Effect of Temperature Upon the Growth Rate of Sugar Beets

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It is generally recognized that a relationship exists between temperature and the growth rate of plants and that there is a difference in the optimum temperature at which different genera produce maximum growth. Several examples of such difference were pointed out by Hilgard *(3)*[2]. This is substantiated by Brandes and Coons *(1)* in the case of sugar beets, to the effect that beets are best and most profitably grown in those temperate regions wherein the mean summer isotherm lies between 67° and 72° F.

Apparently relatively few attempts have been made to study the effect of temperature on the rate of growth of the sugar beet. Tavernetti (6) found, however, that under California conditions relatively little weight accumulated until minimum soil temperatures ranged above 55°. In 1944 the authors presented a preliminary study of this problem to the society *(4).* As result of these studies, a further investigation was instituted in 1945, with the hope of obtaining somewhat more specific information on the growth of the beet root as it responds to seasonal variations in temperature. The present report must be considered as one of progress only, since it is based on results of only 1 year.

Materials and Methods

The field used was located about 4 miles west of Billings, Mont. Here uniformity was good and cultural practices were of the highest order ; the yield of approximately 16 tons per acre was somewhat above average for the factory district.

One thermograph was exposed in a standard instrument shelter 4 feet above ground and another in a similar shelter set directly on the ground with the recording element 3 inches above the surface and immediately adjacent to one row of beets. A soil thermograph was also housed in this ground shelter, with the bull) buried between two rows at a depth of 8 inches. Weekly readings at 2-inch depth were also made by means of thermometer and/or thermocouple, the latter read by use of the conventional Wheatstone bridge.

To obtain information as to the weekly increase in size of the root, a simple arrangement involving use of a test tube, 5-inch length of small laboratory glass tubing, and a piece of oiled-silk fish line about

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[2]Italic numbers in parentheses refer to literature cited.

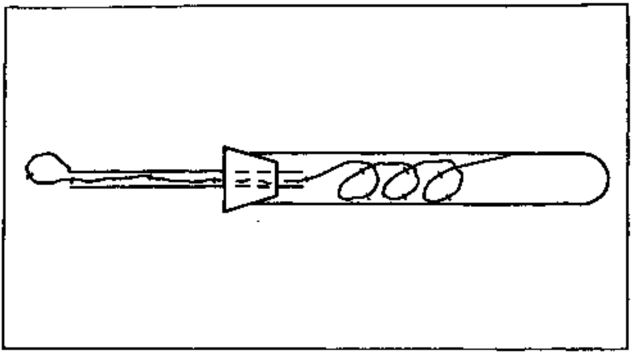

Figure 1.—Apparatus used for circumference measurements of beets.

2 feet long was designed. A sketch of this device is shown as figure 1. The line was marked off in inches with india ink and fastened to the extreme outer end of the glass tubing. It was then extended around the root at the maximum diameter, up through the glass lube, and into the test tube where the excess was coiled. Readings were made with reference to an index mark etched in the glass tube 2 inches from the end.

Information was had verbally that Swedish investigators had made a device for a similar purpose, but the instrument was not obtained.

Twenty-seven beets were selected at random to serve for measurements, and the apparatus shown in figure 1 was applied. The procedure followed throughout the season was to take circumference readings on all 27 beets each Saturday noon and at the same time change thermograph sheets and make check readings and such other measurements as were needed. {Sunshine, wind direction and velocity, rainfall, and cloudiness data were recorded at the United States Weather Bureau office 5 miles due north of the test field. This equipment was installed quite late in the season—June 28—because of delay in receiving some of the instruments needed. The roots at that time averaged about one and one-fourth inches at the major diameter. The last week of record ended on September 29 when the field was harvested.

Results

The general relation which was found to exist between temperature and weekly increments in root size is shown in figure 2.

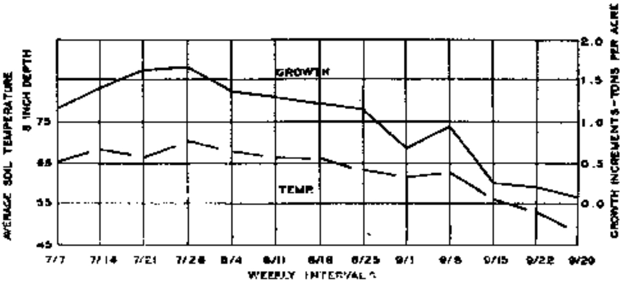

Figure 2,—Temperature and growth-rate curves.

Shown here are weekly increases in the circumference of roots translated into terms of tons per acre, and weekly averages of the soil temperature at the 8-inch depth. Smith *(5),* working at Jerome, Idaho, found a circumference-weight ratio of 6.57. Data taken in this study give a ratio of circumference to weight of 6.36. All things considered, this shows very good agreement.

Soil temperature was selected for correlation with growth only after making a large number of comparisons, including maximum, minimum, and average at the 2-inch and 4-foot levels, frequency of specific temperature levels, a degree-day type of summarization with a 45° base, and a heat unit summarization involving adjustment and weighting of temperature values according to their frequency of occurrence. Eight-inch average soil temperature proved to show a higher correlation with growth than did any of the other factors. The parallelism between the two curves shown in figure 2 is quite striking; in fact the direction of change from week to week was the same except in one instance, that of July 21 when the deficiency of sunshine hours resulted in a depressed soil temperature. It, is interesting to note that there was a rise, both in temperature and growth rate, during the first week of September when the general trend of the seasonal curve was downward.

In figure 3, soil temperature and growth rate have been plotted in the form of a scatter diagram. So far as the 1945 season is concerned at least, this represents the relationship between rate of growth and soil temperature. The curve shown is simply a free-hand fitting of the data by the method of Ezekiel (2), since no satisfactory regression equation for the line has yet been derived. However, the index of correlation computed for this curve is 0.970, a figure considerably above the 1 percent level of significance (0.684). The lower end of this curve would, if extended, reach zero at about 40° F.. which appears reasonable, and its steepest slope occurs between 60° and 65°

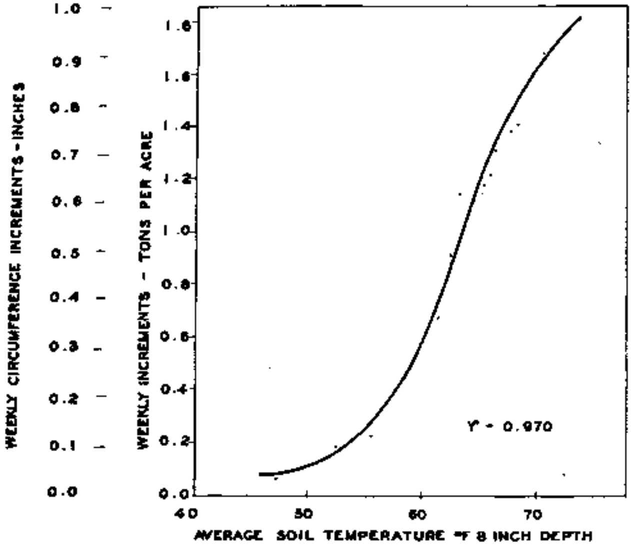

Figure 3.—Seasonal growth rate curve.

F. While the upper end of the curve is shaped to suggest a maximum value somewhere in the seventies, the data do not form any basis for fixing the optimum. The highest weekly temperature of 70.8° occurred during the week of July 28 and in all likelihood is below the optimum. It would be most valuable to know just where this maximum value lies, but since averages much above 70° seldom occur in the Billings area it seems unlikely that it can be determined without resorting to artificially controlled conditions.

Tt will be noticed that weekly increments used in figures 2 and 3 are given in terms of tons per acre increase. Conversion from circumference increase was made on the basis of the ratio between final circumference and weight. It was found that an increase of 1 inch in circumference yielded an average of .157 pounds in weight. Using, then, 23,760 as the number of plants per acre, with 22-inch rows, the figures used as weekly increments in tons per acre were obtained. Figure 4 shows the relation between circumference and weight for each of the 27 roots measured. The relationship is approximately linear, and scattering was due mainly to differences in the shape of

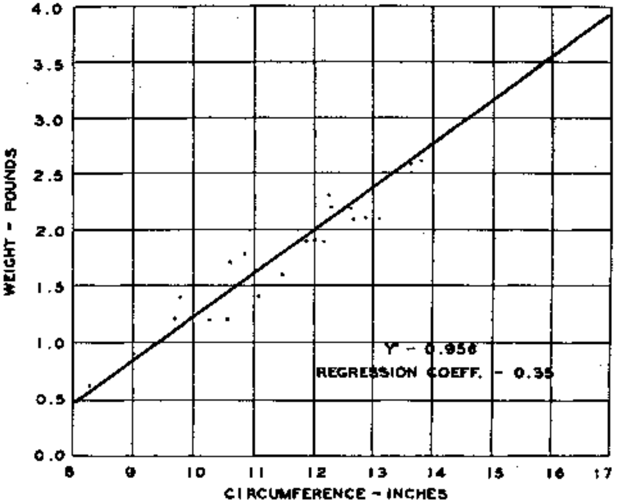

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Figure 4.—Relation of weight to circumference (27 roots).

individual roots. Strictly speaking, weight increment per unit increase in circumference varies with the size of the root, and the relationship shown in figure 3 applies accurately only to the scale of circumference increase shown. However, for the purpose of this paper, these figures have been converted into terms of tons per acre, since these have more practical significance and the error is small.

One of the explanations which seems to account for the superiority of soil over air temperature as an index of the growth rate is that the roots grow in the soil rather than in the air. This may be physiologically important; but a more logical explanation is the fact that the soil tends to act as an intergrating mechanism—through which changes in air temperature, sunshine, relative humidity, wind and all other weather factors, operative in the free air, are combined. Increases in air temperature and sunshine, for example, result in corresponding increases in soil temperature. A rise in the rate of evaporation, and the application of moisture, either as rainfall or irrigation water, on the other hand, tends to cool the soil. Thus, changes in all weather factors are additive in their effect upon the warmth of the soil, which in turn has its effect upon chemical and biological processes going on in support of growth.

Summary

No definite conclusions can or should be drawn from the preliminary information presented. Certain indications may be pointed to, however, as follows:

1. In a pre-harvest estimate of yields, the influence of the seasonal temperatures might beneficially be taken into account.

2. It is shown that there is a strong correlation between the soil temperatures and rate of growth of sugar beets in this area : that such soil temperature may be the best index of tile influence of various climatic factors on the growth of the sugar beet in that it may act as a medium of integration for several environmental forces.

3. As pointed out by Tavernetti *(6)* the soil temperature can have considerable bearing on when to apply commercial fertilizers, in order to have available a plentiful supply of plant food at the time most needed by the plant in rapid growth.

Meteorological Notes

1. Contrary to expectations it is noticeably warmer in the afternoon at the 4-foot level than near the ground. This is due, apparently to the cooling effect of growing plants. Similarly the lowest night, Temperatures were found, not at the ground level, but in the 4-foot shelter.

2. Leaf temperatures, as accurately as could be measured, were found to be 4 to 5 degrees lower on warm sunny afternoons than that of the surrounding air due, of course, to transpiration. This is true in spite of the dark color of the leaves, which should increase their capacity for absorbing heat.

3. The average seasonal temperature of the soil was about 1 degree lower than that of the air. This can be accounted for by evaporation of moisture from the soil surface.

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