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WATER MANAGEMENT WITHIN THE SOIL-PLANT SYSTEM – A CHALLENGE FOR THE 21ST CENTURY

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Water is the most essential substance regarding the physiological processes of any living system. Agricultural activities and global food security are highly influenced by water availability. The value of water and water resources already exceeds that of energy sources today. The water-related concepts are very diverse in agricultural relations. The aim of this paper was to revive some terms related to water and discuss their importance in soil-plant systems. In this paper, eight phrases were selected paying attention to the importance of water management, namely soil water management, soil moisture range for workability, rain stress, water logging, water shortage, irrigation, water intake and water loss, avoiding water loss and reply to climate change phenomena. Findings of water management research point to a relationship between soil quality and improvement of water intake capacity, parallel with climate stress mitigation.

Keywords: soil moisture, rain stress, water shortage, irrigation, climate prognoses

The Pannonian Basin covers the whole or parts of the territory of as many as nine countries. The basin is dominated by the combined effects of Atlantic, Mediterranean and continental climates and fairly exposed to climate extremes (Szalai, Lakatos, 2013). Soil as the largest potential natural water reservoir in the basin has increasing importance under conditions of predicted climate change resulting in an increase of probability of extreme hydrological events (Farkas, Birkás, Várallyay, 2009). The distribution of the amount of precipitation, the number of precipitation events, and longer dry periods show upward tendencies and may have serious effects on the available water amount and the surface water balance (Jolánkai, Nyárai, Kassai, 2013; Jug et al., 2017). A great part of the atmospheric precipitation can be stored in the 0–100 cm layer of the soil; however, this water storage may be reduced by hydrological stresses (Várallyay, 2010). Findings of the water management research point to a relationship between soil quality and improvement of water intake capacity, parallel with climate stress mitigation (Birkás et al., 2018, 2019).

This study highlights various manifestations of the water forms and the discussion of certain consequences of the lack and surplus of water in soils that can be measured and a description of the possible remedies that should be applied to soils so damaged.

Material and method

This paper is based on works and scientific communications reviewing the subjects of water management and on stating in long term experiments underway in the countries as well as on the conclusions drawn from them (Birkás et al., 2015, 2017a,b; Bogunović, Kisić (2017). The water management problem referred to in this paper was also studied in the long term Soil quality – climate experiment that has been underway since 2002 at Hatvan-Józsefmajor (47° 41' 31.7" N 19° 36' 36.1" E, 110 m a.s.l), in the year 2002 with a soil of a clay-loam texture, Endocalcic Chernozems, Loamic (IUSS Working Group WRB, 2015). The experiment was of the single-factor type, in random stripe arrangement in four replications, in which six treatments were applied, that are direct drilling (DD), shallow disking (12–15 cm), shallow and medium deep cultivator (18–20 cm and 22–25 cm) ploughing followed by surface forming (30–34 cm, P) and loosening (40–45 cm). This long-term experiment has given useful information to understand the change in water content in soils that are in different physical conditions (Farkas, Birkás, Várallyay, 2009). On the one hand, the long-term experiments provided important data on the fact that water conservation is actually a reduction of water loss and, on the other hand, confirmed that, despite the difficulties of the climate, there are tillage methods suitable for alleviation of the natural induced damages.

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Results and discussion

Water has a profound impact on our lives and on all agricultural management activities. Nowadays, water in agriculture will continue to play a critical role in global food security. The value of water and water sources already exceeds the value of energy sources today. The water-related concepts are very diverse in agricultural relation. In this paper, eight phrases were selected, relevant to the importance of the soil water management.

Soil water management

There are some new terms often cited by authors in relation to water, such as e.g. the green, the blue and the brown water. The first term can apply to our case, because the water that is stored in unsaturated soil layer forms the green water resource (Velpun, Senay, 2017). Soil water management comprises the amount of water in the soil, its state, form and movement and changes in these factors in time and in space, affected by soil water intake, its water permeability, its capacity to retain and store water and the conditions of its desiccation. Dexter, Bird (2001) noted that loose soil takes water in quickly (infiltration, percolation), later, the process slows down and its rate becomes constant. The amount of water retained by soil against gravitation is referred to as water capacity.

Water availability for plants depends on soil moisture tension that ranges from field capacity to wilting regime and may vary by the soil physical type as it can be seen in Figure 1. Plant species abilities in water uptake range between 1 to 12 at osmotic pressure in general.

Soil moisture range of workability

Soil workability is defined as the ease of working with well-drained soil to produce desirable conditions for sowing that is not consisting of structures that are either too fine or too coarse for crop establishment. Soil is workable within a range of water content and soil tillage operations produce the desirable state for crop production. The various types of soils have their own specific workable moisture range, just like the way they differ from each other in terms of

their specific particle compositions and clay ratios. A soil workable moisture range is determined by the quantity and quality of its clay fraction, organic matter content, structure and compactness. The tillage of any type of soil takes less energy in the moisture range that is favourable from the aspect of workability and tool effectiveness (Birkás et al., 2018). Moreover, soil organic matter plays a crucial role in soil health and represents one of the key functions for determining soil suitability for crop production.

Rain stress

Due to the amount or intensity of rainfall, rain stress can cause damage to the upper layer of soil, either temporary or long-term. Climate change-induced precipitation phenomena tend to have adverse impacts on soils. Intensive spring showers following the dry early spring period wash chemicals distributed on the soil surface into the cracks in the soil, making double damage, as the applied chemicals failed to have exerted their action during the dry period and then when the rains come and soak the soil through they are washed away (Birkás et al., 2017b). On sloping fields, severe damages are caused by heavy downpours washing soil off (Kisić, Bogunović, Bilandžija, 2017).

Water logging

The Carpathian basin, considering the geological formation, geographic location and climate threats, is continuously exposed to water-related phenomena that are water surplus and deficit. Damages and hazards associated with water surplus appearing in the soils or on the surface are expressed with various phrases e.g. excess water inundation, inland excess water, flooding, water-logging, water pond, water saturation and over-moistening. Water-logging may be regarded as naturally induced when the water table of the groundwater is too high and the excess water may appear on the surface and stagnate there for longer time (Pálfai, 2010). A long period of water-logging deteriorates soil workability and fertility and it also reduces the site's economic value. Moreover, the stagnant water saturates the soil, silts the fertile layer, destroys the crops and increases nitrogen leaching which seeping into the groundwater and then finally moving into live bodies of water.

Water shortage

Water output is affected by the type of the land use, soil tillage (water wasting or conserving) and water utilization of plants. A drought-induced loss cannot be avoided in soils where water wasting tillage has been applied for multiple years (Birkás et al., 2018). Soils dry out through evaporation and transpiration. Moisture is lost from the topmost soil layers in the form of water vapour to the near-surface atmosphere, and this process continues until the relative humidity matching. The near surface air layer is permanently replaced by the movement of the air and therefore it takes continuous evaporation to re-establish the equilibrium. Avoiding the water loss from arable soils requires new moisture conservation solutions including optimised soil disturbance and surface protection (Jug et al., 2017).

Figure 1 Water retention curves for three different texture classes

Irrigation

Irrigation is aimed at supplementing the crop's natural water supply under the prevailing weather conditions that prevent water shortage for yield safety, increasing or maintaining the yield quality and biomass and improving crop conditions.

Besides its benefits, irrigation has some negative impacts on soil e.g. regular soaking of soil makes a stress factor, frequent soaking may result in inadequate aeration in soil, water transports colloids, dust and silt into deeper layers which, settling down in a compact layer, aggravate its compaction (Table 1).

There are solutions to prevent soil deterioration in the irrigated soils. The most important factors are as follows: water intake capacity and the water saturation capacity; optimal water infiltration; depth of water table level of soil; regular soil condition tests; preventing anaerobic conditions; organic matter and water conserving; mitigating drought and heat stress; irrigation out of the growing season e.g. covering the surface, growing green manure crops; irrigation in a rotation – in which cropping is practised without irrigation – enables the soil to recover (Liu et al., 2016).

Water intake and water loss

Soil natural water transport characteristics can be altered by means of hydro-melioration procedures (Farkas, Birkás, Várallyay, 2009). Tillage affects the ratio of water intake and water loss that is of the soil moisture transport. The importance of the soil state lies in its impacts on the ratio of the water taken and stored in the soil, relative to utilised and wasted water (Várallyay, 2010). Intake is the part of precipitation that ends up in soil, most often some 65–70%, rarely exceeding 80%. Water infiltration and storage depend

on the depth of the loosened layer and on the water permeability of the soil underneath the disturbed layer. The extent of water loss is affected outside the growing season by the shape of the tilled surface, surface cover and the depth of disturbance (Birkás et al., 2018). The role of the soil condition and that of tillage is illustrated in Table 2.

Soil moisture loss is alleviated by Birkás et al. (2018): loosening any compact layer that impedes water intake; covering the soil with chopped/crushed stubble residues and by reducing the soil surface area by creating water conservation surface; applying organic matter conservation tillage; avoiding the clod formation during dry periods, thus, loosening + crumbling + pressing is recommended; producing crops of different growing seasons with different times of sowing as well as harvesting; adapting crop density to season controlling weed infestation in the field. Soil moisture should be managed reasonably.

Avoiding the water loss in relation with climate change

According to long-term prognoses milder winters with more precipitation, warm and dry summers, extreme fluctuations in the annual distribution of the total precipitation and increased numbers of windy and stormy days should be expected in the Pannonian region from the second decade of the 21st century (Bartholy et al., 2004). After heavy rains water stagnates in the soil surface, suffocating the plants. If there is no impervious layer in soil, water does not stagnate on the soil surface for a long period even after a very heavy rain. Water is lost through the large surface of dry, cloddy soil and it even takes in water less efficiently. The large clumps should be broken down first with heavy slicer rolls, pressing them at the same time into the disturbed soil to create conditions under which they soak through more

Table 1 Important factors affecting the results of irrigation

Unfavourable	Favourable
<ul style="list-style-type: none"> – higher than soil intake capacity – partly utilization for crops or harmful – water surplus or absence 	Amount: <ul style="list-style-type: none"> – crop refreshing – soil saturation in 8–10 hours
<ul style="list-style-type: none"> – >10 mm.h⁻¹, when water waste is unavoidable 	Intensity: <ul style="list-style-type: none"> – 4–10 mm.h⁻¹
<ul style="list-style-type: none"> – crumb degrading, causing harmful leaching (N, dust) 	Form: <ul style="list-style-type: none"> – soil structure conservation method
<ul style="list-style-type: none"> – quick soaking with crumb deterioration – harmful transformation in soil surface: crumb desintegration, siltation 	Impact on soil: <ul style="list-style-type: none"> – slow soaking – no surface siltation or minimal – crumbling may slightly decrease

Table 2 The role of the soil condition and that of tillage in controlling the loss of water

Factor	Basic requirement	Avoiding
– water intake	– loosened structure	– compact structure
– reducing the loss of water	– covered and minimised surface area	– overconsolidation of soil
– increasing the loss of water	– moderate soil disturbance	– large and bare surface area
– tillage	– any depth, as long as the surface area is minimised	– deep disturbance leaving large exposed surface area on hot and/or windy days

effectively (Birkás et al., 2017b). In disturbed soils, levelling and/or consolidating (with rolls) should be carried out in the summer and in the spring, while in the autumn, levelling should be applied before wintering. The levelled soil will take rainwater and water from melting snow and at the same time, it will lose less water on mild and windy days. Any compact layer impeding the intake of water and the flow of the moisture into the root zone must be eliminated and the soil harmonious water transport processes must be restored. Extreme climate conditions require maintenance of the continuity of water storage capability in the soil along with increasing water infiltration and minimising water loss.

Conclusion

The main postulate from our investigation is that under identical ecological conditions, the uniform and over-standardized adaptation of tillage methods for soil moisture conservation poses a risk. Such applications need special care, and the future belongs likely to site-specific precision technologies. It can be concluded that quantification of the soil water balance components (including plant water uptake and transpiration) and water use efficiency calculations would be beneficial concerning the studied soil management systems with respect to moisture conservation.

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