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Soil Moisture Range and the Growth of Young Lemon and Avocado Plants

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Prior to 1913 most investigators found an increase in growth with an increasing total water content over most of its range except in the proximity of complete saturation of the soil where growth was somewhat reduced. A valid objection made by the reviewers of the literature (1) is the impossibility of maintaining a mass of soil at a uniform and low total water content. The lower depths can receive water only after the upper layers of soil first are wetted to their field capacity. The small amounts of water added from time to time to soil cultures in order to return the soils to their original moisture percentages, that are far below the field capacity, fail to moisten the entire soil mass. The roots in such cultures develop largely in the fully moistened upper soil mass, and the desired soil moisture percentages are not obtained. Thus, when water is applied to a soil it penetrates only to a depth throughout which it can raise the soil to its water-holding capacity.

Method Used

Difficulties of this sort are avoided in the method of maintaining soil moisture percentage ranges as used by Veihmeyer (2) and others (3, 4, 5, and 6). The method employed consisted in bringing the soil cultures or plots first to their field capacity and then allowing the total water content to be reduced by the plant to various definite moisture percentages after which water is added to return the percentages to those at the field capacity. This procedure is then repeated over and over. By this means water is available throughout the entire soil mass and the plants withdraw soil moisture in various ranges extending from the field capacity down to the desired lower limiting percentages.

The percentage of soil moisture available for plant growth is represented by the difference between the percentage present and the percentage at the wilting point. Citrus and avocado trees were found (6) capable of utilizing a wide range of available soil moisture without injurious effects. In a soil permeated with roots the conclusion has been reached (7) that no physiological necessity exists for replenishing the supply of readily available soil moisture before it is exhausted. Hendrickson and Veihmeyer (7) have pointed out an ofttimes overlooked but important matter, namely, that the soil mass should be permeated with roots in order that the extraction of water by roots may not involve the ability of the soil to transport moisture from relatively distant areas to the root. Slow capillary movement of water of this kind, together with a poorly distributed root system, may explain in part the lack of agreement between results obtained by various investigators.

Some investigators (6 and 7) have concluded, while others (4 and 5) have not, that plants can utilize, with the same good effects, small as well as large available soil moisture supplies. According to one view, plants either have readily available soil moisture for their use or they have not; according to the other view, plants have varying degrees of difficulty in obtaining water as the soil moisture percentages fall into different ranges.

When little or no water deficit occurred, the rate of growth and final size of lemon fruit were most favorable (4), while with severe water deficits, during which period the fruit growth ceased or the leaves began to roll, there was an accompanying reduction in fruit size. In the field it seemed futile to set a definite percentage above which soil moisture is considered available for growth and below which it is not available, for the root distribution is variable, and varying proportions of root zones are irrigated in the field (4).

Experimental Lemon Cuttings

In controlled cultures in the laboratory some of the difficulties met with in the field can be eliminated. The soil, used in the experiments to be reported, was of the Ramona sandy loam type and represented largely the first foot of soil in an experimental orchard at the Citrus Experiment Station. This soil was used in order to permit an excellent root growth as well as a ready movement of the capillary water. At depths ranging from 1 to 4 feet the orchard soil nearby had moisture equivalent percentages of 12.6, 13.8, 14.4, and 12.5, and permanent wilting point percentages of 4.2, 5.4, 5.8, and 4.9 per cent respectively. The soil obtained was air-dried, screened and thoroughly mixed and had a field capacity of practically 12 per cent, at which moisture content the pH value was roughly 5.5. Distilled water was used at all times.

The culture containers were made of tinned iron and were coated overall with Gilacoat asphalt paint, while the exterior was further coated with aluminum in a phenolic resin vehicle. The size of the containers was 6.5 inches in diameter and 7.5 inches in height, with tight-fitting sunken lids of nearly the same diameter as that of the container. In the center of the lid was a large circular hole in which to fit a spar-varnished cork and accessories for the insertion of the plant and the insulation of the soil. Near one edge of the lid was a small cork-stoppered hole used for the adding of water. Each culture contained 4500 grams of air-dried soil and a rooted leafy-twig Lisbon lemon cutting. The average fresh weights of the cuttings used in each of series 1-4 (table 1) were: 9.0, 9.1, 8.9, and 8.7 grams, respectively.

TABLE 1

Effects of Soil Moisture on Leaf Area and Water Loss of Lemon and Avocado Plants

Series	Minimum soil Moisture* (per cent)	Average number of leaves Per plant	Average leaf area (square inches) Per plant	Average leaf area (square inches) Per leaf	Average water loss (cc.) Per plant	Average water loss (cc.) Per square inch of leaf area
			Lemon Cuttings			
1	12	84.8	372.6	4.39	26,728	71.73
2	10	67.7	319.2	4.72	23,097	72.36
3	7	58.9	293.1	4.98	21,221	72.40
4	5	40.5	199.4	4.92	18,649	93.53
			Avocado Seedlings			
1	12	51.8	631.2	12.2	17,241	27.3
2	8	52.7	508.1	9.6	13,373	26.3
3	5	35.4	181.4	5.1	5,037	27.8

* Maximum soil moisture in all cases was 12 per cent.

At the outset (May 27, 1938) each culture received 0.3650 grams of nitrogen in the form of c.p. ammonium sulfate and the moisture percentages were maintained at the field capacity (12 per cent). The cultures were grown out of doors on a table protected from wind by lath and from rain or direct sunlight by a high overhead covering. This excellent care permitted the penetration of roots throughout the soil mass.

In the late summer of 1939, the tops, including the leaves and twigs, of each plant were removed by pruning and the trunks were allowed to extend 6 to 8 inches above the lid of each culture. The cultures were brought into the glasshouse and were kept at field capacity until January 22, 1940, when the new leaves were considered mature.

The first series (table 1) consisted of 11 cultures and were continually maintained at the field capacity (12 per cent). The second series consisted of 12 cultures and the plants were allowed to reduce the percentage of soil moisture from 12 to 10 per cent, at which time it was again brought to 12 per cent by the addition of water. In the third series consisting of 12 cultures the plants were allowed to reduce the percentage of soil moisture from 12 to 7 per cent before being returned to 12 per cent. In the fourth series consisting of 11 cultures the plants were allowed to reduce the percentage of soil moisture to 5 per cent (which is close to the permanent wilting point percentage) before water was added to increase the percentage to 12 per cent. As the moisture percentages in the soil cultures were reduced in the several series to their respective minima, the soils became more acid (8) and in this respect the cultures with the lower minima were the most favored.

Daily weighings of the cultures permitted the above ranges of soil moisture to be maintained until the termination of the experiment on October 12, 1940. During the progress of the experiment certain cultures (other than those just referred to) were sacrificed in order to determine the weights of the plants and to examine the soil moisture condition. Such procedure permitted readjustments in the weights of the cultures in order, as strictly as possible, to adhere to definite soil moisture percentage ranges. On May 8, 1940, each culture received 0.0857 grams of nitrogen in the form of c. p. calcium nitrate and 0.1460 grams of nitrogen in the form of c. p. ammonium nitrate. The leaf areas were determined accurately with a Keuffel and Esser planimeter from leaf outlines made on paper at the end of the experiment.

Tables 1 and 2 show the data in brief form. The number of leaves, the total leaf area of an average plant, the fresh weights of the leaves, trunk and shoots, the total fresh weights, the dry weights of the leaves and roots, and the total dry weights increased as the range of the soil moisture fluctuation from the field capacity decreased. The gradient in the fresh weights of the roots is the opposite of that of the fresh weights of the leaves, trunk and shoots, while the gradient in the dry weights of the leaves and roots is the opposite of that of the trunk and shoots.

TABLE 2

Effects of Soil Moisture on the Fresh and Dry Weights of Lemon and Avocado Plants

Series	Minimum soil Moisture* (per cent)	Fresh wt. of average plant (grams)			Dry wt. of average plant (grams)		
		Leaves	Trunk and shoots	Roots	Leaves	Trunk and shoots	Roots
			Lemon Cuttings				
1	12	63.5	85.6	68.0	19.9	23.5	44.9
2	10	53.3	82.1	73.9	17.2	27.8	43.4
3	7	47.8	74.3	74.4	16.0	38.3	27.3
4	5	30.9	71.7	76.4	10.5	39.1	29.8
			Avocado Seedlings				
1	12	85.3	70.3	56.0	26.9	22.2	14.6
2	8	65.0	52.3	51.5	20.3	16.6	11.7
3	5	22.1	17.9	18.1	8.1	6.2	4.0

* Maximum soil moisture in all cases was 12 per cent.

The average water loss per square inch of leaf area was nearly uniform in the first three series and strikingly higher in the fourth series, a fact that indicates the marked abscission of leaves from cultures in the fourth series.

Valencia orange cuttings are now becoming established in cultures similar to the above and in due time will be available for a continuation of this study.

Avocado Seedlings

These plants grow more rapidly than lemon cuttings and were used to ascertain whether any confirmation of the non-anticipated results secured with lemon cuttings could be obtained.

A collection was made of numerous seed from the overripe fallen fruits of a large seeded variety at the Citrus Experiment Station. The seed were selected for uniformity chiefly as regards their size and were germinated in an open frame in the propagation bed in the glasshouse. Later a group of uniform seedlings about 4 inches high were selected from these. A seedling was planted in each soil culture containing 11,000 grams of air-dry soil of the same lot as was previously used. The containers were made of galvanized iron and were fully coated with Gilacoat asphalt paint. They were 8 inches in diameter at the top, 6.5 inches at the base, and 12 inches deep. Inch-thick, asphalt-painted cement lids served as covers for the containers. The lids had holes suitable for adding water and for the insertion of the seedlings as well as for the insulation of the soil.

Seventeen cultures were studied throughout the experimental period, other cultures being sacrificed from time to time in order to secure certain information. A miniature soil tube and plunger rod were utilized in sampling the soil and in checking the soil moisture penetration.

The avocado seedlings were placed in the soil containers on April 10, 1941. At the time of planting, each culture received 0.3648 grams of nitrogen, half in the form of c. p. calcium nitrate and half in the form of c. p. ammonium sulfate. In the glasshouse these cultures were maintained at the field capacity and grew rapidly. On May 14, 1941, the differentia] soil moisture treatments were begun.

In the first series consisting of four cultures the soil moisture (tables 1 and 2) was maintained close to the field capacity at all times; in the second series consisting of six cultures the plants were allowed to reduce the moisture percentage to 8 per cent before the addition of water to return the cultures to the field capacity; while in the third series consisting of seven cultures the plants were allowed to lower the soil moisture to 5 per cent before water was added to raise the soil moisture percentage to the field capacity. Such moisture percentage reductions from a pH standpoint (8) were more favorable for growth as the minimum of the soil moisture range decreased.

On August 20, 1941, each culture received 1 gram of c. p. powdered sulfur and 0.4283 grams of nitrogen in the form of c. p. calcium nitrate.

The experiment was terminated on October 3, 1941. At that time the leaf areas and fresh and dry weights were determined as in the case of the lemon cuttings previously described. The average heights of the trunks on May 14, 1941, were 12.2, 12.2, and 11.6 inches, while on October 3, 1941, they were 46.6, 39.6, and 20.6 inches, respectively in series 1, 2, and 3.

The leaf size, the fresh and the dry weights, and the total water loss were markedly increased in the avocado seedlings as the soil moisture content was kept in a smaller or narrower range close to the field capacity. The average water loss per square inch of leaf area was uniform in each series.

Discussion

In many of the citrus and avocado orchards in Southern California a marked improvement in the health of the trees has without doubt been accomplished by means of partially drying out the soil. The pH of the soil under these conditions becomes more acid and the availability of the nutrients is increased. Many growers realize from experience that the drying out process in a soil may seriously reduce the fruit sizes in oranges and in that respect may lower the fruit quality, while when salts are present, a severe leaf burn may result in mature leaves.

The data in tables 1 and 2 suggest that the vegetative growth may be retarded by an increased difficulty of roots in securing moisture and that various moisture ranges extending from the field capacity as the upper limit to various percentages above the wilting point are not of equal value for vegetative growth.

In heavy soils rich in calcium carbonate, the maintenance of the soil moisture percentages continually near that at the field capacity is feasible when drainage is unimpaired and rains together with losses from leaching are taken into consideration. In such soils, maintenance of the soil moisture percentage close to that of the field capacity would without doubt seriously raise the pH values in these soils (8) and by making more unavailable certain plant food elements would seriously offset growth advantages that might be secured at the field capacity, unless the pH values first were lowered by appropriate means. Thus the correction of pH, saline conditions, and other factors, become of first importance if advantage is to be had in growing plants at a soil moisture percentage maintained near that at the field capacity. The data raise questions pertinent to the growing of better trees and its accompaniment of more and better quality fruit. They also properly might raise questions in regard to the utility of plant foods other than water when present in various ranges of concentration.

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