficacy for the cambic chernozem soil.

Table 1
Chemical properties of cambic chernozem from Ezăreni Farm (0–170 cm soil profile).

Nb. crt	Pedogenetic horizon	pH	$CaCO_3$ %	C_{org} %	N_t %	C/N	P mg kg^{-1}	K mg kg^{-1}
1	Ap (0–18 cm)	6.68	0.0	1.30	0.18	6.26	26.00	242
2	Atp (18–25 cm)	6.78	0.0	1.39	0.15	8.00	10.43	178
3	Am (25–34 cm)	7.01	0.0	0.55	0.10	4.53	3.58	178
4	Bv_1 (34–51 cm)	7.12	0.0	0.61	0.17	3.17	2.70	158
5	Bv_2 (51–80 cm)	7.32	0.0	0.26	0.11	2.03	7.89	158
6	BCk (80–96 cm)	7.95	8.9	0.16	0.11	1.26	10.30	136
7	Cca_1 (96–131 cm)	8.11	14.1	0.09	0.08	1.02	5.86	114
8	Cca_2 (131–160 cm)	8.16	13.4	0.18	0.07	2.27	5.07	114
9	Ck (160–170 cm)	8.19	16.5	0.07	0.04	1.40	6.36	114

Ap — ploughing layer; Atp — under arable layer; Am — A mollic horizon; Bv — B cambic horizon, BCk — intermediate BC horizon, with residual carbonate; Cca — C carbonate accumulative horizon; Ck — C horizon, with residual carbonate.

2. Material and methods

2.1. Laboratory experiment

2.1.1. Macro- and micro-images

In the laboratory experiment, the interactions between soil and hydrogel at macro- and micro-level were evidenced by analysing the following samples: Aquasorb, soil and Aquasorb + soil mixtures. Aquasorb 3005A was supplied by SNF Floerger. The soil samples of cambic chernozem with loamy-clay texture type, having different granulations (obtained by sieving the soil through meshes with the Ø diameter equal to 1 or 2 mm) were used. Soil samples were collected at 0–25 cm depth, from Ezăreni experimental field (with chemical properties and granulometric composition presented in Section 2.2). Also, mixtures of Aquasorb (4%) and soil with different granulations (Ø = 1 mm, Ø = 2 mm) were investigated. The samples were investigated in native state as well as after one/three wetting–drying cycles. The wetting was performed by administering deionised water, in ratio of 1:1 (water:sample) while the drying was carried out in a thermostatic chamber at 35 °C. The wetting–drying conditions were established in order to accurately simulate the field conditions on hot periods of time.

Macroscopic images (×60) were obtained using a Sony camera. The microscopic analysis envisaged the description of the surface characteristics for the investigated samples, by using a Hitachi SU1510 scanning electron microscope (SEM). The samples were covered with a thin gold film (~10 nm) by using a Cressington 108 Auto Sputter Coater. The samples were fixed on the microscope supported with a carbon tape. For each sample, the accelerating voltage, pressure, and spot size were adjusted to obtain the best resolution.

2.1.2. Dehydration experiment

A dehydration experiment for different samples of soil and mixture of Aquasorb + soil was conducted. Firstly, the full hydration was performed by adding a known amount of deionised water onto the sample, corresponding to a 1:1 water to sample ratio. Then, the dehydration experiments were carried out, in order to monitor and measure the wet