Storage and Clear Juice Characteristics of Topped and Untopped Sugarbeets Grown in 14- and 28-Inch Rows[1]

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In Michigan, sugarbeets are grown in 28-inch rows to fit with the row width of the much larger acreage of beans grown in the same region. In spite of the obvious disadvantages of a greater row length per acre, many crops have shown distinct advantages in narrow rows. The leaf area is doubled in the early part of the season by doubling the stand, the earlier and more uniform leaf canopy provides better competition with weeds; increased loss of water by transpiration is essentially balanced by decrease in evaporation from the soil due to shading. In the sugarbeet, skips in the stand are less serious from the standpoint of loss of yield and quality, and smaller beets are easier to lift. Narrower row spacing has traditionally been shown to improve both sugar percentage and purity, and, up to a point, total sugar per acre. From previous studies, it was suspected that, with the same fertilizer per acre, topped beets from 28-inch rows would have about the same percentage sucrose and clear juice purity as untopped beets from 14-inch rows. A large amount of recoverable sugar may be left in the field when the crowns are discarded, so that, if quality were not damaged, the untopped beet may have a substantial advantage in yield of extractable sugar per acre. This experiment was designed, first, to investigate the storage and clear juice characteristics of such beets of one variety, and second, to provide beets with a rather wide range of composition for consideration of processing characteristics. The second aspect will be considered in another paper.

Review of Literature

Many papers regarding the effects of spacing, fertilizer, degree of topping, etc. on the yield and sugar content of beets have been published from the sugarbeet areas of the world. In some cases, the effect on storage has been considered. Stout (13)[3] reported greatly increased respiration in topped versus untopped beets,

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[3] Numbers in parentheses refer to literature cited.

and attributes the "wound respiration" to increased invasion and activity of microorganisms at the site of the wound. Rotting at the site of wounds is a commonplace observation (9). Similarly, greatly increased sprouting at suitably warm temperatures has been commonly observed in beets from which the crown buds have not been removed by topping "below the leaf scars" and particularly when the apical buds have not been removed (9, 12, 4). Carruthers *et al.* (4) have emphasized the greater content of minerals, invert sugar and organic nitrogen compounds in the crown than in the root. Differences in storage characteristics of large and small beets have also been described (12, 7, 11), with various conclusions as to rate of sugar loss, circulation of air, degree of wilting, etc. The general subject of storage of beets is reviewed in some detail by Schalit (12).

Materials and Methods

In 1965, 1966 and 1967 beets of the variety (SL 129 × 133) ms × SP6322-0 were planted in the Michigan sugarbeet area in 14- and 28-inch rows, and thinned to 100 plants per 100 feet of row. They were fertilized at the locally recommended rates for best production. In 1966, nitrogen fertilizer was used at two rates, one somewhat below "low" (60 pounds nitrogen per acre) and one somewhat above "high", (120 pounds nitrogen) the recommended rate.

Preparation of samples:

The beets were hand-harvested and the leaves, petioles and apical buds removed in 1966 and 1967 leaving a cut area about 3 cm in diameter. In 1965, apical buds were not removed from untopped beets, and sprouting was appreciable in the warmer storage. In 1966 and 1967 the beets were sorted by specific gravity to discard the highest and the lowest third, thus improving sample uniformity (5). The beets were rinsed, divided into samples of uniform size and weight and permitted to surface dry before weighing. Prior to initial analysis and storage, half of the samples from each trial was topped at the lowest leaf scar in 1967, or by removing about one-half of the crown volume in 1965 and 1966. In each case the loss of weight by crown removal was determined.

In each year, analyses were made promptly after harvest.

In 1965, each sample was placed in a mesh bag which was enclosed in a tightly-tied heavy canvas sack to reduce shrinkage. All samples were stored at 5°C from November 4 to November 29. After November 29, half of the samples was stored at 0 and half at 8°C until March 16, with monthly removals for analysis in the interval. In 1966, each sample was stored in double canvas bags from October 13, to February 23 at 0 and

10°C. Loss of weight in storage was almost completely eliminated in 1967 by enclosing a perforated bag of damp wood chips with the beets in 2 mil polyethylene bags. Storage in 1967 was at 2 and 8°C from November 3 to February 15. Previous investigations had shown that sugar loss in stored beets increased with wilting and with warmer storage (9, 12, 6).

At various intervals during the storage, 3 samples from each treatment were removed from storage, reweighed to determine weight loss and sampled with a brei saw for analysis (8). The percent sucrose in the brei was corrected for wilting loss; corr. %S (on beet) $= \%S \times \frac{\text{weight after storage}}{\text{weight before storage}}$ in all cases. Analysis were made on five dates with the 1965 crop, and twice in 1966 and in 1967. On each date, each beet was examined for sprouting and mold. Clear juice (3, 8) was analyzed for percent purity, and for content of sodium and potassium (flame photometer), and alpha amino nitrogen (ninhydrin) (11). In 1967 raffinose was determined by an enzyme method described by McCready and Goodwin (10) and invert sugar by a colorimetric method described by Bernfeld (2).

Results

In 1965 the beets were grown with replicated plots and yields of untopped beets from 14- and 28-inch rows were determined. Both yielded essentially 20 tons per acre (20.2 and 20.0). In 1966 and 1967, yields per acre were not determined, but an equal and uniform yield of 20 tons of untopped beets per acre is assumed for the sake of simplicity in all years and treatments.

Table 1 shows the percent sucrose, percent CJP, ESPT (extractable sugar per ton) and ESPA (extractable sugar per acre) at harvest and the mean of ESPT and ESPA at four removal dates from storage at 0 and 8°C. ESPA was computed for the topped beets by allowing for loss in weight by topping, (Table 2).

At harvest and at the early dates of removal from storage, topped beets were higher in percent sucrose and CJP than untopped beets, and beets from 14-inch rows were higher than those from 28-inch rows. In beets removed in February and March, the untopped beets were frequently superior to those that had been topped. Differences in shrinkage in storage were small and not significant between smaller beets grown in 14-inch rows and larger ones from 28-inch rows. Nor was there appreciable or significant difference in shrinkage of topped and untopped beets. Wilting was greater in the warmer storage and rot was severe in about 30% of the beets after prolonged storage at the higher temperature. In general, the analytical changes were similar in all four lots of beets, with deterioration appreci-

Table 1.—Percentage apparent sucrose and clear juice purity of beets grown in 1965 in 14- and 28-inch rows, topped and untopped, at harvest and ESPT extractable sugar per ton and ESPA extractable sugar per acre at harvest and the means on four removal dates, (December, January, February, March 16) from storage at 0 and 8°C.

	Before storage				After storage at			
					0°C		8°C	
	S	CJP	ESPT	ESPA	ESPT	ESPA	ESPT	ESPA
	%	%	lb	lb	lb	lb	lb	lb
28T	14.8	92.2	249	4280	235	4040	222	3820
28U	14.0	91.8	233	4660	232	4640	207	4140
Avg. 28	14.4	92.0	241	4470	233	4340	215	3980
14T	15.2	94.7	270	4850	251	4520	234	4210
14U	14.8	92.8	253	5060	240	4800	228	4560
Avg. 14	15.0	93.8	261	4955	245	4660	231	4385
Avg.								
14 & 28T	15.0	93.35	260	4565	243	4280	228	4015
14 & 28U	14.4	92.3	243	4860	236	4720	218	4350
All	14.7	92.8	251	4712	240	4500	223	4182

ably more rapid in those at higher temperaure. In the earlier stages of storage, sprouting was greater in the beets stored without the removal of the apical buds than in those with much of the crown removed.

Table 2 shows the degree of weight loss by topping in the 3 years.

Table 2.—The relative weight of beet roots remaining after topping in each year.

	28-inch rows		14-inch rows	
	Regular Nitrogen	High Nitrogen	Regular Nitrogen	High Nitrogen
1965	0.86	——	0.90	——
1966	0.90	0.89	0.94	0.91
1967	0.81	——	0.85	——

In 1966, beets were grown with two rates of nitrogen fertilization, and stored from October 13 until February 23. In 1967, one rate of fertilization was used and analyses were performed at harvest on November 3 and February 15, after being stored topped and untopped at 3 and 8°C. In 1966 and 1967 beet roots were far higher in sucrose and CJP than in 1965. Table 3 summarizes the ESPT and ESPA as the mean of the yearly means for topped and untopped beets grown in 28- and 14-inch rows.

In each year, a larger proportion of root weight was removed in topping beets from 28-inch rows than from 14-inch rows, and slightly more from beets receiving extra nitrogen.

The number of samples analyzed to provide each figure were 34, 32 and 16 in 1965, 1966, and 1967, respectively.

The results shown in Tables 3 indicate that, with the same yield of untopped beets per acre from 14- and 28-inch rows, the

Table 3.—The means of ESPT and ESPA for all field treatments, storage treatments, and dates of analyses for 1965, and 1966 and 1967.

	ESPT				ESPA			
	1965	1966	1967	Mean	1965	1966	1967	Mean
		lbs				lbs		
28T	235	309	298	280	4040	5530	4830	4800
28U	224	314	280	273	4480	6280	5640	5470
Mean 28	230	312	289	277	4260	5905	5235	5135
14T	252	318	299	290	4540	5880	5080	5170
14U	240	315	288	281	4800	6300	5760	5620
Mean 14	246	317	294	286	4670	6090	5420	5395
28 & 14T	243	314	299	285	4290	5705	4955	4985
28 & 14U	232	314	284	277	4640	6290	5700	5545
All	237	314	291	281	4465	5997	5327	5265

beets from the narrower rows had a higher yield of extractable sugar per ton and per acre. This was true in each year, much as shown in Table 1. The slightly better storage of the untopped beets reduced the mean differences in ESPT at harvest between topped and untopped beets, when all dates of analyses are averaged.

Table 4 shows the raffinose and invert sugar content before and after storage and the consequent corrections in apparent sucrose and CJP. The corrections for raffinose balanced those for invert sugar in the beets stored at 8°C, while at harvest and after storage at 2°C, the relatively higher content of raffinose led to a lowered sucrose percent, and a substantially lowered CJP. This resulted in a lowered calculated ESPT, and a greatly reduced difference between the two temperaures of storage. In a subsequent paper a damaging effect of invert sugar (need for more soda ash) will be considered further, and the losses computed.

Table 5 shows the average percent of sucrose and CJP in the beets on all dates of analyses for the 1965, 1966, and 1967 crops. The average content of potassium, sodium and amino nitrogen expressed as milli-equivalents per 100g sucrose is given, together with the value for $K + Na - NH_2N$ as an indication of the reserve of base minus acid in the juice.

In all years and dates of analyses, K, Na, and NH_2N were lower in topped than in untopped beets and in 14- than in 28-inch rows. Beets from 14-inch rows were higher in percent sucrose and clear juice purity than in 28-inch rows.

Summary and Conclusions

Beets were grown in 14- and 28-inch rows, 100 beets per 100 feet of row, for three successive seasons. They were harvested with minimum (untopped) and moderate (topped) topping and stored at two temperatures, about 2 and 8°C, for several months.

Table 4.—The means of values for raffinose and invert sugar in sugarbeets from 14- and 28-inch rows, topped and untopped and the percent of sucrose and clear juice purity before and after correction for content of raffinose and invert sugar are shown.

	Raff.	Invert	Sucrose		Clear Juice Purity		Extr. (white) sugar/ton		
	mg/ml		Apparent %	Corrected* %	Apparent %	Corrected* %	App. lb	Corr. lb	Diff. lb
At harvest									
Mean	1.13	0.70	16.9	16.7	96.5	95.3	312	300	12
Range	1.1-1.3	.63-.74	16.3-17.5	16.1-17.0	97.4-95.5	96.2-94.5			
After 2°C storage									
Mean	2.07	1.73	16.8	16.5	95.9	94.5	307	293	14
Range	1.8-2.4	1.1-2.3	16.5-16.9	16.2-16.7	95.4-96.4	94.0-95.1			
After 8°C storage									
Mean	0.64	3.50	16.4	16.4	93.6	93.6	285	285	0
Range	0.5-0.8	2.3-4.4	15.7-17.2	15.7-17.2	92.0-94.7	92.0-94.5			

* See (6), Table 1 and 4 for procedure and formulae.

Table 5.—The values are the means of all analyses each year. The means of the 3 yearly values are shown.

	%S	%CJP	Meq per 100g sucrose K	Na	NH_2N	$K+Na-NH_2N$
			1965			
28T	13.9	91.7	31.4	5.5	19.3	17.6
28U	13.6	90.6	34.4	6.4	22.7	18.1
14T	14.2	93.1	26.3	4.6	17.2	13.7
14U	14.1	92.1	29.8	5.6	20.2	15.2
			1966			
28T	17.8	93.5	20.1	2.6	11.9	10.8
28U	18.0	93.7	25.0	3.3	14.7	13.6
14T	18.1	93.9	15.3	2.0	9.2	8.1
14U	18.0	93.7	17.9	2.9	10.1	10.7
			1967			
28T	16.6	95.0	19.4	1.9	7.8	13.5
28U	15.9	94.1	21.3	2.3	9.3	14.3
14T	17.0	94.4	14.3	1.2	7.2	8.3
14U	16.2	94.8	19.6	2.1	9.1	13.6
			Mean 1965-1966-1967			
28T	16.1	93.4	23.6	3.3	13.0	13.9
28U	15.8	92.8	30.2	4.0	15.6	15.3
14T	16.4	93.8	19.0	2.6	11.2	10.0
14U	16.1	93.5	22.4	3.5	13.1	13.2

Analysis for percent sucrose and CJP were made and extractable (white) sugar per ton (ESPT) was computed. Extractable sugar per acre (ESPA) was computed by correction for the weight lost in topping. Potassium, sodium and amino nitrogen in the clear juices were determined.

1. Beets from 14-inch rows and topped beets were regularly higher than those from 28-inch rows or untopped in percent sucrose, CJP, and ESPT at harvest and during most of the storage period. The difference between topped and untopped decreased near the end of storage. Somewhat greater spoilage in topped beets occurred.
2. Beets from 14-inch rows had a lower percentage of weight lost in topping than those from 28-inch rows.
3. The mean relative extractable sugar yields per acre for the 3 years were 100, 113, 108, and 117 for 28 topped, 28 untopped, 14 topped and 14 untopped, respectively.
4. The mean of $K + Na - NH_2N$, meq per 100g sucrose for beets as stored and after storage periods for the three years was 13.1, 15.3, 10.0, and 13.2 for 28T, 28U, 14T, and 14U, respectively. Beets from 28-inch rows, and untopped beets would have a lower need for the addition of soda when the effect of invert sugar is ignored. This relationship was the same in each of the 3 years.

5. Corrections of apparent sucrose,—for raffinose and invert sugar content,—and consequent CJP changes, resulted in substantial decreases in calculated ESPT in beets at harvest and after 2°C storage, but none in storage at 8°C. Thus the differences in ESPT at the two storage temperatures were reduced.
6. The agronomy, engineering and economics of growing higher quality beets in narrower rows needs further examination. Under the present cultural and engineering practices in Michigan, the production of narrow-row beets may be uneconomic in spite of the increased extractable sugar per ton and per acre.

The effects of chemical changes in storage upon the processability of these beets will be considered in another paper.

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