

Seasonal Patterns of Sucrose Accumulation and Weight Increase in Sugar Beets¹

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Studies by Ulrich (5)³ indicated that the sugar beet root remained relatively low in sucrose content until the occurrence of low autumn temperatures, after which there was a rapid increase. Hills et al. (4) reported that consistent differences were observed between varieties during the latter part of the growing season. Bush (2) however observed interactions between varieties and harvest dates and concluded that it was important to consider the date of harvest when evaluating varieties.

The purpose of this study was to assess the importance of date of harvest in evaluating varieties for root weight and sucrose percent and to observe the pattern of growth and sucrose accumulation of two varieties.

Methods and Materials

The rate of growth and development of two diploid varieties of sugar beet was studied in field experiments on the Research Farm of Canadian Sugar Factories, Taber, Alberta, during the 1961 and 1962 growing seasons. The varieties used were CS7, a high-root-yield variety selected for commercial production in Western Canada and A90, a variety with low-root-yield and high-sucrose content. Plots were laid out in a latin square design with eight replications and eight harvest dates. Each main plot was divided into two 35 feet long one-row sub-plots for varieties. The rows were spaced 22 inches apart. After emergence of the seedlings the stand was thinned to 100 to 120 plants per 100 feet of row.

The experiments were planted on May 18 and April 26 in 1961 and 1962, respectively. The harvest dates for each of the two years were as given below.

¹ Contribution of the Canadian Sugar Factories, Taber, Alberta, Canada.

² Plant Breeder.

³ Numbers in parentheses refer to literature cited.

Harvest date	1961	1962
I	July 17	July 17
II	August 1	July 31
III	August 15	August 14
IV	August 29	August 28
V	September 12	September 11
VI	September 26	September 24
VII	October 10	October 9
VIII	October 24	October 19

On each harvest date, roots from 25 feet of row per plot were dug, immediately washed, weighed, and sampled with a multisaw beet rasp to provide a uniform sample of finely divided pulp. Percent sucrose and raw juice purity were determined by a hot water extraction method described by Browne and Zerban (1). Dry matter of the roots was determined by drying the samples in a forced draft oven at 90°C for 48 hours. Sucrose per acre, dry matter per acre and percent sucrose on dry matter basis were obtained by making the appropriate calculations. The analysis of variance was performed as outlined by Goulden (3). The two varieties were compared for each character on each harvest date in each year. Air temperature data were obtained from the Department of Transport Climatological Station, Taber, Alberta and are given in Figure 1.

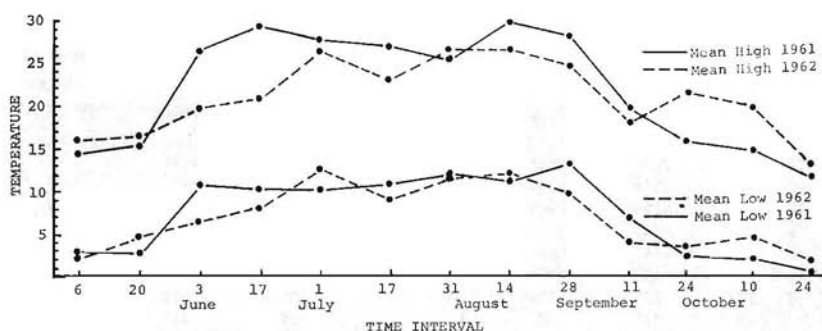


Figure 1.—Mean air temperature (°C) for various time intervals during the growing seasons of 1961 and 1962.

Results

Yield of roots. The yields of roots for both 1961 and 1962 are in close agreement (Table 1). In both years, CS7 yielded significantly more than A90 on each date, with the difference becoming progressively greater as the growing season advanced. In both years, A90 was characterized by a rapid reduction in

growth rate after the end of August, whereas CS7 showed a more gradual reduction. Both varieties continued to increase in weight until the last harvest date, although the growth increments between successive dates were not always statistically significant towards the end of the season.

Yield of sucrose. The yield of sucrose per acre increased on a straight line basis during the portion of the growing season studied in both 1961 and 1962 (Table 2). In both years, CS7

Table 1.—Yield of sugar beet roots in tons per acre for CS7 and A90 on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	3.68	2.94	**	6.51	5.31	**
II	9.63	6.83	**	10.90	8.27	**
III	14.79	10.22	**	15.15	10.66	**
IV	18.32	13.52	**	18.68	12.98	**
V	21.30	14.70	**	20.91	13.13	**
VI	23.26	15.18	**	22.96	15.12	**
VII	24.53	16.22	**	24.80	15.36	**
VIII	25.31	16.75	**	25.13	16.63	**
L.S.D. (5%)	1.54	0.89		1.03	0.95	
L.S.D. (1%)	2.06	1.19		1.37	1.27	

** Varieties significantly different at the 1% level.

Table 2.—Yield of sucrose in pounds per acre for CS7 and A90 sugar beet varieties, on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	556	473	*	1255	1142	N.S.
II	1773	1357	**	2517	2182	*
III	3036	2337	**	4312	3413	**
IV	4361	3696	**	5484	4335	**
V	5195	4025	**	6697	4677	**
VI	6373	4830	**	7930	5756	**
VII	7387	5694	**	9114	6274	**
VIII	7858	5976	**	9467	6872	**
L.S.D. (5%)	355	322		327	358	
L.S.D. (1%)	473	430		436	477	

N.S. Varieties not significantly different at the 5% level.

* Varieties significantly different at the 5% level.

** Varieties significantly different at the 1% level.

made statistically significant increases during each two week period. However, for A90, there was one two-week period in each year during which the increases were not statistically significant. This was between harvest dates VII and VIII in 1961 and dates IV and V in 1962. CS7 yielded significantly more sucrose than A90 on every harvest date except date I in 1962.

Yield of dry matter. CS7 yielded significantly more dry matter than A90 on all dates in both years, except date I in 1962 (Table 3). In both years, the difference between the two varieties became progressively greater as the growing season advanced. In each year, CS7 showed significant increments in yield for each date except date VIII. A90 made significant growth increments except for date VIII in 1961 and date V in 1962. The production of dry matter by both varieties appeared to follow a straight line in each year.

Table 3.—Yield of root dry matter in tons per acre for CS7 and A90 sugar beet varieties on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	0.43	0.36	*	0.98	0.89	N.S.
II	1.22	0.95	*	1.89	1.60	*
III	1.88	1.55	*	3.02	2.36	**
IV	2.63	2.30	**	3.83	2.97	**
V	3.36	2.69	**	4.54	3.17	**
VI	4.26	3.30	**	5.32	3.84	**
VII	5.18	3.93	**	6.01	4.09	**
VIII	5.35	3.97	**	6.18	4.49	**
L.S.D. (5%)	0.25	0.23		0.23	0.24	
L.S.D. (1%)	0.33	0.30		0.31	0.32	

N.S. Varieties not significantly different at the 5% level.

* Varieties significantly different at the 5% level.

** Varieties significantly different at the 1% level.

Percent sucrose. The percent sucrose data for both varieties and both years are shown in Table 4. A90 was consistently higher

Table 4.—Percent sucrose for CS7 and A90 sugar beet varieties on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	7.64	8.15	N.S.	9.65	10.75	**
II	9.15	9.95	**	11.55	13.17	**
III	10.31	11.41	**	14.25	16.00	**
IV	11.91	13.66	**	14.70	16.70	**
V	12.24	13.70	**	16.02	17.82	**
VI	13.76	15.91	**	17.27	19.03	**
VII	15.10	17.56	**	18.38	20.43	**
VIII	15.59	17.81	**	18.83	20.66	**
L.S.D. (5%)	0.78	0.70		0.42	0.41	
L.S.D. (1%)	1.05	0.94		0.56	0.54	

N.S. Varieties not significantly different at the 5% level.

** Varieties significantly different at the 1% level.

in percent sucrose than CS7, although this difference was not significant on the first harvest date in 1961. The increments in percent sucrose between successive harvest dates for CS7 and A90 were not significant for dates V and VIII in 1961 and for A90 for harvest date VIII in 1962. In 1962, the percent sucrose was consistently above that for 1961 on each harvest date.

Percent sucrose on dry weight basis. This character varied greatly from 1961 to 1962 (Table 5).

Table 5.—Percent sucrose on dry weight basis for CS7 and A90 sugar beet varieties on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	64.8	66.9	N.S.	64.0	64.6	N.S.
II	72.7	71.7	N.S.	66.6	68.3	*
III	81.2	75.3	**	71.4	72.3	.
IV	83.1	80.6	N.S.	71.6	72.9	.
V	77.4	75.1	N.S.	73.7	73.7	N.S.
VI	71.5	73.3	**	74.6	75.0	N.S.
VII	71.3	72.5	N.S.	75.9	76.8	N.S.
VIII	73.6	75.2	.	76.4	76.5	N.S.
L.S.D. (5%)	3.70	3.85		1.01	1.04	
L.S.D. (1%)	4.93	5.14		1.35	1.39	

N.S. Varieties not significantly different at the 5% level.

* Varieties significantly different at the 5% level.

** Varieties significantly different at the 1% level.

In 1961, CS7 and A90 differed significantly on three dates with CS7 being higher on date III and A90 being higher on dates VI and VIII. Both CS7 and A90 reached a peak on date IV and dropped significantly until date VI after which there was no significant change.

In 1962, there was a steady increase for both varieties. The increases in percent sucrose on a dry weight basis were significant except for dates IV, VI and VIII for CS7, and dates IV, V and VIII for A90. On dates II, III and IV, A90 was significantly higher than CS7.

Percent dry matter of the roots. In 1961, as well as in 1962, both varieties increased in percent dry matter of the root as the growing season advanced (Table 6). However, the increments were not significant for every harvest date.

In 1961, CS7 made significant increases for all harvest dates except II, III, and VIII, while A90 made significant increases for all dates except VIII.

In 1962, both varieties made significant increases for all except date VIII. A90 was significantly higher than CS7 on all dates in both years except date I in 1961.

Table 6.—Percent dry matter of the roots for CS7 and A90 sugar beet varieties on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	11.78	12.16	N.S.	15.08	16.65	**
II	12.60	13.90	..	17.36	19.28	..
III	12.73	15.18	**	19.95	22.13	..
IV	14.37	16.96	**	20.51	22.90	..
V	15.86	18.30	**	21.74	24.18	**
VI	19.23	21.70	**	23.17	25.37	..
VII	21.16	24.21	**	24.24	26.61	..
VIII	21.18	23.71	..	24.60	27.00	..
L.S.D. (5%)	0.96	0.91		0.49	0.68	
L.S.D. (1%)	1.27	1.21		0.65	0.91	

N.S. Varieties not significantly different at the 5% level.

** Varieties significantly different at the 1% level.

Percent purity. CS7 and A90 did not differ significantly in percent purity except on date VIII in 1962 (Table 7). In 1961 both varieties increased rapidly in percent purity until date III and did not vary significantly from this on subsequent harvest dates.

Table 7.—Raw juice purity for CS7 and A90 sugar beet varieties on each of eight harvest dates in 1961 and 1962.

Harvest date	1961			1962		
	Variety		Level of significance	Variety		Level of significance
	CS7	A90		CS7	A90	
I	64.3	63.2	N.S.	79.5	80.5	N.S.
II	72.5	71.7	N.S.	81.7	82.7	N.S.
III	88.5	87.0	N.S.	85.3	86.3	N.S.
IV	86.9	85.3	N.S.	87.5	88.1	N.S.
V	87.1	88.5	N.S.	87.0	86.6	N.S.
VI	88.0	88.3	N.S.	87.5	88.1	N.S.
VII	87.2	88.8	N.S.	85.8	87.1	N.S.
VIII	86.9	88.3	N.S.	86.1	88.1	..
L.S.D. (5%)	4.10	2.79		1.82	1.42	
L.S.D. (1%)	5.46	3.71		2.43	1.90	

N.S. Varieties not significantly different at the 5% level.

** Varieties significantly different at the 1% level.

Discussion

The difference in yield of roots between CS7 and A90 was evident early in the growing season and became accentuated as growth continued. This observation agreed with the results obtained by Hills et al. (4) but disagreed with the findings of Bush (2), who studied the development of two varieties from August 17 to the end of November and concluded that it was

important to consider date-of-harvest when evaluating varieties.

The observation that percent sucrose increased continuously with no plateau formation during the growing period disagreed with the report of Ulrich (5), who described the process of percent sucrose increase in the roots as going through three distinct phases: 1. an increase to 8 to 10%; 2. a plateau at which it remained stable for an extended period during root growth followed by; 3. a period of rapid increase at the onset of cooler weather.

The rate of fresh weight accumulation declined fairly rapidly after the end of August with the growth-rate of A90 declining more rapidly than that of CS7. The decline in growth-rate corresponded to a rapid drop in air temperature (Figure 1). This is a well known phenomenon of plant growth. Table 3, however, does not reveal any decline in the rate of dry-matter accumulation until after October 10 for CS7. Similarly, the rate of sucrose accumulation for CS7 did not decrease with the onset of cold weather. A90, however, showed a slight decline in the rate of dry-matter and sucrose accumulation after the end of August, corresponding to the lower temperature.

A rapid increase in percent sucrose has been ascribed to the advent of low temperatures late in the growing season. However, the advent of cool temperatures did not stimulate a more rapid rate of increase in percent sucrose. Furthermore, if the high percent sucrose were due primarily to cool temperatures late in the season, then the percent sucrose in 1961 should have exceeded that of 1962, since the temperatures in late September and throughout October were lower in 1961 than in 1962. However, the percent sucrose was higher in 1962 than in 1961. The observations made in this experiment were supported by results from approximately 40,000 acres of commercial beets. The planting dates and average yield of roots were very similar for the two years, however, the average percent sucrose was 15.44 in 1961 and 17.16 in 1962. Thus, the results of this investigation did not lend support to findings (6) that the preharvest temperature is of greatest importance in determining the percent sucrose in the roots. Went (7,8) suggests that night temperature is more important than day temperature. It was difficult to assess this temperature effect in these experiments because in 1961 both day and night temperatures during late September and throughout October were below those for 1962.

In 1961, the percent sucrose based on dry weight reached very high levels during August and then dropped in September. In 1962, this pattern was not observed. Although CS7 and A90 showed consistently significant differences in percent sucrose on

a fresh-weight basis, they were not significantly different in percentage sucrose on a dry-weight basis, except for the last harvest date in 1962.

Summary and Conclusions

In a two year experiment at Taber, Alberta, two varieties of sugar beets were harvested on eight dates. The results of this experiment indicate that varietal differences in yields of root, sucrose, and dry matter, and percents of sucrose and dry matter could be distinguished early in the growing season and that these differences became progressively greater as the growing season advanced. The relative position of the varieties for these characters did not change throughout the growing season.

Although the two varieties differed consistently in percent sucrose on a fresh-weight basis, they did not differ consistently in percent sucrose on a dry weight basis and in percent purity.

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