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Title THE EFFECT OF ORGANIC MATTER ON THE AVAILABLE MOISTURE-HOLDING CAPACITY OF SOIL

Abstract Approved: Redacted for privacy

(Major Professor)

A study of the effect of organic materials on the available moisture-holding capacity of soil is reported. The term, available moisture-holding capacity, as used in this study, is the range between the moisture equivalent as the upper limit and the permanent wilting point as the lower limit.

Organic materials, peat, manure and alfalfa were added separately to five soils ranging from fine sandy loam to clay adobe and representing major soil types of Southern Oregon, at the rates of 3, 6, 9, and 12 percent on a dry-weight basis. The available moisture was calculated from the wilting point and the moisture equivalent determination in each mixture. The wilting point was determined by growing sunflower plants and the moisture equivalent by the soil centrifuge method.

Tables and curves showing the effect of the organic additions on each soil type are presented. A comparison between the actual available moisture increase and the calculated available moisture increase for the peat additions is also presented by tables and curves. The calculated available moisture increase is the available moisture for 100 grams of soil and peat mixture and represents the sum of the available moisture held in the soil and the available moisture held by peat used in each mixture.

The effects obtained by mixing varying amounts of organic matter with the different soil types were significant in every case, each successive addition increasing the available moisture to some degree. This effect though marked on the heavy soils was greatest on the light-textured soils. The effect of peat on each soil in increasing the available moisture capacity is more than additive in every case. It is assumed that a similar correlation would have been found for the manure and the alfalfa had it been possible to determine the available moisture-holding capacity of these materials. It was not possible to make a wilting point determination on the manure or alfalfa.

From the data secured the following conclusions are drawn:

(1) The addition of organic material to the soil increases the available moisture-holding capacity to an extent greater than the additive effect of the organic matter.

(2) The increase due to the addition of organic materials is greatest in the light-textured soils and decreases as the soils become heavier.

(3) There is a definite relationship between the amount of organic matter in the soil and the available moisture-holding capacity.

(4) There is no definite relationship between the increase in available moisture capacity and the amount of organic matter added to the soil, though the two values increase together.

(5) There is no linear relationship between the successive additions of organic materials and the corresponding available moisture increases.

(6) Although organic matter increases the available moisture-holding capacity of the soil, when added in large amounts, the quantities added in ordinary practice would probably have a negligible effect in increasing the available moisture-holding capacity.

(7) The data indicate that there would probably be a considerable loss in available moisture capacity of soils resulting from organic matter depletion.

A bibliography is included in the reported study.

THE EFFECT OF ORGANIC MATTER ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SOIL

by

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THE EFFECT OF ORGANIC MATTER ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SOIL

INTRODUCTION

Centuries before science was developed to acquaint people with the intricacies of soil physics and plant nutrition it was generally recognized that organic materials in the soil were highly effective in promoting the growth and production of plants. The constant renewal of organic matter in cultivated soils has long been recognized as necessary for the maintenance of a desirable physical condition of the soil. The effect of organic matter upon the soil, however, has chemical, biological and physical implications.

First among the physical effects of organic matter has been observed the promotion of a granular structure due to the colloidal condition of the organic materials. Since organic materials in a partially humidified state are loose and porous the corresponding property is imparted to the soil mass. In addition to the granulating effect, organic matter increases the absorptive power of the soil for water during periods of intense precipitation. A knowledge of the capacity of soils to absorb and retain moisture is essential not only to economical irrigation but also to the production of crops in arid regions where production depends largely upon the amount of available moisture that may be stored in the soil during periods of rainfall. The relation of the physical properties of the soil to the moisture capacity makes the study of the effect of organic matter on the water-holding power of the soil of great theoretical and practical importance.

As a result of the studies of the physical properties of soil in relation to moisture storage the question arises as to whether the addition of organic matter actually increases the available moisture-holding capacity.

Experimental data on this subject are limited and are contradictory, and as a result a number of varied opinions exist on the subject: 1. Although organic matter tends to increase the total moisture-holding capacity of a soil, it also increases the wilting point, the net result being that the amount of available moisture is not affected; 2. the application of organic materials to soil will have no effect on either the wilting point or the field capacity of a soil; 3. organic matter because of its high moisture-holding capacity will increase the available moisture-holding capacity of soil; 4. organic matter so improves the structure of the soil that the improved structure gives added moisture-holding capacity to the soil.

It is the purpose of this experiment to study the effect of organic matter on the available moisture-holding capacity of soils in an attempt to clarify the present conflicting opinions. The term available moisture as used herein is the moisture range between the moisture equivalent, as the upper limit, and the permanent wilting point as the lower limit.

REVIEW OF LITERATURE

Only in recent years has the effect of organic matter on the available moisture-holding capacity of soils been studied. Previously, Mosier (1905) stated that organic matter increased the storage capacity and absorbent power for moisture in soil. He showed that when different amounts of organic matter were added to soil the quantity of water retained increased with the increase of organic matter. He noted the effect of the loss of organic matter on the structure and water-absorbing power of the soil on the Morrow plats at the Illinois Experiment Station and concluded that organic matter depletion was detrimental to the moisture-holding capacity. He substantiates his belief by stating that two experimental plots in England on two similar soils, one having no manure or fertilizer added while the other received an application of 14 tons of farm manure per acre each year for 25 years, showed a difference in moisture content of 30.3 percent after a long continued rain. The plot which had the manure added had the higher moisture content. Nystrom (1930) found that when a sandy soil was treated with additions of peat the soil moisture was noticeably increased under a summer of normal rainfall as well as in a season of more than normal precipitation.

The influence of organic matter on the available moisture-holding capacity of soils has recently been studied by Bouyoucos (1939). His data show that, when expressed on a percentage basis, the available moisture was increased markedly by the addition of organic matter to light soil, and to a less extent in heavy soils. He showed that the increase was comparable on either weight or volume basis. In these studies the wilting point was determined by the dilatometer method and the moisture equivalent by the suction method.

When making a detailed study of moisture conditions in two adjacent plots on the Minnesota Agricultural Experimental Station, Alway and Neller (1919) found that the surface foot showed a marked difference in the moisture content, especially in the available portion, the soil higher in organic matter retaining the more available moisture. Sprague and Marrero (1932) report from studies conducted in a greenhouse that the addition of organic matter to soils increased the available moisture-holding capacity for an indefinite period of time. They showed that some time is required before the full effectiveness of the material is attained, and for certain materials as manure and peat moss, this increase in effectiveness is more than offset by their rapid loss through decomposition. Powers (1939) supported the above theory with data indicating that there is a moderate increase in the moisture equivalent with no significant increase in the wilting point due to the addition of manure on a silty clay loam.

Stone and Garrison (1940), in studying Michigan soils under cultivation and comparing them with those in old established fence rows nearby, reported that a correlation existed between the available moisture and the organic matter content, those highest in organic matter having the highest available moisture.

In support of the theory that organic matter does not increase the available moisture-holding capacity of soil, Feustal and Byers (1936) report in their studies of the comparative moisture-absorbing and moisture-retaining capacities of peat and soil mixture that peat mixtures had a moisture content greater than soils alone. However, the content of moisture unavailable to plants in the mixture was considerably higher than in the soil alone, thus offsetting the advantage of the higher moisture content retained. They found the addition of peat to soil increased the wilting point by an amount roughly proportionally to the quantity of peat used and to the magnitude of unavailable moisture held by peat as compared with that of the soil before mixing.

Thorne (1918) has raised the question whether organic matter in addition to that supplied from plant residues in a good rotation possesses a value for soil improvement additional to the value of the nitrogen and mineral elements contained. He attributes the physical improvement of the soil following the use of manure not to the carbonaceous matter of manure, but to the superior growth of plant roots induced by nitrogen and mineral elements carried by the manure. His conclusions are based upon data from experiments at the Ohio Experiment Station conducted on a soil depleted of its organic matter by a long period of tenant farming.

Veihmeyer and Hendrickson (1938) conclude from their studies of soil moisture and organic matter that the wilting percentage is characteristic of the soil and is independent of the kind of plant or variation of climatic conditions likely to be met in the field. "Neither the permanent wilting percentage nor the field capacity can be changed greatly by the application of organic matter or other fertilizers."

A survey conducted by the committee on Physics of Soil Moisture of the American Geophysical Union indicates that divergent opinions exist as to whether organic matter will affect the available moisture-holding capacity of a soil. Veihmeyer et al (1935).

EXPERIMENTAL PROCEDURE

Description of Soils Used

In order to study the effect of organic matter on a wide variety of textural classes the following soils were used: Medford fine sandy loam, Medford loam, Salem clay loam, Meyer silty clay loam and Meyer clay adobe. These soils have been classified by the Bureau of Soils and represent major soil types found in Southern Oregon.

Medford fine sandy loam carries an appreciable quantity of coarse particles. These coarse particles are granitic, angular and vary in size from coarse sand to fine gravel. The surface of the soil is brown or medium brown shading to a dark brown as the lower depth is approached. This soil is the result of former deposition, by numerous streams, of material derived largely from granitic soils in the mountain regions.

Medford loam consists of brown and dark brown slightly sticky loam underlain at various depths by a yellowish brown to black sticky loam. The topography is smooth with a northward slope. The soil is alluvial in origin, being composed of material washed from adjacent mountains and deposited by minor streams traversing this region. This type is well drained.

Salem clay loam consists of a sticky clay, in poorly drained areas somewhat compact, showing a tendency toward an adobe structure. The color ranges from dark brown to black. The soil is alluvial in formation and is composed of materials washed from volcanic rock occurring in the upper part of the drainage basin.

Meyer silty clay loam consists of a light-brown to grayish-brown sticky, silty clay loam, underlain by a yellowish or yellowish-brown clay loam similar in texture to the surface soil. In some cases the soil is underlain by beds of sandstone or shale. This type consists predominately of alluvial and colluvial foot-slope deposits, but includes some residual material derived from weathering of underlying sandstone and shale. The surface is moderately to steeply sloping and fairly uniform.

Meyer clay adobe consists of a light-brown to nearly black clay of a more or less pronounced adobe structure. The texture of the soil is fairly uniform throughout its entire depth. The soil is a result of a mingling of residual material from underlying sandstone and shale with colluvial and alluvial material from more elevated soils derived from volcanic rocks.

Treatment of the Soils

The soils were collected from the field and allowed to become air dry. They were then passed through a 2 mm sieve in preparation for soil moisture studies. To each of the soils the organic materials, peat, alfalfa and manure were added in proportions of 3, 6, 9 and 12 percent on an air-dry basis. The samples were then thoroughly mixed after which the moisture equivalent and the permanent wilting points were determined. The available moisture held in each mixture was then calculated from the wilting point and the moisture equivalent. These values in turn were compared with the available capacity of the original sample in each case in order to determine the effect of the additions of the organic amendments on the available moisture.

Methods Used

The wilting point of the soil and soil mixtures was determined by growing sunflower plants. The method used was essentially the same as that reported by Veihmeyer and Hendrickson (1928) except that the seeds were planted directly in the soil rather than being transplanted from manured plats. Better root penetration through the sample was obtained by direct planting especially in the heavier soils. Some difficulty was experienced in the direct planting but it is thought the resulting benefits more than offset the difficulties encountered. The permanent wilting point was considered to be reached when all of the leaves on the plant remained wilted after being placed in a humidity chamber for a period of twenty-four hours. The wilting point when determined in this way is undoubtedly at the lower portion of the wilting range. The wilting point percentage is the average of eight determinations on each sample.

The moisture equivalent was determined by the soil centrifuge method as described by Briggs and McLane (1907). The moisture equivalent percentage is the average of eight determinations.

The amount of sand, silt and clay in the soil was determined by the Bouyoucos hydrometer method (1934). Total nitrogen was determined by the Kjeldahl method. The organic matter content was determined by the improved Walkley method. Walkley (1934).

These soil properties are reported in Tables I and II.

Table I

Moisture Properties of the Soils Studied

Soil Type	Moisture Equivalent	Wilting Point	Available Moisture
	percent	percent	percent
Medford Fine Sandy Loam	10.42	5.35	5.07
Medford Loam	16.48	8.41	8.07
Salem Clay Loam	25.03	12.66	12.37
Meyer Silty Clay Loam	28.98	15.74	13.24
Meyer Clay Adobe	33.86	19.94	13.92

Table II

Physical Properties of Soils Studied

Soil Type	Mechanical Analysis			Organic Matter	Total Nitrogen
	Sand	Silt	Clay		
	percent	percent	percent	percent	percent
Medford Fine Sandy Loam	55.2	35.8	9.0	3.15	.1034
Medford Loam	45.2	41.5	13.3	4.48	.1674
Salem Clay Loam	38.7	39.9	21.4	5.00	.1509
Meyer Silty Clay Loam	24.4	52.3	23.3	3.46	.1146
Meyer Clay Adobe	20.4	27.8	51.8	4.14	.1386

Organic Materials Used in the Study

The organic materials used for soil amendments in this experiment were Lake Labish peat, alfalfa meal and barnyard manure. The peat in its natural state was passed through a 2 mm sieve while the alfalfa meal and partially decomposed manure were allowed to become air dry before grinding. They were then passed through a 2 mm sieve. The characteristics of these organic materials are shown in Table III. It was impossible to determine the wilting point of the manure and alfalfa as these organic materials alone would not grow plants. The organic matter content was determined by the loss on ignition. The nitrogen contents reported are on a moisture-free basis.

Table III. Physical Properties of Organic Materials

Organic Materials	Moisture Equivalent	Wilting Point	Available Moisture	Organic Matter	Nitrogen
	percent	percent	percent	percent	percent
Peat	92.92	51.71	41.21	55.2	1.540
Alfalfa Meal	155.10	-- --	-- --	81.1	2.149
Manure	124.50	-- --	-- --	53.5	1.981

EXPERIMENTAL RESULTS

Effect on Medford Fine Sandy Loam

The addition of organic matter to the Medford fine sandy loam increased the available moisture holding capacity in each case to a very marked degree. The addition of peat had a considerably greater effect on than either the manure or the alfalfa, the latter two having very nearly the same effect. In each case the wilting point and moisture equivalent of the soil was increased by the addition of organic matter by an amount very nearly in proportion to the amount of organic matter added. From the results shown in Tables IV, V, VI and Figures 1, 2, 3, and 4, it is apparent that the organic materials increased the moisture equivalent by an amount approximately twice that of the increase in the wilting point.

In Table VII the calculated available moisture is shown and a comparison is made between it and the actual available moisture increase. The calculated available moisture is the sum of the available moisture held in that amount of soil used and the available moisture held in the peat used for each mixture. The result thus obtained is the available moisture for 100 grams of the soil and peat mixture. The available moisture which the peat is capable of holding is referred to in this paper as the additive effect of peat. An effort was made to compute the additive effect of manure and alfalfa but no success was attained in the determination of the wilting points of these materials. The additive effect of peat represents less than one-half of the actual increase in available moisture. There is no definite correlation between the amount of organic matter added and the increase of available moisture. However, the available moisture increased with each successive addition at a nearly uniform rate, the last addition having nearly the same effect as the first addition.

Table IV

Effect of Peat on the Available Moisture-Holding Capacity of Medford Fine Sandy Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	10.42	5.35	5.07	-- --	-- --
3	18.67	11.08	7.59	2.52	49.70
6	26.22	15.23	10.99	5.92	116.76
9	31.50	18.14	13.36	8.29	163.51
12	35.40	19.43	15.97	10.90	214.99

Table V

Effect of Alfalfa on the Available Moisture-Holding Capacity of Medford Fine Sandy Loam

Alfalfa Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	10.42	5.35	5.07	-- --	-- --
3	12.85	6.53	6.32	1.25	24.66
6	15.20	7.01	8.19	3.12	61.54
9	18.22	8.08	10.14	5.07	100.00
12	20.36	9.99	10.37	5.30	104.54

Table VI

Effect of Manure on the Available Moisture-Holding Capacity of Medford Fine Sandy Loam

Manure Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	10.42	5.35	5.07	-- --	-- --
3	13.55	6.63	6.92	1.85	36.49
6	15.36	7.11	8.25	3.18	62.72
9	17.30	8.12	9.18	4.11	81.06
12	19.91	9.26	10.65	5.58	110.05

Table VII

Effect of Peat on the Available Moisture-Holding Capacity of Medford Fine Sandy Loam

Peat Added	Actual Available Moisture	Calculated Available Moisture	Difference between Calculated and Actual Moisture
percent	percent	percent	percent
0	5.07	5.07	0.00
3	7.59	6.14	1.45
6	10.99	7.23	3.76
9	13.36	8.26	5.10
12	15.97	9.40	6.57

FIG. 1. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD FINE SANDY LOAM SOIL.

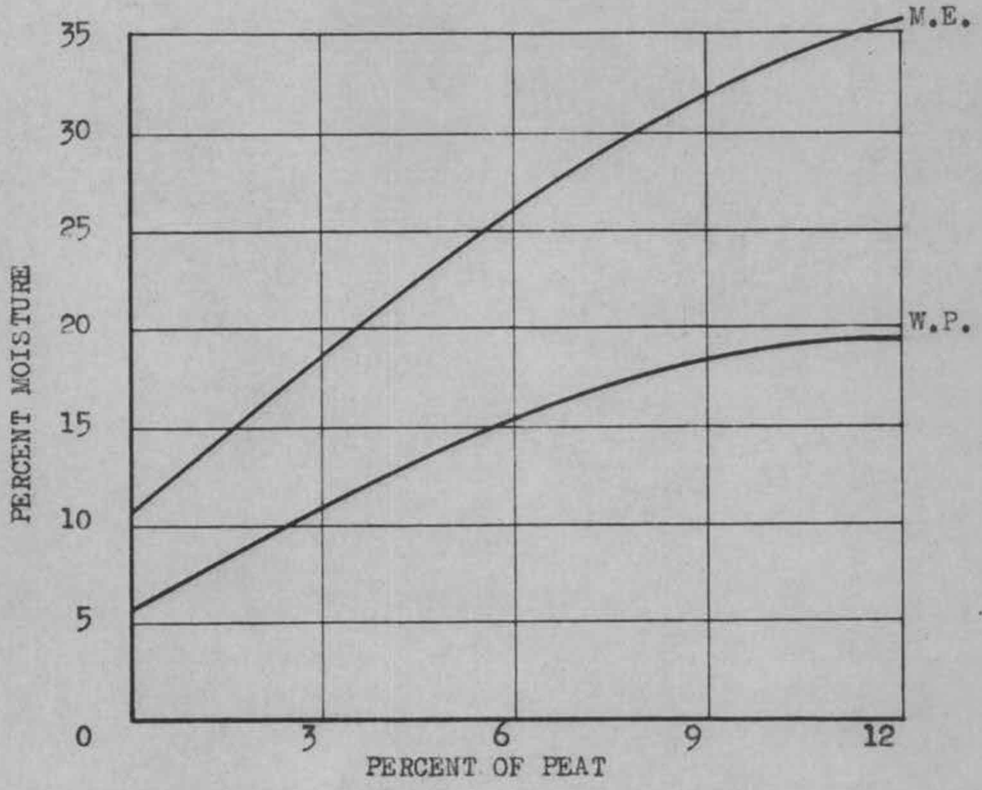


FIG. 2. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD FINE SANDY LOAM SOIL.

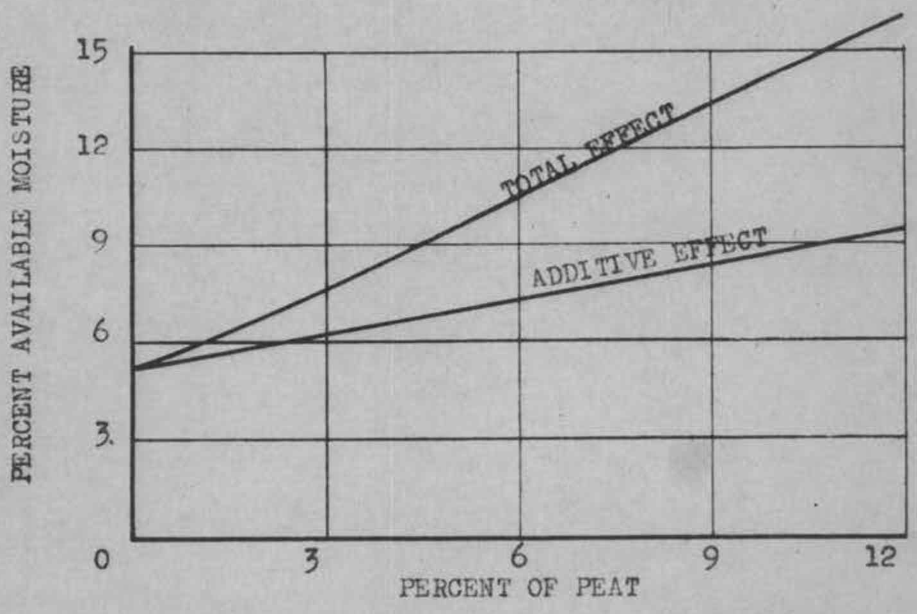


FIG. 3. THE EFFECT OF ALFALFA ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD FINE SANDY LOAM.

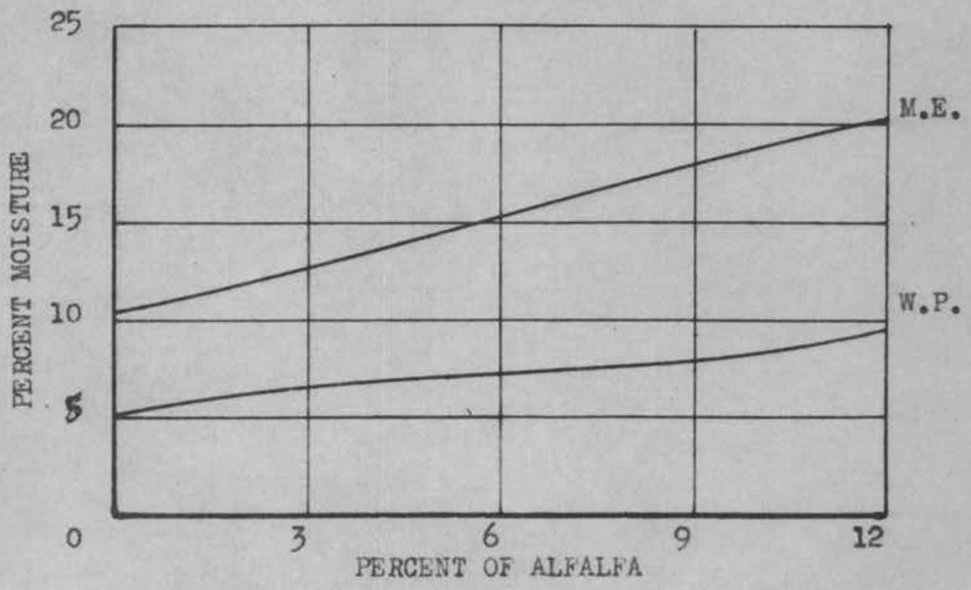
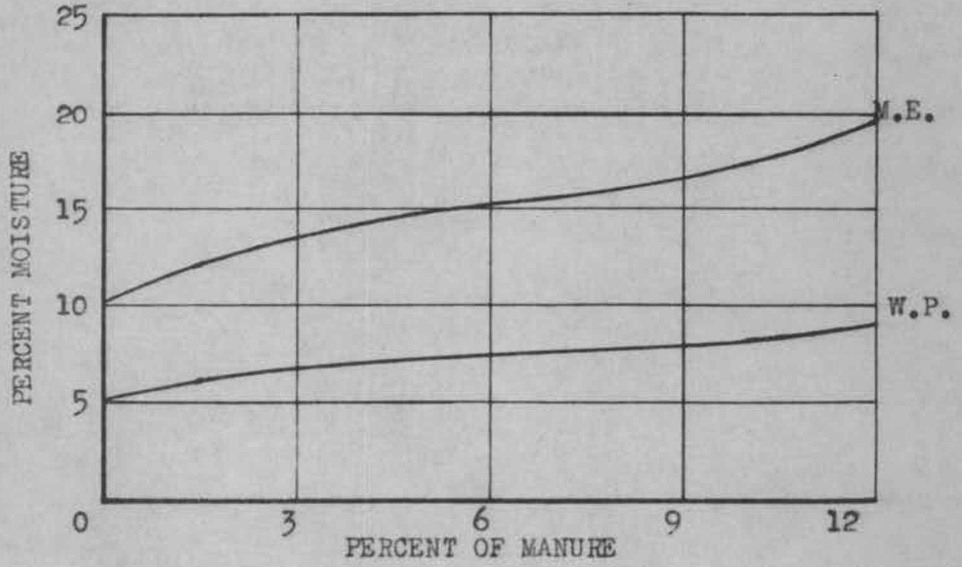


FIG. 4. THE EFFECT OF MANURE ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD FINE SANDY LOAM.



Effect on Medford Loam

The available moisture-holding capacity of the Medford loam soil was increased considerably by each addition of all organic materials. The wilting point in each case was increased and the moisture equivalent was increased to a much greater extent. The peat showed the greatest effect in increasing the available moisture. The addition of manure had a slightly greater effect than that of alfalfa. In every case the wilting point was increased at a uniform rate with the increase of organic materials as shown in Tables VIII, IX and X and in Figures 5, 7, and 8. The additive effect of peat on the available moisture accounted for less than half the total increase as shown in Table XI and Figure 6. There was no definite correlation between the addition of organic matter and the increase but each additional amount increased the available moisture at a rate that was not uniform.

Table VIII

Effect of Peat on the Available Moisture-Holding Capacity of Medford Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	16.48	8.41	8.07	-- --	-- --
3	23.41	12.66	10.75	2.68	33.21
6	30.45	16.02	14.43	6.36	78.81
9	35.83	19.86	15.97	7.90	97.89
12	40.28	23.93	16.35	8.28	102.60

Table IX

Effect of Alfalfa on the Available Moisture-Holding Capacity of Medford Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	16.48	8.41	8.07	-- --	-- --
3	19.65	8.65	11.00	2.93	36.30
6	22.08	9.89	12.19	4.12	51.05
9	23.62	10.45	13.17	5.10	63.19
12	25.00	11.00	14.00	5.93	73.48

Table X

Effect of Manure on the Available Moisture-Holding Capacity of Medford Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	16.48	8.41	8.07	-- --	-- --
3	20.15	8.96	11.19	3.12	38.66
6	21.90	9.14	12.76	4.69	58.11
9	23.08	9.59	13.49	5.42	67.16
12	25.36	10.53	14.83	6.76	83.76

Table XI

Effect of Peat on the Available Moisture-Holding Capacity of Medford Loam

Peat Added	Actual Available Moisture	Calculated Available Moisture	Difference between Calculated and Actual Moisture
percent	percent	percent	percent
0	8.07	8.07	-- --
3	10.75	9.05	1.70
6	14.43	10.05	4.38
9	15.97	11.04	4.93
12	16.35	12.04	4.31

FIG. 5. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD LOAM SOIL.

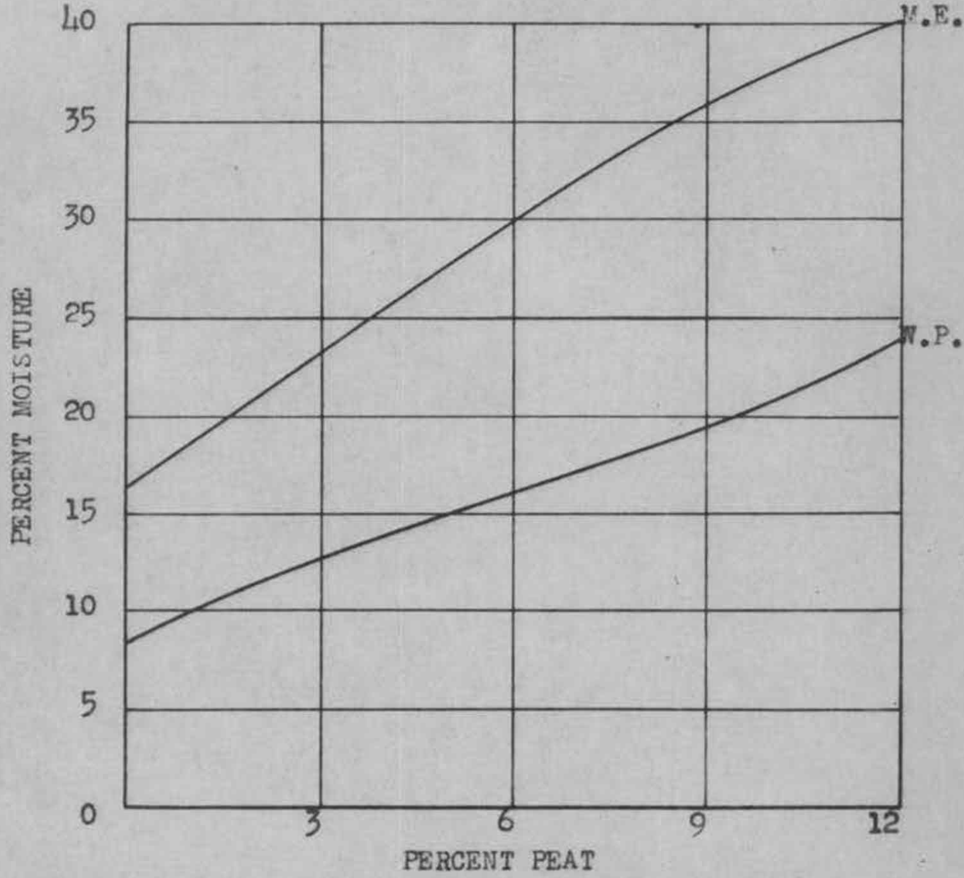


FIG. 6. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD LOAM SOIL.

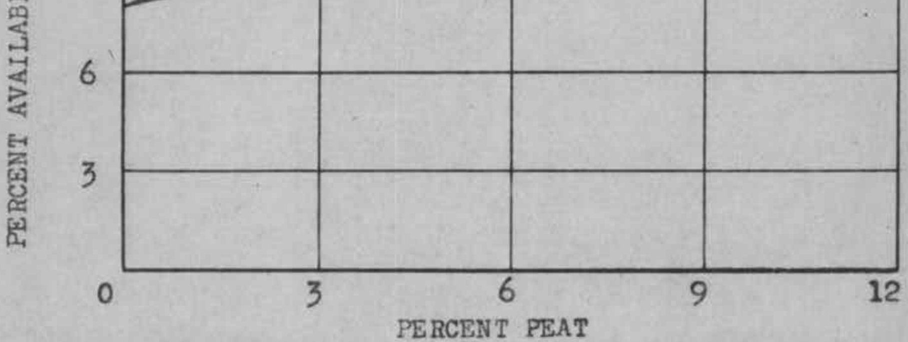


FIG. 7. THE EFFECT OF ALFALFA ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD LOAM SOIL.

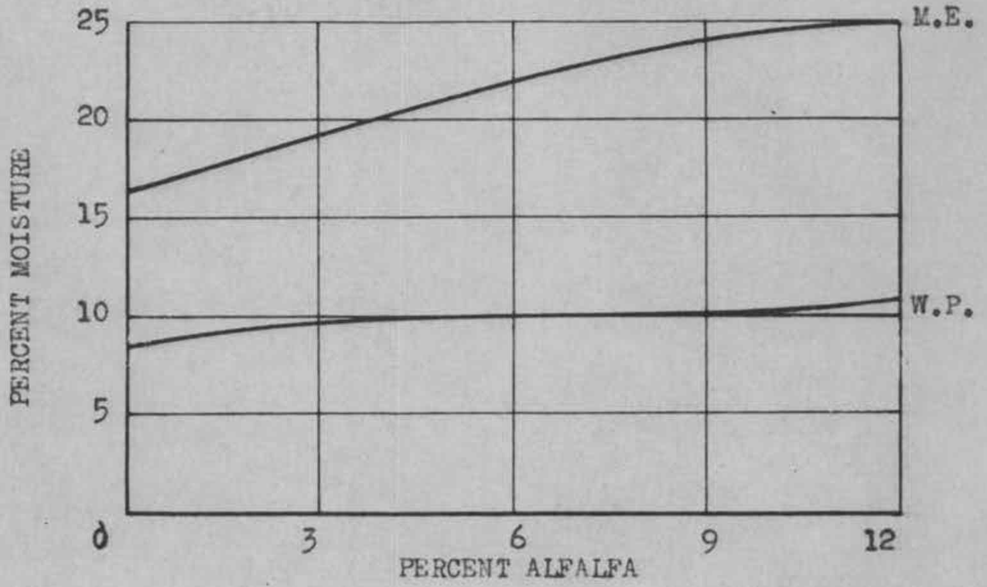
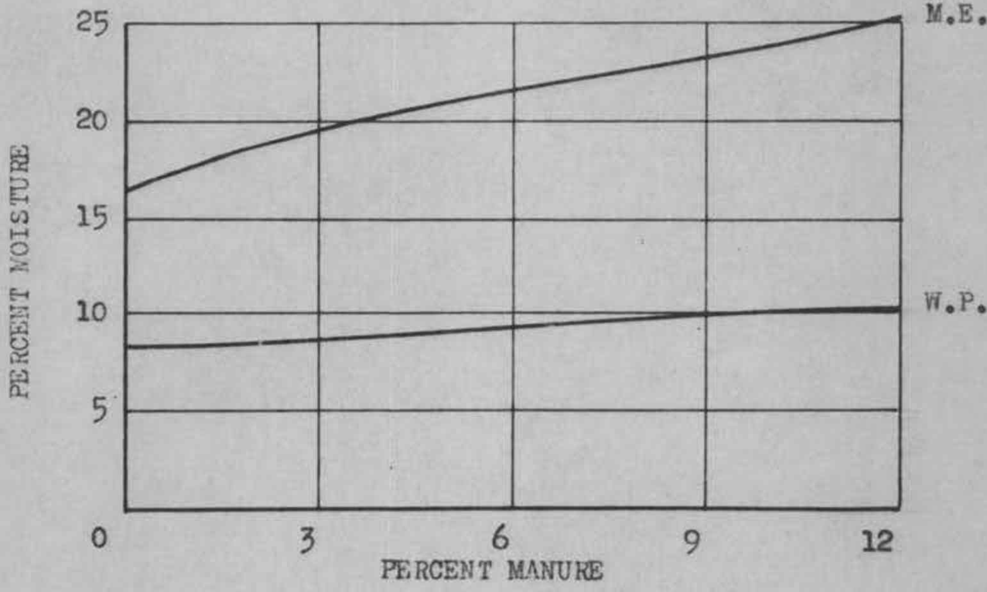


FIG. 8. THE EFFECT OF MANURE ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEDFORD LOAM SOIL.



Effect on Salem Clay Loam

The available moisture-holding capacity of the Salem clay loam was increased by the addition of each organic material. Peat additions showed the greatest effect, alfalfa and manure showing a marked but somewhat lower increase. The increase in available moisture was not directly proportional to the organic matter added but the small increase in the wilting points was nearly at a constant rate. The first additions of peat had a greater effect on the increase than the subsequent additions. This was generally true with the alfalfa and manure additions with this soil but the difference resulting from additions of alfalfa and manure were not as great as those occurring in the peat additions. The effects of the organic materials are shown in Tables XII, XIII, XIV and XV and in Figures 9, 10, 11 and 12. The additive effect of peat on this soil is very small in comparison with the actual increase.

Table XII

Effect of Peat on the Available Moisture-Holding Capacity of Salem Clay Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	25.03	12.66	12.37	-- --	-- --
3	35.51	18.72	16.79	4.42	35.73
6	42.40	20.84	21.56	9.19	74.29
9	50.51	26.68	23.83	11.46	92.64
12	55.05	29.42	25.63	13.26	107.19

Table XIII

Effect of Peat on the Available Moisture-Holding Capacity of Salem Clay Loam

Peat Added	Actual Available Moisture	Calculated Available Moisture	Difference Between Calculated and Actual Moisture
percent	percent	percent	percent
0	12.37	12.37	-- --
3	16.79	13.12	3.67
6	21.56	14.09	7.47
9	23.83	14.95	8.88
12	25.63	15.82	9.81

Table XIV

Effect of Alfalfa on the Available Moisture-Holding Capacity of Salem Clay Loam

Alfalfa Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	25.03	12.66	12.37	-- --	-- --
3	28.56	13.94	14.62	2.25	18.18
6	29.85	13.97	15.88	3.51	28.37
9	32.08	14.67	17.41	5.04	40.74
12	35.17	15.14	20.03	7.66	61.92

Table XV

Effect of Manure on the Available Moisture-Holding Capacity of Salem Clay Loam

Manure Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	25.03	12.66	12.37	-- --	-- --
3	28.35	13.88	14.50	2.13	17.22
6	30.03	14.17	15.86	3.49	28.21
9	31.50	14.58	16.92	4.55	36.78
12	32.63	15.80	16.83	4.46	36.05

FIG. 9. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SALEM CLAY LOAM SOIL.

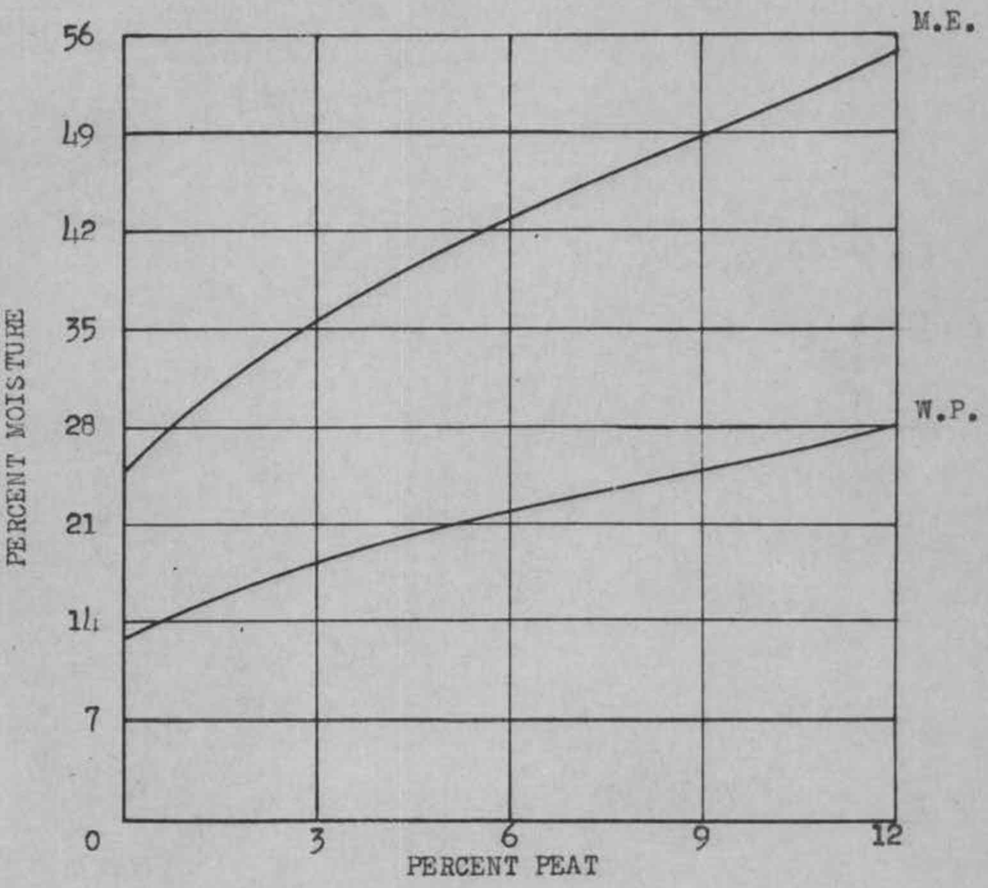


FIG. 10. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SALEM CLAY LOAM SOIL.

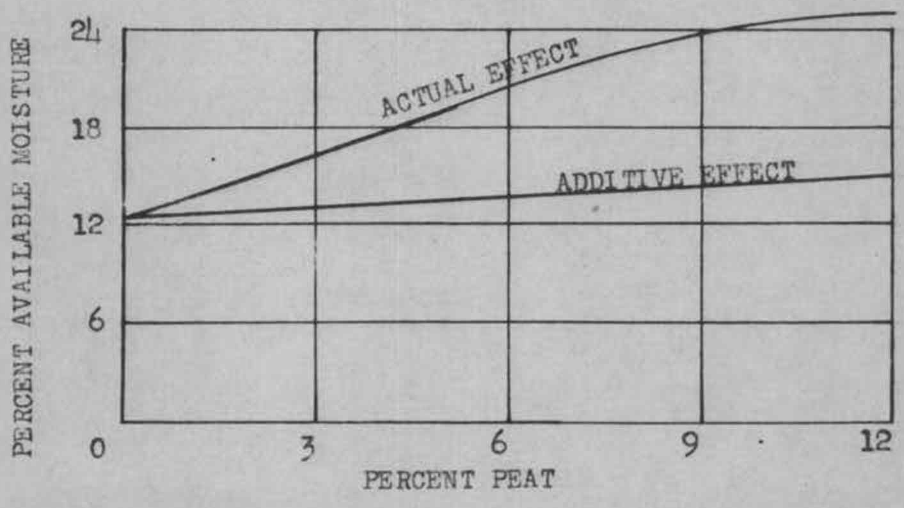


FIG. 11. THE EFFECT OF ALFALFA ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SALEM CLAY LOAM SOIL.

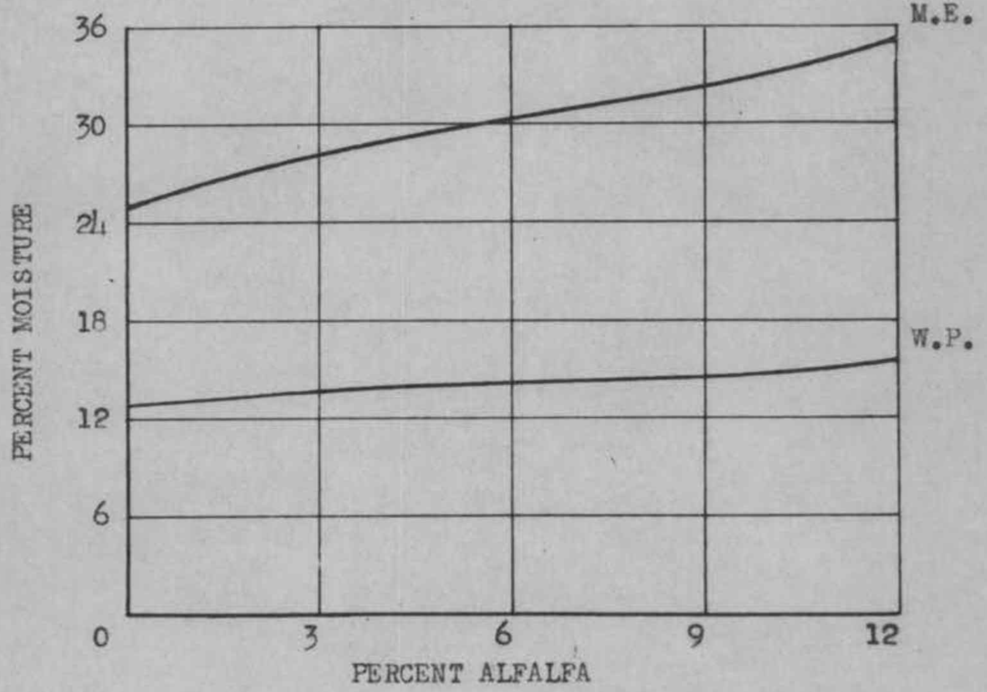
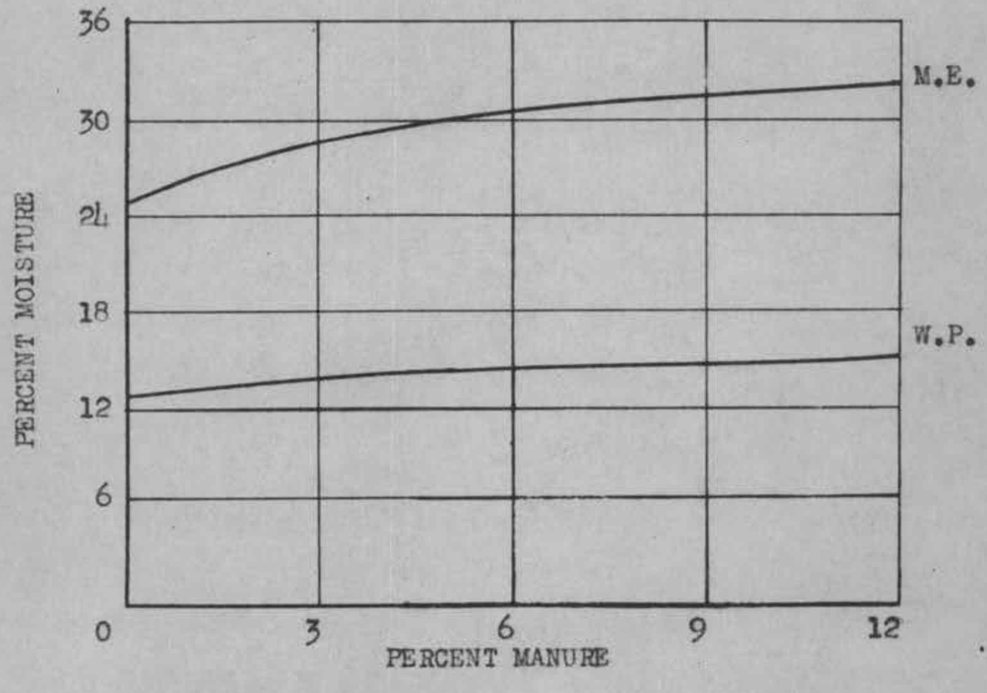


FIG. 12. THE EFFECT OF MANURE ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF SALEM CLAY LOAM SOIL.



Effect on Meyer Silty Clay Loam

The addition of organic matter to Meyer silty clay loam soil showed an increase in its available moisture-holding capacity. As with the other soils the wilting point increased to a lesser extent than the moisture equivalent increased. The increase in this soil was much less than for those soils previously reported. This was especially true of the peat. The increases resulting from the addition of manure and alfalfa more nearly approached the increase produced by the same materials in the previously reported soils. The additive effect of the peat closely approached the actual increase for this soil. There was no correlation between the effect of successive amounts of organic matter with peat and alfalfa additions. However, the applications of manure decreased in effectiveness per unit as increasing amounts were added. Tables XVI, XVII, XVIII and XIX verify these results. Figures 13, 14, 15 and 16 show the effects of organic materials on this soil.

Table XVI

Effect of Peat on the Available Moisture-Holding Capacity of Meyer Silty Clay Loam

Peat Added	Actual Available Moisture	Calculated Available Moisture	Difference Between Calculated and Actual Moisture
percent	percent	percent	percent
0	13.24	13.24	0.00
3	13.41	14.07	-0.66
6	14.65	14.91	-0.26
9	18.81	15.74	3.07
12	21.42	16.59	4.84

Table XVII

Effect of Alfalfa on the Available Moisture-Holding Capacity of Meyer Silty Clay Loam

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	28.98	15.74	13.24	-- --	-- --
3	32.48	16.21	16.27	3.03	22.88
6	34.15	16.44	17.71	4.47	33.76
9	35.62	16.93	18.69	5.45	41.16
12	36.86	17.79	19.07	5.83	44.03

Table XVIII

Effect of Manure on the Available Moisture-Holding Capacity of Meyer Silty Clay Loam

Manure Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	28.98	15.74	13.24	-- --	-- --
3	31.37	16.17	15.20	1.96	14.80
6	31.88	16.45	15.43	2.19	16.54
9	33.31	17.56	15.75	2.51	18.96
12	34.27	17.87	16.40	3.16	23.86
15	36.47	18.26	18.21	4.97	37.54

Table XIX

Effect of Peat on the Available Moisture-Holding Capacity of Meyer Silty Clay Loam

Peat Added Percent	Moisture Equivalent percent	Wilting Point percent	Available Moisture percent	Gain in Moisture percent	Percent Increase percent
0	28.98	15.74	13.24	-- --	-- --
3	33.23	19.82	13.41	.17	1.28
6	38.09	23.44	14.65	1.41	10.65
9	44.06	25.25	18.81	5.57	42.07
12	48.84	27.42	21.42	8.18	61.79

FIG. 13. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER SILTY CLAY LOAM SOIL.

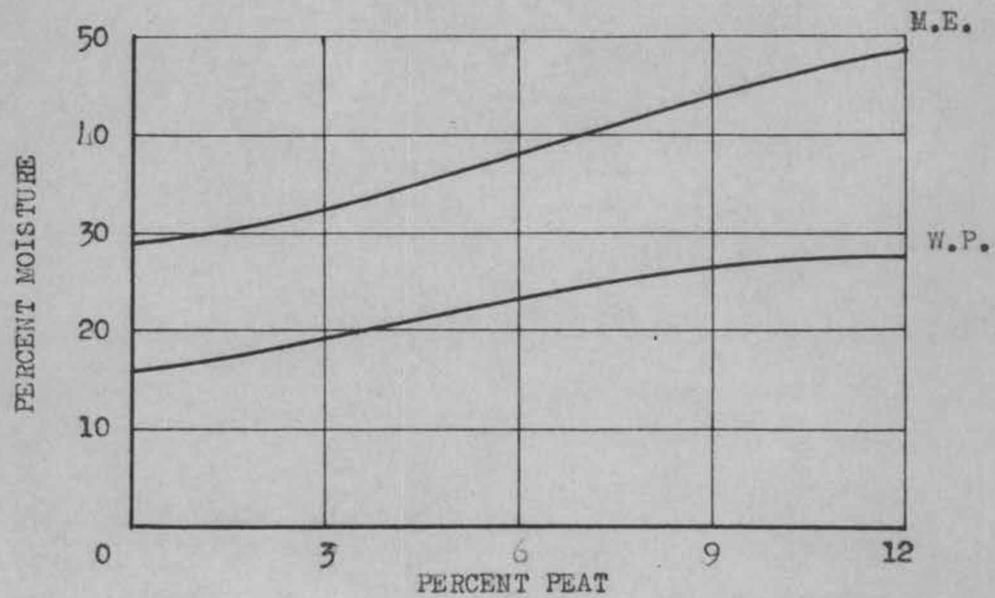


FIG. 14. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER SILTY CLAY LOAM SOIL.

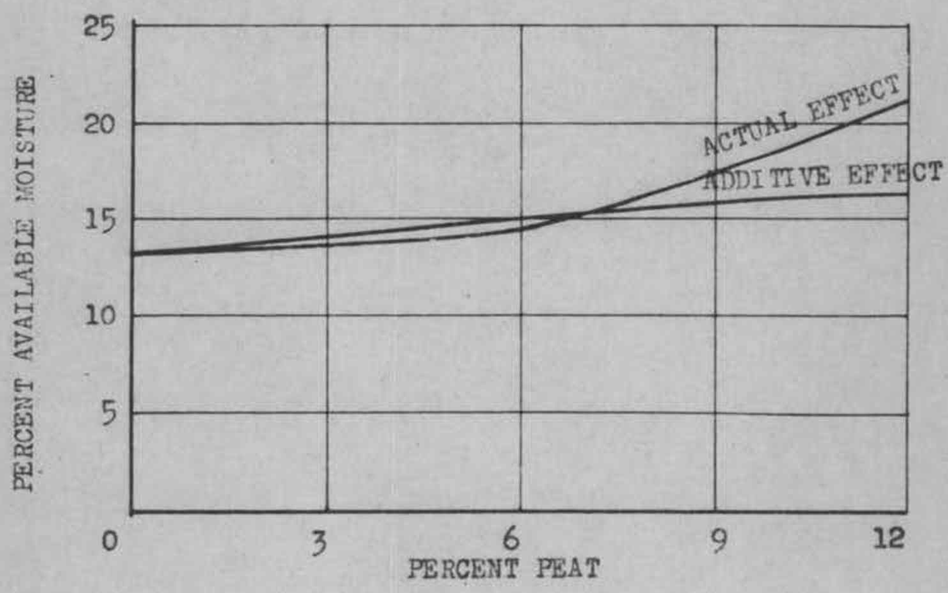


FIG. 15. THE EFFECT OF ALFALFA ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER SILTY CLAY LOAM SOIL.

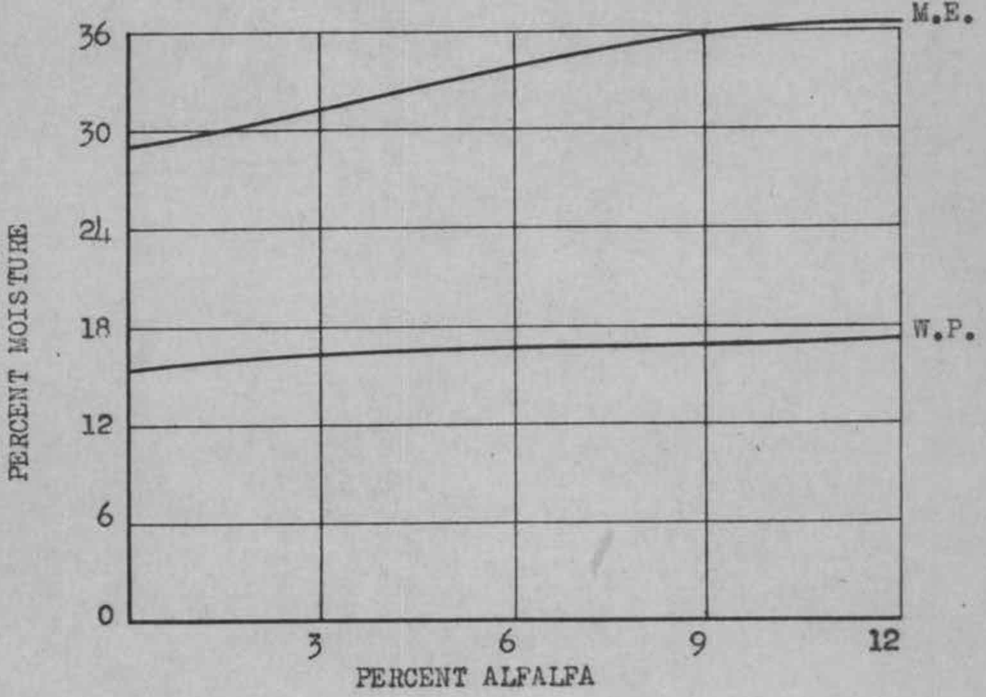
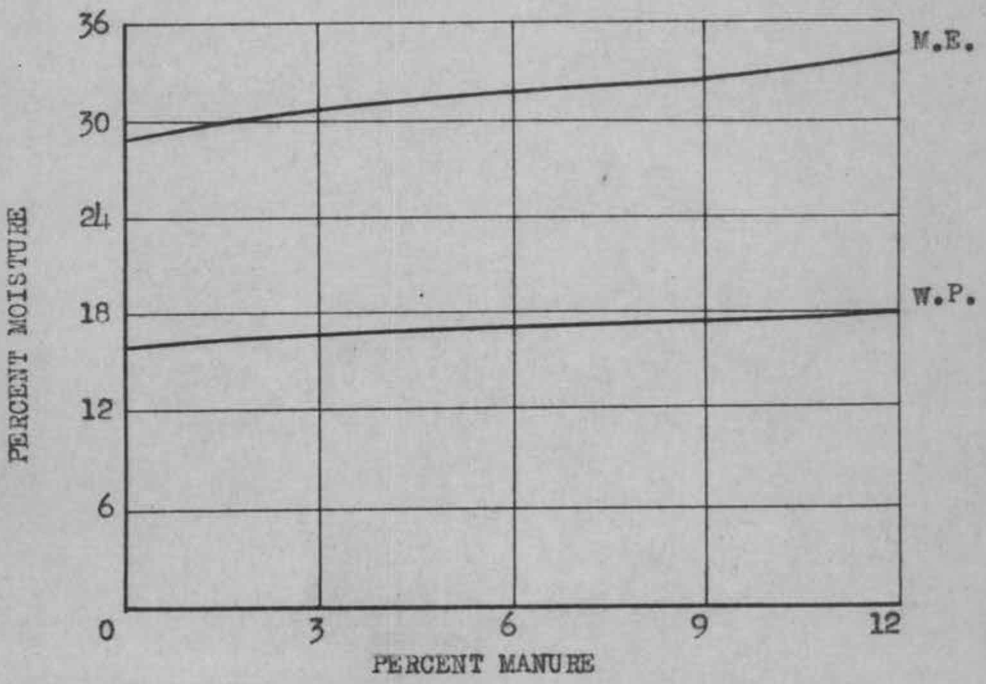


FIG. 16. THE EFFECT OF MANURE ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER SILTY CLAY LOAM SOIL.



The Effect on Meyer Clay Adobe

Figures 17, 18, 19 and 20 show that the available moisture-holding capacity of the Meyer clay adobe soil is increased by the additions of organic material. As shown by Tables XX, XXI, XXII and XXIII the results with this soil closely follow those of the Meyer silty clay loam. The peat did not have a much greater effect than the alfalfa or manure. The additions of six and nine percents of alfalfa decreased the wilting point slightly below the original value. This is true also of the nine and twelve percent additions of manure. There was no definite correlation between the increases and the successive amounts of organic materials added. The calculated additive effect was about one half of the total increase in available moisture.

Table XX

Effect of Peat on the Available Moisture-Holding Capacity of Meyer Clay Adobe

Peat Added	Actual Available Moisture	Calculated Available Moisture	Difference between Calculated and Actual Moisture
percent	percent	percent	percent
0	13.92	13.92	0.00
3	16.05	14.73	1.32
6	15.24	15.55	-0.37
9	21.19	16.36	4.83
12	21.86	17.18	4.68

Table XXI

Effect of Alfalfa on the Available Moisture-Holding Capacity of Meyer Clay Adobe

Alfalfa Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	33.86	19.94	13.92	-- --	-- --
3	36.93	20.10	16.83	2.91	20.90
6	38.85	19.69	19.16	5.24	37.64
9	40.88	19.57	21.31	7.39	53.08
12	41.71	21.01	20.70	6.78	44.39

Table XXII

Effect of Manure on the Available Moisture-Holding Capacity of Meyer Clay Adobe

Manure Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	33.86	19.94	13.92	-- --	-- --
3	34.83	20.38	14.45	.53	3.81
6	37.86	20.20	17.66	3.74	26.86
9	38.25	19.41	18.84	4.92	35.35
12	39.13	19.03	20.10	6.18	44.39

Table XXIII

Effect of Peat on the Available Moisture-Holding Capacity of Meyer Clay Adobe

Peat Added	Moisture Equivalent	Wilting Point	Available Moisture	Gain in Moisture	Percent Increase
percent	percent	percent	percent	percent	percent
0	33.86	19.94	13.92	-- --	-- --
3	38.11	22.06	16.05	2.13	15.30
6	42.50	27.26	15.24	1.32	9.48
9	48.73	27.54	21.19	7.27	52.20
12	51.57	29.71	21.86	7.94	57.04

FIG. 17. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER CLAY ADOBE SOIL.

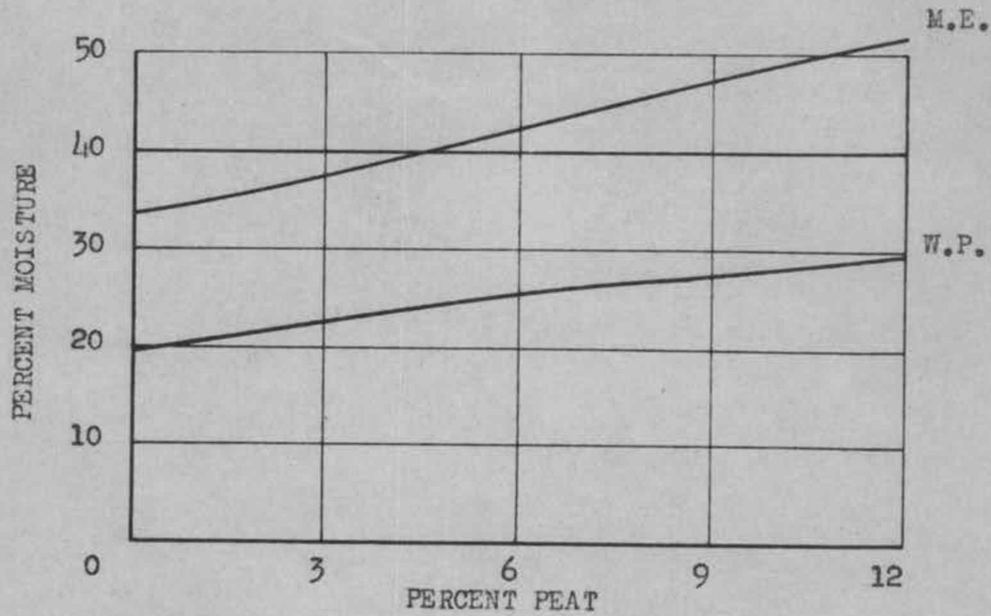


FIG. 18. THE EFFECT OF PEAT ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER CLAY ADOBE SOIL.

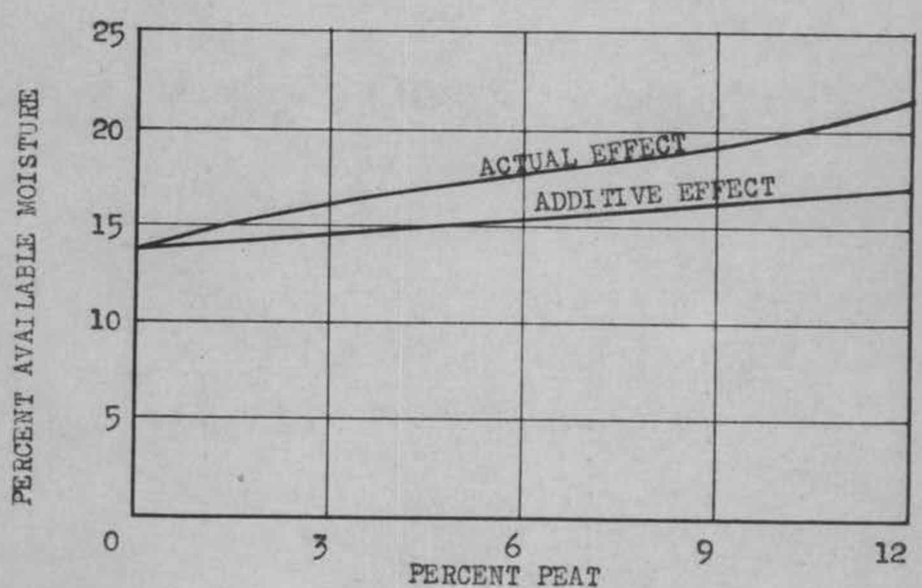


FIG. 19. THE EFFECT OF ALFALFA ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER CLAY ADOBE SOIL.

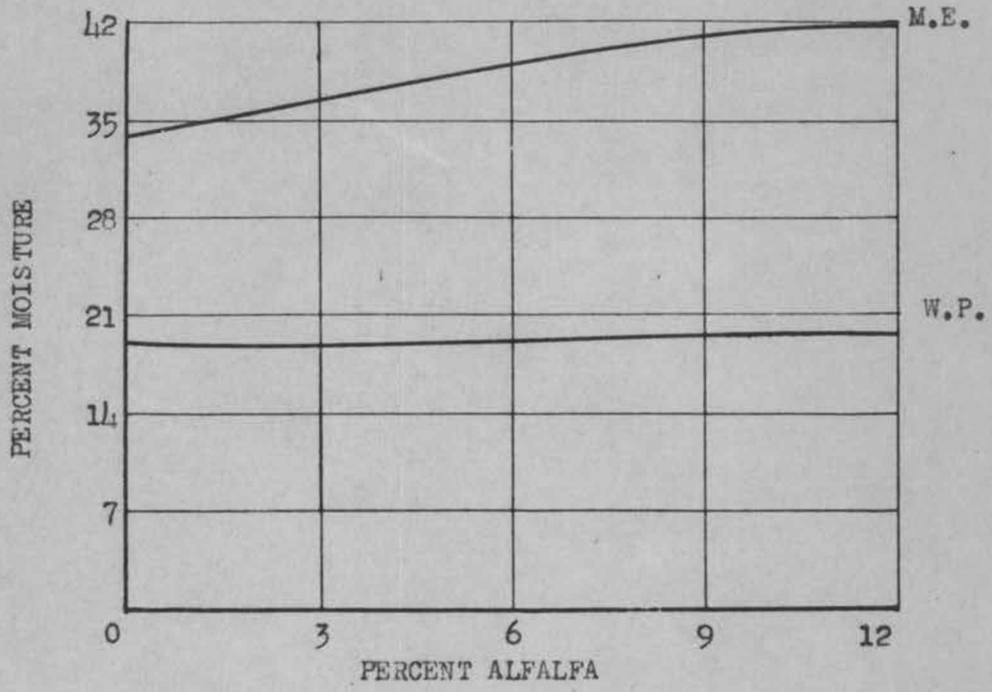
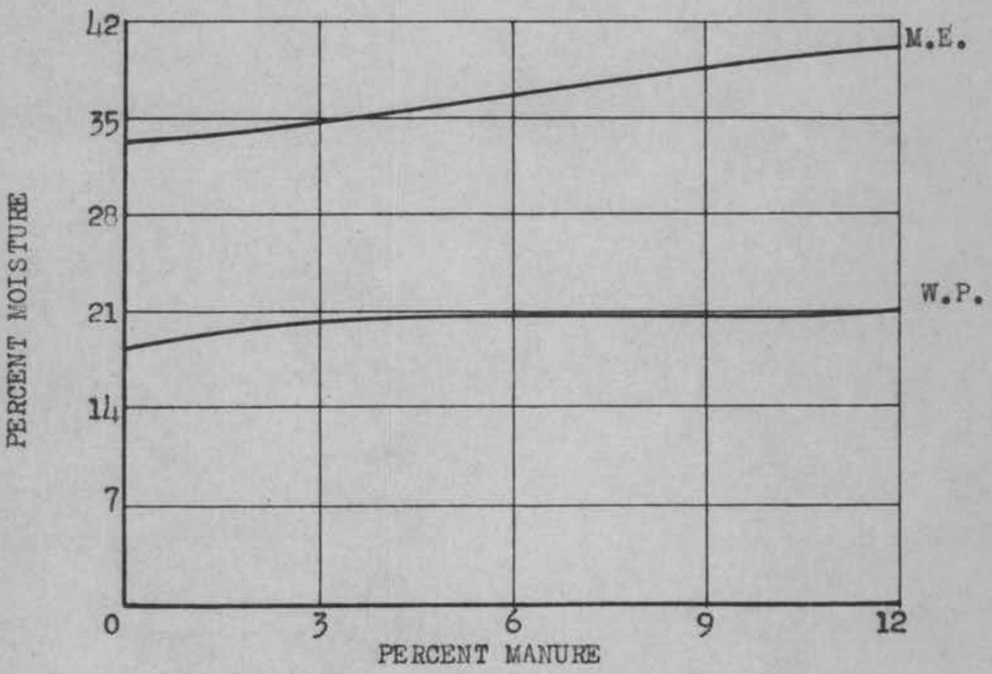


FIG. 20. THE EFFECT OF MANURE ON THE AVAILABLE MOISTURE HOLDING CAPACITY OF MEYER CLAY ADOBE SOIL.



From Table XXIV it is apparent that the peat increased the available moisture capacity to a greater extent than did the alfalfa and manure in the lighter textured soils but to no greater degree in the two heavier soils. The effect of alfalfa and manure is quite the same in all soils. The manure increased the available moisture to a slightly greater extent in the two lighter soils and the alfalfa increased the available moisture to a somewhat greater extent in the two heavier soils. There appears to be no correlation between the effects of the first addition of organic material and the successive amounts added.

Table XXIV

A Summary of the Effect of Organic Matter on the Available Moisture-Holding Capacity of Soils

Organic Material	Amount Percent	Percent Increase in Available Moisture: Medford Fine Sandy Loam	Medford Loam	Salem Clay Loam	Meyer Silty Clay Loam	Meyer Clay Adobe
Peat	3	49.70	33.21	35.73	1.28	15.30
	6	116.76	78.81	74.29	10.65	9.48
	9	163.51	97.89	92.64	42.07	52.20
	12	214.99	102.60	107.19	61.79	57.04
Alfalfa	3	24.66	36.30	18.18	22.88	20.90
	6	61.54	51.05	28.37	33.76	37.64
	9	100.00	63.19	40.74	41.16	53.08
	12	104.54	73.48	61.92	44.03	48.70
Manure	3	36.49	38.66	17.22	14.80	3.81
	6	62.72	58.11	28.21	16.54	26.86
	9	81.06	67.16	36.78	18.96	35.35
	12	110.05	83.76	36.05	23.86	44.39

DISCUSSION

The results obtained by mixing varying amounts of organic matter with the different soil types were significant in every case, each successive addition increasing the available moisture to some degree. This effect, though marked on the heavy soils, was greatest on the light-textured soils. In every case the greatest effect was produced by the addition of organic materials to the fine sandy loam. As the texture became heavier the effects obtained gradually became smaller.

These results compare favorably with those reported by Bouyoucos (1940) who concluded that organic matter increased the available moisture in light soils, and to a less extent in heavy soils. They also agree with the data presented by Sprague and Marrero (1932) indicating that organic materials increased the available moisture-holding capacity of the soil and that heavy applications increased it more than the light applications.

That there is a definite relation between the amount of organic matter in a soil and the amount of moisture the soil may hold for plant use is indicated by these results. Murphy (1933) studied moisture conditions under virgin soil in relation to a nearby cultivated field. He reported that average results showed that the virgin soil would retain

22.64 percent of moisture while similar cropland would retain 19.77 percent, or a difference of 2.87 percent, which represents moisture available for plant use. Jenny (1935) shows curves indicating that the moisture range throughout the growing season on a prairie sod indicated more available growth water in the virgin surface soil than the cultivated field nearby. He concludes that the available moisture varies with the amount of organic matter in the soil. The results of the present experiment verify his findings.

It will be noted that the effect of the peat on each soil in increasing the available capacity is more than additive as shown in the curves. In the light-textured soils this calculated additive effect was much less than the additional unaccounted for effect. As the soils become heavier the difference becomes smaller. These curves show definitely that the effect of peat is more than additive in increasing the available moisture. It may be assumed that the alfalfa and the manure would have shown similar results had it been possible to make a wilting point determination on these materials. This fact is substantiated by the findings of Luxmoore (1905) who concluded that the joint contribution of organic matter and mineral particles to the hydroscopic capacity of a soil is more than additive. He suggests that the reason was to be found in the organic matter being more effective than the coarse mineral particles in keeping the finer particles apart from one another and thus better able to exercise their strong surface attraction for water vapor.

The amount of colloidal material of a soil is a property of its texture, the sandy soil showing the least amount of colloids while the heaviest soils have the most. Table II shows the composition of the soils used in this study. Data have been presented by Baver (1940) indicating that organic matter is conducive to the formation of relatively large stable aggregates. If various soils are grouped according to their colloidal content, the effect of the organic matter is more pronounced in those soils containing the smaller amount of colloid. A high correlation exists between organic matter and aggregation in the soils containing less than 25 percent clay according to Baver. For clay contents above 25 percent the correlation is significant but not nearly so high.

Since the increase of available moisture from the use of organic matter shows a definite similar correlation as that of the degree of aggregation as presented by Baver it seems logical to assume that the effect producing the increased available moisture in this study is due, at least in part, to the influence of the organic materials in the formation of aggregates. Aggregation of the particles in any soil will tend to increase porosity. It is significant to note that the soil showing the greatest response according to Baver was the lowest in porosity. Since porosity varies with the size of the particles and the extent of aggregation the effect of the colloidal matter on aggregation of single-grain structure, to increase the capillary moisture, is quite evident.

A comparison between the organic matter content of a mineral soil and the colloids of the same soil show a much larger amount of organic matter in the colloids than in the coarser fraction of the soil. Tieh (1928). This confirms the general belief that most of the organic matter in soils is colloidal in nature. Thus the larger proportion of the organic material added to the soils would become colloidal in nature and capable of holding hydroscopic moisture similarly as the clay colloids. As the heavy soils are high in clay colloid and also higher in organic matter it would be expected that they would show the least response from the added organic materials. In the lighter textured soils the ratio of the non-capillary to capillary moisture is increased due to the intermingling of the organic colloid in the larger pore spaces of the soil thus decreasing the pore size to one of capillary size. As the wilting points were raised it is evident that all of the water held by the colloid is not available for plant use.

The improvement of moisture conditions in the heavier soils was not as great as in the lighter textured soils as there was a large amount of colloid present in the heavier soils and the organic colloid added did not increase the available moisture to as great an extent as in the lighter soils. Clay also has an effect on aggregation and the soils high in clay were in all probability aggregated to a great extent before the addition of the organic materials. Since organic matter is known to have a greater effect on aggregation than clay it would seem that this additional aggregation may be responsible for the increase in the available moisture.

There appears to be no direct correlation between the increase of available moisture and the amount of organic matter added, even though the greater additions increased the available capacity to a greater degree. There was no correlation between the increases of the same organic material in the various soils though the effect of the additions was greater in the light-textured soils. It is apparent from the data that the clay colloids present in the heavy soils served a part of the function that the organic matter served in the lighter soils. Thus the effects of the addition of organic matter are smaller on the heavier textured soils than on the lighter ones.

The significance of these data in terms of results which could be expected from an average application of organic material on cropland needs consideration. The largest increase in available moisture was from the addition of peat on Medford loam soil. From Table VIII it may be seen that a three percent addition of peat increased the available moisture 2.68 percent. This addition would be equivalent to 30 tons dry weight per acre eight-inch depth. Since peat is capable of holding from two to three hundred percent of moisture it is apparent that any amount of peat that could probably be economically added to soil would have a negligible effect on the available moisture-holding capacity.

The greatest effect of manure addition was on the Medford loam soil. In Table X the increase of available moisture from a three percent addition of manure is found to be 3.12 percent. It may be assumed from the effects produced by additional amounts that one percent addition would have increased the available moisture approximately one percent. A one percent addition to an acre eight-inch depth would require 10 tons of dry weight or approximately 40 tons of ordinary manure. This enormous application which is not only uneconomical but also impossible except in extreme cases would increase the available moisture but one percent.

If, however, organic matter is responsible for much of the available moisture in the soil the loss of humus resulting from poor methods of farming would tend to decrease the available moisture-holding capacity. Herein lies the principal significance of these data. It is commonly known that the virgin supply of organic matter may be depleted by 50 percent through unwise cultural practices. As the supply of organic matter decreases the available moisture holding capacity likewise decreases. It therefore becomes essential that organic matter be returned to the soil to replace and renew that lost through cultural practices. The purpose of management practices and organic additions to the soil is the maintenance of the natural level of the organic matter in the soil thus preventing decrease in available moisture holding capacity. This has been brought out in the results of the previously mentioned Morrow plots where the difference in moisture content on two similar plots after a period of rainfall was over 30 percent. The plot having the lowest moisture content had become depleted of organic matter while a renewal of humus on the other plot had maintained the organic matter supply.

CONCLUSIONS

The complexity of the soil organic matter introduces corresponding complexities in any attempt to formulate quantative physical relationships. The exact nature of the physical changes which take place when organic matter is incorporated into the soil are not definitely known, but from this study the following conclusions may be drawn:

(1) The addition of organic material to the soil increases the available moisture-holding capacity to an extent greater than the additive effect of the organic matter.

(2) The increase due to the addition of organic materials is greatest in the light-textured soils and decreases as the soils become heavier.

(3) There is a definite relationship between the amount of organic matter in the soil and the available moisture-holding capacity of the soil.

(4) There is no definite relationship between the increase in available capacity and the amount of organic matter added to the soil, though the two values increase together.

(5) There is no linear relationship between the successive additions of organic material and the corresponding increases.

(6) Although organic matter increases the available moisture-holding capacity of a soil any amounts added in ordinary practices would have a negligible effect in increasing the available moisture-holding capacity.

(7) The data would indicate the probable effect of organic matter depletion in reducing the available moisture holding capacity of the soil.

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