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Available Moisture Storage Capacity in Relation to Textural Composition and Organic Matter Content of Several Missouri Soils[1]

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ABSTRACT

Analaysis of the available moisture storage data for 271 profile horizon samples from soils of northwestern, central, eastern, and southwestern Missouri show that for these dominantly silty soils available moisture storage capacity (A.W.C.) decreases with clay and increases with silt content. Coarse silt (0.05 to 0.02 mm.) increases A.W.C. more than fine silt (0.02 to 0.002 mm.). A.W.C. also increases generally with organic matter content but since organic matter increases with coarse silt and decreases with clay the effect can be attributed to textural changes. The silt-rich surface is higher in organic matter and A.W.C. than the clay-rich subsoil (particularly the clay pans). Only in a grouping of samples between 13 and 20% clay is there evidence that organic matter may improve storage, possibly by forming silt sized microaggregates in the clay. This effect is not apparent in soils dominated by fine textural components and relatively low in organic matter.

THE CAPACITY of different soils to absorb and store water that is available to growing plants is of great importance to agronomists, soil scientists, and agricultural engineers alike. Considerable attention has been given to the effect of texture, organic matter, and structure on soil-water relationships. The soils of fine texture, high organic matter content and structural development are high in total water retention at the field-capacity state. This fact is often stressed without due consideration being given to the amount of moisture that will be retained by soils at the permanent-wilting point. Also, comparisons are sometimes made on the soil dry weight rather than the volume basis (10). Since soils high in organic matter or clay are low in bulk density, data reported in this manner may be misleading.

Available water storage capacity is generally believed to increase with fineness in texture. From theoretical considerations silty soils should retain more available moisture than clays or sandy soils. The release of moisture from a silt loam over the suction range of availability is high. Unless a clay soil has fine stable microstructure with most of the aggregates in the size ranges of very fine sand and silt, it will retain a large portion of its storage moisture after the wilting point is reached. Jamison (7) found that an alluvial silt loam soil had a higher available storage capacity than clay soils from the Southeastern United States. On the other hand, Lehane and Staple for certain Canadian brown and dark brown prairie soils (9) have reported higher storage for a fine-textured clay than for silt loams and silty clay loams.

There is some confusion as to what extent and under what conditions organic matter and other aggregating agents will improve water storage. Jamison (6) found for soils of the Southeastern United States, that except for sandy soils, organic matter increases did not increase the capacity of a soil to store available moisture. Feustal and Byers (3) found that little is to be gained by adding peat or muck to a clay soil in equal proportions by volume. They found that retention of water by organic soils at the wilting point is high. On the other hand, Millar and Turk (11) reported a much larger available storage capacity in soil samples taken from fence rows as compared with samples from the cultivated field nearby and attributed the difference to the higher organic matter content found in the fence row samples.

More information is needed on the relationships of soil texture and organic matter to available water storage capacity. The results to date of a statewide available soil moisture capacity survey of Missouri soils that has been in progress for 2 years are presented here. The soils studied thus far are mostly of medium texture. The very fine clays and coarse sand groups are not adequately represented. Also, the organic matter content of most of these soils is less than 2%. As the survey is expanded to include a large number of soils that are high in organic matter as well as more clays and sandy soils, the information will be more conclusive. The results thus far show interesting and informative trends.

EXPERIMENTAL PROCEDURE

The soils in this study include 54 profiles, there being one or more from each of the following silt loams: Mexico, Putnam, Weldon, Sharon, Menfro, Shelby, Wabash, Grundy, Sharpesburg, Marshall, Newtonia, Baxter, Lindley, Lebanon, Guthrie, Eldon, Gerald, Nixa, and Huntington. Also, there is a Baxter sandy loam as well as a Baxter cherty silt loam profile. In many cases the texture of the subsoil layers is finer

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than the silt loam surface. This is particularly true of the clay pan soils represented by Mexico, Putnam and Weldon.

All samples for moisture release were taken as "undisturbed" cores with modified Lutz type samplers (5). Small cores, 1 cm. thick, were used for 0.33-, 1-, 3-, and 15-atm. suctions. Medium-sized cores, 3 cm. thick, were used for 0.1-atm. suction, and large, 6-cm. thick cores (470 cc. volume) were taken for bulk density and field moisture measurements. Samples were taken from the walls of profile pits opened just before sampling. At least 3 cores were taken for each depth and determination. The samples were taken at or near the field-capacity condition in most cases. Where drier large cores were taken they were pre-wet and brought to 0.1 atm. and trimmed to volume before determining the dry weights and bulk densities.

For the 0.1-atm. point, the medium-sized cores were brought to constant weight after soaking and allowing 24 hours drainage in contact with the silt surface of a suction column (8). For either the 0.33- or the 1-atm. point small cores were sealed by a thin layer of silt to pressure plates. The cores were soaked 2 hours and one set was subjected to 0.33- and another to 1-atm. differential plate pressure to give the corresponding soil suction values when drainage stopped (usually after 2 days). Other small cores were sealed by a thin layer of kaolin on pressure membranes, soaked 2 hours, and subjected to differential membrane pressures to give 3- or 15-atm. suction at cessation of drainage (after 3 to 5 days).

Moisture-release curves were drawn for each profile horizon from the average results for the cores. The field moisture at sampling was used with each release curve to estimate the suction at sampling. Most of the sampling was done during the spring and early summer of 1957 when the rainfall in Missouri was unusually high. In most cases the sampling pits were excavated at the different locations 1 to 2 days after rainstorms. It is believed that most of the profiles, at least in the surface foot, were near the "field capacity" condition at sampling. Hence, the overall results were used to test the reliability of the selection of the 0.33-atm. point to represent the field capacity. Of 121 soil horizons sampled, 30 were at less than 0.1-atm., 54 between 0.1- and 0.5-atm., 21 between 0.5- and 1-atm., and 16 over 1-atm. suction. These over 1-atm. suction were in the soil surface or in the deep subsoil which had not been rewet since the drought years of 1953 and 1954.

The available moisture storage capacities were calculated using the 0.33-atm. value as an estimate of the field capacity and the 15-atm. value to represent the permanent wilting point. The results were converted to volume percentages, assuming an average soil particle density of 2.67. Data for some representative profiles are shown in table 1. Composite samples were made of the large cores for each soil horizon. These were crushed and all but stones and roots were made to pass a 2-mm. sieve. Organic matter content was estimated by wet oxidation using chromic acid (4). Mechanical composition was estimated by a modification of the hydrometer method (2).

Analyses

The available moisture storage data, organic matter content, and mechanical composition for all the soil horizons were assembled and correlation coefficients calculated for the various amounts of sand, silt, coarse silt, fine silt, clay, and organic matter in relation to available moisture storage. In addition various groupings were made of the samples. One group included only those from the surface layer. Other groups were made on the basis of sand, silt, or clay content. The correlation coefficients for the available storage capacity in relation to textural and organic matter components were also calculated for the various groups. In addition to this, correlation coefficients were calculated for surface samples taken from 30 Sanborn Field plots.[3]

Table 1.—Moisture retention data for several representative Missouri soils.

Depth represented inches	Bulk density g./cc.	Volume percent moisture 0.1 atm.	0.33 atm.	1 atm.	3 atm.	15 atm.
		Putnam silt loam, Callaway County				
0- 6	1.38	40.1	38.8	32.2	18.9	12.0
6-12	1.44	38.6	34.0	29.6	25.3	16.5
12-25	1.22	49.4	47.6	43.3	40.0	38.4
25-X	1.51	40.9	39.7	37.9	35.3	30.6
		Menfro silt loam, St. Charles County				
0- 6	1.41	38.7	35.5	20.4	11.5	7.3
6-12	1.45	33.6	32.9	23.6	13.9	9.6
12-24	1.47	36.1	35.4	33.2	27.6	24.5
24-36	1.53	39.3	39.3	36.2	32.3	28.6
36-X	1.49	40.3	38.8	36.5	33.5	29.1
		Sharon silt loam, Lincoln County				
0- 6	1.52	38.2	32.7	24.7	19.1	13.9
6-12	1.50	37.3	32.5	24.7	21.0	13.0
12-24	1.39	37.0	30.5	23.5	18.8	13.8
24-36	1.36	40.8	31.7	20.8	16.6	13.5
36-X	1.48	38.4	33.1	25.5	19.0	13.5
		Lebanon silt loam, Lawrence County				
0- 4	1.38	—	54.6	54.2	24.2	22.5
4- 8	1.67	34.1	31.6	26.5	15.7	7.8
8-12	1.52	34.3	31.4	30.2	24.1	21.2
12-26	1.41	44.0	43.7	38.0	37.7	31.1
		Nixa silt loam, Christian County				
0-10	1.45	35.7	30.4	23.7	14.5	10.0
10-22	1.56	37.1	33.8	30.3	25.8	22.1
22-X	1.67	34.5	32.5	31.7	25.9	17.9
		Gerald silt loam, Lawrence County				
0- 8	1.27	47.9	43.8	33.8	24.7	17.3
8-16	1.44	37.1	34.1	27.0	19.0	13.1
16-20	1.42	37.5	33.4	27.8	26.6	18.3
20-X	1.29	44.9	43.1	42.5	38.0	31.9
		Huntington silt loam, Greene County				
0-12	1.38	35.6	29.2	22.0	16.9	14.2
12-24	1.38	35.2	29.6	24.6	18.0	13.2
24-36	1.54	32.6	29.8	25.8	21.5	16.1
36-X	1.62	32.3	30.7	28.7	22.4	17.9
		Shelby silt loam, Harrison County				
0- 7	1.33	31.8	28.2	26.6	23.0	16.1
7-12	1.47	30.6	28.1	24.6	21.3	17.4
12-20	1.46	30.4	27.3	25.7	22.9	18.7
20-36	1.60	28.8	27.3	25.3	22.1	17.9
		Marshall silt loam, Nodaway County				
0- 6	1.34	38.3	33.1	29.7	26.2	23.5
6-12	1.31	37.7	34.7	31.5	27.7	23.1
12-24	1.37	39.3	36.3	34.3	30.3	26.6
24-36	1.43	39.0	37.4	35.0	30.5	27.7
36-48	1.44	38.5	37.8	34.3	28.0	25.5
48-X	1.46	42.7	40.8	38.0	34.0	27.0

RESULTS

The average composition of the samples in the various groupings is shown in table 2 and results of the analyses in table 3. Since the coefficients for sand were all negative they are not shown. In general, as clay increases in these survey samples or in the different groups the available storage capacity (A.W.C.) is reduced. Values near zero were found for the low clay group having less than 12% or more than 21% clay, otherwise the coefficients were numerically large and statistically significant in most cases.

The coefficients for coarse silt × A.W.C. indicate that for these soils in general the coarse silt fraction is closely associated with available moisture storage. Fine silt takes an intermediate position between coarse silt and clay. Organic matter also shows a positive relationship to storage for most groups but with only the 13 to 20% (F) clay group is the coefficient numerically higher than the corresponding value for coarse silt × A.W.C. In most cases organic matter increases with coarse silt; that is the samples taken from the soil surface where the organic matter is highest are generally highest in silt content. Only in the case of Group III, those highest in sand and lowest coarse silt content for the I-IV set of groupings, does the coarse silt content decrease significantly as the organic matter increases. In this group there is little evidence of a relationship between A.W.C. and organic matter. Since coarse silt increases with A.W.C. and de-

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[3] Unpublished data from a graduate student research problem by Sher S. Verdi, Soils Department, University of Missouri.

Table 2.—Average composition of soil sample groupings used in available moisture storage analyses.

Group	Grouping limits		Organic matter	A.W.C.* volume	Sand >0.05 mm.	Coarse silt 0.05-0.02 mm.	Fine silt 0.02-0.002 mm.	Clay <0.002 mm.
			%	%	%	%	%	%
All survey	Profile samples from northwestern, southwestern, central, and eastern Missouri	271	1.5	14.3	12	26	40	21
All survey	Survey surface (plow layer) samples only	58	2.5	18.2	11	33	43	11
I	1-7% sand, 29-77% silt	78	1.3	12.3	4	23	41	31
II	1-7% sand, 78-95% silt	77	1.6	16.4	3	38	47	10
III	8-58% sand, 20-63% silt	58	1.3	11.6	25	14	31	29
IV	8-25% sand, 64-82% silt	58	1.8	16.9	13	27	44	14
A	1-3% sand	77	1.3	13.6	2	32	44	21
B	4-7% sand	78	1.6	15.1	5	29	44	21
C	8-15% sand	63	1.6	15.7	11	24	43	21
D	16-58% sand	53	1.4	12.6	29	18	31	21
E	3-12% clay	67	1.8	17.5	9	37	44	8
F	13-20% clay	73	1.5	15.7	9	29	46	15
G	21-29% clay	68	1.4	12.2	13	21	41	24
H	30-57% clay	63	1.2	11.5	9	17	34	39
Sanborn surface	Surface (plow layer) Samples from field plots	30	2.4	16.1	20	70†	—	8

*Available water storage capacity.

†Value is for total silt instead of coarse silt.

creases with organic matter for this grouping, any positive influence of organic matter on A.W.C. may be nullified by coarse silt variation. Except for this group and two others, coarse silt and organic matter increase together and coarse silt generally shows a better relationship to A.W.C. than organic matter. Hence, the influence of organic matter on A.W.C. may be more apparent than real. Also the negative but not significant correlation for A.W.C. $\times$ organic matter for survey surface samples may arise mostly from the effect of clay content variations. Organic matter increases with clay (Table 3, footnote 3) and A.W.C. decreases with clay content for these samples. The indirect influence of clay is further shown by the correlations for Group I. For this grouping A.W.C. and organic matter both decrease with clay content. Hence, the tendency of A.W.C. to increase with organic matter in this group of soils high in silt is related to the effect of variation in clay content.

Since the correlation coefficients for all the survey samples as a group are all highly significant ($P < 1\%$), the regression lines for the relationship of textural and organic matter composition are shown in figure 1. Also the general relationship of organic matter content to textural composition for these soil samples is shown by regression lines in figure 2. For soils in this range of composition, silt increases and clay decreases with available moisture storage capacity. For these soils, A.W.C. also increases with organic matter, but since organic matter increases with silt and decreases with clay content this effect can be attributed to the indirect influence of textural composition.

DISCUSSION

It is interesting that organic matter appears to influence available water storage capacity more than silt content only in the grouping of soils of medium low clay content

Table 3.—The influence of soil organic matter and texture on available water capacity for various soil sample groups.

Soil sample group	Degrees of freedom	Variables									
		A.W.C. × clay		A.W.C. × fine silt		A.W.C. × coarse silt		A.W.C. × organic matter		Organic matter × Coarse silt	
		R†	P‡	R†	P‡	R†	P‡	R†	P‡	R†	P‡
All samples of survey§	269	-0.41**	< 1	+0.18**	< 1	+0.38**	< 1	+0.22**	< 1	+0.20**	< 1
Surface layer‖	56	-0.25	6	+0.27**	4	+0.15	27	-0.14	30	+0.01	50
I¶	76	-0.23*	3	-0.0002	50	+0.28*	2	+0.13	26	+0.10	39
II	75	-0.24*	3	-0.38**	< 1	+0.38**	< 1	+0.14	23	+0.14	23
III	56	-0.18	18	+0.15	27	+0.38**	< 1	+0.08	50	-0.33**	< 1
IV	56	-0.45**	< 1	-0.04	50	+0.35**	< 1	+0.27	4	-0.02	50
A	75	-0.45**	< 1	+0.01	50	-0.55**	< 1	+0.11	34	+0.23*	3
B	76	-0.55**	< 1	+0.07	50	+0.51**	< 1	+0.23*	3	+0.31**	< 1
C	61	-0.53**	< 1	+0.21	10	+0.51**	< 1	+0.27*	4	+0.12	35
D	52	-0.72**	< 1	+0.32*	3	+0.64**	< 1	+0.22	9	+0.05	50
E	65	-0.09	47	-0.05	50	+0.14	26	-0.02	50	-0.25*	4
F	71	-0.35**	< 1	-0.06	50	+0.29*	2	+0.38**	< 1	+0.17	16
G	66	-0.06	50	+0.11	35	+0.22	8	+0.001	50	+0.09	46
H	61	+0.03	50	+0.12	35	+0.20	12	+0.03	50	-0.24	7
Sanborn Field surface	28	-0.68**	< 1	----------		+0.56**††	< 1	+0.25	22	+0.35††	7

† Correlation coefficients.

‡ Probability levels expressed in percent. Values above 5% are usually considered "not significant", those between 5 and 1% as "significant" (*) and those below 1% as "highly significant" (**).

§ For all survey samples R = -0.27** (P<1) for clay × organic matter and R = +0.14* (P = 3) for fine silt × organic matter.

‖ For this group of surface soils R = +0.=7* (P = 4%) for clay × organic matter.

¶ For this group R = -0.28* (P = 2%) for clay × organic matter.

†† Coefficients for total silt instead of coarse silt.

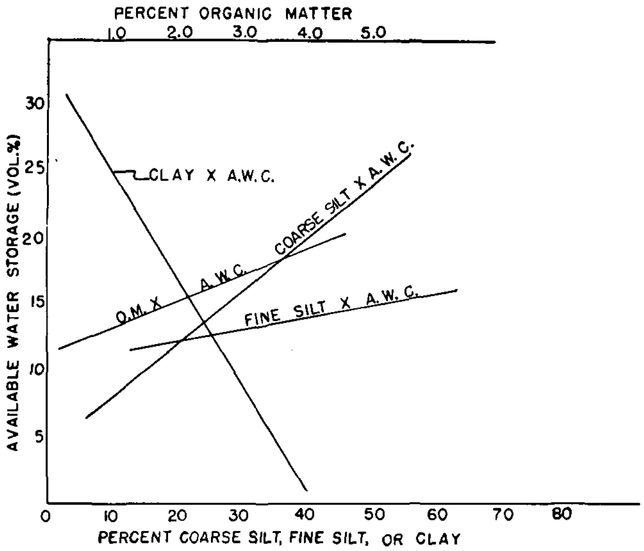

Figure 1.—Regression lines within composition limits for available moisture storage survey samples showing the relation of organic matter and textural components to available storage capacity.

(13 to 20%). It may be that organic matter tends to form stable microaggregates in clay soils that are of about the same size as coarse silt. With these soils that are not very high in organic matter, this effect may be overcome by the influence of large quantities of silt or clay. It is of interest that the grouping lowest in clay content (table 3, E) shows no relationship between available water storage and organic matter. This doubtless arises from the effect of coarse silt since with this group it decreases as organic matter increases.

One should expect soil particles that release the most water per unit volume between 0.33 and 15 atm. of suction to be in the silt size range. Using the approximate formula derived from the capillary rise equation, $D = 3000/S$, where D is the effective pore diameter in microns and S the suction head in centimeters, the limits of effective pore sizes between 0.33 and 15 atm. can be estimated. The effective pore size limits would be about 10 and 0.2μ. A study of soil separates by Bradfield and Jamison (1) indicates that the particle sizes are about 5 times larger than associated effective pore diameters. Particles smaller than silt may be expected to retain considerable moisture in the unavailable state unless they are cemented together in microaggregates of about silt size. It may be that certain organic substances act as bonding agents to form small stable aggregates in clay soils. Clay soils that are rich in organic matter may also be high in available storage capacity. This may help explain results that appear to be at variance with those reported here (9, 11).

The retention of water in the available moisture range will depend upon particle size distribution as well as soil structure. Generally, available storage will increase with silt content and decrease with clay or sand content. From theoretical considerations the order of available moisture storage capacity of particle size fractions should be coarse silt > fine silt > clay > fine sand > coarse sand. Hence an increase in any textural component will tend to change available storage capacity by its effect upon the effective pore size distribution. An increase in clay in a silt loam will reduce storage by dilution of the soil mass with clay and clogging of voids between the silt particles with smaller particles that retain more of the stored moisture in the unavailable range. For sandy soils low in silt content an increase in clay content should increase the available moisture storage capacity.

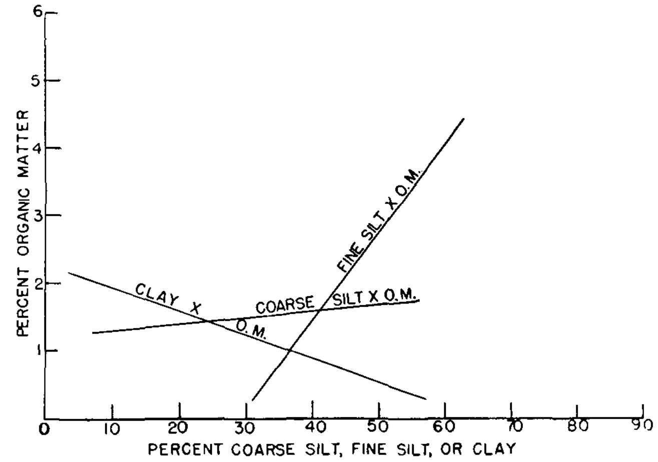

Figure 2.—Regression lines within composition limits for available moisture storage survey samples showing the relation of organic matter to textural components.

The development of soil structure, at least to the extent that large complex aggregates are formed, does not necessarily improve water storage capacity (6, 12). Stable aggregation of soils will improve air-water balance and water intake rate. Also, a soil with a very high storage capacity will not necessarily have other good physical properties. The surface layer of a Lebanon silt loam had an estimated available water storage capacity of 32% by volume (table 1), and the air-filled pores were less than 15% at 0.33-atm. suction. The 4- to 8-inch depth layer of this same profile had a bulk density of 1.67, the available storage capacity measured 23.8% and the air-filled porosity at 0.33-atm. suction only 5.5%. Improvement in soil structure will often result in a loss in available water storage capacity but an increase in permeability and in soil air capacity.

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