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THE EFFECT OF VARIOUS SOIL SURFACE MODIFICATIONS ON EVAPOTRANSPIRATION INTENSITY

WPŁYW RÓŻNYCH MODYFIKACJI POWIERZCHNI GLEBY NA INTENSYWNOŚĆ EWAPOTRANSPIRACJI

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Abstract. In recent decades much attention has been devoted to topics dealing with temporal and spatial distribution of water capacity in the soil profile and evapotranspiration. The aim of this paper was to examine and describe the effect of soil surface modifications on evaporation intensity and then recommend options with the best ability to minimize evaporation for agricultural practice.

During the year 2011 the effects of the soil surface modifications on the soil water storage, the amount of evaporated water and the evaporation intensity have been observed in the experimental area – Botanical Garden of Slovak Agricultural University. The experiment used different soil surface modifications – change the surface shape (convex and concave shape), change the hydrophysical properties (detergent application), agrotechnical controls (aerating, rolling, mulching). The soil moistures to a depth of 1 m soil profile were measured using the ADR method. Then the soil water storages to a depth of 0.6 m were determined with using planimeter. Using the simplified water balance equation the amounts of evaporated water and the evaporation intensity were calculated for each experimental variant. Based on the calculated amounts of evaporated water from individual variants can be noted that evaporation was minimized the most effective by applying detergent on the soil surface with convex shape. During the monitoring period this variant was showing the lowest evaporation intensity and the total amount of evaporated water from soil (664.7 mm), about 3.25 % lower value than variant – soil without modification. This result is considered by authors for the most valuable, because it „opens door“ to the new ways how to minimize evaporation using substances which lower the surface tension.

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Streszczenie. W ciągu ostatnich dziesięcioleci wiele uwagi poświęcono tematom czasowego i przestrzennego rozkładu pojemności wody w profilu glebowym i ewapotranspiracji. Celem niniejszej pracy było zbadanie i opisanie wpływu modyfikacji powierzchni gleby na intensywność parowania, a następnie zarekomendowanie opcji z najlepszymi możliwościami do zminimalizowania parowania w praktyce rolniczej.
W 2011 roku, w strefie eksperymentalnej w Ogrodzie Botanicznym Słowackiego Uniwersytetu Rolniczego obserwowano wpływ modyfikacji powierzchni gleby na magazynowanie wody w glebie, ilość odparowanej wody i intensywność parowania. W eksperymencie stosowano różne modyfikacje powierzchni gleby: zmianę kształtu powierzchni (wypukły i wklęsły), zmiany właściwości hydrofizycznych (zastosowanie detergentów), zabiegi agrotechniczne (napowietrzanie, walcowanie, rozdrabnianie). Wilgotność gleby na głębokości profilu 1 m mierzono za pomocą metody ADR. Następnie magazynowana woda w glebie na głębokości 0,6 m została oznaczona z wykorzystaniem areometru. Przy wykorzystaniu uproszczonego równania bilansu wodnego ilość odparowanej wody i intensywność parowania zostały obliczone dla każdego wariantu eksperymentalnego. Na podstawie obliczonej ilości odparowanej wody w poszczególnych wariantach można stwierdzić, że ewaporacja była minimalizowana najbardziej efektywnie przy zastosowaniu detergentu na powierzchni gleby o wypukłym kształcie. W okresie monitorowania wariant ten wykazywał najniższą intensywność parowania i całkowitą ilość odparowanej wody z gleby (664,7 mm) – o 3,25% mniej niż w wariancie gleba bez modyfikacji. Wynik ten jest uważany przez autorów za najbardziej wartościowy, bo otwiera drzwi do nowych sposobów minimalizacji parowanie za pomocą substancji, które obniżają napięcie powierzchniowe.

Key words: evapotranspiration, evaporation intensity, soil cultivation, soil water regime

Słowa kluczowe: ewapotranspiracja, intensywność parowania, uprawa gleby, reżim wodny gleby

INTRODUCTION

Water is one of the basic life conditions on Earth. As it is indispensable in all areas of everyday human activities, is also an essential part of agricultural production [Kalúz and Pokrývková 2010].

It is estimated that from our planet is annually evaporated 380 000 km^3 of water. 304 000 km^3 of this amount evaporates from the seas and oceans, which corresponds to the average annual evaporation 842 mm. 76 000 km^3 of water evaporates from the land, i.e. the equivalent of 503 mm per year. It is expected for the conditions of Central Europe that 60% of water from the precipitation is evaporated – 45% of the plants transpiration, 14% of evaporation from bare soil and 1% of evaporation from water flows and reservoirs [Tlapák et al. 1992].

Water losses by evaporation are very important. The reduction of these losses is closely linked to the preservation of soil moisture for crop production [Fuska and Bárek 2010]. According to FAO [1994] many countries must take an important role – to increase food production to ensure food for the population and additionally to optimize the water resources use.

Crop production assess evaporation from the economic and biological terms as productive (transpiration) and unproductive (evaporation from the soil), it does not participate in the production of vegetable matter. Each plant in the creation of organic matter loses a certain amount of water consumed by the basic physiological process – respiration. Other soil water losses are evaluated usually negative in agro-meteorological terms, because they are unproductive losses of soil moisture. A major challenge for farmers is to reduce unproductive evaporation from the soil and to increase crop production with the smallest losses of soil moisture. Reducing water losses by influencing the soil evaporation requires action from which the most effective and easy are modifications of soil surface layers by agro-technical interventions that improvesoil water management and positively affect many other processes and soil characteristics [Štér 1961].

GOAL

The goal of this paper was to identify and describe how different methods of soil cultivation and various additives, added on the soil surface, affect the evaporation intensity from the soil.

The following soil surface modifications were carried outonthe experimental area:

- soil aeration,
- soil compaction,
- convex and concave shape of soil surface,
- detergent application on the soil surface,
- mulching the soil with the plants residues on the soil surface.

MATERIAL AND METHODS

Experimental area

Field measurements were carried out in the experimental area – Botanical Garden of the Slovak Agricultural University. The site is located at an altitude of 144 m and situated between mountains Zobor, Kalvária and Šibeničný Hill. The area is one of the hottest and driest locations in Slovakia. The average annual air temperature measured over the period 1991–2000 is 10.2°C, average annual rainfall is 539.0 mm. During the summer vegetation period is here periodically a lack of rainfall and high daily temperatures [Charakteristika územia 2009].

There are alluvial soils with a high content of clay fraction, which was formed by the river Nitra. The soil type is brown soil with a soil reaction from 7.4 to 7.7 (slightly alkaline soil) [Atlas... 2002].

The organization of field experiment

In assessing the impact of different soil surface modifications and the supplied additives on the soil moisture regime was used ADR method of soil moisture measuring with profile probes (Fig. 1). Soil moisture measuring with using Profile Probe required installation of 1 m long plastic tubes. 7 tubes were installed, around each probe was set a circular area with a diameter of 1 m, where were made the various soil surface modifications (Fig. 2).

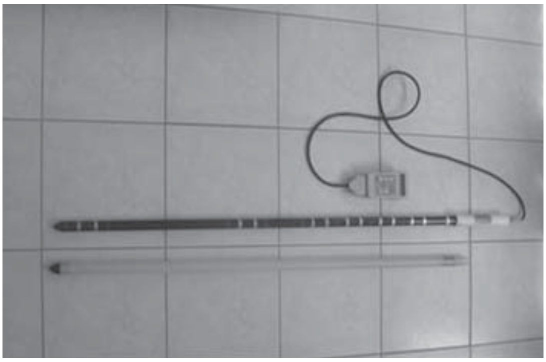

Fig. 1. ADR sensor with profile probe
Rys. 1. Czujnik ADR z sondą profilu

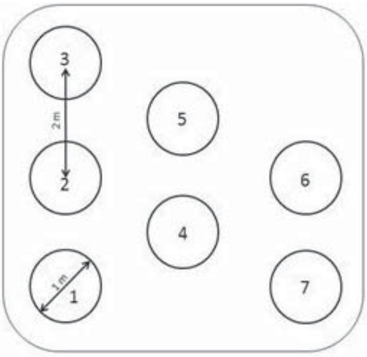

Fig. 2. The experimental area
Rys. 2. Obszar eksperymentu

Variant 1 – soil without any treatment: for purposes of comparison.

Variant 2 – convex surface: soil surface was modified to the convex shape (Fig. 3).

Variant 3 – convex surface with applied detergent: detergent (with non-ionic group) was applied on the soil surface several times during the experiment.

Variant 4 – concave surface: soil surface was modified to the concave shape (Fig. 4).

Variant 5 – aerating: soil surface was aerated to a depth of 30 cm to simulate tillage.

Variant 6 – mulching: soil surface was covered with plant residues.

Variant 7 – compacting: soil surface was compacted to simulate the agrotechnical action – rolling.

Fig. 3. Convex shape
Rys. 3. Kształt wypukły

Fig. 4. Concave shape
Rys. 4. Kształt wklęsły

Barley (*Hordeum vulgare* L.) was sown in the experimental area after the measures implementation. During the experiment were carried out no further soil surface modifications around the probes, except variant 3 – convex surface with applied detergent, where the detergent had been applied in approximately monthly intervals.

THE PROCEDURE FOR OBTAINING THE MEASUREMENT RESULTS

Soil moisture was measured for each probe at five different depths: 10 cm, 20 cm, 30 cm, 40 cm and 60 cm, with two repetitions. Subsequently, the average soil moisture for each depth was calculated. Soil water storage was calculated from the soil moisture values using equation [Antal and Igaz 2008]:

$$W_z = \int_0^z \Theta(z) \cdot d_z$$

where:

W_z – soil water storage, m,

$\Theta(z)$ – course of changes in soil moisture with depth,

z – depth, m.

$\Theta(z)$ is usually not possible to express in analytical form, the equation is solved by integration of soil moisture profile. The evaporation values were calculated from the simplified water balance equation [Antal 2003]:

$$H_z + H_p - H_o - H_e = H_R$$

where:

H_z – precipitation, mm,

H_p – subsurface and surface inflow to the experimental area in the time interval, mm,

H_o – subsurface and surface runoff from the experimental area in the time interval, mm,

H_e – evaporation from the experimental area in the time interval, mm,

H_R – change of soil water content in the experimental area in the time interval, mm.

In the case that no surface or subsurface water inflow exist at the experimental area, the value of $H_p = 0$.

The water table ranges in the experimental area from approximately 1.6 to 2 m and there is not any drainage, the value of runoff in the water balance equation is neglected.

The evaporation values for individual variants were then compared each other, taking into account meteorological factors that affect evaporation: the global radiation, precipitation, air temperature, soil temperature, wind speed and relative humidity. Meteorological data are obtained from automatic agro-meteorological station in Botanical Garden of Slovak Agricultural University. The data were processed by mathematical and statistical program MS Excel.

RESULTS AND DISCUSSION

Moisture condition monitoring of the soil profile in the experimental area – Botanical Garden of Slovak Agricultural University, took place during the months of March to November 2011. Based on the calculated quantities of evaporated water from the individual variants, cumulative evaporation curves were constructed for the spring (Fig. 5), summer (Fig. 6) and autumn period (Fig. 7).

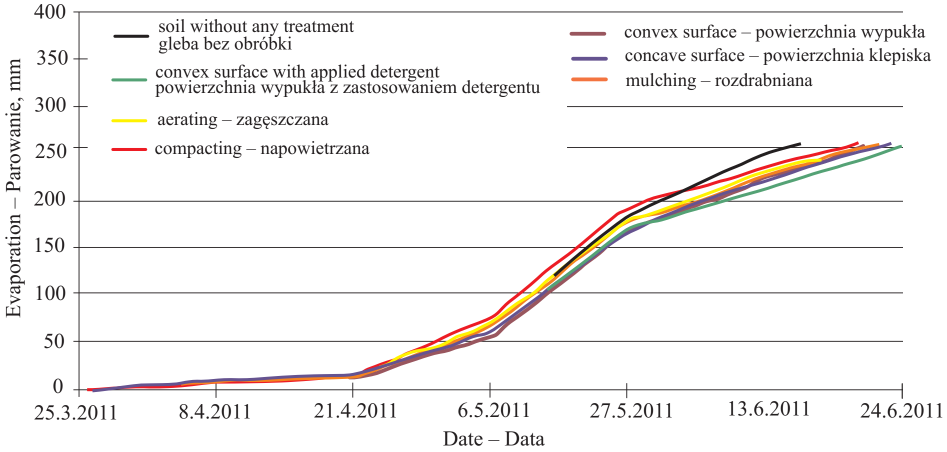

Fig. 5. Cumulative evaporation curves for the spring period
Rys. 5. Sumaryczne krzywe parowania w okresie wiosennym

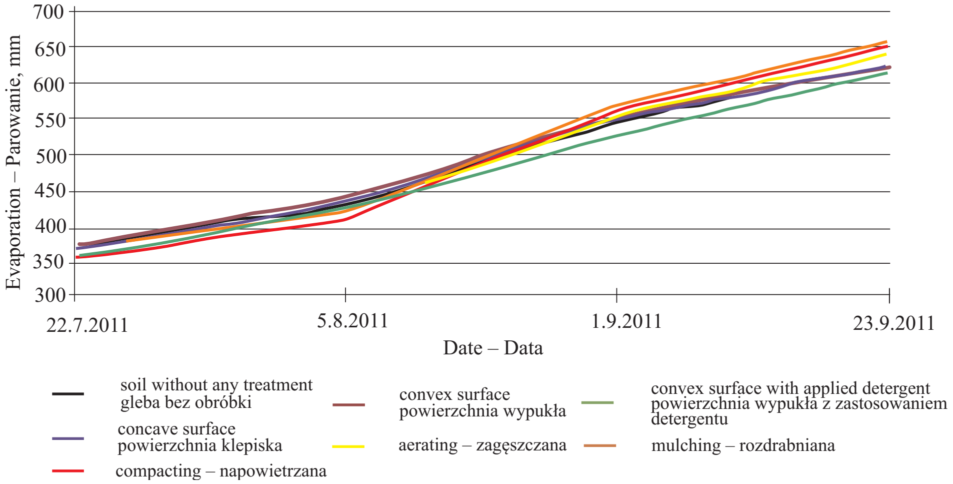

Fig. 6. Cumulative evaporation curves for the summer period
Rys. 6. Sumaryczne krzywe parowania w okresie letnim

In the spring period the most water was evaporated from the soil without any treatment (292.4 mm), all other variants achieved a lower amount of evaporated water at the end of the period. The lowest total evaporation was achieved with a variant of convex surface with applied detergent (257.9 mm).

Variant with applied detergent showed the smallest amount of evaporated water (613.2 mm) at the end of the summer period. On the contrary, the variant soil with plant residues showed the highest value of evaporated water (657.6 mm).

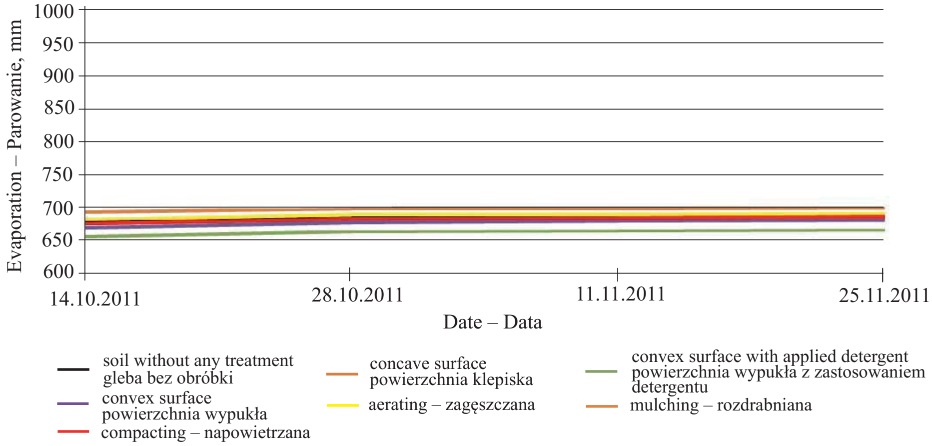

Fig.7. Cumulative evaporation curves for the autumn period
Rys. 7. Sumaryczne krzywe parowania w okresie jesiennym

After the field experiment we can say that based on the cumulative evaporation curves the most water was evaporated from a variant the soil with plant residues (698.6 mm). Mulching reduces evaporation from the soil in the initial phase of the evaporation process, but then the speed of evaporation begins to rise. The cause of the high evaporation intensities may be the lack of crop residues on the soil surface, and also the fact that the certain amount of water from the crop residues is consumed by microorganisms in decomposition of these residues and therefore is not involved directly in the evaporation process. The smallest amount of the evaporated water showed a variant of convex surface with applied detergent (664.7 mm), i.e. about 3.25% less than a variant soil without any treatment.

CONCLUSIONS

Effect of the water loss in small water cycle and forecasts of the hydrological cycle inscrutable behavior are employing scientists around the world. Slovakia also illustrates the typical current hydrological problems. Characteristics of potential and actual evapotranspiration, soil moisture, radiation and global radiation balance show that especially south of Slovakia is gradually dried, potential evapotranspiration increases and soil moisture decreases. The problem of minimizing the water evaporation from the soil surface is therefore highly relevant.

Based on the data of soil moisture measured by ADR method on the experimental basis in the Botanical Garden of Slovak Agricultural University and by comparing the calculated values it is concluded:

- At the beginning of the growing season, when the global radiation, the air and soil temperatures reached lower values, the evaporation from individual variants was low (average 0.5 mm per day). The highest evaporation intensities in the spring period were recorded during the month of May, when the high values of the global radia-

tion, rising soil and air temperatures, sufficient precipitation (also from the previous period) were measured. The average intensity of evaporation from individual variants ranged from 5.1 to 5.6 mm per day.
- Aerating soil showed the minimized evaporation in most of the measurement dates during the spring period, compared with a variant soil without any treatment on average 10% lower values of evaporated water amount. The values of evaporated water from a variant the compacted soil usually exceeded evaporation from the soil without any treatment (on average 25% higher).
- The highest values of the evaporation intensities of all observed variants were recorded during period of 22.07–05.08.2011. The evaporation intensities ranged from 6 to 7.7 mm per day. This period had sufficient rainfall and higher air and soil temperatures. Even immediately after the crop growing season (01.08.2011) the evaporation intensities of the variants were relatively high (ranging from 4.3 to 5.7 mm per day). The exception was the variant with a convex surface shape and applied detergent, which showed in that period the value of the evaporation intensity less than 4 mm per day.
- At the beginning of the autumn period the variants showed the evaporation intensity values ranged from 1.6 to 2.4 mm per day.
- Based on the cumulative evaporation curves of all variants we can say that evaporation was effectively reduced by applying detergent to the soil surface with a convex shape. Throughout the experiment this variant showed the lowest evaporation intensity values and also the total amount of evaporated water from the soil surface.

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