The Relationship of Yield and Size of Beets to Sucrose Percentage of Beets Grown in Southern Alberta, Canada

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THE EXISTENCE of an inverse relationship between weight of beet and sucrose percentage seems to be generally accepted. Much research has been conducted to evolve agronomic practices which would increase the yield of beets without lowering the percentage of sucrose. Heretofore, no information has been available in regard to the correlation between yield and sucrose percentage of beets grown in Alberta but a deviation from usually accepted behavior has been suspected.

The Experimental Station at Lethbridge, Alberta, Canada, is approximately in the centre of the most northerly sugar beet producing area in North America. The latitude is 49° 42′ and the longitude is 112° 50′. The summer climate is characterized by very long days with warm to hot temperatures and cool nights. The average growing season has been 141 days.

During the 23 years since the establishment of the present sugar beet industry the consistently high percentage of sucrose in beets grown in this area has been apparent. In a previous publication (4)[2] the average yield of beets has been quoted at 12.18 tons per acre and the average percentage of sucrose at 17.85.

Brewbaker and McGreevy (1), working in Colorado, report significant correlations of $r = -.6310$ for an unselected population and of $r = -.1839$ for a selected group of beets. Cook et al (2) of Michigan observe that larger beets are generally recognized to be lower in sucrose percentage than are smaller beets. However, in Alberta it has been observed, as reported previously (4), that application of manure which increased the size of beets, did not depress the sucrose percentage, and also that plots of beets grown in rotational studies differed widely in yield but were similar, if not identical, in sucrose percentage. Furthermore, it has been observed that imported American varieties frequently have shown a higher percentage of sucrose under Alberta conditions than under the more southerly climate where they were developed. These apparent divergencies have prompted the present investigation.

Materials and Methods

A random population of roots from each of four pairs of sugar beet plots growing in an experimental rotation was selected, weighed, and

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

analysed individually. This rotation has 2 successive years of beets following a manurial treatment. Triple superphosphate fertilizer has been applied each year at the time of seeding the beets. In an additional study several hundred selected roots from a breeding block of the Kuhn variety of beets were weighed and analysed individually. Correlations between weight and sucrose percentage were calculated for each plot of beets in the former and for each group of one hundred beets (in order of analysis) in the latter test. Similar correlations were calculated also for the total population of beets from each of the two tests.

In addition studies were made on the yield-sucrose percentage relationship of beets grown in a sweetclover rotation experiment. This rotation is of 4 years' duration and consists of beets, beets, wheat and sweetclover, and sweetclover summer-fallow. The sweetclover has been plowed under at various stages of growth or cut for hay. There were six different methods of handling the sweetclover in the summer-fallow year. Sugar beets have been grown after sweetclover summer-fallow and the next year beets have followed beets. Since the rotation is continuous, direct comparisons were available every year for yield and sucrose percentage between beets grown after sweetclover summer-fallow and beets grown after beets under the same fertility treatment.

Experimental Results

The correlation coefficients and yield performance of beets from the four pairs of plots are presented in table 1.

Table 1.—Average yield performance and correlation coefficients between weight and sucrose percentage of sugar beets grown under different fertility treatments at Lethbridge, Alberta.

			10-year average		Correlation coefficients	
Fertility treatments	Crop	Rep.	Yield per acre (tons)	Sucrose percentage	Calculated	5 percent level
30 tons manure and 100 pounds triple superphosphate per acre	First	1	19.77	15.8	.186	.304
		2	18.84	15.7	-.241	.325
	Second	1	19.53	16.3	-.393	.273
		2	19.11	16.2	-.402	.286
100 pounds triple superphosphate per acre	First	1	13.87	16.0	.090	.273
		2	11.74	15.5	-.003	.325
	Second	1	16.09	16.4	-.145	.325
		2	16.01	16.0	-.285	.286
For complete experiment					-.154	.108

The data in table 1 indicate considerable variability between the correlation coefficients of the various groups. Only one pair of plots showed significant negative correlations between weight and sucrose percentage. In the remaining six plots the correlation coefficients varied from a non-significant positive value to a negative value which approached significance.

The correlation coefficients for a total of 800 selected roots and for each group of 100 comprising this total are presented in descending order of average weight of beet in table 2.

Table 2. Average weight and sucrose percentage and the correlation between weight and sucrose percentage of eight groups of selected beets grown in a breeding block at Raymond, Alberta.

Group	Mean weight (ounces)	Mean sucrose percentage	Correlation coefficients	
			Calculated	5 percent level
1	43.7	18.6	—.400	.197*
3	42.9	18.0	.302	.197
2	41.1	18.3	-.405	.197
4	37.6	17.3	-.204	.197
7	36.5	17.8	—.153	.197
8	36.5	17.3	—.140	.197
5	34.2	17.8	—.061	.197
6	33.9	17.6	.001	.197
Total population			-.093	.075

*Values are approximated by interpolation from Table 7.3 of "Statistical Methods", G. W. Snedecor, The Collegiate Press, Ames, Iowa, 1946.

The results presented in table 2 also are extremely variable. The correlation coefficients varied from —.405 to .001. In this experiment beets were selected on the basis of morphology and weight beginning on one side of a small field and continuing across. The group numbers in table 2 give the order in which the lots of 100 were analysed. In a general way they also indicate the position in the field from which the roots were selected (that is, groups 1 and 2 were adjacent). The field was considered to be very uniform. It will be noted that there were significantly negative correlations for four of the groups while the value for the other four groups were nonsignificant; three being negative and the remaining one positive.

Four years' results for the yields and sucrose percentages of the first and second crops of beets following sweetclover summer-fallow are presented in table 3.

Whereas the data in tables 1 and 2 dealt with the analyses of individual roots those in table 3 have been obtained from analyses of samples of populations of sugar beets grown under different fertility treatments. The four seasons selected include "high" and "low" sugar years (1942 and 1946, respectively) as well as years of average sucrose percentage. It will be noted that the mean yields for the first and second crops were 17.84 and 14.89 tons per acre, respectively. The difference between these means was statistically significant. However, there was no significant difference between the means of sucrose percentage for the first and second crops. This was true of each year as well as for the total of 4 years. Since the number of beets per acre in the first and second crops was of the same order it must be concluded that the large beets of the first crop were equal in sucrose percentage to the comparatively smaller beets of the second crop. This is not in agreement with the observations of Cook et al (2).

The difference in suitability of the land for the first and second crops of beets is thought to be made up of physical fitness as well as fertility considerations. Sweetclover summer-fallow has left the soil in excellent tilth and apparently well supplied with readily available nutrients. The comparative deficiency in both of these factors is thought to be the reason for the yield reduction in the second crop of beets.

Table 3. Four years' results for yield in tons per acre and sucrose percentage of first and second crops of beets under six fertility treatments after sweetclover summer-fallow.

Year	Fertility treatment	First crop Yield	First crop Sucrose percentage	Second crop Yield	Second crop Sucrose percentage
1942	1	17.17	18.6	13.45	18.3
	2	14.41	18.5	14.31	18.1
	3	15.63	17.3	15.64	17.6
	4	15.39	17.5	14.54	18.8
	5	16.54	17.9	15.19	18.7
	6	15.64	18.2	14.39	18.2
1944	1	16.97	16.8	16.70	16.6
	2	18.29	18.5	16.01	17.6
	3	17.69	17.5	15.29	17.2
	4	19.11	18.1	18.29	17.6
	5	17.73	16.3	17.00	16.8
	6	19.25	17.0	16.60	17.4
1946	1	18.97	16.2	12.72	15.9
	2	18.37	16.8	12.42	15.0
	3	18.22	16.5	12.54	15.8
	4	18.32	16.0	11.54	16.0
	5	17.92	15.0	15.00	14.8
	6	15.40	15.3	11.14	15.7
1947	1	21.44	17.6	15.86	17.1
	2	20.49	17.8	15.92	17.0
	3	19.18	17.1	16.99	16.2
	4	17.58	16.9	16.57	16.7
	5	19.48	17.6	14.50	16.7
	6	19.01	17.3	14.67	17.4
Means		17.84	16.5	14.89	16.9

Discussion of Results

Correlation between weight and sucrose percentage. A significant negative correlation between the weight and sucrose percentage of sugar beets usually is regarded as a maxim (1) (2).

It appears from table 2 that the larger beets in groups 1 to 4 were of such constitution as to display a significant negative correlation between weight and sucrose percentage, whereas the slightly smaller beets in the remaining groups failed to do so. It has not been possible to find an explanation for this behaviour. Since the general correlations (—.093 and —.154, respectively) for the two total populations discussed in tables 1 and 2, even though significant, were of much lower magnitude than usually reported for sugar beets (1) it is felt that the relationships between weight and sucrose percentage for these populations are not close and in fact the existence of a relationship of practical value may be questioned.

A regression coefficient of —.014 percent sucrose per ounce of weight has been calculated for the data summarized in table 2. This factor is so small in comparison with the experimental error that it is of negligible value in prediction.

According to table 3, under Alberta conditions a ton of beets from a field yielding 18 tons per acre may be expected to have as high sugar content as a ton of beets from a less fertile field yielding 15 tons per acre. If this apparent conclusion is real it is of great agronomic significance.

Effect of climate.— The climatic environment may be an influential factor in the yield-sucrose percentage relationship of beets grown in southern Alberta. Because of the northern latitude, the total hours of daylight during the summer months exceed most other beet-producing areas. The total hours of daylight (sunrise to sunset) for Lethbridge and Salt Lake City are compared by months in table 4.

Table 4.—Total hour of daylight (sunrise to sunset) at Lethbridge and Salt Lake City during the summer months.

	May	June	July	August	Sept.	Total
Lethbridge	477.9	488.7	492.1	447.4	378.3	2,284.4
Salt Lake City	448.2	451.0	457.5	427.0	374.1	2,157.8

Northern Colorado, northern California, and northern Ohio are approximately comparable in latitude to Salt Lake City.

Ulrich (5) has studied the conditions most favorable to the formation of sugar in the beet. The most favorable environment for the storage of sugar in the beet would embody intense sunlight, warm to hot days, and cool nights; this would allow for a maximum of photosynthesis with a minimum of respiration. The summer climate of southern Alberta satisfies this requirement quite well. The mean daily maximum and minimum temperatures for several beet-producing areas are compared with Lethbridge in table 5.

Table 5.—Monthly averages of daily mean maximum and mean minimum temperatures in degrees Fahrenheit for several beet-producing areas of the United States compared with Lethbridge, Alberta.

	Lethbridge, Alberta		Woodland, California		Fort Collins, Colorado		Salt Lake City, Utah	
Month	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
May	62.7	37.4	71.0	62.0	67.0	40.3	71.8	44.9
June	67.6	46.3	76.2	63.6	76.1	48.1	81.7	52.1
July	80.8	50.9	86.2	69.5	85.5	54.7	92.4	61.4
August	76.6	47.5	80.2	65.8	84.4	54.5	89.7	59.4
September	65.4	40.6	76.8	63.5	76.2	43.0	79.0	49.1

It will be noted that the climate of Lethbridge, Alberta, is characterized by both cooler days and cooler nights than the other beet-producing areas to which it has been compared in table 5. It is agreed generally that the rate of photosynthesis may be reduced if the temperature rises above 85 degrees to 95 degrees Fahrenheit. Hence, the extremely hot weather of some areas may have an inhibiting effect on photosynthetic activity.

Summary

Correlation coefficients between weight and sucrose percentage are presented for several groups of individually analysed sugar beets. Comparisons are made also between the yield and sucrose percentage of sugar beets grown under different fertility treatments in a sweetclover-sugar beet rotation.

The correlation coefficients were extremely variable and less than half were significantly negative beyond the 5 percent level. Large beets were equal in sucrose percentage to small beets (with comparable stands) in the sweetclover-sugar beet rotation.

It is suggested that climate may be an important factor in the relationship which exists between yield and sucrose percentage in Alberta. Tables are presented which show the summer climate of Alberta to be characterized by more hours of daylight and cooler temperatures in comparison with several beet-growing areas of the United States.

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