Plant Structure as Influenced by Soil Moisture

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Introduction

In planning culture methods for a study of the influence of differing quantities of soil moisture upon plant structure, a general review was undertaken of the moisture properties of several soils to be used. These moisture contents in order of decreasing magnitude are (1) water-logged condition, (2) maximum water-holding capacity, as defined by Hilgard (1914) for a column of soil one centimeter high, (3) water-holding capacity for columns of varying height, with four inches predominant, since this was the height to be used in plant cultures, (4) optimum moisture content (the lower limit of plasticity), (5) field capacity, (6) moisture equivalent, (7) permanent wilting percentage, (8) hygroscopic coefficient, and (9) moisture content of air-dry soil. These moisture values for fine (dune) sand, sandy loam, brown silt loam, and black clay loam are exhibited in Table I.

TABLE I.—Summary of Moisture Properties of Soils

	Fine Sand	Sandy Loam	Brown Silt Loam	Black Clay Loam
Water-logging Percentage	40.66	42.77	61.30	79.22
Hilgard (1 cm.) Water-holding Capacity	32.86	36.80	60.90	78.73
4-inch Water-holding Capacity	26.00	31.70	43.30	57.23
"Optimum Moisture Content"	20.24	25.60	39.80	52.91
Field Capacity	9.8	16.43	26.20	30.00
Moisture Equivalent	6.04	14.88	26.80	33.29
"Safe" value above Permanent Wilting Percentage	4.50	8.50	13.60	16.80
Provisional Permanent Wilting Percentage	2.70	6.64	11.96	14.86
Hygroscopic Coefficient	3.03	5.00	5.82	8.98
Moisture content of Air-dry Soil	0.66	1.42	2.80	7.24

Culture Experiments

On the basis of moisture values determined it is possible to establish a control method for plant cultures employing three ranges of moisture variation—wet, moist, and dry. The upper limit of the high moisture range should not exceed the water-holding capacity of a four-inch column or an excessive wetness will prevail in the bottom part of the four-inch depth of soil in each container. The upper limit of the low

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moisture range should not be less than the field capacity, or, when water is added to replace that lost from the plants, the bottom soil will not receive any of the water added. The lower limit of the low moisture range must be a safe margin above the value of the permanent wilting percentage. Thus the upper limit of the wet range and the upper and lower limits of the dry range were the starting points. The moist range was spaced equally between the wet and dry. This was accomplished by dividing the interval between the upper limit of the wet and the upper limit of the dry into six equal parts. The upper two of the sixths represent the wet range; the next sixth is the gap between wet and moist ranges; the next two sixths represent the moist range; and the last sixth is the gap between moist and dry ranges. Thus, in each of the three ranges, the soil moisture, though it could not be held constant at a particular percentage, varied only within limits not widely separated, and the moisture values within any one range were at all times different from those in other ranges.

Zinnia (Red Riding Hood variety), Phaseolus (Stringless Green Pod variety), Impatiens (balsam), and Ricinus (castor bean) were selected for growth experiments. No. 2 tin cans which were paraffin-lined and tared to equal weight by drops of liquid paraffin were used throughout the experimental work. Cover lids punched with a central one-half inch hole were also tared to equal weight. The lids were not sealed nor the holes plugged with cotton; the lids thus retarded surface evaporation greatly but did not interfere with the diffusion of gases. This method of preparing the cans for planting is a modification of the method used by Veihmeyer and Hendrickson (1928) in their direct determination of permanent wilting.

Equal weights of an air-dry soil which had been passed through a one-sixteenth-inch mesh screen were placed in the plant containers. Packing was accomplished by dropping each container five times through a distance of three inches. Thirty cans were assigned to Zinnia (ten to each of the three moisture series), and fifteen to Phaseolus, Impatiens, and Ricinus, respectively.

On the basis of oven-dry weight of soil in each container the upper and lower moisture limits were calculated in grams, and water to bring the moisture content to the upper limit was added. By daily weighings and the addition of water at the top to bring to the upper limit when the lower limit was approached or reached, the range of soil moisture for each series was maintained. The alternate loss by transpiration and evaporation and replacement of water by addition at the top approximates field conditions of both watering (by rainfall) and the effect of watering upon the movement of gases in the soil. Furthermore, the wettest layers of soil are brought nearer the source of gaseous supply.

The pot cultures of the wet, moist, and dry series were kept on a large turn-table (to eliminate inequalities of lighting) in a greenhouse with temperature ranging usually between 65°-75°F. Above this turntable were strong Mazda lamps to extend the winter hours of lighting in early morning and late afternoon.

From the time of expansion of the first leaves, leaf and internode measurements were followed in careful detail. The size and number of flowers were recorded for all plants. Root distribution and abundance were studied in each moisture series.

Material for anatomical study was collected from roots, stems, and leaves. Measurements of tissue thickness and cell size were made with an ocular micrometer ruled in the form of a square.

Fresh and dry weights of both tops and roots were determined for the plants of each culture experiment.

The total amounts of water required by the pot cultures of each moisture series were calculated on the basis of the number of cubic centimeters of water necessary to bring each culture to the upper limit of the particular moisture range when the lower limit had been reached.

Summary of Significant Results

Culture methods involving watering at the top appear definitely superior to bottom watering methods, since in the former the influences of gravity, absorption, and evaporation all tend toward more nearly equable distribution of moisture throughout the soil mass.

All data upon the growth and distribution of roots and the form and size of shoot in the four plants studied indicate that there is an optimum moisture content for growth in soils. Zinnia exhibited best growth and development in the moist range, although approaching the lower values of this range in the finer-textured soils. Plants of Impatiens in the moist series were far superior to those in the other two series. Phaseolus showed a like response although here the optimum appeared to lie toward the upper limit of the moist range. The entire development of Ricinus was best in the wet range.

With the exception of Ricinus, the shoots exhibited a greater size than roots in all plants.

The fresh weight of the roots was greater in the moist series. The greatest loss of weight upon oven-drying likewise took place in roots of the moist series, thus giving the smallest proportion of dry-matter as an end result in the moist series of Phaseolus and Ricinus, but in the dry series of Zinnia and Impatiens.

In all instances the shoots showed an increase in weight over the roots. Both fresh and dry weights of Zinnia, Phaseolus, and Impatiens were greatest in the moist series, but in the wet series for Ricinus.

Number of flower heads and individual ray and disc flowers of Zinnia were greatest in the moist series. This was true also for number of flowers in Impatiens. However, in Phaseolus the number and size of flowers and fruits showed a distinct overlapping between moist and wet series. Branches, where present in any of the plants, were of greater number in the moist series.

Anatomical data from Zinnia indicated a greater diameter of stem in the moist and wet cultures but a greater size and number of xylem vessels and larger vascular bundles in the moist series. However, the bundles were more numerous and the strengthening tissue proportionately greater in the dry series.

The plants of the dry moisture range showed smaller and more compactly arranged cells, a second partially-developed palisade layer, fewer air spaces, a better development of veins, a slightly thicker upper epidermis, and a higher stomatal frequency than plants of the other two series. These features of xerism are attributed solely to the soil moisture conditions, since the plants of all three moisture ranges were kept under the same atmosphere conditions.

The slightly larger number of chloroplasts constantly in evidence throughout the leaf sections of the moist-series plants, together with a greater leaf surface, would effectively indicate a greater photosynthetic surface.

The total water requirement of each plant studied was closely correlated with the developmental and structural response of that plant, thus lending greater emphasis to the conclusion that Zinnia, Phaseolus, Impatiens, and Ricinus have an optimum moisture range for growth.

The essence of the method of moisture control used in these experiments is the recognition that truly constant moisture values are neither possible nor desirable to maintain and that such a condition is practically never found in nature. It is possible, however, to restrict alternations in moisture content within controlled limits. Non-overlapping moisture ranges further enable one to produce an experimental contrast for testing the influence of different soil moisture values.

By this mode of soil-moisture control there is provided a means of exact comparison with soils of varying texture, since, after the required physical determinations of moisture properties have been made, the soil moisture ranges for one texture of soil can be calculated to be exactly equivalent to those for another texture.

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