Climatic Periods and Thresholds Important To Sugarbeet Production

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The dependence of crop yield on climatic factors has been recognized for many years. For example, temperate zone plants generally undergo vegetative growth from 30°F to about 100°F but optimum growth is obtained in the range of 77-86°F (5)[2]. Went (6) found in greenhouse studies that the optimum temperature for sugarbeets was 68-73°F while sugar percentage varied inversely with temperature. He obtained the lowest sugar percentage at 86°F, which was the highest temperature of his study. Bauer et al., (1) found that root dry matter production was related to growing degree units which were calculated using a 40°F base temperature and a maximum temperature of 86°F.

The average weather conditions generally determine adaptability of a particular crop for a particular area, while variations in crop yields can be attributed largely to year-to-year variations in weather. Indentification of early season climatic patterns which significantly affect crop production may indicate management decisions to complete production of crops. This paper describes the application and results of a particular method of correlating short term weather patterns with the production of sugar beets for three stations in Wyoming.

Procedures

Caprio's (2) method of using a chi-square statistic to provide a qualitative association between climatological data and yield was employed. A subjective method of selecting the most important periods for sugar beet production was then applied by following procedures similar to those proposed by Cornia, et al., (3) for winter wheat production.

Data

Sugarbeet yield data were obtained for the Powell (for the years 1932 through 1972), Wheatland (1944-1972), and Worland (1940-1972), Wyoming areas from the factory manager or field man

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[2]Numbers in parentheses refer to literature cited.

for each area. The yields were expressed in both tons of beets per acre and sugar percentage. A linear correlation of yield as a function of years was used in an attempt to define yield trends due to technological advances and changes in management. Each of the years was then categorized according to "good," "normal," or "poor" yields. "Good" years were defined as years with the largest yields in excess of the trend line while "poor" years were defined as years with yields which were the smallest percentage of the trend line. The number of years defined as "good" and "poor" years was determined by ranking the years according to the above definitions and then selecting at the best break in the ranking to give 5 to 10 years in both the "good" and "poor" categories. This was equivalent to placing approximately one-fourth of the years in each the "good" and "poor" categories with the remainder categorized as normal. Yields, in tons of beets and sugar percentage, as a function of years for Powell are shown in Figures 1 and 2, respectively. The trend line parameters and categorized yield years for identification of climatic periods for each of the three stations are given in Table 1.

Daily occurrences of maximum and minimum temperatures and percipitation were used in the chi-square analysis. The climatic data were obtained from the National Weather Servicer, NOAA, stations in the respective areas.

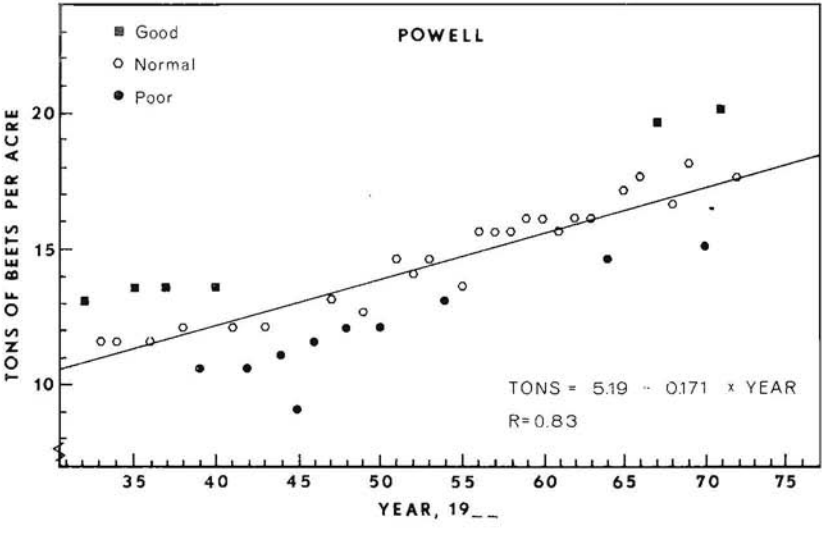

Figure 1. — Tons of beets per acre as a function of year for Powell.

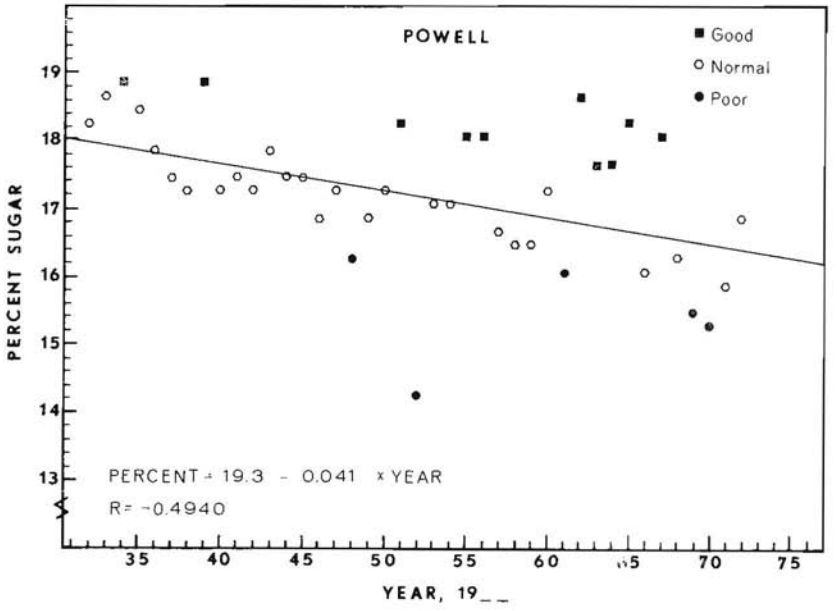

Figure 2. — Percent sugar as a function of year for Powell.

Yield-Weather Association

Indices of Association, i.e., qualitative measurements of crop response to weather, were determined between sugarbeet yields (tons of beets per acre and percent sugar) for each of the climatic parameters of daily maximum and minimum temperature and precipitation for each station. Indices were calculated for each week between January 8 and December 23 using climatic data for that week plus the week previous and the week after, giving a 21 day period associated with each index.

Caprio's (2) method, which uses a chi-square statistic to compare frequency of daily occurrences of weather events in good (poor) years with frequencies in normal years, was employed. Maximum and minimum temperatures and precipitation were divided into class intervals. Five degree Fahrenheit temperature intervals were used. The precipitation intervals (in inches) were: 0.00, trace, 0.01-0.03, 0.04-0.08, 0.09-0.15, 0.16-0.24, 0.25-0.35, 0.36-0.48, 0.49-0.63, 0.64-0.80, 0.81-0.99, 1.00-1.49, 1.50-1.99, and greater than 2.00. A chi-square value was calculated for each interval using the accumulated frequency of occurrences for all previous intervals. The chi-square statistic used was:

$$X_k^2 = \frac{(O_{n,k} - T_{n,k})^2}{T_{n,k}} + \frac{(O_{g,k} - T_{g,k})^2}{T_{g,k}},$$

Where:

k = class interval number,

$O_{n,k}$ = observed occurrences in normal years at class interval k,

$T_{n,k}$ = theoretical number of occurrences for normal years at class interval k,

$O_{g,k}$ = observed occurrences in good (or poor) years at class interval k,

$T_{g,k}$ = theoretical number of occurrences for good (or poor) years at class interval k.

The index of association for any 21-day period is defined as the highest chi-square value for that period. Intervals with less than 14 occurrences were ignored. An index was significant at the 1% level if its absolute value was greater than or equal to 6.6, i.e., the 1% level for a chi-square distribution with 1 degree of freedom. A significant index of association indicated that for the week in question, the good (poor) year's weather was significantly different than the weather in normal years. The temperature or precipitation value of the upper (or lower) limit of the interval having the largest chi-square value is defined as the threshold of the weather parameter.

Table 1. — Categorized yield years for identification of climatic periods.

	Powell (32-72)		Wheatland (41-72)		Worland (40-72)	
	Tons Beets	Percent Sugar	Tons Beets	Percent Sugar	Tons Beets	Percent Sugar
Trend Line:						
Constant	5.19	19.27	2.72	17.99	−1.12	16.77
Slope	0.171	0.041	0.163	−0.008	0.284	−0.006
R^2	0.69	0.24	0.24	0.01	0.68	0.01
Good Years*	32	34	43	44	40	43
	35	39	47	45	41	51
	37	51	49	50	69	53
	40	55	63	60	71	54
	67	56	72	68		56
	71	62				68
		63				
		64				
		65				
		67				
Poor Years*	39	48	54	42	45	40
	42	52	55	48	48	41
	44	61	56	52	61	42
	45	69	62	54	62	48
	46	70	64	55	64	61
	48		70	69	65	65
	50					71
	54					
	64					
	70					

*Years not listed were categorized as normal years.

Selection of Periods

Once indices of association were calculated for all weeks and weather parameters, it was necessary to select the periods considered most important to sugar beet production. As discussed by Cornia, et al., (4) these periods could be selected either objectively, by considering all or an arbitrary percentage of the indices which were statistically significant, or they could be selected subjectively by using criteria established for this purpose. For this study the subjective method was used, with the criterion that an important period was one having significant indices for both high and low values of the weather parameter. For example, an important period would be one with significant indices for both high and low maximum temperatures. This is further illustrated in Figure 3 which is a plot of the index of association as a function of weeks of the year for maximum temperature in poor years (with yields expressed in tons of beets) at Powell. The significant indices are indicated by the hatched areas. A negative index indicates a deficit of temperatures above or below the threshold while a positive index indicates an excess of temperatures above or below the threshold. The period of July 7 to August 10 is an important period according to the criteria set up since an excess of maximum temperatures greater than 70°F is significant while a deficit of maximum tempertures less than 70°F is also significant in poor years. The period of September 7 - 28 is not considered important, however, since there is no complement to the excess of maximum temperatures greater than 80°F.

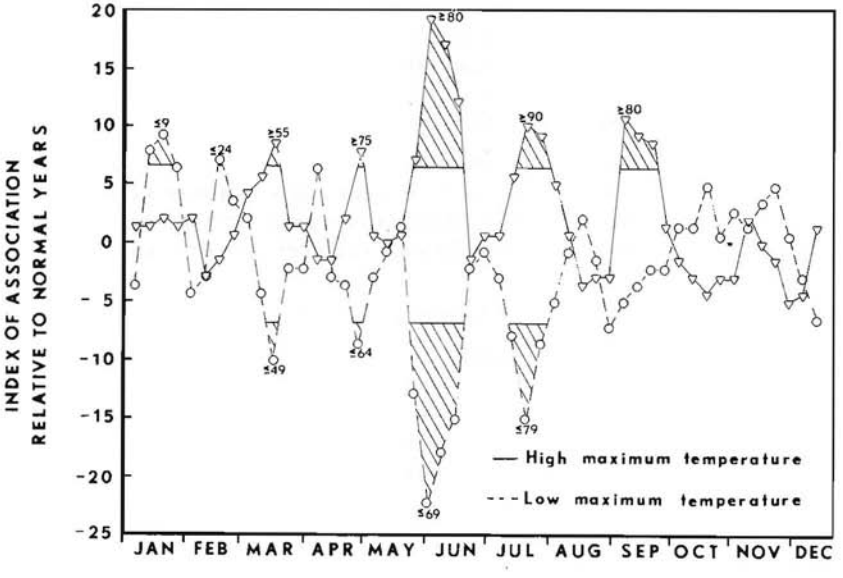

Figure 3. — Association between high and low maximum temperature and tons of beets, poor years vs normal years, 1932-1972, Powell, Wyoming.

Results and Discussion

No important periods were identified for precipitation. This is probably as expected in an irrigated area unless there is a correlation between precipitation and temperature or field operations. Apparently delays and losses experienced due to excess precipitation at planting and harvest of sugarbeets do not occur frequent enough or do not cause large enough losses to become significant in this type of analysis. Obviously losses of this type do occur, but probably not to the magnitude to turn a good year into a normal year or a normal year into a poor year.

Important periods indentified for temperatures for Powell, Worland and Wheatland are shown in Tables 2, 3, and 4, respectively. In an attempt to generalize, nonconflicting periods and thresholds indicate that:

1. Good yields of tons of beets are obtained when there is an excess of maximum temperatures less than 90°F in July and August and less than 70°F in September.
2. Poor yields of tons of beets are obtained when there is an excess of maximum tempertures less than 60°F in May and greater than 84°F in July and when there is an excess of minimum temperatures less than 35°F in May and less than 55°F in July.
3. Good sugar percentages are obtained when there is an excess of maximum temperatures less than 70°F in October and less than 48°F in November and when there is an excess of minimum temperatures greater than 50°F in August and less than 30°F in October.
4. Poor sugar percentages are obtained when there is an excess of maximum temperatures less than 80°F in late May and early June, less than 90°F in August and less than 48°F in November and when there is an excess of minimum temperatures less than 45°F in August.

It should be noted that the generalizations are for three specific stations. This is not an attempt to obtain a growth model for sugar beets, but rather an attempt to differentiate good and poor yield years for specific locations based on climatic differences for those areas.

Summary

The dependence of sugarbeet production on temperature and precipitation has been investigated for three Wyoming stations. The most important periods have been defined by applying Caprio's (2) method of using a chi-square statistic to provide a qualitative association between climato logical data and yield.

Results for each of the stations and generalizations for the three stations are presented. No important precipitation periods were identified. Most of the temperature periods which depressed yields were excesses of warm temperatures, especially for tons of beets per acre.

Table 2. — Climatic periods and thresholds identified for Powell sugarbeet production.

Period	Temperature Occurrences and Levels	Effect
Jan. 1 - Jan. 28	An excess of max. temp. above 34°F and a deficit of max. temp. below 33°F	Good Yield*
Jan. 1 - Feb. 18	An excess of min. temp. below 15°F and a deficit of min. temp. above 19°F	Good Sugar %
Feb. 19 - Mar. 17	An excess of max. temp. above 34°F and a deficit of max. temp. below 40°F	Good Sugar %
Mar. 11 - Mar. 31	An excess of max. temp. above 54°F and a deficit of max. temp. below 50°F	Poor Yield
Apr. 22 - May 11	An excess of max. temp. above 74°F and a deficit of max. temp. below 65°F	Poor Yield
May 12 - June 15	An excess of max. temp. below 75°F and a deficit of max. temp. above 79°F	Poor Sugar %
May 12 - June 15	An excess of min. temp. below 50°F and a deficit of min. temp. above 49°F	Poor Sugar %
May 19 - June 29	An excess of max. temp. above 79°F and a deficit of max. temp. below 70°F	Poor Yield
May 19 - June 15	An excess of min. temp. above 49°F and a deficit of min. temp. below 45°F	Poor Yield
July 7 - Aug. 10	An excess of max. temp. above 89°F and a deficit of max. temp. below 80°F	Poor Yield
July 14 - Aug. 24	An excess of min. temp. above 59°F and a deficit of min. temp. below 50°F	Poor Yield
July 28 - Sept. 7	An excess of max. temp. below 85°F and a deficit of max. temp. above 89°F	Good Yield
Aug. 4 - Aug. 31	An excess of max. temp. below 90°F and a deficit of max. temp. above 89°F	Poor Sugar %
Sept. 29 - Oct. 19	An excess of max. temp. below 45°F and a deficit of max. temp. above 74°F	Good Sugar %
Sept. 29 - Oct. 19	An excess of min. temp. below 30°F and a deficit of min. temp. above 34°F	Good Sugar %
Oct. 20 - Nov. 9	An excess of min. temp. below 20°F and a deficit of min. temp. above 34°F	Good Sugar %
Oct. 20 - Nov. 16	An excess of max. temp. below 50°F and a deficit of max. temp. above 49°F	Good Sugar %

*Yield refers of yield in tons of beets per acre

Table 3. — Climatic periods and thresholds identified for Wheatland sugarbeet production.

Period	Temperature Occurrences and Levels	Effect
Jan. 8 - Jan. 21	An excess of max. temp. above 39°F and a deficit of max. temp. below 30°F	Poor Yield*
Jan. 8 - Jan. 28	An excess of min. temp. above 19°F and a deficit of min. temp. below 0°F	Good Yield
Jan. 22 - Jan. 28	An excess of max. temp. above 44°F and a deficit of max. temp. below 35°F	Good Yield
Feb. 12 - Feb. 25	An excess of max. temp. below 45°F and a deficit of max. temp. above 54°F	Good Yield
Mar. 11 - Mar. 24	An excess of max. temp. above 59°F and a deficit of max. temp. below 25°F	Poor Sugar %
Mar. 18 - Mar. 24	An excess of min. temp. above 34°F and a deficit of max. temp. below 20°F	Poor Yield
Apr. 8 - Apr. 14	An excess of max. temp. below 60°F and a deficit of max. temp. above 59°F	Poor Sugar %
Apr. 15 - Apr. 28	An excess of max. temp. above 59°F and a deficit of max. temp. below 60°F	Good Sugar %
Apr. 22 - May 4	An excess of min. temp. above 34°F and a deficit of max. temp. below 35°F	Good Sugar %
Apr. 29 - May 18	An excess of max. temp. below 60°F and a deficit of max. temp. above 79°F	Poor Yield
May 5 - May 18	An excess of min. temp. below 35°F and a deficit of min. temp. above 44°F	Poor Yield
June 23 - Aug. 10	An excess of min. temp. below 55°F and a deficit of min. temp. above 59°F	Poor Yield
July 7 - July 13	An excess of max. temp. below 90°F and a deficit of max. temp. above 89°F	Poor Sugar %
July 21 - Aug. 3	An excess of max. temp. below 85°F and a deficit of max. temp. below 94°F	Good Yield
Aug. 4 - Aug. 10	An excess of min. temp. below 55°F and a deficit of min. temp. above 54°F	Good Yield
Aug. 11 - Aug. 17	An excess of min. temp. above 54°F and a deficit of min. temp. below 45°F	Good Sugar %
Aug. 18 - Aug. 31	An excess of max. temp. below 80°F and a deficit of max. temp. above 94°F	Poor Sugar %
Aug. 18 - Sept. 7	An excess of min. temp. below 45°F and a deficit of min. temp. above 54°F	Poor Sugar %
Sept. 15 - Oct. 5	An excess of max. temp. below 70°F and a deficit of max. temp. above 74°F	Good Yield
Oct. 13 - Oct. 19	An excess of max. temp. below 65°F and a deficit of max. temp. below 74°F	Good Sugar %
Nov. 24 - Nov. 30	An excess of max. temp. above 44°F and a deficit of max. temp. below 45°F	Poor Sugar %
Nov. 24 - Dec. 7	An excess of min. temp. above 29°F and a deficit of min. temp. below 25°F	Good Sugar %

*Yield refers to yield in tons of beets per acre.

Table 4. — Climatic periods and thresholds identified for Worland sugarbeet production.

Period	Temperature Occurrences and Levels	Effect
Jan. 15 - Jan. 21	An excess of max. temp. below 15°F and a deficit of max. temp. above 54°F	Good Sugar %
Mar. 25 - Apr. 7	An excess of max. temp. above 54°F and a deficit of max. temp. below 55°F	Poor Yield*
Mar. 24 - Apr. 14	An excess of min. temp. below 35°F and a deficit of min. temp. above 34°F	Good Yield
Apr. 8 - Apr. 14	An excess of min. temp. above 24°F and a deficit of min. temp. below 25°F	Good Sugar %
Apr. - Apr. 28	An excess of min. temp. below 35°F and a deficit of min. temp. above 34°F	Good Yield
June 9 - June 15	An excess of max. temp. below 80°F and a deficit of max. temp. above 84°F	Poor Sugar %
June 9 - June 22	An excess of min. temp. below 45°F and a deficit of min. temp. above 60°F	Poor Sugar %
July 21 - Aug. 24	An excess of min. temp. below 50°F and a deficit of min. temp. above 54°F	Good Yield
Aug. 18 - Sept. 7	An excess of min. temp. above 44°F and a deficit of min. temp. below 45°F	Poor Yield
Sept. 8 - Sept. 14	An excess of max. temp. above 84°F and a deficit of max. temp. below 55°F	Poor Yield
Sept. 8 - Sept. 21	An excess of min. temp. above 44°F and a deficit of min. temp. below 30°F	Poor Yield
Sept. 22 - Sept. 28	An excess of max. temp. above 84°F and a deficit of max. temp. below 55°F	Poor Yield
Sept. 22 - Sept. 28	An excess of max. temp. above 69°F and a deficit of max. temp. below 65°F	Poor Sugar %
Sept. 22 - Oct. 5	An excess of max. temp. above 74°F and a deficit of max. temp. below 70°F	Good Yield
Nov. 10 - Nov. 30	An excess of max. temp. below 35°F and a deficit of max. temp. above 54°F	Good Sugar %

*Yield refers to yield in tons of beets per acre.

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