Int. Agrophysics, 1995, 9, 49-54

EVAPORATION FROM AGGREGATES OF A PODZOLIC, A LIGHT BROWN AND A CHERNOZEM SOIL

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Accepted August 31, 1994

A b s t r a c t. The results of influence of the size of soil aggregates formed from podzolic, light brown and chernozem soils on evaporation are presented. It has been found that aggregation of the investigated soils strongly modified evaporation. Evaporation from aggregated soils sharply decreased with the increasing size of aggregates. This effect was very strong, especially for high radiation.

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

INTRODUCTION

Evaporation of water from soils is a very important process because it may cause losses of water reaching, under some conditions, up to 40 to 90 % of precipitation [1,3,7]. Studies aiming at determination of the relation between the rate of evaporation and the level of precipitation, radiation, ground water level and distribution of moisture in the soil profile showed that with unchanged external conditions the rate of water evaporation from the soil depends primarily on the structure of the top horizon of the soil, and with improving soil structure the possibility of utilization by plants of water supplied to the soil profile increases from 15 to 85 % [2,4-6].

The objective of this study was to determine the effect of aggregate size of podzolic, light brown and chernozem soil on evaporation at different external conditions.

MATERIAL AND METHODS

The object of investigations were a podzolic, light brown and chernozem soil, samples of which were taken from arable layer. Following drying up of the soil samples in the laboratory to the air-dry state, the aggregation of the soils was determined by the standard sieve method [8]. Then, soil columns were filled with aggregates of the fractions separated, i.e., <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 successive wetting-drying cycles. This procedure allowed soil materials with stable physical characteristics to be obtained [8] (Tables 1,2). Measurements of evaporation were conducted using the apparatus which is shown in Fig. 1 [9].

The soil samples, prepared as described above, were saturated with water by setting a water table at the upper surface of the loess layer (silt block). After reaching equilibrum, i.e., when the moisture in the samples equalized, which usually lasted from 5 to 7 days, depending on the properties of the particular soil sample, measurements of the extent of water evaporation could begin. Thickness of soil samples was 32.5 cm, it means that water potential on the upper surface of soil samples was equal at pF 1.5. For these measurements the soil samples were uncovered and a bubble of air was introduced into the calibrated tube using the air feeder. The measurement of the water evaporation rate consisted in measuring the

Table 1. Basic properties of the aggregates from the investigated soils

Soil	Fraction of aggregates (mm)	Content of elementary particles (%) 1 - 0.1 mm	0.1 - 0.02 mm	<0.02 mm	Humus content (%)	Specific surface area (m^2g^{-1})	pH_{KCl}
Podzolic	10 - 5	54	26	20	1.77	20.7	4.2
	5 - 3	50	28	22	2.30	29.2	4.1
	3 - 1	55	23	22	2.33	27.5	5.7
	1 - 0.5	75	10	15	1.62	15.2	3.9
	0.5 - 0.25	71	16	13	1.16	12.7	4.0
	<0.25	10	64	26	1.70	25.4	4.2
Light brown	10 - 5	11	47	42	1.83	47.6	7.0
	5 - 3	11	47	42	1.87	54.2	7.1
	3 - 1	12	43	45	1.85	52.2	7.1
	1 - 0.5	17	38	45	2.00	52.0	7.2
	0.5 - 0.25	25	37	38	1.94	47.8	7.3
	<0.25	4	53	43	1.55	43.4	7.2
Chernozem	10 - 5	3	53	44	4.1	77.8	6.0
	5 - 3	5	52	43	4.4	80.1	5.8
	3 - 1	3	55	42	4.5	83.0	5.6
	1 - 0.5	4	53	43	4.4	82.5	5.9
	0.5 - 0.25	4	52	44	4.6	86.2	5.9
	<0.25	3	61	36	3.4	62.8	6.0

Table 2. Characteristics of physical status of stabilized soil samples built of aggregates formed from the investigated soils

Soil	Fraction of aggregates (mm)	Content of aggregates (%), (diameter in mm)						Mean weight diameter of aggregates (mm)	Bulk density ($g\ cm^{-3}$)
		<0.25	0.25 - 0.5	0.5 - 0.1	1 - 3	3 - 5	5 - 10		
	10 - 5	54	30	13	6	7	10	1.40	1.24
	5 - 3	16	20	11	19	33	1	1.36	1.06
Podzolic	3 - 1	33	24	27	16	-	-	0.67	1.07
	1 - 0.5	11	33	56	-	-	-	0.56	1.24
	0.5 - 0.25	20	80	-	-	-	-	0.32	1.65
	<0.25	98	2	-	-	-	-	0.13	1.26
	10 - 5	17	21	17	14	10	21	2.48	0.96
	5 - 3	18	22	18	21	20	1	1.54	0.93
Light brown	3 - 1	13	15	19	51	2	-	1.31	0.99
	1 - 0.5	19	25	55	1	-	-	0.55	0.94
	0.5 - 0.25	18	81	1	-	-	-	0.33	1.05
	<0.25	98	2	-	-	-	-	0.13	1.20
	10 - 5	21	9	17	24	6	23	2.64	0.84
	5 - 3	15	9	13	43	18	2	1.89	0.83
Chernozem	3 - 1	19	7	19	53	2	-	1.33	0.95
	1 - 0.5	20	10	68	2	-	-	0.62	0.90
	0.5 - 0.25	58	39	3	-	-	-	0.25	0.96
	<0.25	96	4	-	-	-	-	0.13	1.03

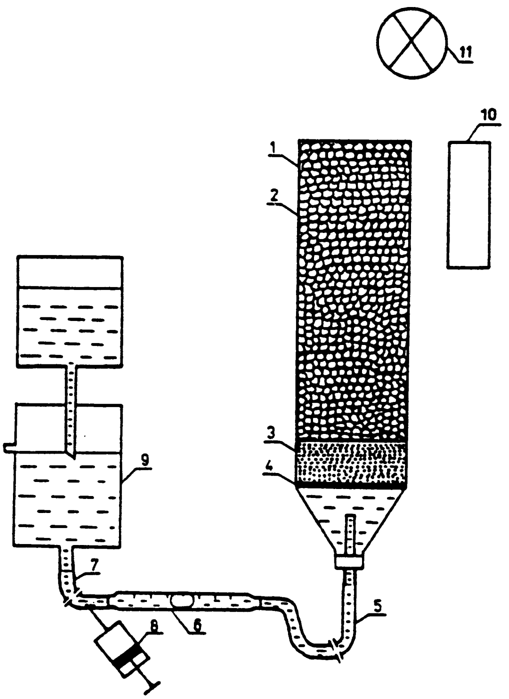

Fig. 1. Scheme of the equipment for the measurement of water evaporation from the soil surface. 1-soil column, 2-soil aggregates, 3-loess layer, 4-perforated plate covered with *tiffon*, 5,7-elastic hoses, 6-calibrated tube, 8-air feeder, 9-water table setting container, 10-radiation energy flux meter, 11-radiation source.

time elapsed from the moment the air bubble was at the initial mark on the calibrated tube to the moment the bubble reached the final mark. Knowing the volume of the calibrated tube section between the two marks (the initial and the final marks) and having the measured time for air bubble to cover the distance between them, the amount of water that evaporated from the surface of the soil sample could be calculated. Another measurement could be taken when the air bubble travelled beyond the calibrated tube.

The external conditions of the experiment were as follows:

Variant I - radiation - 11.6 W m^{-2}, air temperature - 20 ± 0.5 °C, air humidity - 50 ± 3 %.

Variant II - 163 W m^{-2}, 27.5 ± 0.5 °C, 33 ± 3 %, respectively.

RESULTS AND DISCUSSION

The results of this study on the rate of water evaporation from the surface of soil samples of different aggregation are presented in Figs 2 and 3, for low (11.6 W m^{-2}) and high (163 W m^{-2}) radiation, respectively. In both cases the evaporation rate increased systematically with decreasing aggregate size, reaching the highest values for the chernozem, mean values for the light brown soil, and the lowest in the case of the podzolic soil. In the case of low radiation (Fig. 2), the maximum values of the rate were about three times as high as the minimum, being respectively: for podzolic soil aggregates of the 10-5 mm fraction - 0.32 mm day^{-1}, and <0.25mm - 1.22 mm day^{-1}; light brown soil - 0.70, and 2.25 mm day^{-1}; chernozem - 1.08 and 2.77 mm day^{-1}. With the high level of radiation (Fig. 3), the maximum values of the evaporation rate were three times higher for the chernozem, at 3.41 mm day^{-1} for the 10-5 mm fraction and 10.8 mm day^{-1} for the fraction <0.25 mm, four times higher for the podzolic soil, at 1.5 and 5.99 mm day^{-1}, respectively, and five times higher for the light

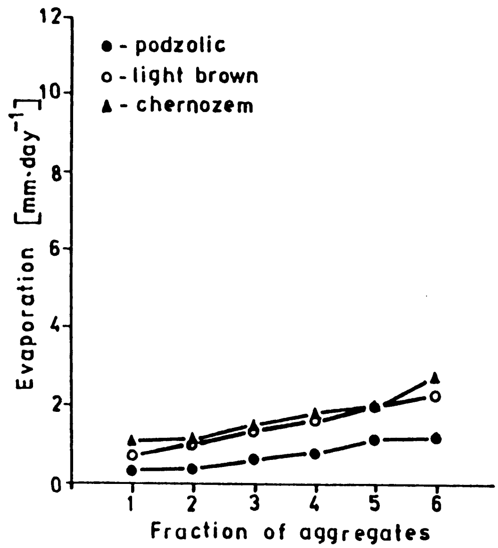

Fig. 2. Relationship between the size of aggregates (1 corresponds to 10-5 mm; 2 to 5-3; 3 to 3-1; 4 to 1-0.5; 5 to 0.5-0.25; and 6 to <0.25 mm, respectively) and evaporation for low radiation (11.6 W m^{-2}).

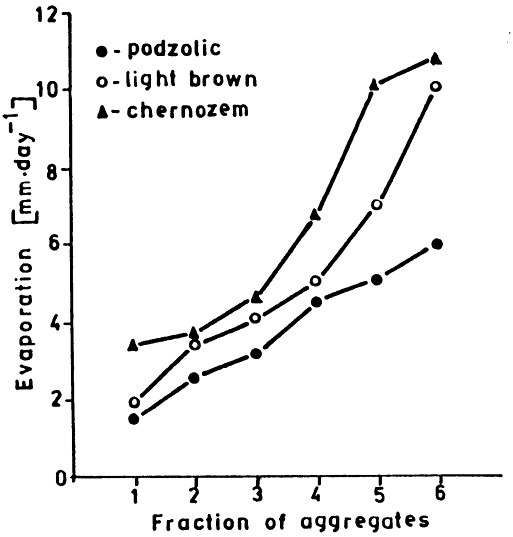

Fig. 3. Relationship between the size of aggregates and evaporation for high radiation (163 W m^{-2}). For explanation see Fig. 2.

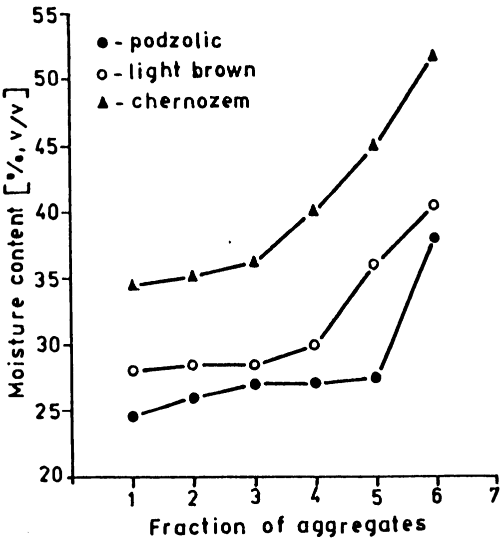

Fig. 4. Relationship between the size of aggregates and water content at pF 1.5. For explanation see Fig. 2.

brown soil, at 1.93 and 10.4 mm day^{-1}. The differences in the values of the evaporation rate for the same aggregate fractions of each particular soil at various radiation levels were the greatest in the case of the podzolic soil (4-6.5 times), and the smallest for the light brown soil (3-4 times). In none of the cases was a distinct relationship found between the differences and the aggregate size.

In the discussion of the results obtained it should be emphasized that the experiment was conducted for soil samples of identical properties under changing external conditions, i.e., at different levels of energy supplied to the soil surface and at different temperature and relative humidity values of the air. It is known that water evaporation is determined by the external conditions and by the water transmission properties of the soil, where the greatest role is played by the soil water content. Water content in soil samples of different aggregation is presented in Fig. 4. As follows from the figure, the highest moisture was observed in the chernozem aggregate fractions (34.4-51.9 % v/v), intermediate for the light brown soil (28.0-40.5 % v/v), and the lowest for the podzolic soil (24.0-38.0 % v/v). This relationship, therefore, is similar to the evaporation rate.

Analyzing the above it should be emphasized that when the water table is at the soil surface from which it evaporates, the evaporation rate is determined solely by the external conditions, among others the amount of energy supplied to the soil surface, necessary for the phase shift of water from the liquid to the gaseous phase, the air temperature, the moisture deficiency and the wind velocity. When the water table gets lower, and therefore the water potential on the soil surface increases, the evaporation rate depends also on the properties of the soil sample, i.e., on its ability to deliver water to the soil surface. In this situation, the soil properties may restrict evaporation, irrespective of how high the potential evaporation is. In the case of evaporation, the moisture of the surface layer of the soil decreases, which causes an increase in the absolute value of water potential, and thus an increase in the water potential gradient [4,5]. This gradient is the driving force for the water movement up to the upper layer of the soil, and the intensity of the upflow is determined by the non-saturated hydraulic conductivity, and the value of that conductivity can be a factor limiting water evaporation. In the assessment of the depth of the soil layer which takes a direct part in evaporation it should also be stressed that soil samples initially made up of aggregates from the same fraction have, as a result of water effect, a differentiated aggregate composition and consequently a varied pore distribution.

CONCLUSIONS

On the basis of the investigations carried out, the following conclusions can be formulated:

1. The value of the evaporation rate increased with decreasing size of aggregates making up the soil.

2. The value of the evaporation rate increased with increasing water content in soils of different aggregation.

3. The values of the evaporation rate at low and high radiation levels were the highest for the Chernozem and the lowest for the podzolic soil.

4. Differences in the values of the evaporation rate for the same aggregate fractions at different radiation levels were the greatest for the Podzolic soil and the smallest for the light brown soil.

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