SOIL MOISTURE RETENTION CHARACTERISTICS OF CERTAIN OREGON SOILS AS RELATED TO MECHANICAL COMPOSITION AND ORGANIC MATTER CONTENT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SOIL MOISTURE RETENTION CHARACTERISTICS OF CERTAIN OREGON SOILS AS RELATED TO MECHANICAL COMPOSITION AND ORGANIC MATTER CONTENT

CHAPTER I

INTRODUCTION

In order to serve as a medium for plant growth the soil must store and deliver the moisture required by growing plants. All chemical and biological activities within the soil are dependant on this moisture. The amount and availability of moisture in soil determine which plants will grow and their relative abundance of yield.

Because of the importance of moisture in the growth of all plants soil moisture knowledge is of primary concern wherever soil is used for economic plant production. Studies of the problems of soil moisture absorption, storage, and movement are of particular interest in semi-arid and arid regions, for here soil moisture is the limiting factor in crop production. Thus we find irrigation to be the backbone of western agriculture. In the Willamette Valley, despite a comparatively heavy annual rainfall, the lack of rain during the latter part of the growing season has resulted in widespread installation of supplemental irrigation systems on farms in this area.

The need for more knowledge of soil moisture relationships, particularly its retention and movement, has developed with this increase in irrigated acreage.

With the understanding of moisture retention characteristics and the use of tools developed in recent years for the quantitative measurement of soil moisture in terms of moisture potential, it is possible to obtain a much broader insight into soil moisture movement and retention characteristics of agricultural soils. This study was instituted to apply these concepts and tools in obtaining a comparison of the moisture retention characteristics of certain cultivated and uncultivated Willamette Valley soils as related to their organic matter content and mechanical composition.

CHAPTER II

REVIEW OF LITERATURE

Water is held in the soil by forces of attraction. These forces are the result of the attraction of the soil particles for the water molecules and the cohesion of the water particles among themselves. This fundamental concept has long been accepted by soil scientists, and numerous attempts have been made to classify soil moisture into a definite number of categories on the basis of the kind of forces holding the soil water.

One of the earliest and most familiar of these attempts was that developed by Briggs (5) in 1897. He called that water held in thin films by adsorption on the soil particles hygroscopic. Capillary water was that portion held in the soil voids by surface tension, and gravitational water that which moves in and through these voids under the influence of gravity. Water in this latter category does not long remain in open, well-drained soil.

This classification attempts to explain the soil-water relationships on the basis of the types of forces exerted by the soil mass under varying moisture conditions, and is frequently referred to as the capillary tube hypothesis. The assumption could easily be drawn from this classification that soil moisture exists as distinct and separate "kinds" of water, and that all soil moisture falls readily into one of the categories. Such definitely is not the case, however, for there are no abrupt changes in soil water properties over the entire range of moisture conditions. An additional difficulty in the use of the system is that while it is qualitatively descriptive, its component parts are not readily determinable. Moreover, values in given categories vary widely from soil to soil, especially with respect to texture.

As the colloidal and absorptive properties of soil became more and more recognized many attempts were made to improve on this soil moisture classification. An example is that of Bouyoucos (1) which he based upon dilatometer studies. In view of the close agreement existing between the wilting coefficient and the unfree water as determined by the dilatometer method, he proposed the determination of this factor by the dilatometer method. The percentage of water that failed to freeze for the first time at the supercooling of -1.5° C was taken to represent the upper limits of moisture content at which plants may begin to wilt. The percentage of moisture that failed to freeze at -4° C was taken to represent the lower limits at which plants are able to extract moisture from soil. Bouyoucos then classified soil moisture as follows:

1. Gravitational - unsuitable or superavailable

2. Free - readily available

3. Unfree -(Capillary adsorbed - very
(slightly available
(
((water of hydration)
(combined (water of solid so-
lution) unavailable

Widtsoe and McLaughlin (43) worked with irrigated soils and designated a point of lento-capillarity in soils as that point below which capillary movements become sluggish.

Lebedeff (19) considered the following forms of water in soil:

1. Vapor phase. Water, or moisture in the gas state, moving from a gradient of higher to lower vapor pressure.

2. Hygroscopic water. Molecules of water vapor held on the surface of soil particles by the forces of cohesion.

3. Film water. Water under the influence of the molecular forces of cohesion between the soil particles and the water.

4. Gravitational water. Moisture moving under the influence of gravitational forces.

   (a) Capillary water was that filling up the pores which are capable of drawing water upward from the water table.

(b) Suspended water represented gravitational water having no connection with the ground water as if it were suspended in the soil.

(c) Gravitational water in a condition of falling.

5. Solid phase.
6. Water of crystalization.
7. Chemically combined constitutional water.

All three of these classifications of soil moisture had the same drawbacks as the capillary tube hypothesis.

In 1907 Buckingham (8) had first proposed the use of a potential function psi (ψ), better known as capillary potential to describe soil moisture conditions. He defined capillary potential as the work required to move unit mass of water from a point in the soil to a free water surface. It marked the beginning of the energy concept of soil moisture relationships as recognized today.

Buckingham's paper went unnoticed for over a decade, then his potential function was redefined by Gardner (14) bringing it more into line with other potential functions recognized by physicists. The new definition, promptly accepted by soil scientists (17), made the capillary potential represent the work done against the capillary field force[1] in moving unit mass of water from the flat

[1] Capillary field force is interpreted in this case to be the force set up in the soil water configuration due to attraction of the soil particles for the water molecules.

water surface to the point in question. This changed the algebraic sign of Buckingham's function, but did not alter it numerically.

L. A. Richards recognized the value of the potential concept in moisture flow phenomena (24). He stated that it explained capillary flow in the dynamic soil system. Since the velocity of flow in unsaturated soils is proportional to the difference in the potential between any two points, it is then proportional to the difference in capillary potential, and direction of flow is from regions of high potentials to low, or in other words, low to high tensions. Russell (34) pointed out the fact that since it is a function of soil water, capillary potential is not influenced by the texture, structure or composition of the soil, and therefore provides a logical basis for comparing many soil properties which are affected by moisture conditions.

Soon after the new energy concept was outlined, apparatus for the quantitative determination of capillary potential appeared in the form of autoirrigators (20). Livingston apparently was not aware of Buckingham's work at the time, but his equipment could be used as a quantitative means of controlling the capillary potential in soil.

In 1922 Gardner and associates (15) outlined a method of measuring the value of capillary potential by the use of porous clay equipment. L. A. Richards began with a capillary potentiometer (24) and developed it into the tensiometer (29), which is essentially the combination of a porous clay cup connected to a closed system including a mercury manometer. Equilibrium is established between the soil and the cup by moisture movements in and out of the cup which create volume differences measured by the mercury manometer. This apparatus, now widely used in field studies, functions within the one atmosphere tension range. Thus, when relatively high moisture conditions prevail, it is useful in water depth and penetration studies, for studies of rates of water use by plants at different levels, and as a means of timing applications of water, thereby increasing the efficiency of irrigation.

Suction plate apparatus for moisture extraction was developed by Richards and Weaver (32) to obtain sorption data in the one atmosphere range of tension. Pressure was found to be more convenient than suction, so pressure plate equipment (28) is used at present. In the procedure, details of which will be described later in this paper, natural cores of soil are placed on ceramic plates, subjected to pressure, and moisture retention noted. The equipment is valuable in obtaining a quantitative measure of moisture transfer rates in unsaturated soils, and in studying hysteresis effect.

Porous plate apparatus of Richards (27) is a variation of the pressure plate equipment and since it involves the use of a large pressure-cooker chamber, it is particularly adapted to large numbers of samples. It is not suitable for obtaining moisture characteristic curves over a series of tension equilibria by measuring water outflow, but rather for measuring moisture retention at discrete tension values in the one atmosphere range. By mounting the soil column in the pressure chamber between two copper-backed porous plates it is claimed that this apparatus is quite suitable for measuring the unsaturated permeability of soil columns.

Richards and Weaver developed a sorption-block moisture meter (30) for direct measurement of moisture at low tensions under field conditions. The equipment is based on the fact that carefully made porous blocks will absorb moisture and come to equilibrium when placed in contact with moist soil. The blocks are removed and weighed to determine the amount of sorption.

One atmosphere tension represents about six per cent of the so-called useful range of soil moisture content in terms of numerical tension values and while the major portion of the moisture for plant use falls within this limit, it is desirable to follow moisture movements in soil at tensions above one atmosphere.

Bouyoucos and Mick (3) designed absorption blocks for such studies under field conditions. These blocks are based on the same principle as the sorption block moisture meter which appeared later. Electrodes are imbedded in plaster of Paris blocks or fabric adsorption units (4), which are placed in the soil. Since the moisture content determines its electrical resistance, the block is wired to an adaptation of the Wheatstone bridge, and thus capillary potential is expressed as ohms of resistance.

Whitney, Gardner, and Briggs (42, 13, 6) carried out elaborate investigations on the electrical resistance of soils, using two carbon electrodes in the soil and an alternating current to avoid polarization. Objections to the two-electrode method include 1) errors in the measuring of variations in moisture content due to interference caused by variations in salt content, and 2) the fact that the method measures the sum of both the soil resistance and the contact resistance between the electrode and the soil. This latter resistance is very erratic and not reproducible.

McCorkle (21) and Goldsmith (16) began using four electrodes as a means of eliminating the contact resistance between the electrodes and the soil, but it was Edlefsen and Anderson (11) who improved the equipment by using tinned iron electrodes rather than carbon, and made this method feasible for indicating variations in soil-moisture content.

For laboratory studies, L. A. Richards' (25) pressure membrane apparatus involves the application of air pressure to previously wetted disturbed soil samples on a cellulose membrane in a closed chamber, and moisture retention at equilibrium is noted for each applied pressure.

Other equipment and techniques have been used in the determination of moisture tension relationships. Russell and Richards (36) used the centrifuge to determine pF at various moisture percentages. Schofield and Da Costa (37) modified Bouyoucos' freezing point method to determine the pF at permanent wilting percentage and moisture equivalent. The principle of the freezing point dilatometer method is based upon the fact that water expands upon freezing, and if the amount of expansion that a certain quantity of water, one gram, produces upon freezing is known then the quantity of water that freezes in the soil can be calculated from the magnitude of expansion produced.

Attempts have been made to adapt the dielectric constant property of soils to measurement of moisture, and Fletcher (12) described equipment for this purpose. A special condensor is placed in the soil and after equilibrium with soil water is attained readings are made by means of a suitable capacitor. Water has a high dielectric constant and soil has a low constant, and in the lower ranges of moisture content a linear relationship exists between dielectric constant and amount of moisture in soil.

From the preceeding it can be seen that there are many methods of expressing the energy relationships of soil and water. Generally, researchers have plotted the capillary potential, as centimeters of water or mercury suction or pressure, pF, or ohms of resistance, against the soil moisture content. Such curves are called moisture sorption curves or soil moisture characteristic curves (10). Kohnke (18), in presenting an interesting table of soil moisture relationships, urges popular acceptance of the term pF in the hope that it will make soils men conscious of the energy relationships between soil and water.

Since the energy concept of soil moisture relationships entered the thinking of soil scientists considerable attention has been directed at moisture movement and availability to plants, for the potential theory is particularly applicable to these phenomena (24). Richards explained soil moisture movement in terms of capillary potential in the following cases: 1) Flow of moisture downward through soil after rainfall or irrigation, 2) flow of moisture upward from a saturated water table, and 3) movement of moisture in a horizontal direction. The availability of soil water to plants involves two factors, the "security" with which the soil holds its water, and the readiness with which moisture moves in to replace that taken up by the plant. The capillary potential is a direct measure of this "security" factor.

The energy concept explains the effect of the water table on moisture movement. The maximum tension that can be developed at a given point in field soil by downward drainage is equal to the elevation of the point above the water table (26).

The application of the potential theory to soil moisture problems has led to some interesting basic information applicable to all soils. Richards (25) observed that at 16 atmospheres tension, or pF 4.22, soils were slightly drier than at wilting percentage, and has since designated 15 atmospheres as extracting pressure for this determination (39). Unpublished data at this station indicates close corelation between these values.

Richards and Weaver (31) found that the moisture equivalent of soils closely approximated the one-third atmosphere percentage, or pF 2.54, for medium textured soils. Schofield and Da Costa (37), using the freezing point technique, report that moisture equivalent lies within the limits of pF 2.5 and 3.0. Kohnke (18) recommends that the following soil moisture constants be recognized:

Moisture point	pF
Maximum moisture-holding capacity	∅
Aeration porosity limit	1.7
Field capacity	2.7
Wilting percentage	4.15
Hygroscopic coefficient	4.5

Russell (35) studied the relationship between the moisture content and capillary potential in four texturally different Iowa soils over the entire range of moisture content from saturation to oven-dryness and plotted soil moisture sorption curves for them. He found that the pF at the wilting point decreased as the texture became finer.

There is now a large literature on the subject of soil moisture based upon the energy concept of soil and water relationships and using the tools for the measurement of these relationships. These measurements have not been made on many Oregon soils, and this paper covers a study of five agriculturally-important soil series of this region.

CHAPTER III

DESCRIPTION OF SOILS AND SOIL SITES

Five representative Western Oregon soil series were chosen for this study. The Chehalis and Newberg series represent the best of the recent-alluvial soils which include stream-laid deposits still in the process of accumulation or deposited so recently that they have undergone little if any profile development. Two extremes in agricultural value of the group of transported soils occupying the main valley floor are represented by the Willamette and Dayton series. The Melbourne series is one of the group of residual soils that have been formed by the weathering in place of consolidated sedimentary rock materials. Detailed descriptions of all these soils and their types can be found in the soil survey report of Benton County, Oregon (9).

The river-bottom or alluvial soils should not show much variation in soil moisture retention characteristics as a result of cultural practices because they have not long been subjected to weathering processes. On the other hand, considerable changes in these properties due to management procedures may have occurred in the more weathered valley floor and residual groups of soils. Therefore, sites representing long-time cultivation and, in contrast, as nearly virgin conditions as possible, were selected for the Willamette, Dayton, and Melbourne series.

Field volume weight determinations on the upper horizons of the soils were made on November 13, 1949, about 36 hours after a rainfall. The autumn rains had not as yet wetted the entire profiles, in the case of some series, only 20 inches of soil was moist, so moisture contents at the time of sampling may not have been reliable field capacity values.

<u>Location of Sampling Sites</u>:

Bulk samples from all sites were obtained during April, 1949, at which time the soils were moist but below field capacity. Natural cores for pressure plate studies were procured in August, 1949, when all the soils were considerably drier. Very satisfactory cores were obtained by using specially prepared steel cans rather than conventional steel rings.

The Newberg site was a gently-undulating field about one and one-half miles from Corvallis in the north half of SW¼SW¼, T11S, R5W. Hops have been grown on the area for several years. In 1948 a mixed grass pasture for sheep was seeded, and in 1949 after the bulk sample was obtained the area was seeded to oats. Harvest was completed prior to the date core samples were secured.

The Chehalis site was located not far from the Newberg in the southwest quarter of NW¼SW¼, T11S, R4W. The field had a slightly undulating topography. In recent years the field was in strawberries and at the time of bulk sampling the winter cover crop of grass had not been plowed under. In the 1949 crop season the field was handled similarly to the Newberg site.

The Willamette cultivated site was located in the south half of NE¼SW¼, T11S, R5W. This gently-sloping, well-drained field was in a young filbert orchard. Apparently not cover cropped, the field was overgrown with thistles and weeds.

The uncultivated site was located in the southwest quarter of SE¼, T11S, R5W. This area is a vacant block within the Corvallis city limits which has supported wild hay and weeds for many years.

Samples of Dayton soil, both cultivated and uncultivated, were obtained from the "whiteland" flat south of Corvallis in the southeast quarter of SW¼NE¼, T12S, R5W. The cultivated field was in pasture at the time of bulk sampling, although probably a seed crop had been harvested in 1948. The field was plowed and disked just prior to core sampling. The uncultivated site samples were obtained along a fence row adjacent to the cultivated field.

The samples of cultivated Melbourne soil were obtained from a typical grain farm on a hill west of Corvallis in the east half of NW¼NW¼, T12S, R5W. The virgin Melbourne site was a grass and forested area bordering the grain field.

CHAPTER IV

METHODS OF ANALYSIS

Mechanical analysis: The percentages of the soil separates were obtained by the Bouyoucos hydrometer method (2). Silt percentage was calculated by the formula 100 - (percent sand + percent clay). Textures were assigned from the guide of the U. S. Department of Agriculture (38), which recognizes the two micron limit of clay size particles.

Organic matter content. This was obtained by the Walkley and Black wet oxidation method (41, 40), using 0.4N ferrous ammonium sulfate in place of N ferrous sulfate.

Moisture equivalent: The standard method as outlined by Briggs and McLane (7) was used for this determination. Maximum speed that could be developed by the centrifuge employed was 2390 revolutions per minute, which would introduce some error in the results, tending to make them a little high.

Moisture sorption data: Moisture retention of disturbed samples in the tension range from two to fifteen atmospheres was determined by the method of Reitemeir and Richards (23, 25) utilizing pressure-membrane apparatus. Nitrogen tanks were used to supply the necessary pressures. Data on moisture retention in the one atmosphere tension range with natural cores was obtained by the Richards and

Fireman procedure (28, 39). A pressure well consisting of 6 six foot sections of pipe with an inside diameter of about two inches was employed. Pipe sections were connected from the top of one to the bottom of the next by lengths of rubber pressure tubing, giving the effect of a pressure well 36 feet high, which it was not feasible to construct in one piece. Pressure was supplied from a compressed air source and provision for filling with water was made at the top of each section of pipe by means of three-inch long nipples to which short sections of rubber tubing were wired. Water was admitted by pouring into a funnel in these sections of tubing. When the apparatus was in use, these extensions were clamped off. Drainage was provided by a radiator-type draincock at the bottom of each six-foot section. A mercury manometer was connected to the air line system and used to determine extraction pressures.

Steel cans 5.8 centimeters in diameter and 4 centimeters high with a 1/16 inch diameter hole in the base were used for collecting the undisturbed samples, and moisture retention data was obtained by inverting the cans on the porous plates and removing and weighing cans at each equilibrium point. Determinations were made in duplicate throughout the moisture retention studies.

Points on the moisture retention curves were chosen at 20, 100, 345, 500 and 1000 centimeters of water pressure. Considerable time would have to be spent in adjusting to these exact values, so an estimated amount of water was added to the well for each new equilibrium pressure desired. No attempt was made to obtain the exact pressure, but manometer readings were carefully noted at each equilibrium point.

Field volume weight: Iron rings of about 200 cubic centimeters capacity were driven into the A horizons of the soils, removed, and weighed. In the B horizons, the samples were removed very carefully by means of an orchard-type auger, the soil immediately weighed and volume of the hole measured. Reweighing after oven-drying gave moisture content and data for field volume weight, which was computed by the formula:

$$\text{field volume weight} = \frac{\text{dry weight of soil in ring}}{\text{volume of ring in cc.}}$$

Notations and terminology used in this paper: The following table is presented to show relationships and notations for certain values to be used throughout this paper.

Value	Centimeters of water equivalent	pF equivalent	Notation used in paper
Moisture content at a tension of 100 centimeters of water	100	2.00	100 centimeter point
Moisture content at a tension of 1000 centimeters of water	1000	3.00	1000 centimeter point
Moisture content at a tension of 2 atmospheres	2072	3.32	2 atmosphere point
Moisture content at a tension of 15 atmospheres	15540	4.19	15 atmosphere point

Soil moisture from the 100 centimeter point to the 15 atmosphere point will be termed useful water capacity. Moisture from the 100 centimeter point to the 2 atmosphere point will be referred to as the lower range or readily available range of moisture. The upper range or slowly available range of moisture will refer to moisture from the 2 atmosphere point to the 15 atmosphere point. High tension means a low moisture content and low tension means a high moisture content.

CHAPTER V

TABLE I

MECHANICAL ANALYSES, ORGANIC MATTER CONTENT, AND MOISTURE EQUIVALENT

Soil	Depth (inches)	% of Separates Sand .05 mm	Silt .05-.002	Clay .005	Clay .002	Org. Matter Content %	Moisture Equiv. %
Newberg cultivated	0-12	64.1	24.2	14.2	11.7	1.23	17.4
	12-24	66.5	24.2	15.8	9.3	1.03	15.2
	24-36	66.6	22.1	13.4	11.3	.72	18.4
Chehalis cultivated	0-12	45.8	34.5	25.7	19.7	2.82	24.8
	12-24	49.4	32.6	24.3	18.0	2.33	24.4
	24-36	40.6	40.6	26.1	18.8	1.48	26.9
	36-48	33.4	42.0	30.1	24.6	.34	27.6
Willamette uncultivated	0- 9	15.7	53.3	38.6	31.0	4.74	30.4
	9-19	12.8	54.4	41.6	32.8	3.33	27.8
	19-30	15.9	52.5	41.2	31.6	1.66	25.6
	30-38	11.4	56.4	41.3	32.2	1.41	31.2
	39-48	8.5	64.8	38.8	26.7	.49	35.4
Willamette cultivated	0- 9	12.6	55.2	39.9	32.2	3.40	28.8
	9-18	13.8	55.9	37.7	30.3	2.18	23.2
	18-27	8.6	61.7	38.3	29.7	.77	25.0
	27-34	8.6	65.6	34.4	25.8	.54	35.3
	38-47	8.5	64.8	35.8	26.7	.24	27.6

TABLE I

continued

Soil	Depth (inches)	% of Separates: Sand .05 mm	Silt .05-.002	Clay .005	Clay .002	Org. Matter Content %	Moisture Equiv. %
Dayton uncultivated	0-12	12.0	60.0	37.6	28.0	2.38	30.8
	14-20	14.0	54.2	38.8	31.8	1.28	27.3
	20-29	10.0	49.4	50.6	40.6	.85	33.0
	29-42	8.6	39.0	45.4	52.4	.51	37.9
	42-45	6.0	61.6	40.0	32.4	.22	38.2
Dayton cultivated	0- 8	12.2	64.0	32.4	23.8	2.08	30.0
	8-14	12.4	57.6	36.6	30.0	.99	27.4
	14-22	8.4	44.2	55.0	47.4	.60	38.3
	22-33	10.4	53.0	44.6	36.6	.48	38.8
	33-48	10.4	67.4	29.6	22.2	-	34.2
Melbourne uncultivated	0-12	26.3	40.3	33.4	33.4	3.34	30.2
	12-24	24.6	36.7	38.7	38.7	1.51	29.1
	24-37	36.8	31.8	31.4	31.4	.61	28.0
Melbourne cultivated	0- 8	25.8	41.3	40.0	32.9	2.35	21.6
	8-20	24.5	38.4	41.2	37.1	1.62	22.4
	20-30	32.8	32.8	35.4	34.4	.83	24.9

The mechanical analyses of the soils studied are shown in Table I. The Newberg series is the lightest-textured of all the soil samples, with over sixty percent of its constituents in all horizons being sand. There is little variation in texture throughout the profile. The texture of the Chehalis sample is somewhat heavier than the Newberg; there is less sand but more silt and clay. Here also little change in texture occurs between horizons, although in the C horizon the sand content decreases and clay content increases in relation to the other two horizons.

The Willamette samples are finer-textured than the Chehalis, having higher silt and clay percentages at the expense of the sand content. There are no significant textural differences between the cultivated and uncultivated site samples. Generally, the sand and clay percentages tend to decrease and the silt content to increase with depth. As in the case of the Newberg and Chehalis soils, all of the Willamette horizons fall within the same textural class, in this case silty clay loam. The cultivated and uncultivated Dayton series samples do not fall into the same textural classes by horizons. The textural classes of the uncultivated site, by horizons and subhorizons from A to C are: silty clay loam, silty clay loam, silty clay, silty clay loam, and silty clay loam. The classes of the cultivated site horizons are: silt loam, silty clay loam, silty clay, silty clay loam, and silt loam. In both cases the soils are somewhat finer-textured at the middle of the profile than at either the surface or parent material horizons. In other words, in the B_1 horizon of the Dayton soils sand content is considerably lower and clay content considerably higher than the other horizons.

All horizons of the two Melbourne sites are classed as clay loam, and in both cases there is a tendency for the percentage of sand to increase and silt to decrease with depth.

Results of organic matter determinations are shown in Table I. In all cases the percent of organic matter decreased with depth. The Newberg soil contained the least amount of organic matter; the Chehalis contained roughly twice as much. The Willamette cultivated soil contained from 3.40 percent organic matter in the A horizon down to 0.24 percent in the C horizon, while the uncultivated horizons went from 4.74 percent down to 0.49 percent. A similar condition was noted in the two Dayton samples. The cultivated soil contained 2.08 percent organic matter in the A horizon and none in the C horizon, while the horizons from the uncultivated site varied from 2.38 percent in the surface horizon to 0.22 percent in the C horizon.

More marked differences in organic matter content between cultivated and virgin sites appeared in the Melbourne series. The surface soil of the virgin site contained 3.34 percent organic matter and the corresponding cultivated site sample contained only 2.35 percent. In this series, however, it should be noted that the cultivated site B and C horizons contained higher percentages of organic matter than the virgin site.

Moisture equivalent data for these soils also appear in Table I. The relatively coarse-textured Newberg soil had the lowest moisture equivalent points. The B horizon had a lower value than either the A or C horizons. The moisture equivalent percentage tended to increase slightly with depth in the Chehalis soil, proceeding from 24.75 percent in the surface soil to 27.63 percent at the 36 to 48 inch depth. Moisture equivalent percentage decreased with depth in the first three horizons of the Willamette uncultivated site sample from 30.45 percent to 25.65 percent, then rose again to a C horizon value of 35.35 percent. A somewhat similar condition prevailed in the cultivated site from sample with a decrease in percentage of the A_2 from the A_1 horizon, followed by a rise to the high value of 35.3 percent in the B_2 horizon, and then a drop to 27.6 percent in the C horizon.

Moisture equivalent values for the Dayton uncultivated soil generally followed the trend of the

Willamette cultivated site, but were somewhat higher and did not decrease in the C horizon. The Dayton cultivated soil did follow the Willamette cultivated soil pattern in moisture equivalent points; the surface soil value was 29.97 percent, then down to 27.35 percent in the A_2 layer, and up to 38.27 percent in the B_1 horizon, climbing to 38.75 percent in the B_2 horizon, and falling to 34.2 percent in the parent material. Moisture equivalent points were much higher in the Melbourne virgin site horizons than the cultivated site horizons, and while the values increased with depth in the cultivated site, they decreased with depth in the virgin site.

Data on the moisture retention characteristics of these soils in the one atmosphere and the two to fifteen atmosphere range of tensions appear in Table II and the moisture-tension curves appear in Figures 1_A to 1_H. Field volume weight data appears in Table III.

The natural cores that were used for the one atmosphere range study were procured at two depths, 0 to 6 inches and from 6 to 12 inches. The disturbed samples used in the two to fifteen atmosphere range were taken from horizon levels. A preliminary examination of the data indicated the desirability of moisture retention information on disturbed samples in the one-atmosphere range as a means of bringing together the data on the

TABLE II

MOISTURE RETENTION CHARACTERISTICS[1]

Soil	Depth (inches)	Percent Water Retained at centimeters of water: 100	345	500	1000	atmospheres: 2	15
Newberg cultivated	0- 6	22.4	18.0	17.2	16.2		
	6-12	23.5	19.9	18.2	16.5		
	0-12					12.62	9.26
	12-24					11.50	8.58
Chehalis cultivated	0- 6	26.0	22.7	21.5	19.3		
	6-12	23.8	21.4	20.3	18.2		
	0-12					17.60	11.50
	12-24					17.56	11.38
Willamette uncultivated	0- 6	31.4	28.9	28.0	26.6		
	6-12	30.8	28.2	26.6	25.6		
	0- 9					26.21	14.06
	9-19					23.39	12.02
Willamette cultivated	0- 6	29.8	27.3	26.7	24.2		
	6-12	29.6	26.8	24.4	21.6		
	0- 9	36.7*	31.2*	29.3*	25.9*	24.69	11.00
	9-18					23.96	11.27

[1] Undisturbed samples were used in the 100-1000 centimeters of water range except as noted, and disturbed samples were used in the 2-15 atmosphere range.

* Disturbed sample

TABLE II

continued

Soil	Depth (inches)	Percent Water Retained at centimeters of water 100	345	500	1000	atmospheres 2	15
Dayton	0- 6	33.7	30.6	28.7	26.2		
uncultivated	6-12	31.9	28.4	26.3	26.0		
	0-12					20.65	9.83
	14-20					20.12	10.78
Dayton	0- 6	32.6	29.5	27.5	23.6		
cultivated	6-12	31.2	27.3	26.7	25.8		
	0- 8	42.1*	36.2*	32.7*	24.2*	15.75	8.29
	8-14					17.90	10.98
Melbourne	0- 6	26.0	24.3	22.4	18.6		
uncultivated	6-12	28.5	25.8	24.2	21.7		
	0-12	39.5*	29.8*	28.3*	25.2*	22.89	14.02
	12-24					21.20	13.27
Melbourne	0- 6	31.1	26.7	25.6	24.0		
cultivated	6-12	26.2	24.1	23.5	21.6		
	0- 8					22.61	12.48
	8-20					21.96	13.37

* Disturbed sample

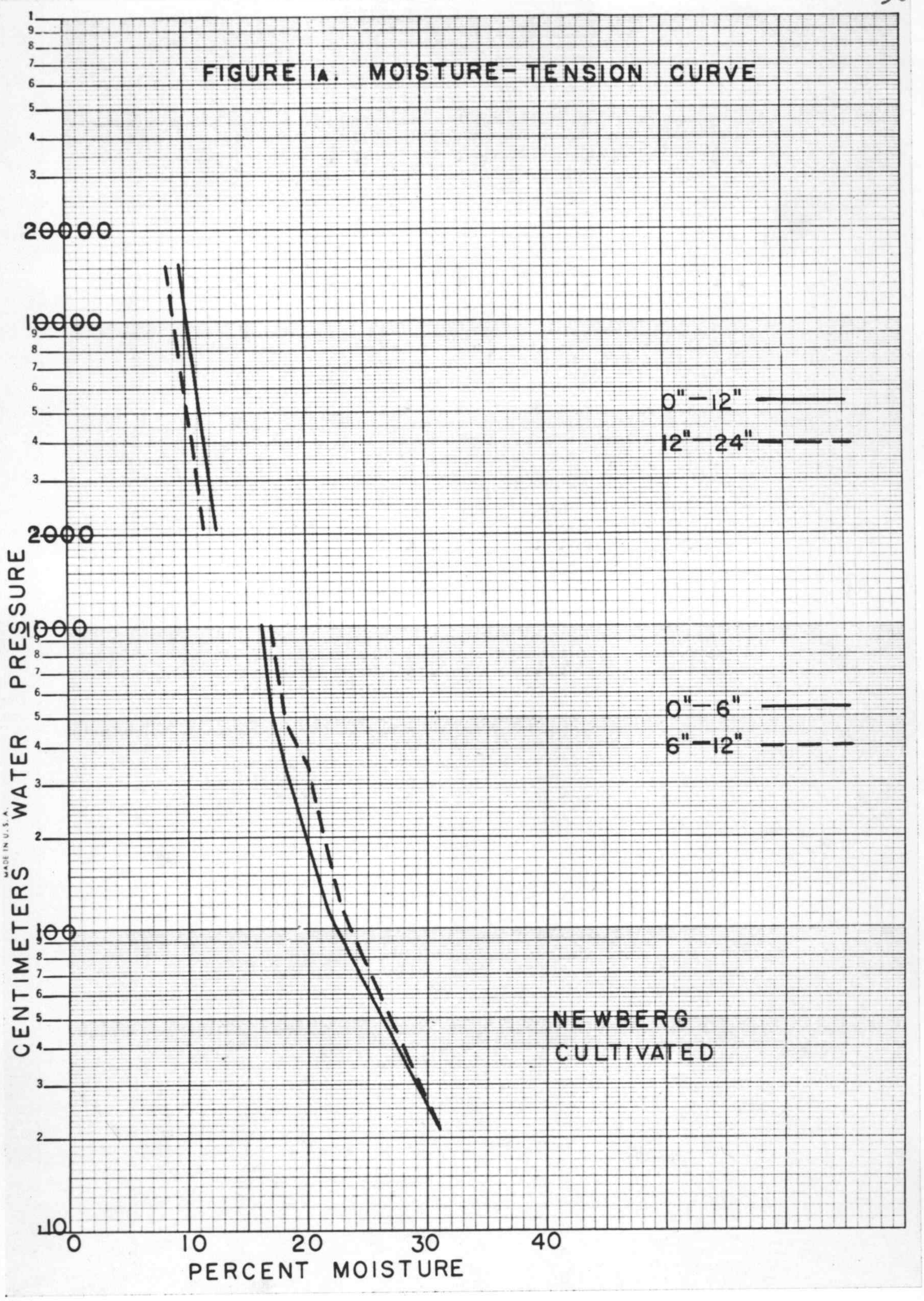


FIGURE IA. MOISTURE-TENSION CURVE
0"-12"
12"-24"
0"-6"
6"-12"
NEWBERG
CULTIVATED
20000
10000
2000
1000
100
10
0
10
20
30
40
PERCENT MOISTURE
CENTIMETERS WATER PRESSURE
MADE IN U.S.A.

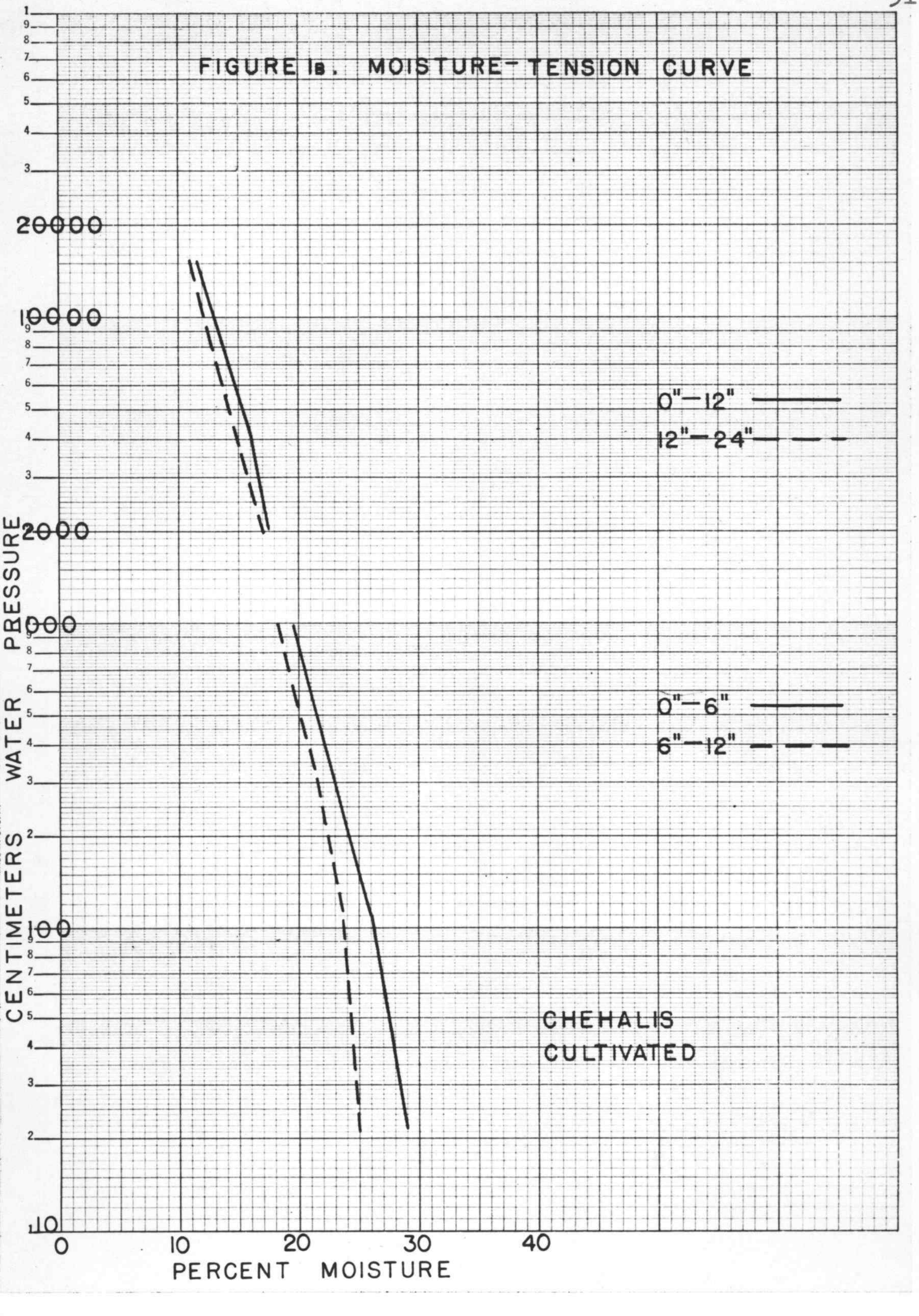


FIGURE 1B. MOISTURE-TENSION CURVE
20000
10000
2000
1000
100
10
0
10
20
30
40
PERCENT MOISTURE
CENTIMETERS WATER PRESSURE
0"-12"
12"-24"
0"-6"
6"-12"
CHEHALIS
CULTIVATED

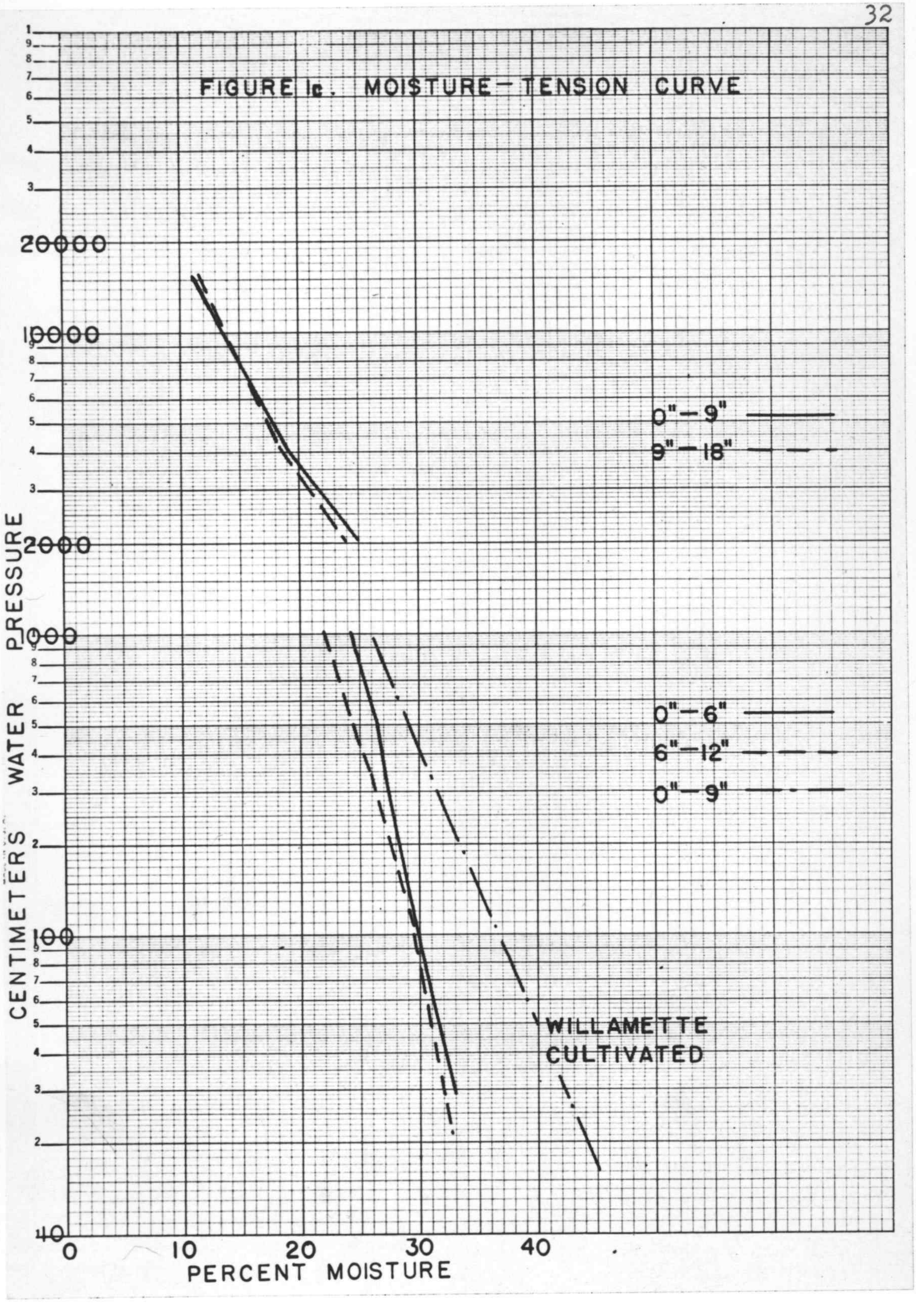


FIGURE Ic. MOISTURE-TENSION CURVE
CENTIMETERS WATER PRESSURE
20000
10000
2000
1000
100
40
0
10
20
30
40
PERCENT MOISTURE
0"-9"
9"-18"
0"-6"
6"-12"
0"-9"
WILLAMETTE
CULTIVATED

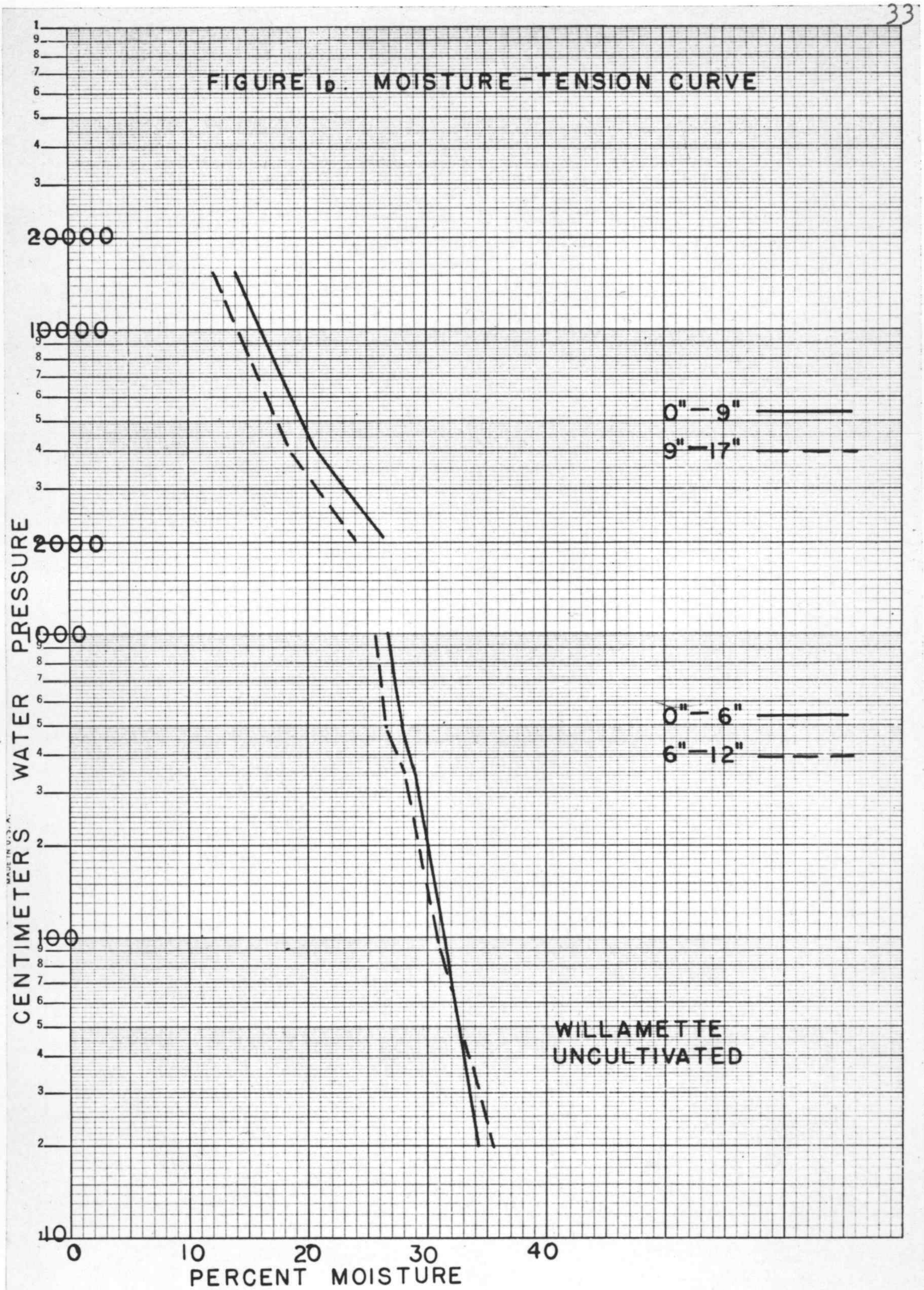


FIGURE I D. MOISTURE-TENSION CURVE
20000
10000
2000
1000
100
10
0
10
20
30
40
PERCENT MOISTURE
CENTIMETERS WATER PRESSURE
0"—9"
9"—17"
0"—6"
6"—12"
WILLAMETTE
UNCULTIVATED

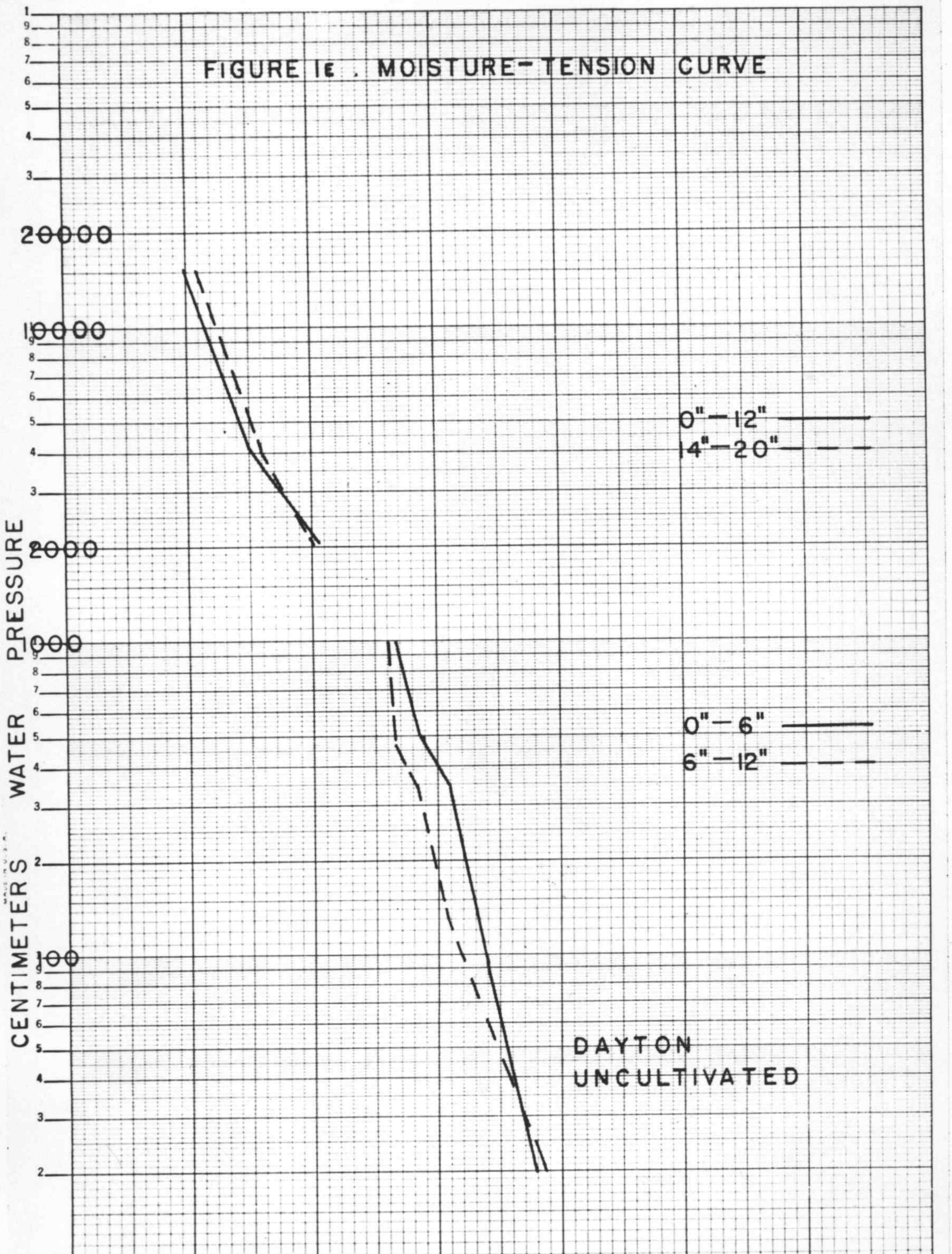


FIGURE 1E . MOISTURE-TENSION CURVE
0"-12"
14"-20"
0"-6"
6"-12"
DAYTON
UNCULTIVATED
CENTIMETERS WATER PRESSURE
20000
10000
2000
1000
100
10
0
10
20
30
40
PERCENT MOISTURE

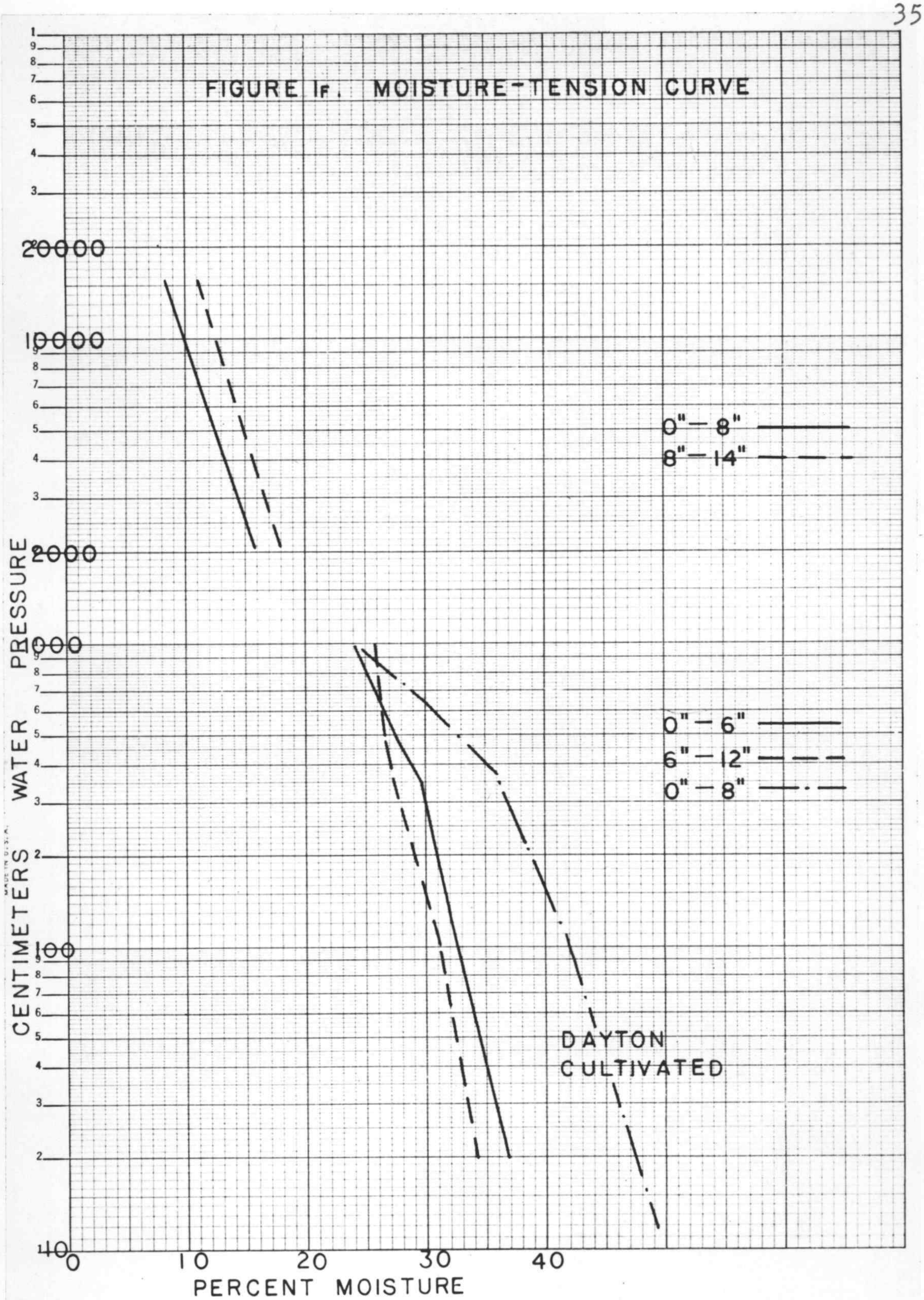


FIGURE 1F. MOISTURE-TENSION CURVE
20000
10000
2000
1000
100
10
0
10
20
30
40
PERCENT MOISTURE
CENTIMETERS WATER PRESSURE
0" - 8"
8" - 14"
0" - 6"
6" - 12"
0" - 8"
DAYTON
CULTIVATED

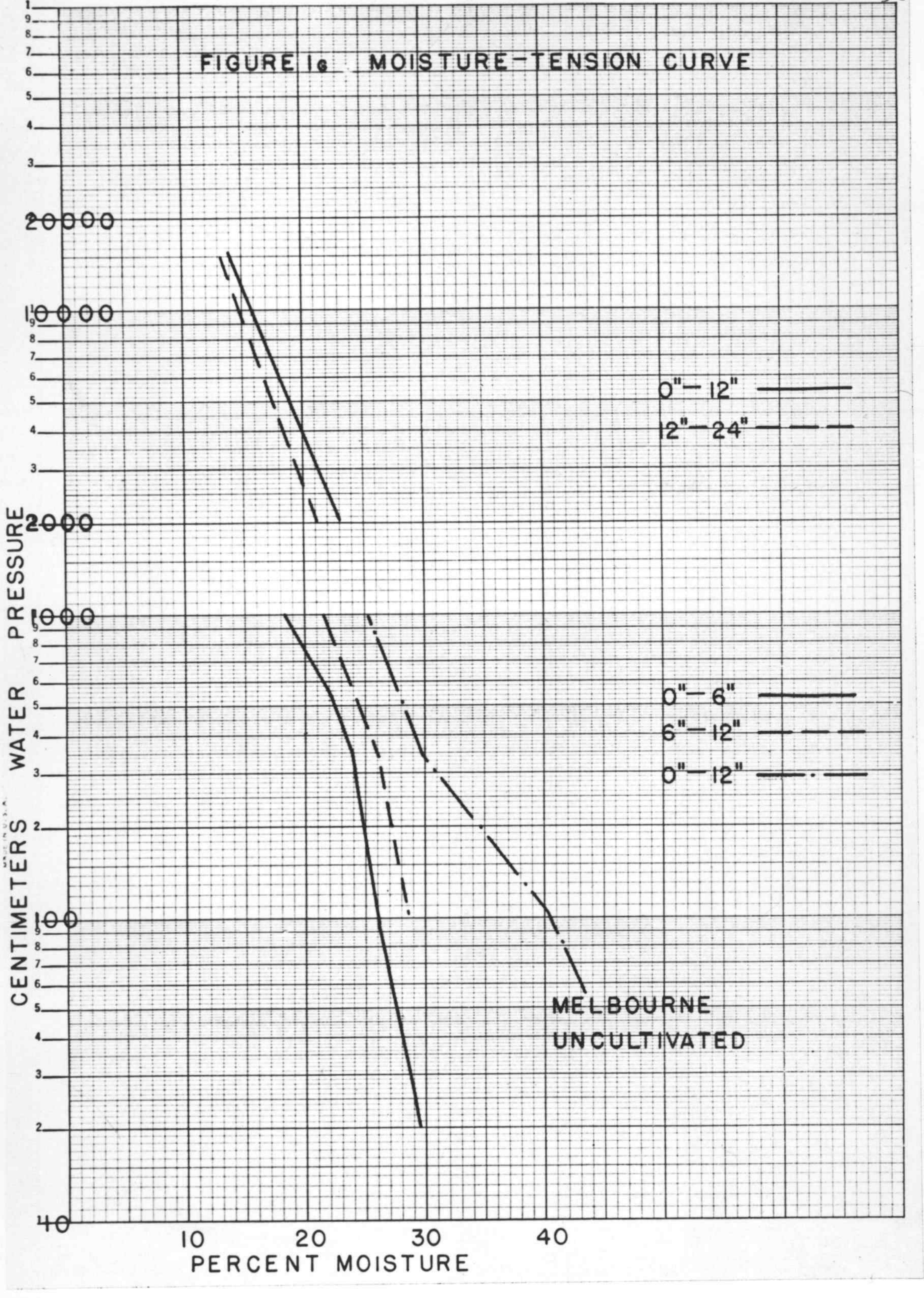


FIGURE 16 MOISTURE-TENSION CURVE
20000
10000
2000
1000
100
40
0"–12"
12"–24"
0"–6"
6"–12"
0"–12"
MELBOURNE
UNCULTIVATED
CENTIMETERS WATER PRESSURE
10
20
30
40
PERCENT MOISTURE

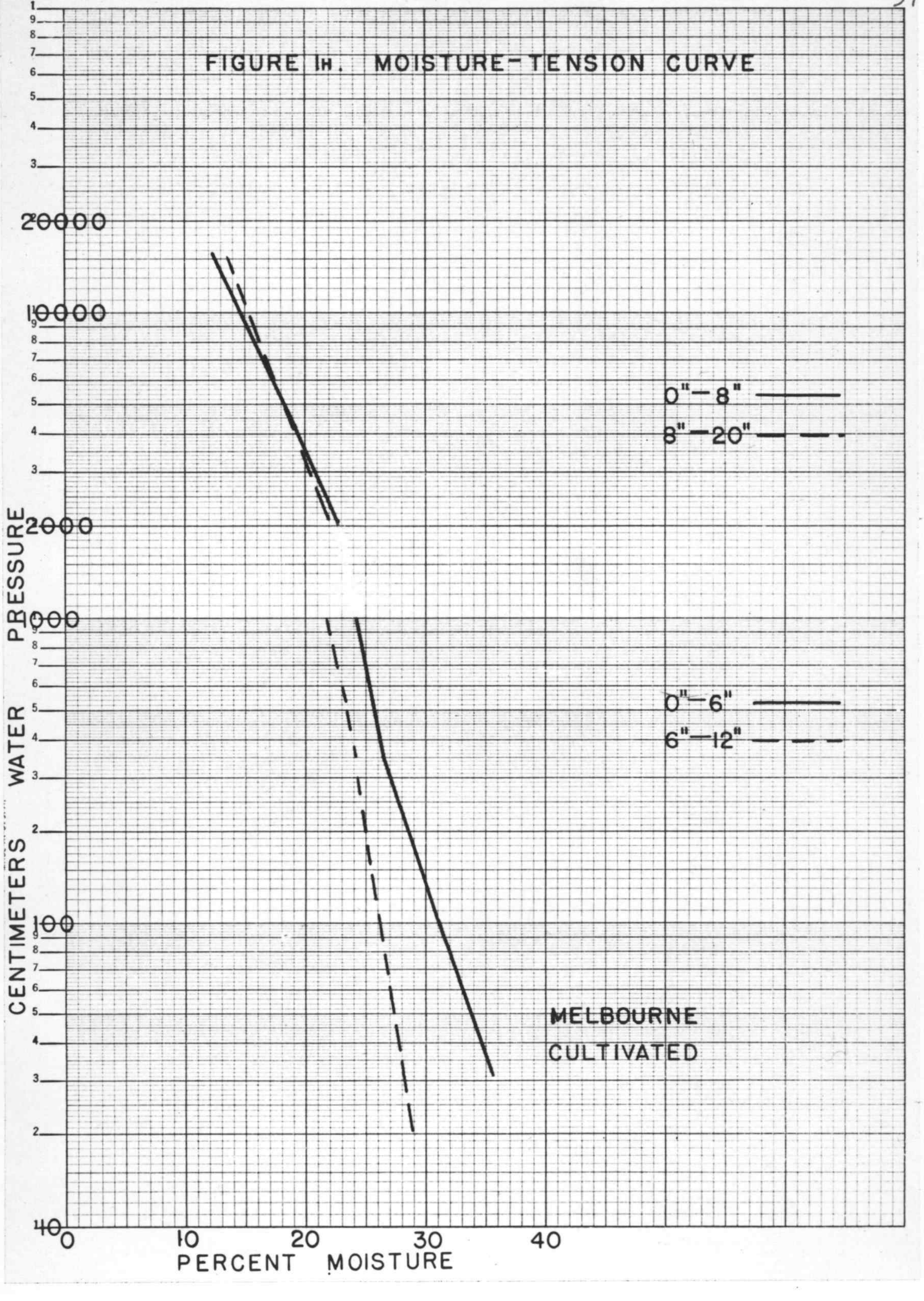


FIGURE 1H. MOISTURE-TENSION CURVE
CENTIMETERS WATER PRESSURE
20000
10000
2000
1000
100
40
0
10
20
30
40
PERCENT MOISTURE
0"-8"
8"-20"
0"-6"
6"-12"
MELBOURNE
CULTIVATED

TABLE III

FIELD VOLUME WEIGHT AND USEABLE WATER CAPACITY IN FIRST FOOT OF SOIL

Soil	Depth (inches)	Field Volume Weight	Useable Water* Capacity (inches)	Useable Water* Capacity: Inches in first foot
Newberg cultivated	0-12	1.315	2.16	2.16
Chehalis cultivated	0-12	1.304	2.10	2.10
Willamette cultivated	0- 6	1.314	1.48	
	6-12	1.317	1.46	2.94
Willamette uncultivated	0- 6	1.285	1.34	
	6-12	1.283	1.37	2.71
Dayton uncultivated	0-12	1.215	3.34	3.34
Dayton cultivated	0- 6	1.197	1.75	
	6-12	1.259	1.63	3.38
Melbourne uncultivated	0-12	1.343	2.13	2.13
Melbourne cultivated	0- 6	1.385	1.55	
	6-12	1.395	1.24	2.79

* % water at 100 cm - % water at 15 atm pressure

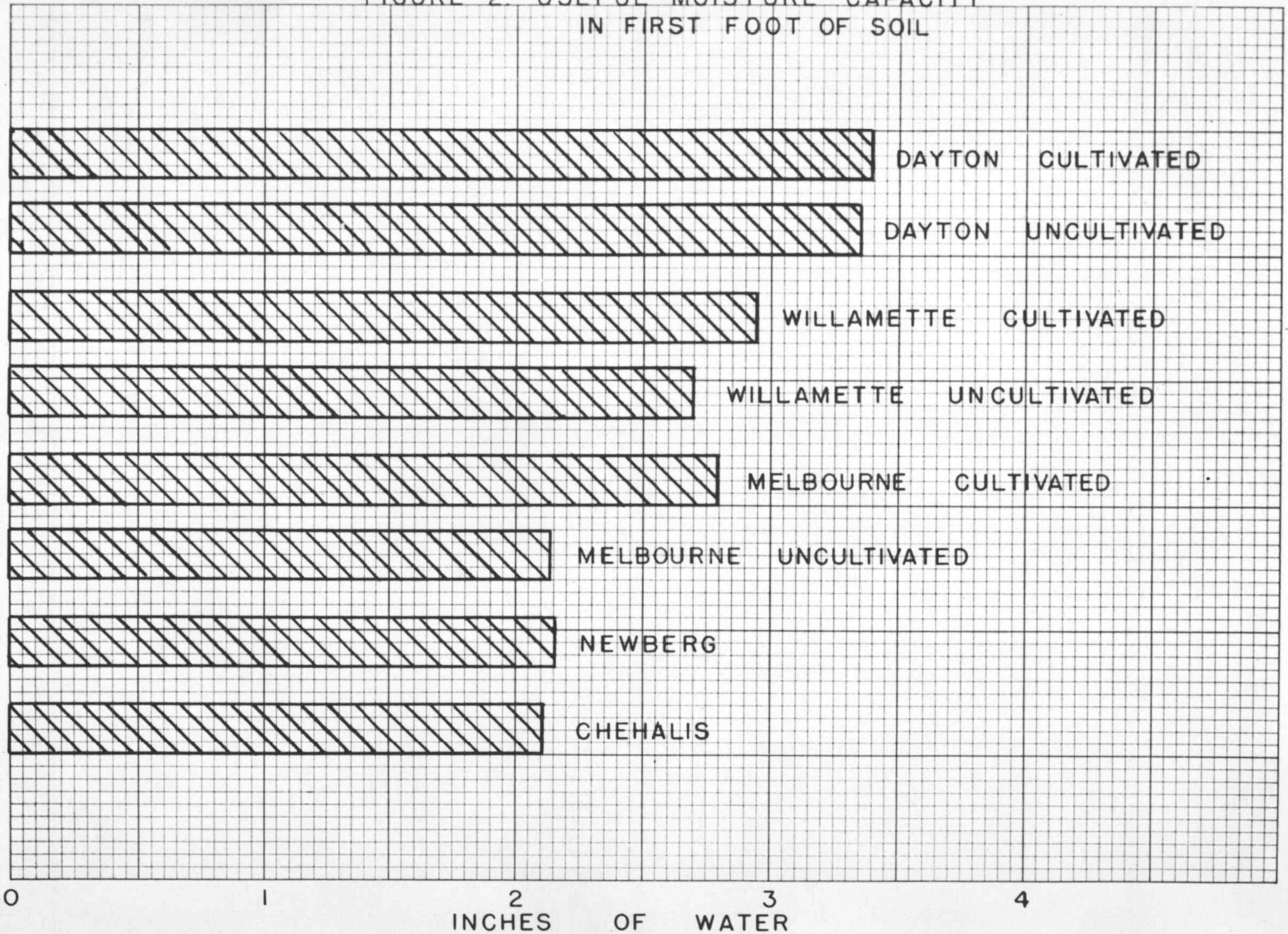
disturbed and undisturbed samples in the two ranges of pressure. Surface soil samples of Willamette cultivated, Melbourne uncultivated, and Dayton cultivated soils were used and these results also appear in Table II and Figures 1_C, 1_F, and 1_H.

It was not feasible to obtain exact field capacity values of these soils, however observations at this experiment station using tensiometers during and after irrigation have indicated that 100 centimeters of water tension reasonably approximates field capacity in these soils, so that value was used as the upper limit of useable moisture. The 15 atmosphere pressure values were used to represent wilting point, the lower limit of useable moisture. Useful moisture capacity of these soils appears diagramatically in Figure 2.

On this basis, the Newberg sample had a useful water capacity of 2.16 inches in the upper foot of soil. The 0 to 6 inch sample and the 6 to 12 inch sample vary in that the latter released its moisture at a more uniform rate than the 0 to 6 inch sample. The A horizon retained more water than the B horizon in the 2 to 15 atmosphere range, although the rates of release were the same.

Retention at corresponding pressures was higher in the Chehalis soil, but useable water capacity was slightly lower, 2.10 inches. The 0 to 6 inch sample retained more

FIGURE 2. USEFUL MOISTURE CAPACITY
IN FIRST FOOT OF SOIL



moisture than the lower sample. There was little difference between the two depths of the Willamette uncultivated soil, and useful water capacity was 2.70 inches. The cultivated sample of this soil series had a useful water capacity of 2.94 inches.

The range of useful moisture in the Dayton uncultivated soil was from 32.7 percent to 9.83 percent, or 3.34 inches of water, while the cultivated soil had a useful water capacity of 3.38 inches of water. The cultivated Melbourne soil had a useful water capacity of 2.79 inches, which was 0.66 inches greater than the uncultivated sample.

Smallest volume weight was exhibited by the A horizon of the Dayton cultivated soil, 1.197, and the highest value, 1.395, was found in the lower level of the cultivated Melbourne soil. Where cultivated and uncultivated sites were studied, only in the case of the Dayton did the cultivated surface soil have a lower volume weight than the uncultivated sample.

CHAPTER VI

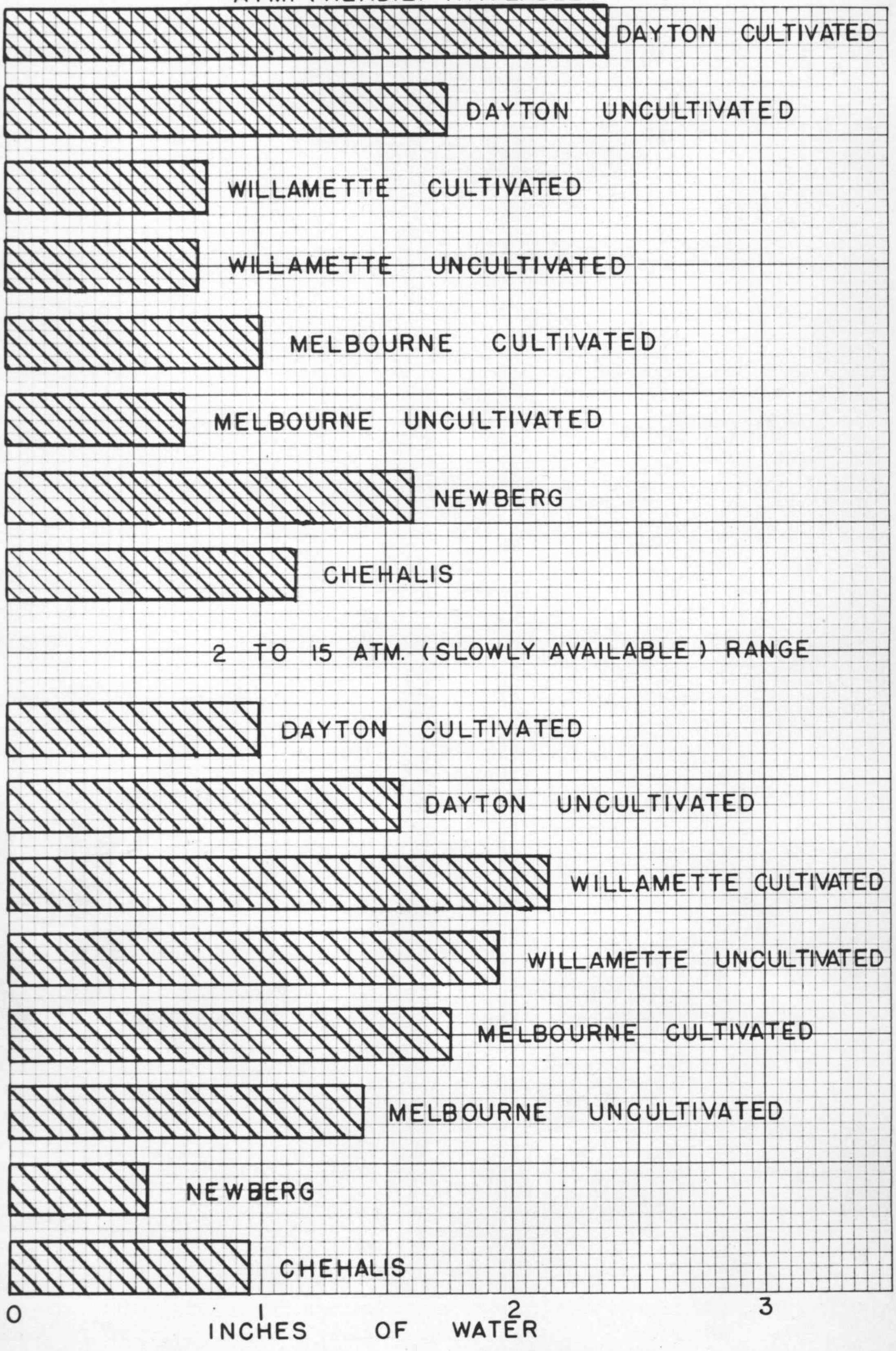
DISCUSSION

With an understanding of moisture retention characteristics and by using some recently developed tools for the quantitative measurement of soil moisture in terms of capillary potential, an attempt has been made to obtain a broader insight into the soil moisture retention properties of certain Willamette Valley soils, with special attention being given to the influence of mechanical composition and organic matter content on these properties.

It will be noted in Figures 1_A to 1_H that a discontinuity exists between the two curves obtained by using on the one hand disturbed samples in the 2 to 15 atmosphere range and on the other hand undisturbed core samples in the one atmosphere range. Disturbed surface soil samples were run in the one atmosphere range on three soils, as previously noted, in an attempt to gain some insight into this discontinuity. Figures 1_C, 1_F, and 1_G show that these disturbed samples appear to make a continuous curve on up to the higher range. This may mean either that values from the disturbed samples should not be considered too reliable in the 2 and 4 atmosphere range, or that the variation is caused by the difference in times of taking disturbed and undisturbed samples. Curves obtained in the one atmosphere range using disturbed samples represent the same soil samples used in the 2 to 15 atmosphere range.

The comparatively coarse-textured and well-aerated Newberg soil contained the lowest percentage of organic matter and had the lowest moisture equivalent point. The finer-textured Chehalis soil contained over twice as much organic matter and it should be noted that its moisture equivalent point was seven percent higher than that of the Newberg soil. The wilting point of the Chehalis soil was slightly higher also. Figures 1_A and 1_B show that the moisture equivalent point of the Newberg soil corresponded to a tension of about the 440 centimeter point and of the Chehalis soil about the 155 centimeter point. In other words, between the 100 centimeter point and moisture equivalent, the Newberg soil held 0.867 inches of water in the first foot of soil while the Chehalis soil held 0.016 inches of water. Moisture held in soils at tensions from the 100 centimeter point to the 15 atmosphere point is not equally available to plants over the entire range; the lower end of the range is more readily available than the upper. The useful moisture capacity diagram of Figure 2 is therefore separated in Figure 3 to show the readily available range, from the 100 centimeter point to the 2 atmosphere point, and the slowly available range, from the 2 atmosphere point to the 15 atmosphere point.

FIGURE 3. USEFUL MOISTURE CAPACITY — 100 CM. TO 2 ATM. (READILY AVAILABLE) RANGE



Examination of this diagram shows that the Newberg soil gave up most of its moisture readily, while the Chehalis soil released its water about equally between the two ranges.

The Willamette uncultivated soil contained more organic matter than the cultivated sample and its moisture equivalent point was higher. Wilting point of the uncultivated soil was higher, but the volume weight of the cultivated soil was higher and useable water capacity was also higher than the uncultivated Willamette soil. Figure 3 shows that, unlike the Newberg soil, both Willamette samples released more moisture in the slowly available range than the readily available range, and the additional useful water capacity of the cultivated soil appeared in this slowly available range.

Moisture equivalent and organic matter content were higher in the uncultivated Dayton soil than the cultivated. Wilting point was higher in the uncultivated sample, but volume weight was slightly lower, and there was no significant difference in useful water capacity. However, moisture release was not the same in these soils. The uncultivated sample gave up slightly more water in the readily available than in the slowly available range, while the cultivated Dayton released almost 2.5 times as much moisture in the readily available range as in the slowly available range. Stated differently, the cultivated Dayton soil gave up its moisture more easily than the uncultivated soil. The higher organic matter content of the uncultivated soil may explain some of this greater retention. It should be noted that field volume weight values of the cultivated Dayton soil were low, probably because natural structural conditions had not been reestablished after recent disking and seeding operations.

The virgin Melbourne soil contained more organic matter and had a much higher moisture equivalent point than the cultivated soil. The virgin site profile was seven inches deeper than the cultivated soil profile, and its A horizon made up four inches of the difference. The sites had approximately the same slope, and it is extremely likely that a portion of the topsoil of the cultivated field had been eroded away. In other words, at least some of what was considered as the A horizon of this profile was in reality B horizon soil not many years ago. An examination of the data on organic matter content seems to support this possibility. The lower horizons of the cultivated soil contained more roots, being more a part of the root zone, than the lower horizons of the virgin profile, and therefore organic matter content of these lower horizons was higher in the cultivated soil. Moisture equivalent values decreased with depth in the virgin site and increased with depth in the cultivated site, thus showing a tendency to meet. The very low value for the

A horizon of the cultivated soil may be an effect of the influence of cultivation.

Useful moisture capacity of the cultivated Melbourne soil was higher than the virgin soil, and, like the Willamette soils, both Melbourne samples released a greater portion of the moisture in the slowly available range. The cultivated sample released more water than the virgin sample in both ranges.

In all three cases where comparisons could be made the cultivated samples gave higher useful water capacity values than the uncultivated samples.

Powers (22) determined useful moisture capacity by the formula

useful water capacity = [(wilting point x 2) - wilting point] [field volume weight]

and reported average values per foot of soil as follows:

Newberg fine sandy loam	1.57 inches
Chehalis loam	1.80 "
Willamette silty clay loam	2.15 "
Dayton silty clay loam	2.15 "

Average values for this study were as follows:

Newberg sandy loam	2.16 inches
Chehalis loam	2.10 "
Willamette silty clay loam	2.83 "
Dayton silty clay loam	3.34 "
Dayton silt loam	3.38 "
Melbourne clay loam	2.46 "

In all cases, results of this study were higher, especially the Dayton soil.

With the exception of the Newberg series these soils were quite fine-textured. Highest clay contents were found in the Melbourne soils, and the valley floor series, Willamette and Dayton, contained most silt and least sand.

The effect of cultivation on organic matter content of the A horizon was very marked. The amount of organic matter in the cultivated surface soils of the three series, represented as percent of organic matter in the same horizon of the uncultivated soils was as follows:

Melbourne	70.4%
Willamette	71.7
Dayton	87.4

Greatest decline in organic matter content was exhibited by the Melbourne and least by the Dayton soil. The Melbourne soil was grain-farmed, the Willamette soil was in orchard, and the Dayton was in grass seed and hay production.

Uncultivated soils had higher moisture equivalent values than the cultivated sites of the same soils. Texture was of prime importance in this property, with organic matter content exerting some influence.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The aim of this study was to apply the energy concept of soil moisture and some of the tools which measure moisture in terms of this concept in obtaining a comparison of the moisture retention characteristics of certain Western Oregon soils, with special attention being paid to texture, organic matter content, and effects of cultivation.

It was not possible to obtain reliable field capacity values in this study, but such data would be valuable in studies of this kind. Perhaps a valid field of study, as an outgrowth of this work, would be to procure a large number of soil samples at field capacity and later run pressure membrane and pressure plate studies on them in attempting to arrive at average tension values of field capacity and moisture equivalent for major Oregon soils.

However, this study of soil moisture relationships from the concept of the potential theory has added to the information about these five soils. In general, the coarse-textured soil had the least organic matter content, lowest moisture equivalent point, and low water-holding capacity. The finer-textured soils contained more organic matter, had higher moisture equivalent points, and greater water retention in the range of moisture content available to plants.

Organic matter content was appreciably higher in the uncultivated soils, and these soils generally had higher moisture equivalent values but not as wide a range of available moisture as the cultivated soils. Both the Willamette and Melbourne cultivated soils had higher field volume weight values than the uncultivated samples indicating lower total porosity. In general, there was no correlation between organic matter content and useful water capacity within the range of soils studied.

Greatest useful moisture capacity was found in the Dayton soils, followed by Willamette and Melbourne cultivated, Willamette and Melbourne uncultivated, and Newberg and Chehalis soils. The Willamette and Melbourne soils, both cultivated and uncultivated, released more water in the slowly available range than in the readily available range, while the reverse was true in the case of the Newberg and Dayton soils. The Chehalis soil released its useful moisture about equally in the two ranges. Generally, the finer-textured soils had higher useful water capacities.

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