# RELATIONSHIP OF WEATHER TO SUGAR BEET PRODUCTION

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This paper represents a preliminary report of a study conducted mainly in Billings with the object of establishing a usable relationship between growing season temperatures and acre yield of sugar beets. The authors do not consider that any outstanding results have been obtained as yet, but believe that presentation of a progress report at this time is highly desirable in that it may serve to stimulate thought and additional study on this important problem. Furthermore, presentation of this paper at the Denver meeting offers an opportunity for the speaker to represent the U. S. Weather Bureau at the meeting and to demonstrate to the sugar beet industry that the Bureau is interested in agricultural problems, including research.

The immediate objective of this study was to devise an additional and, we hope, effective means for predicting the tonnage of beets which will be available for the factory run in the fall. This is important because it has a direct influence upon the volume of supplies to be purchased in advance, the length of factory run, the maintenance and repairs required, etc. Predictions of yield are useful, of course, insofar as they are reliable; and they are of more value in July than in September.

With this in view, then, and knowing that weather is perhaps the most important factor determining the yield of crops, we sought to establish a measurable relationship, which might be used to help predict beet yields in the Yellowstone Valley. It seemed logical that since beets are grown under irrigation, and since precipitation is very light during the growing season, rainfall might be ruled out for all practical purposes as a limiting factor in influencing yields. Therefore, temperature must be the dominant weather control. Accordingly, it was decided to correlate temperature figures at the Billings Municipal Airport with yield data from the Yegen District. This district was chosen because it has the same approximate elevation as the Airport.

In an effort to devise a method closely related to the plant's reaction to temperature, hourly values were chosen. We visualized the sugar beet as a plant growing under generally favorable moisture conditions due to irrigation, and varying its rate of growth throughout the season with variations in temperature. We assumed that, since beets are grown most

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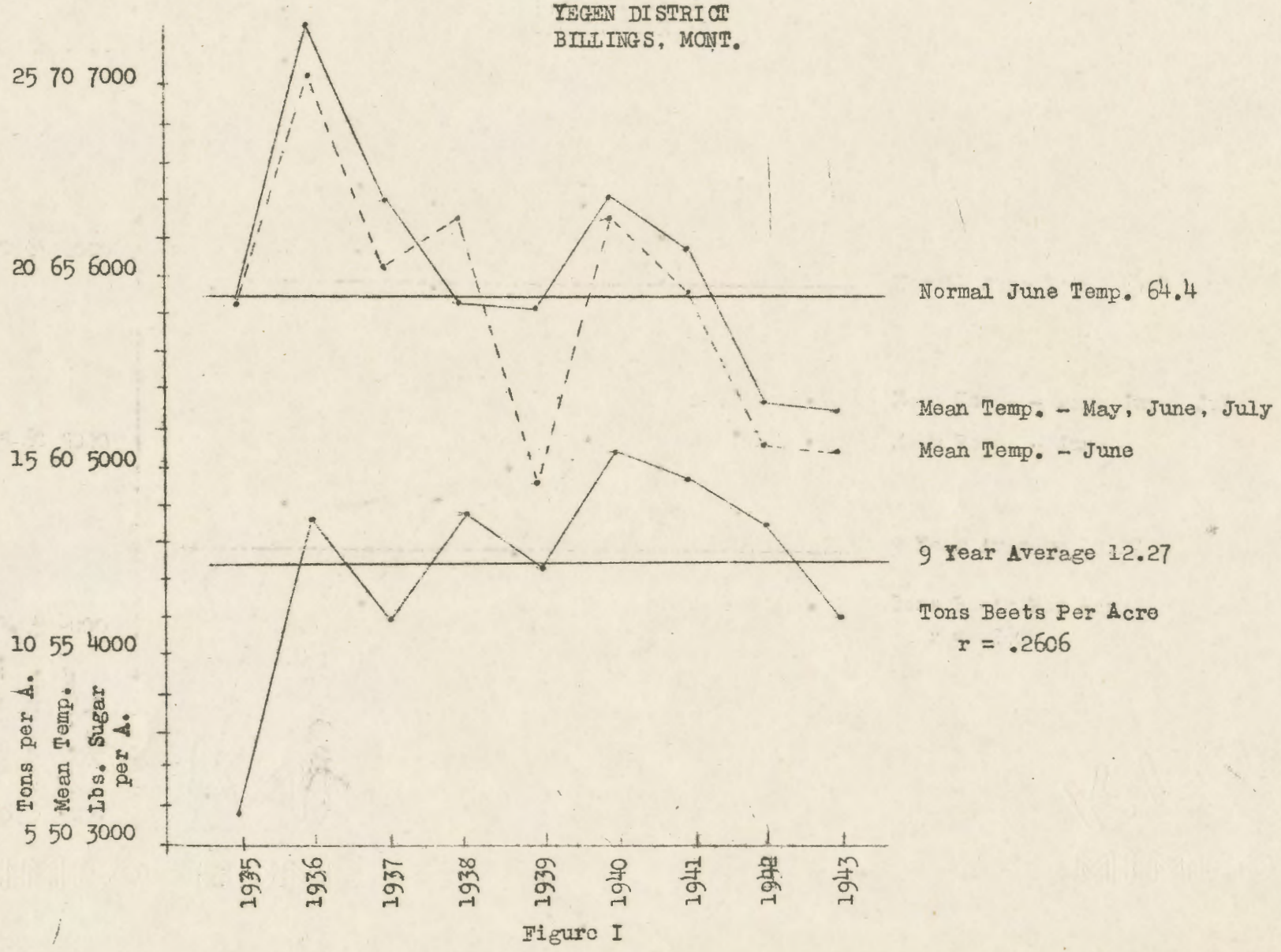
YEGEN DISTRICT
BILLINGS, MONT.
25 70 7000
20 65 6000
15 60 5000
10 55 4000
5 50 3000
Tons per A.
Mean Temp.
Lbs. Sugar per A.
1935
1936
1937
1938
1939
1940
1941
1942
1943
Normal June Temp. 64.4
Mean Temp. - May, June, July
Mean Temp. - June
9 Year Average 12.27
Tons Beets Per Acre
r = .2606

Figure I

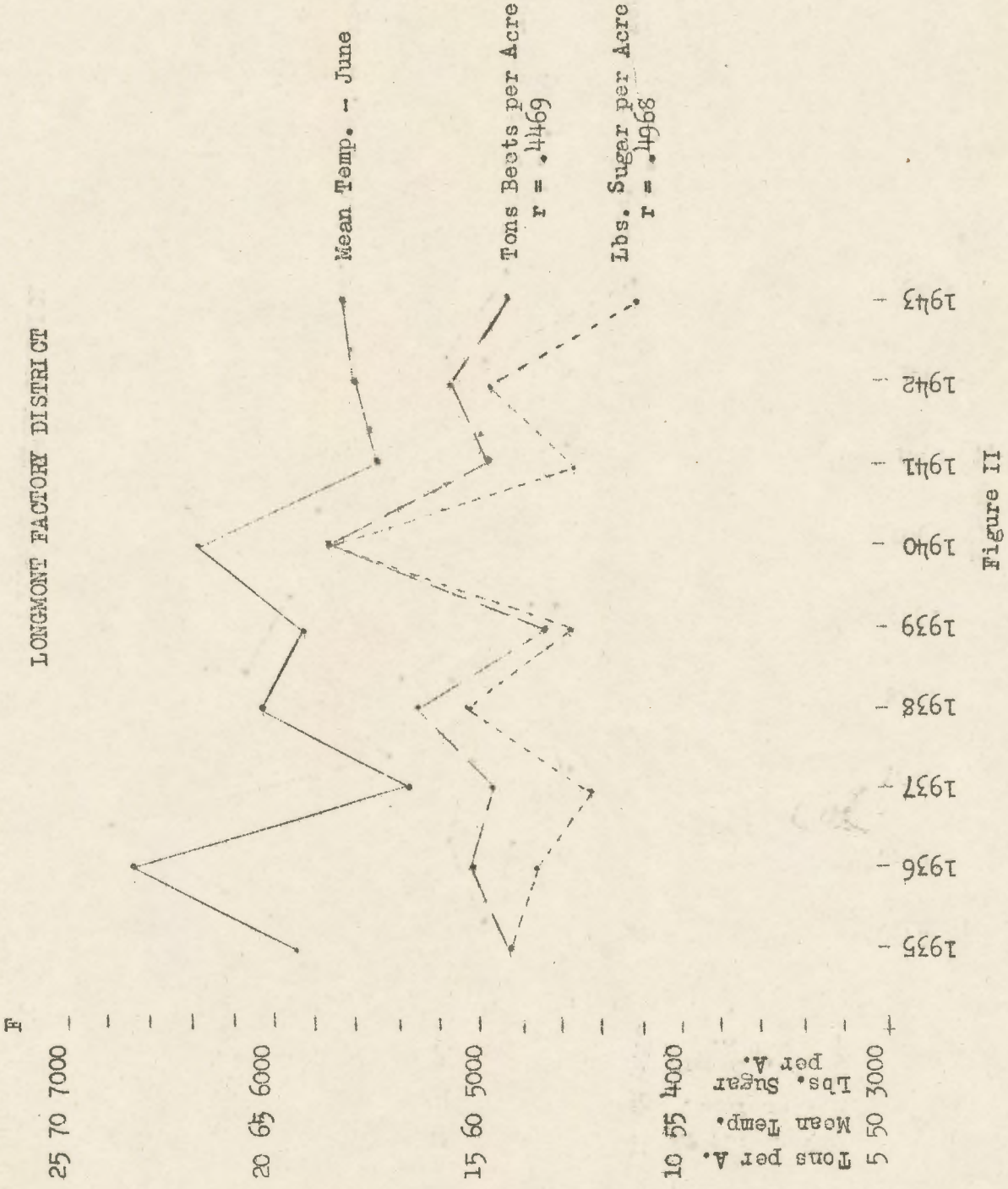
LONGMONT FACTORY DISTRICT
Mean Temp. - June
Tons Beets per Acre
r = .4469
Lbs. Sugar per Acre
r = .4968
F
25 70 7000
20 65 6000
15 60 5000
10 55 4000
5 50 3000
Tons per A.
Mean Temp.
Lbs. Sugar per A.
1935
1936
1937
1938
1939
1940
1941
1942
1943

Figure II

successfully within the climatic zone in which mean summer temperatures range between 67 and 72 degrees, the most rapid growth rate must be within the moderate temperature ranges, and slower at both higher and lower temperatures. We were unable to find any literature bearing on the subject of growth rate variations of beets with temperature, so constructed a synthetic curve, incorporating all available information on the subject. Next a tabulation was made showing the number of hours during the 1936, 1939, 1940, 1941, and 1942 growing seasons that the temperature stood at individual levels (50, 51, 52, etc.) from 40 degrees to the maximum for the season. These are the years for which both yields and hourly temperature values were available at that time. Combining these hourly frequencies of specific temperatures with the assumed growth rate curve, then, and computing totals for each season, we obtained heat unit totals for the season, which we hoped would bear a reasonable relation to the average size of beet, hence yield per acre.

Unfortunately, either the above method was not appropriate, the assumed growth curve was seriously in error, or the temperature data used were not sufficiently representative of the area from which yield figures were taken, for the results were very discouraging. I am inclined to the opinion that the method is essentially a good one, in that it represents an accumulation of heat units. The error must, therefore, be mainly concerned with our method of handling the data and lack of sufficient basic knowledge concerning the physiology of sugar beets. Suffice it to say for the present, therefore, that the original records are being retained for further study.

Partly as a test of the representativeness of the data and partly in an attempt to determine, through a relatively simple process, what, if any, relationship existed between temperature and yield, we then turned to simple monthly mean temperatures. Averages for various two- and three-month periods during the growing season were plotted as well as those for individual months. After this was done, it became apparent that a fairly close relationship existed between yield and temperature averages for the period May-June-July, as well as for June alone. Correlation coefficients were then computed with the result that June temperatures showed a closer relationship than any other month or combination of months.

Figure I shows the relation between yield in the Yegen factory district and average temperatures for the Billings Airport. The solid line in the upper portion of this diagram represents average temperatures for the three month period; and the dashed line those for June alone, the period covered by this study being 1935 to 1943. Yield data are shown in the lower portion. It is quite evident that the peaks and valleys on these curves coincide remarkably well, indicating the validity of the relationship. The correlation coefficient for June turned

out to be .2606, which is statistically significant. However, for use in predicting the yield per acre, this is not good enough, for you see that the highest yield during this nine-year period was in 1940, while the highest June temperature was in 1936. Similarly, the coldest June was in 1939, when the yield was about average. This was the year when farmers in the Yegen district had some hail damage, and also an infection of leaf spot, else the yield would have been even higher. You will note that the 1935 yield was unusually low. This was due to the extremely late completion of contracts with farmers; hence greatly delayed planting.

After finding this relation between June temperature and yield in the Billings district, Mr. Bush worked out a similar correlation between yields at the Longmont Factory Station and June temperatures at the experiment station there. These curves are shown in Figure II. Here the same parallelism between temperature and yield is evident, with the single exception that there is a slight reversal for 1943. The correlation coefficient for yield in tons of beets per acre was .4469 and for pounds of sugar per acre .4968. Both of these coefficients are statistically significant.

To add further evidence regarding the existence of a true relationship between temperature and yields, the following short article by C. J. Maroney, Vice President and General Manager of the Spreckles Sugar Company is quoted from the Honey Dew News for June, 1943. Mr. Maroney treated temperature, not as monthly means, but rather as an accumulation of monthly departures from normal for the months of March through September; and yields as percent of the 5-year average from 1938 to 1942. He says:

> "It is interesting to note the relationship between yields of sugar and temperature during the most recent five-year period, as shown on the chart. This relationship is rather significant in that the growers' yields are a composite, embodying such variations as producing areas, types of soil, time of planting, time of harvesting, cultural practices and crop rotation.
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> "Comparing the temperature chart for the year 1938 with 1942, we would look for a much better yield in 1938 than in 1942. However, in 1938 the excessive precipitation during February and March, both months having double the normal amount, definitely had an added adverse influence on the production of sugar."

Since some correlation has been found to exist between June temperatures and acre yields of sugar beets; and since temperatures for no other month or combination of months during the growing season give as high a correlation as do June temperatures, it is indicated that June may be the critical month in the development of the beet crop. A partial explanation of this may be found in the fact that thinning operations in this part of

the country are generally performed during June. Mild temperatures would surely be favorable for recovery of the plants left in the rows, thus giving them a healthy start toward maturity. Farmers are quite careful about irrigating at this time also, so as to give the plants plenty of moisture; consequently, the effect of temperatures really shows up. Furthermore, high air temperature means ample sunshine, hence warm soil, both of which are necessary for rapid plant growth.

In view of the fact that this study is aimed directly at the future possibility of using weather data as a tool for predicting acre yields of beets, it might be well at this point to elucidate somewhat on the method of prediction now in use by the Great Western Sugar Company. Pre-harvest samples are taken in early September according to a pre-arranged plan. Fields to be sampled are chosen at random after elimination of contracts below a certain size. The field men then harvest a sample of ten feet or row selected in such a manner as to preclude any human influence in the selection. One sample is taken to represent 90 to 100 acres. Three weeks later a second set of samples is taken in the same manner and location as before, and the increase in weight noted. From these two dates of early sampling, a curve is projected and serves as a basis for the prediction of the expected yield for that year. Any method of prediction which deals with as many variables as are found to influence the yield of beets cannot be expected to give the correct answer 100% of the time. Therefore, every available tool should be used which will in any measure reduce the error of prediction. June temperature may be an added tool.

Let us not kid ourselves into thinking, just because June temperatures show a significant relation to yields, that the problem is licked. Rather, this should be considered as a preliminary report only, since there are definite indications that the value of such a study as this might be enhanced by the inclusion of other variables, such as duration and intensity of sunshine, humidity, average wind movement, rate of evaporation, etc., as well as stand, varieties and cultural practices. Furthermore, I am firmly convinced that it would be possible to obtain far more significant results in this study if we had adequate knowledge of the way in which sugar beets react to variations in temperature. For the purposes of this type of research, then, I should like to urge that fundamental research on the physiology of sugar beets be undertaken. Suffice it to say for the present, however, that we have drawn no final conclusions on the basis of work already accomplished on this study, but will continue working on this intensely interesting and pertinent question of weather relationships in the hope of securing more conclusive results at a later date.