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INFLUENCE OF AGGREGATE SIZE OF EUTRIC CAMBISOL AND GLEYIC PHAEOZEM ON EVAPORATION

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A b s t r a c t. This work presents results of research on the influence of aggregate size of Eutric Cambisol and Gleyic Phaeozem on water evaporation from their surface for different external conditions. The results showed that evaporation from the surface of aggregated soils depends on the size of aggregates, i.e., in all the cases the rate of evaporation decreased with the increase of aggregate size. The decrease of evaporation was bigger for the aggregates of Gleyic Phaeozem than Eutric Cambisol, especially for high evaporativity.

K e y w o r d s: evaporation, soil aggregates

INTRODUCTION

Soil determines circulation of water in the biosphere, because it not only transforms rainfall into surface and subsurface water, but also determines the values of water balance components through water capacity and transmission properties. Soil transmission properties of soil depend on the parameters of its structure. Physical properties of the soil arable layer, which change in the processes of its treatment, include, first of all, bulk density and aggregate size distribution [1,15,16,19-21,23].

Evaporation of water from soil is the most important process in the water balance, because it may cause very significant losses of water from the soil profile. Water losses from the soil profile may reach, under some conditions up to 90% of precipitation. Results of numerous investigations show that some soil structures improve possibilties of water utilization by plants. Utilization of water supplied to the soil profile can increase from 15 to 85% [2-4,12,14].

The aim of this research was to determine the effect of aggregate size of two different soils on evaporation from the soil surface at low and high evaporativity.

MATERIAL AND METHODS

The object of the present investigations were Eutric Cambisol and Gleyic Phaeozem, samples taken from the arable layer. In the natural state, Eutric Cambisol was derived from clay silt (loess) in which content of organic matter was 3%, pH in KCl - 7.4 and specific surface area (H_2O) vapour) - 39 m^2g^{-1}, while Gleyic Phaeozem was derived from loam silt in which content of organic matter was 26%, pH in KCl - 4.2 and specific surface area (H_2O vapour) - 140 m^2g^{-1}. After drying up to the air-dry state, the aggregation of the soils was determined by the standard sieve method. Basic properties of the investigated soil aggregates are presented in Table 1. Then, soil columns were filled with aggregates of the separated fractions, i.e., smaller than 0.25, 0.25-0.5, 0.5-1, 1-3, 3-5 and 5-10 mm, compressing them by means of a vibrator to ensure uniform density. When the columns were filled with aggregates, they were subjected to suc cessive wetting-drying cycles. This procedure allowed to obtain soil materials

T a b l e 1. Basic properties of Eutric Cambisol and Gleyic Phaeozem aggregates

Soil	Fraction of aggregates (mm)	Grain size distribution (%) (diameter in mm)			Humus content (%)	Specific surface area (m^2g^{-1})	pH_{KCl}	Organic matter (%)
		1-0.1	0.1-0.02	<0.02				
Eutric Cambisol (I)	<0.25	4	62	34	0.4	32	7.8	4
	0.25-0.5	5	53	42	0.8	39	7.5	4
	0.5-1	4	50	46	0.6	44	7.7	3
	1-3	4	50	46	0.9	47	7.5	3
	3-5	3	54	43	0.8	41	7.6	2
	5-10	3	54	43	0.7	38	7.4	3
Gleyic Phaeozem (II)	<0.25	14	65	21	-	115	4.1	18
	0.25-0.5	70	18	12	-	103	4.2	13
	0.5-1	51	29	20	-	142	4.0	24
	1-3	30	46	24	-	160	4.0	26
	3-5	29	47	24	-	147	3.9	25
	5-10	32	44	24	-	189	4.1	28

with stable physical characteristics, i.e., aggregate size distribution and bulk density (Table 2) [18]. Measurements of the evaporation rate were conducted using the special apparatus [22,24]. Thickness of the soil samples was about 32 cm and they stood on the saturated sand block, it means that at the start of the experiment the value of water potential in the upper surface of the soil samples was close to 3.16 kJ m^{-3} (pF 1.5) (Table 2). External conditions of the experiment were as follows: variant I (low evaporativity) - radiation -11.6 W m^{-2}, air temperature - 20±0.5 ^oC, air humidity - 50±3%; while variant II (high evaporativity) - 163 W m^{-2}, 27.5±0.5 ^oC, 33±3%, respectively. The potential evaporation (Ep) for variant I of the experminent was equal to 4.5 mm day^{-1} and for variant II - 11 mm day^{-1}. Stabilization of the evaporation rate was noticed between 7 and 10 days of the experiment. Water diffusion coefficient was calculated with the Mualem model on the basis of water retention curves and water conductivity coefficient in the saturated zone [13].

T a b l e 2. Characteristics of physical status of stabilized samples formed of aggregates of Eutric Cambisol and Gleyic Phaeozem

Soil	Fraction of aggregates (mm)	Aggregate size distribution (%) (diameter in mm)						Bulk density (g cm^{-3})	Water content at pF 1.5 (%, v/v)
		<0.25	0.25-0.5	0.5-1	1-3	3-5	5-10		
Eutric Cambisol (I)	<0.25	99	1	-	-	-	-	1.25	47
	0.25-0.5	52	47	1	-	-	-	1.18	43
	0.5-1	45	18	37	-	-	-	0.97	35
	1-3	30	14	14	42	-	-	0.93	33
	3-5	34	15	11	17	22	1	0.90	35
	5-10	31	20	12	13	8	16	0.88	32
Gleyic Phaeozem (II)	<0.25	96	4	-	-	-	-	0.80	65
	0.25-0.5	13	86	1	-	-	-	1.15	49
	0.5-1	7	25	67	1	-	-	0.56	33
	1-3	11	12	16	60	1	-	0.41	34
	3-5	11	14	5	23	45	2	0.39	36
	5-10	9	4	2	5	27	53	0.52	35

RESULTS

Evaporation of soil water after wetting may be characterized by three stages. The first stage is controlled by external conditions, and lasts as long as the soil profile can supply water to the surface at a sufficient rate to satisfy evaporative potential. As the soil progressively dries out, at a certain point in time the profile can no longer supply water at the rate at which it is being evaporated. At this point, the second stage begins during which evaporation rate decreases rapidly and is governed by the soil hydraulic properties. When the evaporation rate reaches a small but fairly constant rate, the third stage can sometimes be recognized. The second and third stages are commonly known collectively as the falling rate stage [5,6,8-11].

Evaporation rate can be limited either by the external evaporative conditions or by the maximum rate at which the soil can transmit water to its surface. If the water table is near the surface, the external conditions will govern the evaporation rate whereas, if the water table becomes deeper, the evaporation rate approaches the limiting value which is determined by the capability of the soil profile for water transmission regardless of the external conditions [9].

The results on the investigations of the impact of the aggregate size of the Eutric Cambisol and Gleyic Phaeozem on the evaporation rate for the same depth of the ground water table and for low and high evaporativity is presented in Fig. 1. It results from the course of the curves that in both investigated cases the evaporation rate decreased successively with the increase of

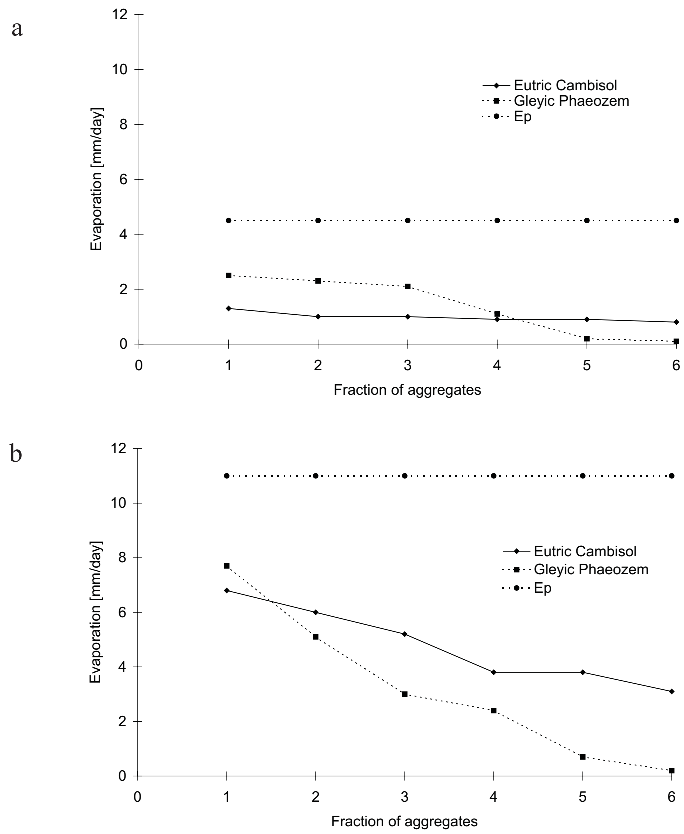

Fig. 1. Relationship between the size of aggregates (1 corresponds to <0.25 mm, 2: 0.25-0.5, 3: 0.5-1, 4: 1-3, 5: 3-5 and 6: 5-10 mm, respectively) and evaporation for low (a) and high (b) values of evaporativity.

the aggregate size of which soil samples were built. In the case of Eutric Cambisol at low evaporativity, evaporation rates for the aggregates smaller than 0.25 mm equalled 1.3 mm day^{-1} and for the aggregates in 5-10 mm diameter - 0.8 mm day^{-1}. However, in the case of the Gleyic Phaeozem, evaporation rates for the smallest aggregates reached 2.5 mm day^{-1}, while for the biggest aggregates, i.e., 5-10 mm, only 0.1 mm day^{-1}. It can be seen that under low evaporativity the aggregate size of the Eutric Cambisol had in practice considerably small effect upon evaporation (the ratio of the maximum to minimum evaporation was 1.6). However, in the case of the Gleyic Phaeozem a decrease of the evaporation rate with the increase of aggregate diameter was considerably high (the ratio of the maximum to the minimum evaporation was 25). This increase was especially strongly marked between the aggregate fractions of 0.5-1 and 3-5 mm (from 2.1 mm day^{-1} to 0.2 mm day^{-1}, that is nearly 10 times). It should be emphasised that the values of evaporation rate for the aggregates of the Eutric Cambisol smaller than 3 mm were lower than these values for same size aggregates of the Gleyic Cambisol, while for the aggregates bigger than 3 mm the result was reversed.

In the second variant of the experiment, i.e., under high evaporativity, the evaporation rates in the case of the aggregates of both investigated soils were considerably higher than in the first variant. However, they decreased, at low evaporativity, with the increase in aggregate sizes. Generally, evaporation rates were higher for the aggregates of the Eutric Cambisol than for the aggregates of the Gleyic Phaeozem, with the exception of the smallest aggregates. The values of evaporation rate for the Eutric Cambisol were 6.8 mm day^{-1} for the fractions smaller than 0.25 mm, and for the aggregates of fraction 5-10 mm was 3.1 mm day^{-1} (a decrease of over 2 times), while for Gleyic Phaeozem, respectively - 7.7 and 0.2 mm day^{-1} (a decrease of nearly 38 times).

The extreme values of the ratios of evaporation rates for the same aggregate fractions of particular soils under high and low evaporativity oscillated between 5.2 and 1.6, respectively for the fraction smaller than 0.25 mm and 0.25-0.5 mm of the Eutric Cambisol and from 3.5 to 1.4, respectively, for the aggregates of fraction 3-5 and 0.5-1 mm of the Gleyic Phaeozem. This leads to the conclusion that in the investigated cases, the size of the aggregates has considerably higher impact on the soil evaporation rate than the external conditions.

Some theoretical solutions describing steady state evaporation predict that when external evaporativity is increased, the soil eventually attains the maximum evaporation rate which depends upon water table depth and profile transmissivity and which remains constant regardless of how high external evaporativity may became [7,17]. In the case of the presented experiments in which ground water table was relatively close to the soil surface (about 32 cm), the evaporation rate was limited by the external conditions and soil transmitting properties. The information about the soil transmitting properties is expressed by the water diffusion coefficient, which was calculated according to the Mualem model [13] on the basis of water retention curves and water conductivity coefficient in the saturated zone. The courses of water diffusion coefficient for different soil water potentials of the investigated aggregate fractions are presented for the Eutric Cambisol, and for Gleyic Phaeozem in Fig. 2. It results from Fig. 2a, that with the increase of the aggregate size of the Eutric Cambisol to 3 mm, the soil water diffusion coefficient decreases considerably from $0.16 \cdot 10^6$ cm^2 day^{-1} for the aggregates smaller than 0.25 mm to 2.6 cm^2 day^{-1} for the aggregates of 1-3 mm fraction at the lowest potential value and from 3.6 cm^2 day^{-1} for the aggregates smaller than 0.25 mm to $0.25 \cdot 10^{-3}$ cm^2 day^{-1} for the aggregates of 1-3 mm fraction at the highest potential value. For the aggregate fractions of 3-5 and 5-10 mm, the values of water diffusion coefficient increased slightly. In the case of the Gleyic Phaeozem (Fig. 2b), soil water diffusion coefficient decreases with the increase of aggregate size in the whole investigated range of the aggregate diameters.

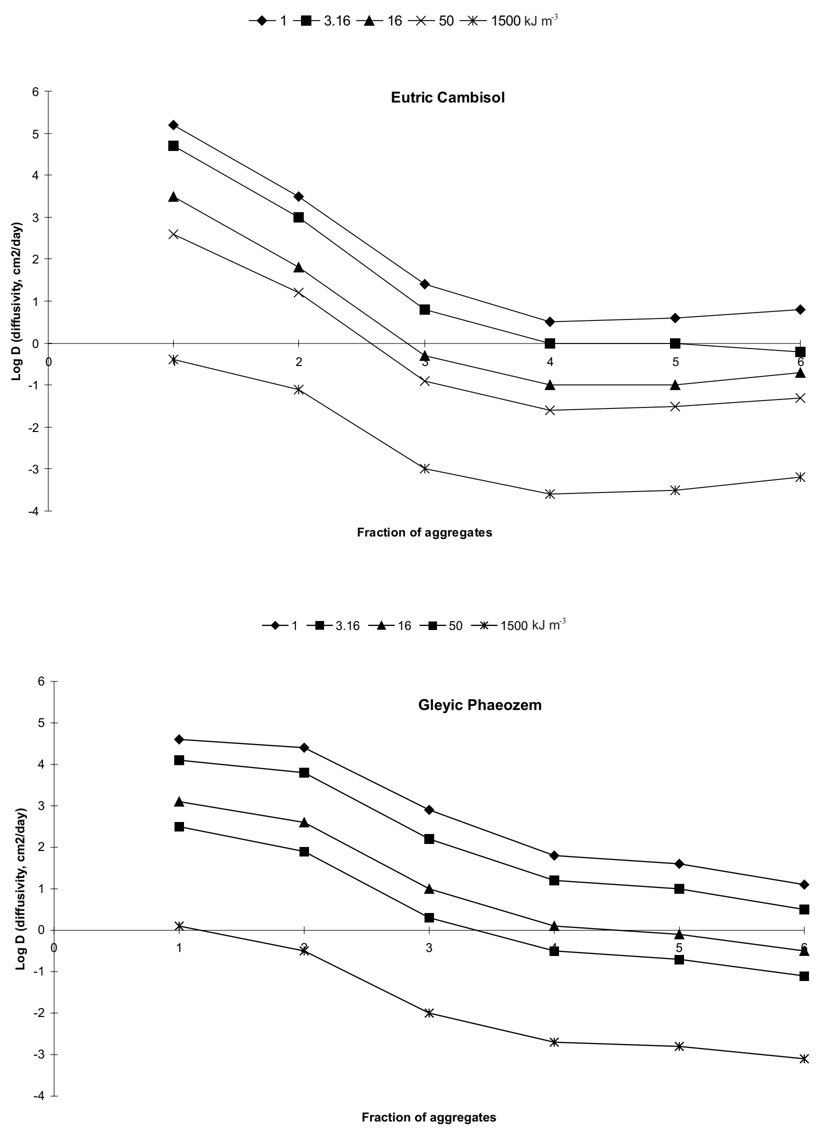

Fig. 2. Relationship between the size of aggregate (1 corresponds to <0.25, 2: 0.25-0.5, 3: 0.5-1, 4: 1-3, 5: 3-5 and 6: 5-10 mm, respectively) and diffusivity for different soil water potential for Eutric Cambisol and Gleyic Phaeozem.

The maximum values of the soil water diffusion coefficient for the potential of 1 kJ m^{-3} are $0.4 \cdot 10^5$ cm^2 day^{-1} for the smallest aggregates and $0.12 \cdot 10^2$ cm^2 day^{-1} for the biggest aggregates. However, for the potential 1500 kJ m^{-3}, water diffusion coefficient reaches the value of $0.29 \cdot 10^3$ cm^2 day^{-1} for the aggregates of the fraction smaller than 0.25 mm, and $0.82 \cdot 10^{-1}$ cm^2 day^{-1} for the fraction of 5-10 mm.

Generally, it can be stated that a decrease of soil water diffusion coefficient is the most rapid with the increase of the aggregate size for the fractions from the smallest to 1-3 mm. After exceeding the diameter of 3 mm, water diffusion coefficient values increase slighly for the Eutric Cambisol and decrease slightly for the Gleyic Phaeozem. The above results showed that evaporation is limited by hydraulic conductivity. The aggregates of the smallest fractions under the same external conditions exibit moisture level higher than the other fractions, which leads to higher values of hydraulic conductivity in the upper layer of the column. For the soil with bigger aggregates, humidity in the upper layer of the column is lower because water rises only by the contacts between the aggregates. This factor is so significant that it is not compensed for the effective surface resulting from the existence of big pores between the aggregates with the diameters higher than 3 mm on the soil surface.

CONCLUSIONS

The results obtained in the present investigations lead to the conclusion that soil type, aggregate size and external evaporativity strongly determine evaporation from the soil surface:

- an increase in the aggregate sizes both for low and high evaporativity causes a decrease in the evaporation,

- evaporation decreases with the increase of aggregate size for the Eutric Cambisol: for low evaporativity of about 1.6 times and for high evaporativity of about 2.1 times,

- evaporation decreases with the increase of aggregate sizes especially strongly for the Gleyic Phaeozem: for low evaporativity about 25 times and for high evaporativity about 38 times,

- a decrease of evaporation with the increase of aggregate sizes for low and high evaporativity is caused by the decrease of water diffusion coefficients with the increase of aggregate sizes,

- a decrease of evaporation with the increase af aggregate sizes for both experiments is caused by the decreasing capillary rise through interaggregate pores and by loosing the aggregate junctions close to the surface of the soil samples.

The above described relations seems to be useful to achieve a decrease of evaporation from the soil surface by changing soil aggregate distribution applying mechanical, biological or chemical treatment.

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