Influence of Cultural Practices and Storage Conditions on Quality Losses During Storage

Roger E. Wyse, USDA-ARS

Storage losses of recoverable white sugar per ton (RWST) are influenced by many pre- and postharvest practices. Although much is known concerning the effect of postharvest conditions on sucrose losses, the influence of preharvest environmental conditions on sucrose losses during storage is not well understood.

Preharvest practices The most important cultural practice affecting quality at harvest is nitrogen fertilization. However, nitrogen fertilization appears to have very little effect on quality losses during storage. Table 1, derived from data published by Dexter *et al.*, (1966), shows the percent of original RWST remaining after storage at two temperatures. No consistent effect of nitrogen fertilization was observed. In another experiment, roots of five varieties grown in soil with 30 and 150 lb of applied nitrogen and stored at 3 C for 120 days showed no effect of nitrogen fertilization. Although nitrogen does not affect storage losses, quality of the low-nitrogen beets is much higher at harvest and remains higher throughout storage.

Table 1. Effect of nitrogen fertilization on RWST losses in storage (Dexter *et al.*, 1966)

Storage temperature	Percent of original RWST remaining after 113 days of storage — Applied nitrogen, lb/Ac: 230	90	30
		Percent	
35 F	82	87	86
50-60 F	56	53	62

Thorough topping of the beet root at harvest removes the petioles, but has a detrimental effect on storage characteristics. For this discussion, a topped beet is one with the crown removed at the lowest leaf scar. An untopped root has only a minimum of the terminal bud removed, but is free of petioles. The decline in RWST during 100 days of storage for topped and untopped roots is given in Table 2 (Dexter *et al.*, 1970). In all tests, topped roots lost more RWST than untopped roots. Topping inflicts severe injury on the root and greatly increases the respiration rate (Table 3). It also exposes the hollow crown cavity, which normally is the area where mold is first observed. Therefore, it is not surprising that topping increases the loss of sucrose during storage.

A rather minor preharvest factor affecting postharvest metabolism is harvest date. Beets harvested early accumulate more raffinose during storage (Figure 1). This was observed in two successive years. However, harvest date has the opposite effect on reducing-sugar accumulation (Figure 2).

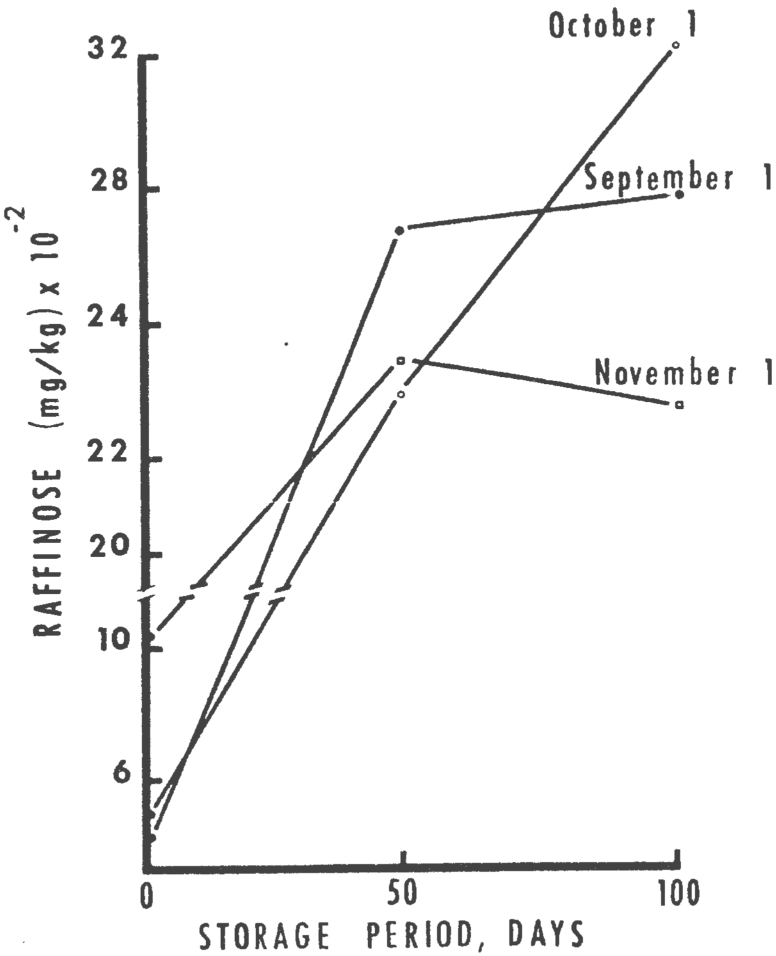

Figure 1. Effect of harvest date on the raffinose content of sugarbeet roots stored for 100 days at 3 C.

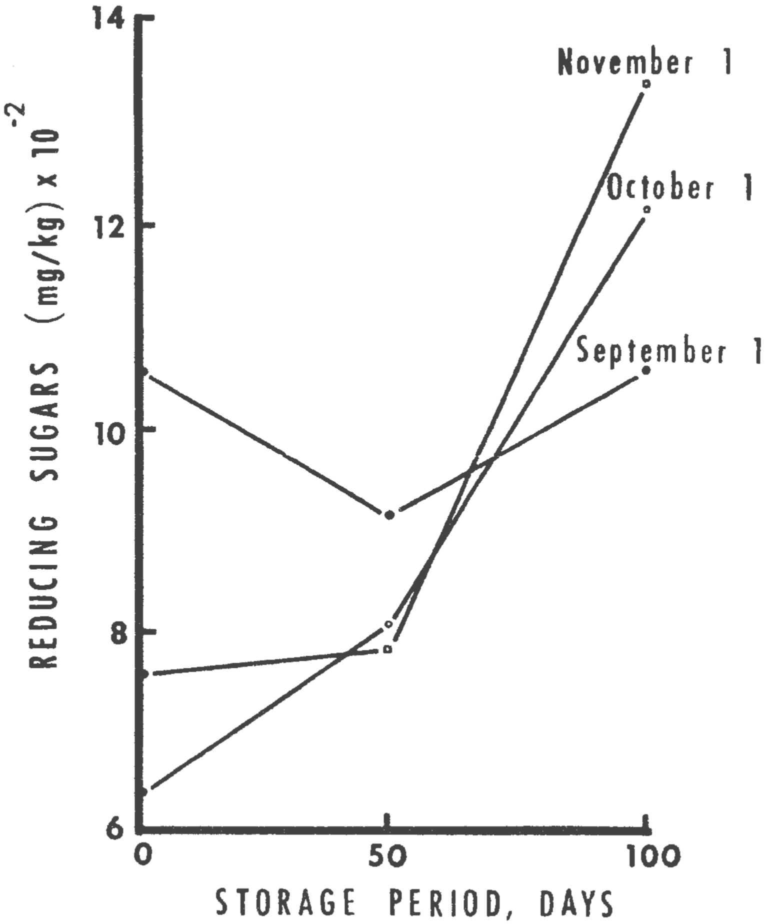

Figure 2. Effect of harvest date on the reducing sugar content of sugarbeet roots stored for 100 days at 3 C.

Table 2. Effect of topping on RWST losses at three temperatures

	RWST losses in 100 days lb		
	0 C	7 C	8 C
Topped	17	22	32
Untopped	7	13	25

Table 3. Effect of postharvest handling on subsequent respiration rates

Treatment	Respiration rate Untopped	Topped
	lb/T-D	
Cooled immediately to 5 C	0.125	
Held at 24 C	0.374	0.515
Held at 24 C and allowed to wilt 10%		0.718

Diseases during the growing season, particularly those caused by fungal organisms, commonly increase the physical deterioration in storage (Ruppel and Smith, 1972). Roots infected with curly top and beet mosaic have a higher respiration rate at harvest and throughout storage, but do not appear to be more susceptible to physical deterioration than healthy roots.

Postharvest conditions There has been some discussion as to whether high-quality roots store better than low-quality roots, high quality being high sucrose and high clear juice purity. Figure 3 shows the RWST during storage in 1971 and 1972. These data are an average of 15 varieties in each year (The dashed line is the 1971 line moved up for ease of comparison with 1972). The lower-quality beets in 1971 lost more RWST than the higher-quality beets in 1972. However, the nitrogen data in Table 1 dispute this. The beets grown on low N were of considerably higher quality, but storage losses were not significantly reduced, compared to the lower-quality high-nitrogen beets.

Note that the curves in Figure 3 show no sharp decline in RWST during the 120-day storage period. There does not appear to be a drastic physiological change, resulting in a more rapid deterioration, during storage periods of less than 120 days.

The major factor influencing storage losses under good storage conditions is variety. Table 4 shows the range in RWST losses in lb per ton per day at 5 C. The range was about 3-fold in both years. It would appear possible to improve the storage characteristics of commercial varieties by using proper selection techniques. Therefore, it is also obvious that new variety releases must be screened for storageability.

Table 4. Influence of variety on RWST losses during storage

	RWST losses in lb/ton/day at 5 C Range	Mean
1972 (15 varieties)	0.125-0.400	0.250
1971 (10 varieties)	0.142-0.492	0.342

Varieties differ widely in their rates of respiration (Table 5). In 1970 the rate for the highest-respiring variety was 2.6 times that for the lowest. In 1971 and 1972 the highest rate was 1.6 times the lowest. Since respiration accounts for 60 to 70% of the losses in RWST during storage, selection for low-respiring varieties may be a means of selecting superior storing lines.

Varieties differ in their rates of respiration at low temperature and also in their response to temperature per se (Table 6). The respiration rates of these varieties were determined at 5 and 25 C, and the Q_{10} (the magnitude of rate increase per 10 C rise in temperature) was determined. The respiration rate of variety 1 would triple for each 10-C rise, while the others would double.

Table 5. Respiration rates of varieties in 3 years, measured at 5 C

	Mean	Range
	lb/ton/day	
1970 (8 varieties)	0.204	0.107-0.279 (0.172)
1971 (8 varieties)	0.161	0.128-0.192 (0.064)
1971 (15 varieties)	0.167	0.128-0.199 (0.071)
1972 (15 varieties)	0.173	0.137-0.218 (0.081)

Table 6. Respiration rates at 5 and 25 C

Variety	5 C	25 C	Q_{10}
1	0.141a	0.914bc	3.2
8	0.153ab	0.698a	2.3
14	0.178b	0.842b	2.4
15	0.235c	1.010c	2.1

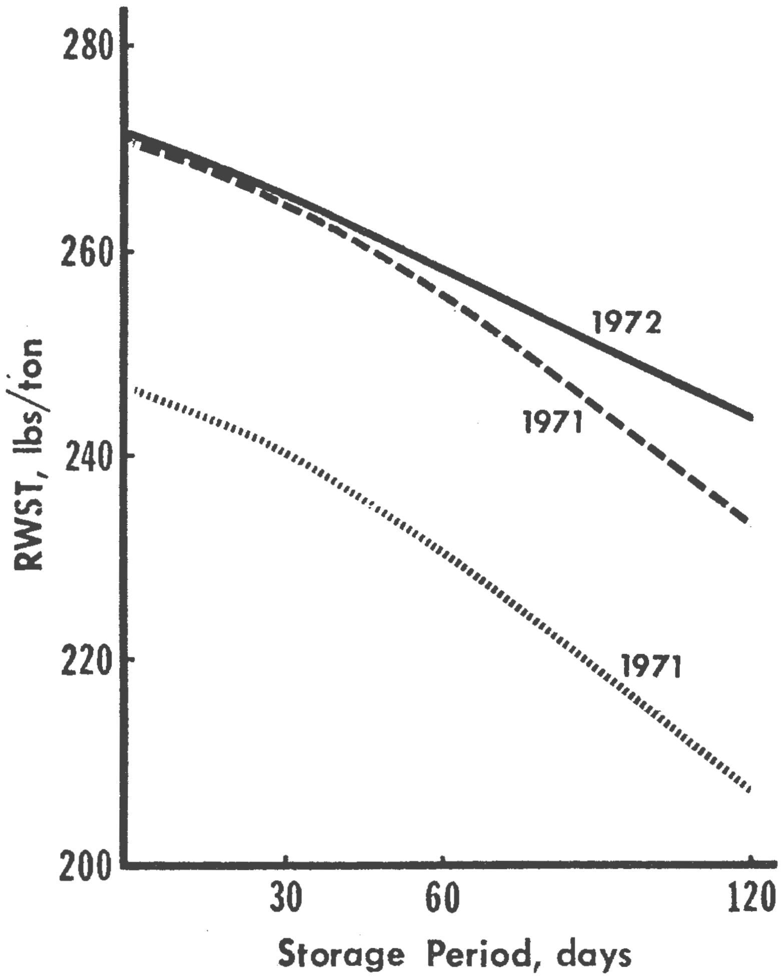

Figure 3. Decline in recoverable white sugar per ton (RWST) during 120 days of storage at 5 C in 1971 and 1972.

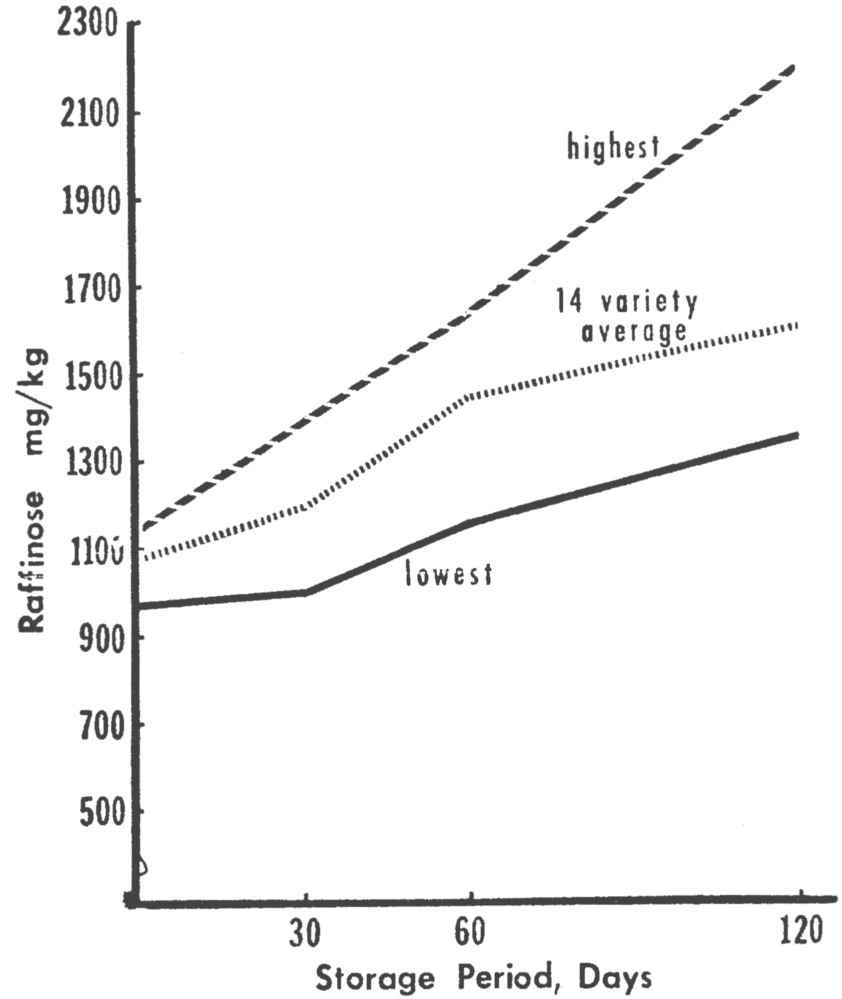

Figure 4. Range between varieties in raffinose content during storage at 5 C.

It has been well established that variety has a strong influence on the tendency of beet roots to accumulate raffinose during storage at low temperature. Figure 4 shows the range between varieties in the accumulation of raffinose at 5 C (40 F) in a typical 14-variety storage experiment. The variety that originally contained the most raffinose accumulated twice as much more during storage as did the variety starting with the least.

Variety also influenced the accumulation of reducing sugars (Figure 5), but the difference between varieties in rate of accumulation is much greater than that for raffinose. In some cases the varietal effect on reducing sugars reflects susceptibility to mold. For example, I have noted that some varieties develop a russet condition on the surface, which affects only the epidermal cells of the root. However, roots showing this russet condition will be 4-6 times higher in reducing sugars than roots not having this condition.

In the earlier talks it was mentioned that in commercial pile storage a 10% weight loss caused by desiccation is quite common. In 1926 Pack (1926) published data (Figure 6) showing the relationship between desiccation and sucrose losses. A weight loss of only 5% sharply increased the loss of sucrose. This increased loss was probably caused in part by increased respiration rates (Table 3). Water loss also increases the accumulation of invert sugars (Figure 7) but reduces the accumulation of raffinose (Figure 8).

The effect of desiccation on RWST losses at three temperatures is shown in Table 7. In every test, the treatments that lost more water also lost the most RWST (Dexter, 1969).

Table 7. Effect of desiccation on total and recoverable sucrose during storage at three temperatures

	Change during 140 days		
	Wgt	Total sucrose	RWST
	%	lb/T	lb
2 C	-11.7	-18.8	-27
	-16.1	-26.4	-38
4 C	-13.1	-21.6	-34
	-16.0	-43.2	-49
7 C	- 0.8	-26.2	-39
	- 7.9	-47.2	-70

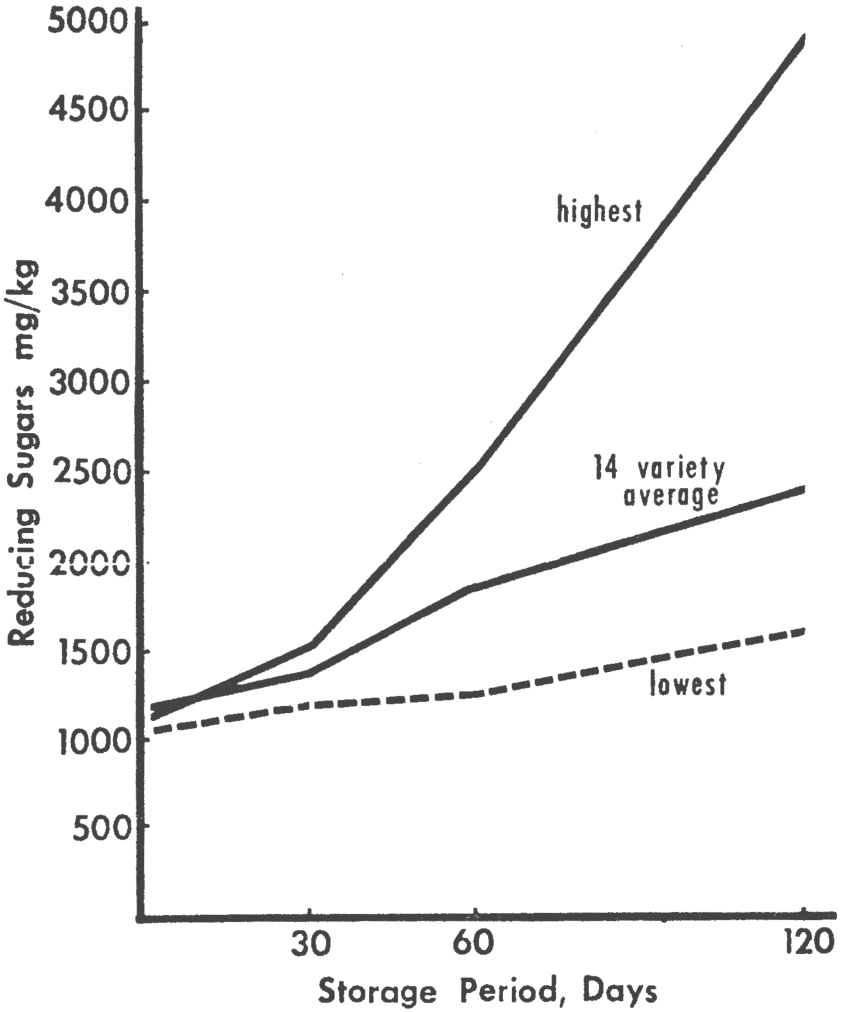

Figure 5. Range between varieties in reducing-sugar content during storage at 5 C.

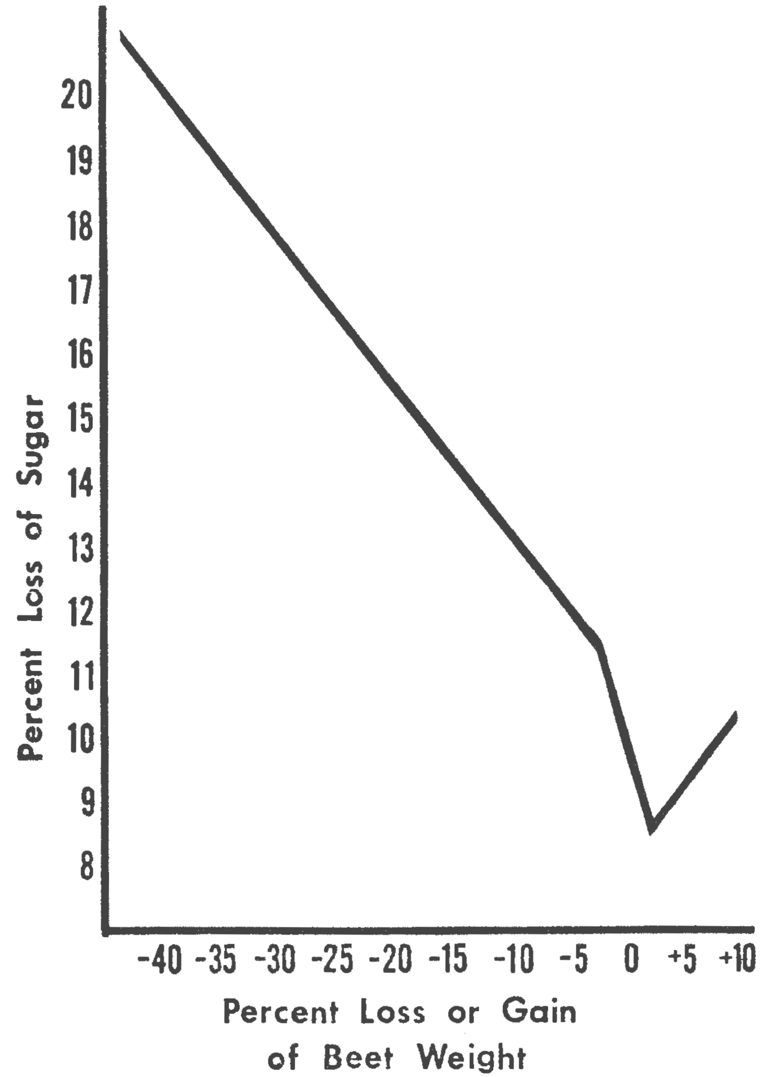

Figure 6. Relationship between desiccation and loss of sucrose after 103 days of storage at 4.4 C (Pack, 1926).

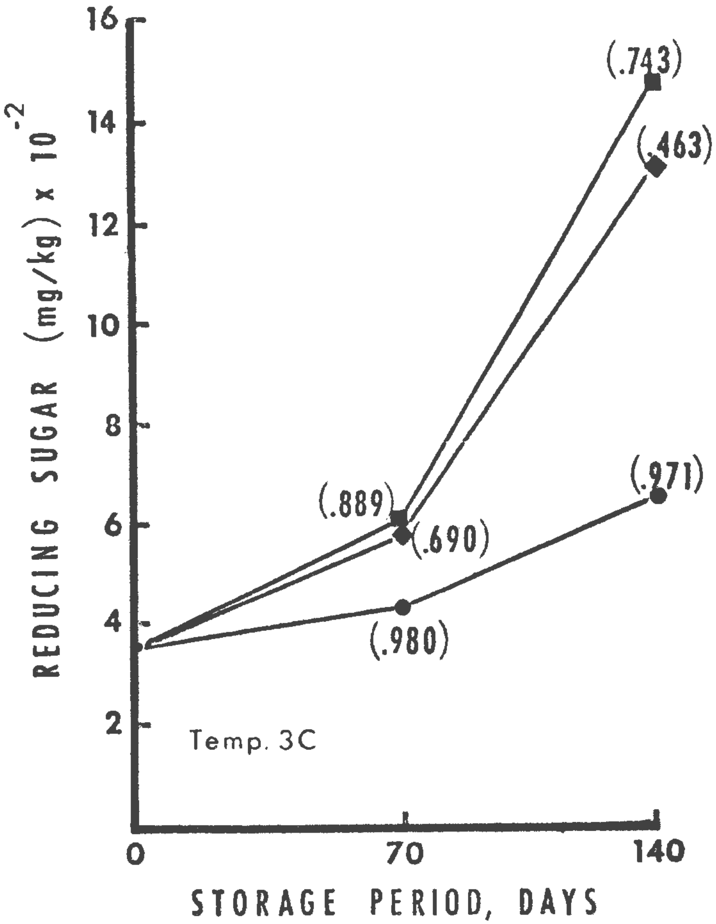

Figure 7. Effect of desiccation on the reducing-sugar content of sugarbeet roots during 140 days of storage at 3 C. Storage treatments: polyethylene bag with wet wood chips (●); polyethylene bag with holes (■); canvas bag (◆). Numbers in parenthesis indicate the proportion of original weight remaining after storage

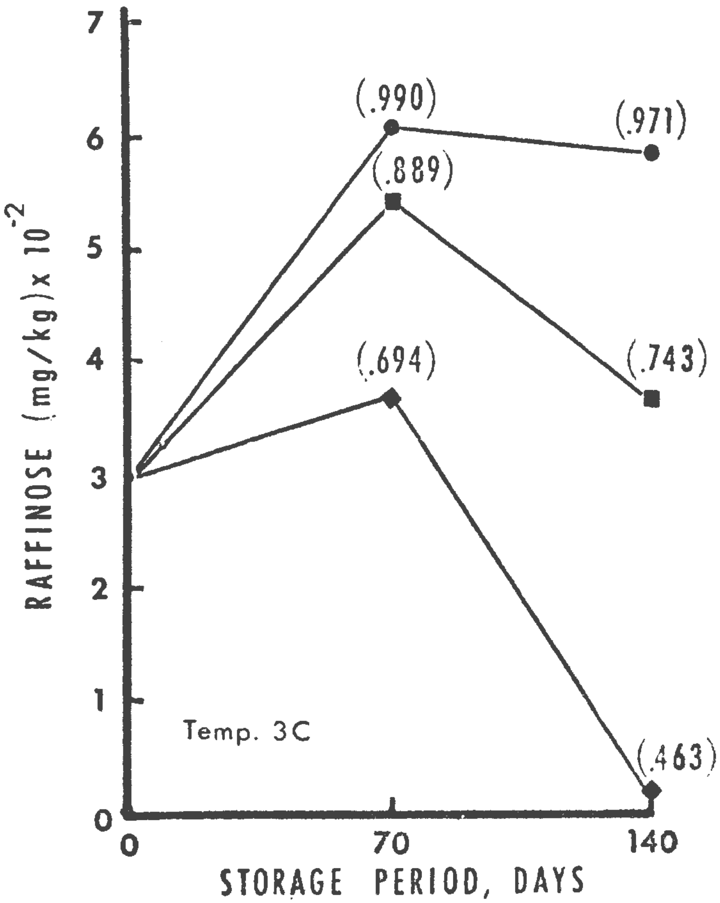

Figure 8. Effect of desiccation on the raffinose content of sugarbeet roots during 140 days of storage at 3 C. Storage treatments: polyethylene bag with wet wood chips (●); polyethylene bag with holes (■); canvas bag (◆). Numbers in parenthesis indicate the proportion of original weight remaining after storage.

SUMMARY

Very little is known concerning the effect of environmental conditions and cultural practices before harvest on the subsequent storage characteristics of a given variety. Nitrogen fertilization has little or no effect on quality losses during storage. Topping, which inflicts severe injury on the beet root, should be avoided.

The most significant environmental factor influencing losses during storage is temperature. Low-temperature storage (0-5 C) can cure many ills, such as excessive injury, and reduce mold invasion. The only deterimental effect of low temperature is raffinose accumulation.

Desiccation increases respiration, impurity accumulation, and susceptibility to mold invasion. Desiccation is probably second only to warm temperature as a detrimental factor in storage.

Under relatively good storage conditions, variety plays an important role in determining the magnitude of sucrose loss. All new varieties should undergo rigorous storage-testing before release. The genetic makeup of a variety seems to influence all aspects of sucrose losses in storage; i.e. physical deterioration, impurity accumulation, and respiration.