Some Soil-Moisture Conditions in Relation to Growth and Nutrition of the Sugar-Beet Plant[1]

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Sugar beets utilize soil moisture over a wide range without affecting growth or sugar content. This has been shown by investigations extending over a period of 8 years on the irrigation of beets by the University of California. The range in which sugar beets can utilize moisture is the same as for other crops (1), extending from field capacity, which is the moisture held in a soil when movement has practically ceased after a rain or irrigation, to the permanent wilting percentage, or the soil-moisture content at which plants wilt and do not recover unless water is added to the soil.[3] The results show that sugar beets readily secure water between the field capacity (when determined in the laboratory, this is known as the moisture equivalent) and the permanent wilting percentage. This range of soil moisture has been termed "readily available moisture." The above statements assume that there is a thorough distribution of roots in the soil.

A study was made of the rooting habits of the sugar-beet plant by soil sampling and obtaining moisture-extraction curves. Beets planted in January or February have the advantage of the late winter and early spring rains. Under these conditions the roots will extend and utilize all the readily available moisture even between the rows, to a depth of about 4 feet. A month later the root system will have permeated the soil to about 5 feet in depth. This seems to be about the limit of root penetration, except under a prolonged period of wilting when some moisture will be extracted from the sixth-foot depth. Beets planted late in the spring, after the rains, and making their early growth under warmer weather conditions, will usually wilt before all the available moisture has been extracted in the top 4 feet, and wilting may occur when the first 2 or 3 feet have reached the permanent wilting percentage.

Although the above results have been secured in several different parts of California, some investigators believe that better growth is produced when the soil moisture is maintained at a relatively high level, enabling the plant to obtain more nutrients more

[1] The author takes this opportunity to express his indebtedness to the Spreckels Sugar Company for making this work possible. The Spreckels Sugar Company provided the land, grew the sugar beets, sampled the soil for moisture, harvested the beets for yields, and determined the sugar in the roots.

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[3] Figures in parentheses refer to Literature Cited.

readily than when the soil moisture is allowed to he depleted nearly to the permanent wilting percentage. This is thought to he particularly true of nitrogen, as the availahility of this element is due primarily to the biological activity of soil organisms, and it is supposed that relatively moisl soil may favor their growth. High soil-moisture content is usually obtained by light frequent irrigations.

This report is concerned with the effect of various soil-moisture conditions on the nitrogen availability to the sugar-beet plant. The nutrient element, nitrogen, was selected because (a) it is the principal element which may be deficient in this area, and (b) its availability is due primarily to biological activity of soil organisms which may be influenced by soil moisture.

Experimental Plan and Methods of Procedure.—The experiment was conducted on Yolo loam. Twenty-seven plots, 20 feet by 300 feet (12 rows wide), were laid out contiguously having their long axis perpendicular to an irrigation ditch. The plots were randomized into three irrigation treatments as follows:

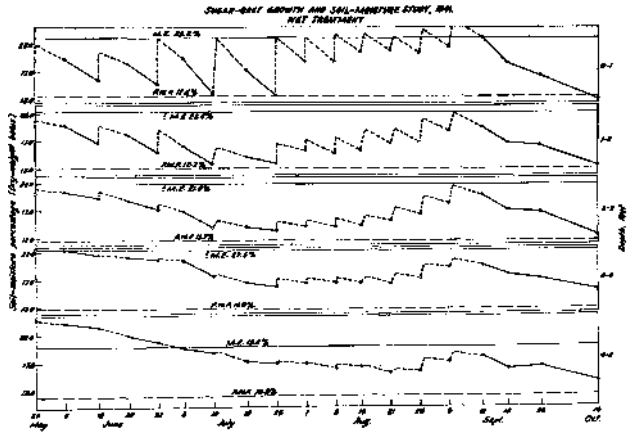
a. Plots in which the soil-moisture content was maintained a1 a relatively high level so that the plant always had a large[1] amount of readily available moisture throughout the growing season. This series of plots was termed the "wet treatment" as it received 11 irrigations on the following dates: May 29. June 13, 27. July 11, 25, August 1, 8.]5, 22, 29. and September 8.

b. I*n* the "medium treatment" the readily available soil moisture was reduced to a lower level than in the "wet treatment," but the soil moisture was not allowed to reach the permanent wilting percentage. Six irrigations were applied as follows: June 20. July 1. 25, August I5), September 8. and 19.

c. The third series of plots was not irrigated until the soil moisture was reduced to the permanent wilting percentage in the 3 top feet of soil. Several times slight wilting occurred before water was applied. This series was termed the "dry treatment" and received 5 irrigations, which were applied on the dates of June 27, July 11, August 1, 29, and September 19.

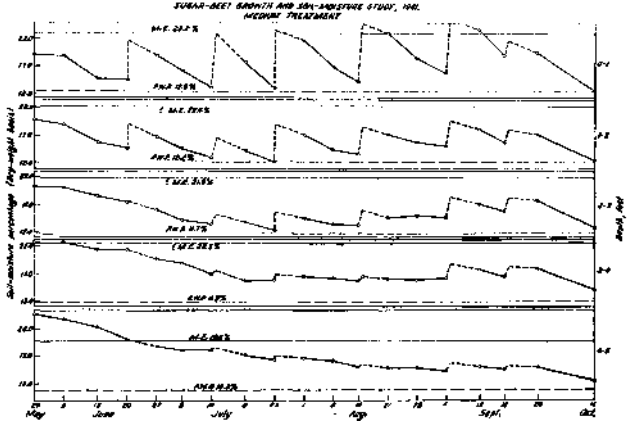
Soil samples were taken from two locations in each plot at approximately weekly intervals in 1-foot sections to a depth of 5 feet for soil-moisture and for nitrate-nitrogen studies. In presenting the results, the samples were combined by foot depths for each treatment. The permanent wilting percentage and moisture equivalent were determined from representative soil samples for each foot section.

Growth rates were obtained by harvesting 20 beets per plot, or 180 beets for each treatment at 2-week intervals. Five consecu-



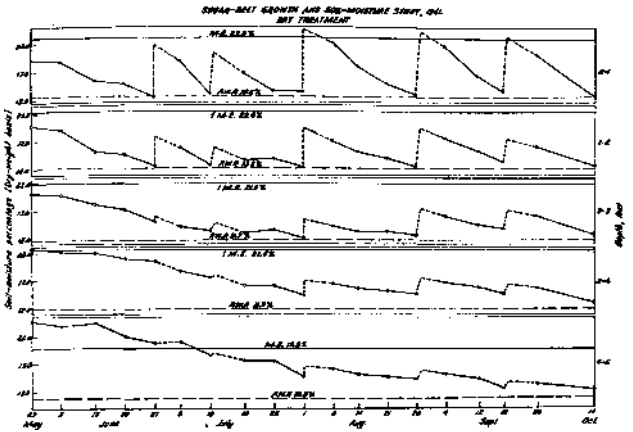
(Courtesy of Spreekels Sugar Company)

Fig. 1.—Soil-moisture conditions in the "wet treatment" for sugar beets 1941 (average of 9 plots). The moisture equivalent (field capacity) and the permanent wilting percentage are indicated by the solid and broken horizontal lines, respectively.



(Courtesy of Spreekels Sugar Company)

Pig. 2.—Soil-moisture conditions in the "medium treatment" for sugar beets 1941 (average of 9 plots). The moisture equivalent (field capacity) and the permanent wilting percentage are indicated by the solid and broken horizontal lines, respectively.



(Courtesy of Spreckels Sugar Company)

Fig. 3.—Soil-moisture conditions in the "dry treatment" for sugar beets 1941 (average of 9 plots). The moisture equivalent (field capacity) and the permanent wilting percentage are indicated by the solid and broken horizontal lines, respectively.

tive beets were harvested in a row from four different areas in each plot. At each harvesting date, one beet was left in the row as a buffer, and the next five beets were used. The beet tops were weighed and representative samples were taken for percentage moisture and total nitrogen determinations. The sugar-beet roots were weighed and analyzed for sugar and total nitrogen.

Nitrate-nitrogen content of the soil was determined by a slightly modified phenoldisulphonic-acid method. Total nitrogen content of the plant was determined by a modified Kjeldahl method.

Results.—The soil-moisture conditions for the three treatments are shown graphically in figures 1, 2, and 3. According to these records, the soil moisture in the "wet treatment" reached the permanent wilting percentage in the first foot twice during the season, July 10 and 25. No wilting was observed on any of the nine plots in this treatment. In the "medium treatment," the soil moisture nearly reached the permanent wilting percentage to a depth of 3 feet in 3 of the 6 irrigations during the summer, and the moisture in the fourth and fifth foot was also reduced to a low level of available soil moisture. At all times there was sufficient moisture to pre-

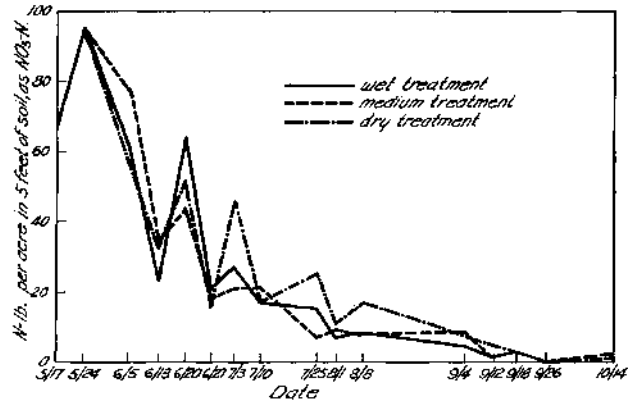


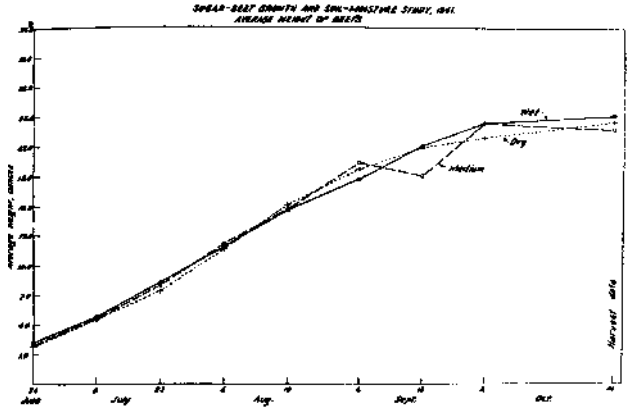
Fig. 4—Nitrogen, in the form of nitrate nitrogen, for surface 5 feet of soil, at the various soil-sampling dates, for the three irrigation treatments, 1911.

vent willing. In the "dry treatment" the moisture usually reached the permanent wilting percentage in a large mass of the soil before it was irrigated. Slight wilting occurred in some of the soils before the irrigation on August 1. and a more severe wilting before August 28. Although the graph shows some readily available soil moisture in the fourth and fifth-foot depths, individual records of the nine plots showed some of lliem to be at the permanent wilting percentage, in the top 5 feet of soil, and it was in these plots that wilting occurred.

The quantity of nitrogen (in form of nitrate-nitrogen per acre) in the top 5 feet of soil is given in figure 4. General soil samplings were made on May 15 and 24 over the area previous to the differentiation of treatments. Comparison of figure 4 with 1, 2, and 3 shows no relation of nitrate-nitrogen with soil moisture or frequency of irrigation. But figure 4 illustrates that as the root system of the beet develops, the nitrate-nitrogen is reduced to a low level.

The growth rate of the fleshy sugar-beet root is not affected by soil-moisture conditions, provided available water is present in the area of root development (fig. 5). The percentage sugar in the beet roots from the three treatments is given in figure 6.

On July 22, the study was enlarged to include the percentage nitrogen in the tops and roots. At this date, the average weight of sugar-beet roots was 7.7 ounces. The green weight, oven-dry weight, and the percentage nitrogen of the leaves are given in figure 7.



(Courtesy of Spreckels Sugar Company)

Fig. 5.—Average weight of 180 sugar beets per treatment at the individual harvesting dates, for the three irrigation treatments, 1941.

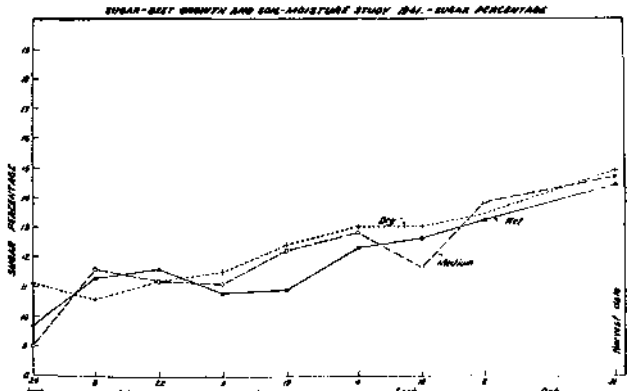


Fig. 6.—Average percentage sugar of 180 sugar beets per treatment at the individual harvesting dates, for the three irrigation treatments, 1941.

There was a marked difference in the weight of leaves as harvested from the "dry plots" when compared to the "wet" or "medium" treatments. It is interesting to note that the dry leaves weighed about the same, which shows that the difference in weight of leaves is due primarily to the water content. The slight reduction of dry-leaf weight in the "dry treatment" was probably caused by the loss of dead leaves at harvesting. Some variability occurs in the percentage nitrogen in the leaves; but in general, it decreases as the season advances, (fig. 7) and apparently is not influenced by soil moisture. The percentage nitrogen in the roots decreases slightly as the season advances until about September 1 when an increase

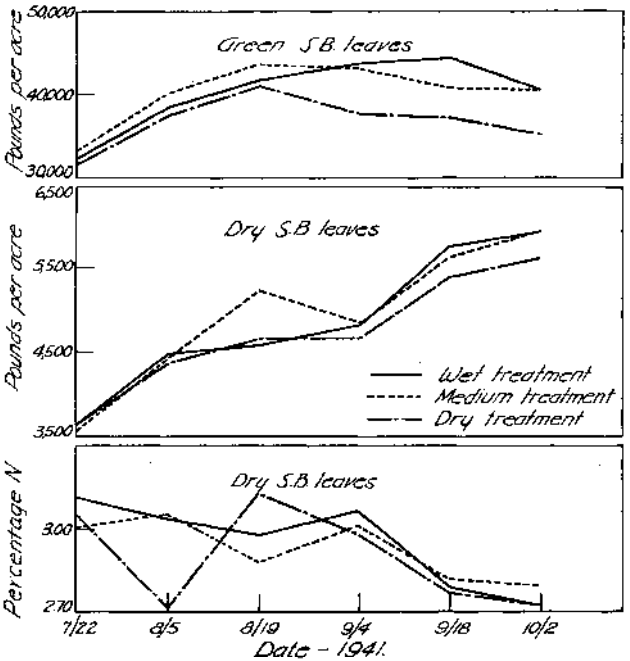


Fig. 7.—Weight of green leaves, oven-dry leaves, and percentage nitrogen in dry leaves for sugar beets (S. B.) at various harvesting dates for three irrigation treatments, 1941.

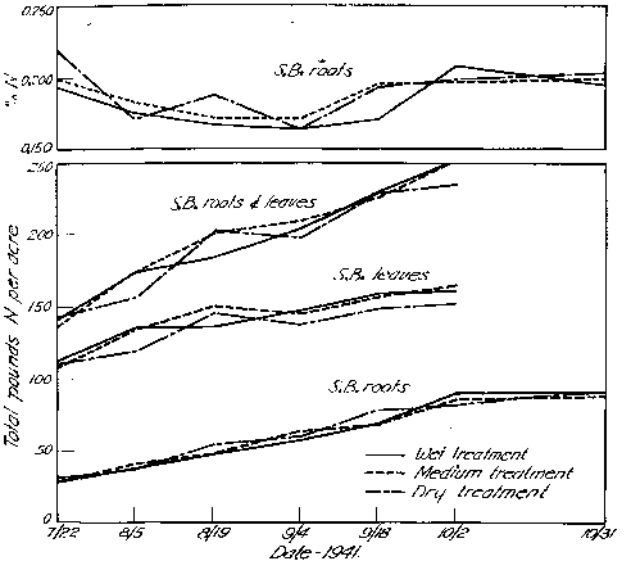


Fig. 8.—Percentage nitrogen in roots of the sugar beet and the total nitrogen in the sugar-beet roots and tops, and. separately, at various harvesting dates, for three irrigation treatments, 1941.

occurs (fig. 8). This is accompanied by a marked decrease in percentage nitrogen of the leaves (fig. 7).

The weights of nitrogen in roots, leaves, and total nitrogen per acre are given in figure 8. The weight of nitrogen is obtained by multiplying the percentage nitrogen by the yield per acre at the various harvesting dates. This represents the quantity of nitrogen the plant removed from the soil with the exception of that in the small fibrous roots. When this phase of the investigation was started, the sugar beets contained approximately 145 pounds of nitrogen per acre, and at this date the amount of nitrate-nitrogen in the soil was very low (fig. 4). However, between July 22 and October 2, the plants obtained approximately 105 pounds of nitrogen from the soil. Markedly different soil-moisture conditions existed for the three treatments in this period: The wet treatment received 7 irrigations, the medium, 4, and the dry, 3. However,

the total amount of nitrogen the plant obtained from the soil was approximately the same for the various irrigation treatments. These investigations would suggest that the soil organisms functioned in the production of nitrate-nitrogen over a wiide range of soil moisture, and probably there is no optimum percentage above the permanent wilting percentage at which organisms grow best.

Summary

1. The growth of sugar beets is independent of soil moisture as long as readily available water is present in the soil; or the mass of soil in contact with the roots is maintained above the permanent wilting percentage.

2. Nitrate-nitrogen of the soil is not affected by varying the readily available soil moisture by frequent irrigations. Even though the soil reached the permanent wilting percentage, there was no reduction of nitrate-nitrogen.

3. The nitrogen content of the roots and leaves and the total nitrogen removed by the crop is not influenced by variation of soil moisture in this experiment.

Literature Cited

(1) Veihmeyer, F. J. and Hendrickson, A. H. Essentials of irrigation and cultivation of deciduous orchards. Calif. Agr. Exten. Cir. 50, 1936.