THE WATER-HOLDING CAPACITY OF COLUMNS OF SOILS OF VARYING LENGTHS

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Frequent inquiries concerning the water-holding capacities of soils as a basis for moisture control in certain lines of investigations have been made. The height of the containers of soil used in these experiments often vary from one to three feet and may or may not be provided with outlets for drainage, depending on the nature of the work. Where drainage is not provided, a water table is likely to develop in the bottoms of the containers which serves as a source of supply of water for the soil above through the action of capillary forces within the soil.

Several investigators have secured data indicating the existence of a rather definite ratio between the water-holding capacity of certain soils and their moisture equivalents and hygroscopic coefficients. It is the purpose, therefore, of this investigation to study the effect of texture and height of column of five different soils on their water-holding capacities when in capillary equilibrium and also to see if any definite ratio exists between them and the moisture equivalent and hygroscopic coefficient.

Plan of the Experiment

The soils employed were Coloma sand, Coloma fine sand, Coloma sandy loam, a very fine sandy loam subsoil from Illinois, and Carrington silt loam. A mechanical analysis was made of each soil according to the Bureau of Soils method (3), the results of which are given in table 1.

TABLE 1.

MECHANICAL ANALYSES

Coloma fine sand, Coloma medium sand, very fine sandy loam, Coloma sandy loam and Carrington silt loam.

Name of Soil	Fine gravel percent	Course sand per cent	Medium Sand percent	Fine sand percent	Very fine sand percent	Silt percent	Clay per cent	Total per cent
Coloma fine sand (subsoil)	.027	.99	13.30	73.13	9.42	1.69	2.54	101.097
Coloma medium sand (surface)	2.0145	6.5605	30.674	44.1375	6.999	6.2825	3.8935	101.5615
Very fine sandy loam (subsoil)	.3095	.1785	.4045	.7155	66.7915	27.08	3.778	99.2575
Coloma sandy loam (surface)	5.178	4.535	17.879	38.962	18.784	10.783	3.744	99.865
Carrington silt loam (subsoil)	.183	.079	.486	1.556	21.43	53.61	18.98	99.488

The moisture equivalents of each soil were determined by the method adopted by Briggs and McLane (2) as well as the hygroscopic coefficient by the Hilgard method (4). The results of which are shown in table 2.

Sufficient moisture was added to the Coloma medium sand, Coloma fine sand and the very fine sandy loam to increase their moisture content to ten times their hygroscopic coefficient, and the moisture content of the Coloma sandy loam and Carrington silt loam was increased to five times their hygroscopic coefficient.

Nine different lengths of columns were used; 1 centimeter, 3 inches, 6 inches, 9 inches, 12 inches, 18 inches, 24 inches, 30 inches, and 36 inches. Determinations for each length were made in triplicate. The soils for the 1 centimeter columns were placed in brass cups, with perforated bottoms, 3.8 centimeters in diameter and 1 centimeter deep. For the other length of columns, glass tubing, 2 inches in diameter was used, one end of which was covered with two layers of hospital gauze. The tubes were numbered and weighed and filled with uniformly compacted soils.

The tubes and soils were then weighed and the weight of dry soil in each computed. After weighing, the tubes of soil were vertically placed in water to a height corresponding to the height of the soil. After the soils had become thoroughly saturated, they were weighed.

The tubes were then vertically placed in racks with the covered ends just touching free water surface. Evaporation at the upper ends was prevented by securely tying heavy paper over the tops of the tubes. Weighings of the tubes were made at regular intervals until practically constant weights were secured. The moisture which remained in the soil at this time was considered to be the water-holding capacity of that particular soil column under conditions of capillary equilibrium.

The weighings covered a period of several months. Each determination was run in triplicate.

Results

The results of the moisture equivalent, hygroscopic coefficient, and water-holding capacity determinations are given in table 2.

From these data it is seen that texture and the length of column of soil have a marked influence on the water-holding capacity of these soils. The maximum amount of water

TABLE 2

The moisture equivalents, hycroscopic coefficients, water-holding capacities, and ratios of water-holding capacity to moisture equivalent and hygroscopic coefficient of varying lengths of columns of Coloma fine sand, Coloma medium sand, very fine sandy loam, Coloma sandy loam and Carrington silt loam.

Name of Soil	Moisture Equivalent	Hygroscopic Coefficient.		Height of Column.									*Only two determinations used for calculations
				1 cm.	3 in.	6 in.	9 in.	12 in	18 in	24 in.	24 in.	30 in.	36 in.
Coloma fine sand (Subsoil)	1.298	.2545	Water-holding Capacity in per cent	23.040	21.58	18.8786	21.976	18.678	11.136	10.21 *	11.74	10.036	8.64 *
			Ratio: Water-holding Capacity to Moisture Equivalent	17.74	16.61	14.93	16.92	14.39	8.578	7.905 *	9.036	7.723	6.665 *
			Ratio: Water-holding Capacity to Hygroscopic Coefficient	90.55	87.77	74.16	86.35	73.38	44.06	40.06 *	46.116	39.426	33.93 *
Coloma medium sand (surface)	4.8875	.497	Water-holding Capacity in per cent	39.3026	18.775 *	20.20 *	20.400	22.88	16.875 *	15.57	14.824	15.52	12.07 *
			Ratio: Water-holding Capacity to Moisture Equivalent	5.99	3.837 *	4.13 *	4.175	4.68	3.451 *	3.185	3.8636	3.175	2.4695 *
			Ratio: Water-holding Capacity to Hygroscopic Coefficient	56.98	37.795 *	40.675 *	41.05	46.076	33.95 *	31.333	29.816	31.25	24.31 *
Very fine sand {Ill. soil subsoil}	12.505	.885	Water-holding Capacity in per cent	41.1895	30.06	32.95	35.7935 *	16.895 *	31.793	32.130	33.1426	31.435	36.1185 *
			Ratio: Water-holding Capacity to Moisture Equivalent	3.295	2.41	2.635	2.861 *	1.351 *	2.538	2.570	2.6516	2.515	2.891 *
			Ratio: Water-holding Capacity to Hygroscopic Coefficient	46.785	33.976	37.23	40.41 *	19.09 *	35.84	36.296	37.966	35.51	40.80 *
Coloma sandy loam (surface)	7.70	1.595	Water-holding Capacity in per cent.	35.251	21.98 *	24.186	25.08	23.5186	17.255	15.658	17.465	16.366	16.716
			Ratio: Water-holding Capacity to Moisture Equivalent	4.576	2.855 *	3.141	3.257	3.055	2.241	2.0326	2.268	2.125	2.170
			Ratio: Water-holding Capacity to Hygroscopic Coefficient	22.10	13.775 *	16.166	15.72	14.72	10.82	9.82	10.946	10.256	10.478
Carrington silt loam (subsoil)	25.39	5.92	Water-holding Capacity in per cent	58.244	—	46.31	46.331 *	43.85	44.975 *	46.0333 *	46.2975 *	37.87 *	35.206
			Ratio: Water-holding Capacity to Moisture Equivalent	58.244	—	1.8226	1.825 *	1.726	1.771 *	1.8085 *	1.823 *	1.492 *	1.387
			Ratio: Water-holding Capacity to Hygroscopic Coefficient	9.83	—	7.80 *	7.825 *	7.41	7.5975 *	7.755 *	7.825 *	6.395 *	5.946

held by each soil is in the 1 cm. column, due to the extremely short distance through which gravity exerts its force, leaving it in a saturated condition.

It is also shown that the moisture content of these soils decreases as the length of column increases, the least variation being found in the very fine sandy loam, which because of its uniform sized particles, possesses the ability to move water by capillarity to an unusual degree. Mosier and Gustafson (5) found this to be true in their studies of the capillary lift of different soils. The uniform composition of this particular soil is observed from its mechanical analysis in table 1.

The rate of decrease in the amount of water held between the 1 cm. and 36 inch columns is more uniform in the coarser textured Coloma medium and fine sands and sandy loam than in the fine textured very fine sandy loam and Carrington silt loam.

The above facts point out that it is unwise to use the water-holding capacity of a soil which may have been determined on a column of a length differing from one which is to be used in experimental work for growing crops.

Alway and McDole (1) found that loam soil saturated with water and allowed to stand protected from surface evaporation for several months, lost water until the amount retained bore a close relationship to the hygroscopic coefficient, being from 2.1 to 3.1 times this value, according to the particular soil.

"The water retaining capacity of loams, as determined by laboratory experiments was found to bear a somewhat closer relation to the moisture equivalent than to the hygroscopic coefficient; the ratio varying between 0.8 and 1.2.

"Field studies show that when loams, after rains sufficiently heavy to moisten them thoroughly, are protected from losses by evaporation and transpiration they loose water by downward movement until the ratio of moisture content to hygroscopic coefficient lies between 1.8 and about 2.5, and accordingly on the uplands of dry-land regions this is the ratio to be expected in the deeper subsoil - the portion below the range of plant roots."

From the data in table 2 it is seen that in the 18 to 36 inch columns of the very fine sandy loam, Coloma sandy loam and Carrington silt loam, which conform more closely to Alway's and McDole's conditions, the ratios of the water retained to the moisture equivalent vary from 2.52 to 2.89 in the first, from 2.12 to 2.27 in the second, and from 1.39 to 1.82 in the last. Considering that these values were obtained from soils in capillary equilibrium when in contact with free water, they are in close agreement.

The coarser textured Coloma medium and fine sands reach very much higher values for this ratio and point out the fact that the ratios of 1.39 to 2.27 hold true in only the finer textured, sandy loam and silt loam.

By taking an average of the ratios of the water-holding capacity to the hygroscopic coefficient for the 18 inch to 36 inch columns of each soil, it is seen that a wide variation between this average and the value for the hygroscopic coefficient exists. The average ratios for the Coloma fine sand, Coloma medium sand, very fine sandy loam. Coloma sandy loam, and Carrington silt loam are 40.72, 30.13, 37.28, 10.46 and 7.10, respectively or represent corresponding values of 122.8, 60.2, 42.3, 6.5 and 1.2 higher than the hygroscopic coefficient. Of these values only that of 1.2 for the Carrington silt loam approaches that of 2.1 to 3.1 reported by Alway and McDole. The wide variations from 122.8 to 1.2 clearly show that each soil type possesses a particular value of its own and cannot be used interchangeably with that of any other type.

Summary

The common practice of determining the water-holding capacities of soils under one set of conditions and using the results as a basis for computing the optimum moisture content, when used under different conditions, led to the study of the effect of varying lengths of columns of different soils on their water-holding capacities when in capillary equilibrium with a constant supply of water at their lower ends.

Nine different lengths of columns were used, namely; 1 cm., 3 in., 6 in., 9 in., 12 in., 18 in., 24 in., 30 in., and 36 in. 2-inch glass tubes were used except in the case of the 1 cm. column. For this a brass cup 3.8 cm. in diameter with perforated bottom was used.

The soils used were Coloma fine sand, Coloma medium sand, very fine sandy loam, Coloma sandy loam, and Carrington silt loam.

The lower ends columns of soil were in contact with a free water table. With evaporation eliminated they were allow-

ed to come to capillary equilibrium as indicated by a constant weight, from which the water-holding capacities for each column was determined.

A summary of the results and conclusions is as follows:

1. The maximum amount of water held by each soil is in the 1 cm. column.

2. The moisture content of these soils decreases as the length of column increases, the least variation in this respect being in the case of the very fine sandy loam.

3. The rate of decrease in the amount of water held between the 1 cm. and 36 inch columns is more uniform in the coarser textured Coloma fine sand, medium sand, and sandy loam.

4. Because of the wide variations in the amounts of water held by the varying lengths of columns, it is unwise to use the water-holding capacity of a soil which may have been determined on a column of a length differing from the one which is to be used in experimental work for growing crops.

5. The ratios of the water-holding capacities to the moisture equivalent for the very fine sandy loam, Coloma sandy loam, and Carrington silt loam in the 18 to 36 inch columns range from 1.39 to 2.27, but that of the coarser textured soils reach much higher values.

6. A comparison of the average ratios of the water-holding capacities to the hygroscopic coefficient shows the extreme range between the 18 inch and 36 inch columns of 40.72, 30.13, 37.28, 10.46, and 7.10 for Coloma fine sand, Coloma medium sand, very fine sandy loam, Coloma sandy loam, and Carrington silt loam, respectively, or corresponding values of 122.8, 60.2, 42.3, 6.5 and 1.2 higher than the hygroscopic coefficient.

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