Effect of Chemicals on Sucrose Loss in Sugarbeets During Storage

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INTRODUCTION

Chemicals are used extensively in sugarbeet production but relatively few chemicals have been evaluated to determine adverse effects on root quality during storage. Nematicides, herbicides and insecticides are applied to soil before planting, at planting or to foliage after plant emergence, and fungicides are applied to foliage in later stages of growth. More recently, fungicides have been applied to sugarbeet roots after harvest to control storage rots (8).

Most storage investigations have involved treatment of the foliage prior to harvest or the roots after harvest with materials being tested to reduce sugarbeet storage losses. Dilley et al. (6) reported that the respiration rates of whole beets receiving postharvest treatments of potassium azide, Merck HZ 3456, Botron and ethylene were higher than those of non-treated beets. Wu et al. (10) reported that preharvest applications of Randox, and postharvest dips in N^6-benzyladenine and Randox solutions reduced the loss of sucrose, raffinose concentration, and respiration during storage; however, several chemicals applied as preharvest foliar sprays or postharvest dips increased sucrose loss, reducing sucrose accumulation, or both.

Mumford and Wyse (9) reported that Penicillium and Botrytis Spp. will infect beets wherever the surface is injured;

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thereby, significantly increasing respiration and invert sugar accumulation. A spray application of benomyl (Benlate) or thiabendazole (Mertect) at a concentration of 500 ppm prevented infection by these fungi during storage. Thiabendazole controlled storage rot in commercial sugarbeet piles when applied as a spray at a concentration of 1500 ppm (8).

These reports show that some preharvest and postharvest applied chemicals increase sucrose loss and impurity accumulation in whole sugarbeet roots during storage, whereas, others may have a beneficial effect. The material presented in this paper is a summation of research work conducted at Longmont, Colorado to determine whether a number of commercial or potentially commercial agricultural chemicals had any adverse effect on root quality in storage.

METHODS AND MATERIALS

HERBICIDES AND NEMATICIDES

Tests to evaluate herbicides were conducted in 1972 and 1973 and those to evaluate nematicides were conducted in 1972. Sugarbeets (GW MONO HY A_1) were grown in plots that received herbicide treatments shown in Table 1 or nematicide treatments shown in Table 2. Plots, 4 rows wide and 25 feet long, were replicated 6 times. Eighteen foot sections from each row were harvested and washed. Roots from rows 1 and 3 of each plot were analyzed immediately for sucrose (2) and clarified juice purity (CJP) (3) while those from rows 2 and 4 (25 to 35 lbs) were placed in nylon net bags, identified with numbered safety pins and placed into storage at 40°F. Thus, 12 samples of each treatment were analyzed immediately while 12 samples were stored. Respiration measurements were made daily as previously described (1) at 40°F. Air which had been humidified and scrubbed clean of carbon dioxide, flowed through chambers containing beets, flushing out the carbon dioxide given off by respiration of beets. The carbon dioxide was captured in 1N sodium hydroxide solution and then deter-

mined by back titration with 0.5 N hydrochloric acid to phenolphthalin and methyl orange end points. After respiration measurements were completed, the samples were analyzed for sucrose, CJP and invert sugars (4).

GROWTH REGULATORS

A test of four growth regulators at two rates (Table 3) each was established in 1971. The test was identical to the herbicide and nematicide tests except that the chemicals were applied as foliar sprays 19 days prior to harvest. None of the chemicals gave agronomic benefits and so were not tested for storage loss in subsequent years.

FUNGICIDES

Evaluation of fungicides applied after harvest for control of storage rot was made in 1976. Twenty-pound samples were selected at random from two truck loads of machine harvested MONO HY D_2 beets. Eighteen samples were immediately analyzed for sucrose and CJP. The remaining samples were dipped in fungicide solutions shown in Table 4, for 30 seconds and then allowed to drain or were exposed to a gaseous atmosphere of sulfur dioxide or ozone. Liquid treatments included benomyl, thiabendazole, BayDam 18654, Topsin M, and sulfur at 500, 1500, and 5000 ppm. Gaseous treatments were sulfur dioxide at 1000 and 10,000 ppm for 24 hours or ozone at an undetermined concentration for two hours. Two controls were included in the test. One control received no treatment while the second was dipped in water for 30 seconds. Eighteen replications were prepared for each treatment. Respiration measurements were made continuously from 7 through 133 days storage at $40^{\circ}F$. When not in respiration chambers, beets were stored at $55^{\circ}F$ for 45 days and at $40^{\circ}F$ for the remaining time. After 104 days, 12 replications, and after 133 days, six replications were analyzed for sucrose, purity and invert sugars.

Thiabendazole was evaluated in captive pile tests in 1977-78 and 1978-79, and in a controlled temperature storage test in 1978-79. One hundred 25-pound samples were pre-

pared from a truck load of commercially harvested MONO HY D_2 beets for each test. Fifty samples were left untreated and 50 samples were sprayed with a 1500 ppm thiabendazole solution at the rate of 50 ml per 25 lb sample. The samples were turned over and resprayed to insure complete coverage. Thus, a total of 100 ml of solution was applied. The samples, placed in nylon net bags and identified with safety pins, were stored in a commercial pile at Eaton, Colorado, for 75 days in 1977-78; a commercial pile at Berthoud, Colorado for 120 days in 1978-79; and in a controlled temperature room for 98 days in 1978-79. The beets were stored in the controlled temperature room at 55°F for 50 days and 40°F for 48 days at 100% relative humidity. The purpose of this test was to have sufficient temperature and humidity to produce mold growth. After removal, the samples were analyzed for weight, sucrose, purity, raffinose (7) and invert sugars.

RESULTS AND CONCLUSIONS

HERBICIDES AND NEMATICIDES

The herbicides and nematicides, when applied to the soil before planting or to the foliage after emergence, had no adverse effects on respiration, invert sugars after storage, or sucrose loss (Tables 1 and 2). Betanal perhaps had some effect since respiration was significantly lower while invert sugars and sucrose loss of beets treated with that compound were numerically lower than the control. The two herbicide tests were averaged together for data in Table 1. None of the chemicals tested increased any of the storage loss parameters which may have been due to the early treatment and lack of chemical residue at harvest.

GROWTH REGULATORS

The growth regulators listed in Table 3 have not been used in commercial production, but the study illustrates the potential effect of chemicals applied to the foliage prior to harvest on storage loss. Two chemicals had no effect on respiration, invert sugars, or sucrose loss at either

Table 1. Effect of herbicides on respiration, invert sugar accumulation and sucrose loss during storage. Mean of two years tests.

Treatment			Respiration	Invert Sugar[a]	Sucrose Loss
Herbicide	Dosage lb AI/A	Application Time	mg CO_2/ kg/hr	g/100 RDS	lb/Ton/ Day
			85 Days	104 Days	104 Days
Check	0	--	8.25	0.988	0.292
Ro-Neet	3.5	Preplant	8.62	0.962	0.293
Nortron	3.5	Preplant	8.27	0.978	0.278
Betanal	1	Post-Emergence	7.18	0.852	0.273
L.S.D. (0.05)			0.72	N.S.	N.S.

[a]Invert sugar after storage. Harvest invert sugar was not determined.

Table 2. Effect of nematicides on respiration, invert sugar accumulation, and sucrose loss during storage.

Treatment		Respiration	Invert Sugar[a]	Sucrose Loss
Nematicide	Dosage: lb AI/A	mg CO_2/kg/hr	g/100 RDS	lb/Ton/Day
		104 Days	106 Days	106 Days
Check	--	9.07	1.225	0.320
Telone[b]	15 gal.	8.64	1.201	0.351
Carbofuran	4 gal.	8.15	1.115	0.315
Oxamyl	4 gal.	8.24	1.456	0.290
Fenamifos	4 gal.	9.47	1.375	0.310
Aldicarb	4 gal.	9.44	1.105	0.272
L.S.D. (0.05)		N.S.	N.S.	N.S.

[a]Invert sugar after storage - harvest invert sugars are not available.

[b]Telone = 78% 1,3 dichloropropane.

Table 3. Effect of preharvest applied growth regulators on respiration, invert sugar accumulation, and sucrose loss.

Treatment		Respiration	Invert Sugar[a]	Sucrose Loss
Chemical	Dosage: oz/A	mg CO_2/kg/hr	g/100 RDS	lb/Ton/Day
		19 Days	110 Days	110 Days
Check	--	8.44	0.716	0.264
Randox	1	8.51	0.752	0.255
Randox	4	8.15	0.685	0.250
60-CS-16	3	8.67	0.650	0.271
60-CS-16	5	8.28	0.710	0.280
Ni-10656	8	8.18[b]	0.790[b]	0.271[b]
Ni-10656	32	9.36[b]	1.115[b]	0.325[b]
CHE-8728	1	7.95	0.620	0.249

Table 3 Cont.

Treatment				
Chemical	Dosage: oz/A	Respiration mg CO_2/kg/hr	Invert Sugar[a] g/100 RDS	Sucrose Loss lb/Ton/Day
		19 Days	110 Days	110 Days
CHE-8728	4	9.08[b]	1.123[b]	0.331[b]
L.S.D. (0.05)		0.51	0.251	0.050

[a]Invert sugar after storag- - harvest invert sugar is not available.
[b]Significant at 0.05.

concentration. The other two chemicals had no effect at the lower dosages, but significantly increased respiration rate, invert sugar accumulation, and sucrose loss when the dosages were increased four-fold. Even though the chemicals were applied to the foliage, sufficient material may have been translocated to the roots to cause toxic effects. Since the materials were applied only 19 days prior to harvest, chemical residues undoubtly remained in the beets after harvest to cause the effects. The test was originally set up to determine whether the chemicals might reduce storage loss as was previously reported for Randox (10). No chemical significantly reduced the storage loss parameters. The limited data show that one is more likely to increase or have no effect, than reduce storage loss by preharvest applications of growth regulator chemicals.

FUNGICIDES

Postharvest applications of fungicides to roots for control of fungus diseases which cause storage rots is a new area of investigation for eventual commercial applications. The storage rots cause abnormally high rates of sucrose loss when beets are stored for the longer periods (100 days or more) of time. Microorganisms causing the rots stimulate respiration by tissue damage, invert sugar accumulation, and accumulation of other impurities which inhibit crystallization, thus adversely affecting processing. Much rot and mold growth occur as a result of poor storage handling conditions. Mechanical injury, dehydration, freezing and thawing, high temperatures and poor pile

ventilation due to trash and soil inhance rot and mold growth. The above conditions can be improved by careful handling and good storage practices and may not be improved by use of fungicides. Under some conditions when beets have been properly handled and protected as under canopies, extensive mold growth occurs during extended storage periods of over 100 days. The studies described in this section were established first to determine the effectiveness of several selected fungicides for control of storage rots and second to determine whether chemicals might produce phytotoxic effects which in turn could increase storage losses.

Respiration rates for 28-, 91- and 133-day storage periods and invert sugar accumulation after 104- and 133-day storage periods for beets treated with fungicides are given in Table 4. Benomyl and Topsin M appeared to lower respiration during the early period (28 days). The respiration rates for benomyl and Topsin M treated beets decreased relative to the control beets with increasing concentrations of the respective chemicals and became significant at 5000 ppm. Mold growth was not evident after 28 days and so the chemicals effect on respiration was probably not related to mold control. The effect, if any, was short lived since no improvement in respiration was seen for benomyl or Topsin M after 91 or 133 days. Thiabendazole and BayDam 18654 at 5000 ppm and sulfur dioxide at 10,000 ppm had significantly higher respiration rates than the non-treated beets after 91 days. After 133 days all treatments were numerically higher than both controls, with thiabendazole, Topsin M, and BayDam 18654 at 5000 ppm, sulfur dioxide at 10,000 ppm and ozone treatments being significantly higher than both controls.

Benomyl treatments at 500 and 1500 ppm showed the most promise in reducing invert sugar formation at 104 and 133 days, although they were not significantly lower than the check. Thiabendazole at 1500 and 5000 ppm, Topsin M at 5000 ppm, BayDam 18654 at 1500 and 5000 ppm, sulfur at

Table 4. Effect of fungicides applied at harvest on respiration rate and invert sugar formation during storage.

Treatment			Respiration Rate-mg CO_2 kg^{-1} hr^{-1}			Invert Sugar-g/100 RDS	
Fungicide	Dosage:ppm	Appl. Method	28 Days	91 Days	133 Days	104 Days	133 Days
Check	--	--	11.51	12.69	11.63	1.422[a]	1.536[a]
Water	--	dip	11.60	12.75	11.70	1.440	1.495
Benomyl	500	dip	11.59	13.18	12.02	1.247	1.387
Benomyl	1,500	dip	11.45[b]	13.19	12.47	0.977	1.335
Benomyl	5,000	dip	10.18[b]	12.88	12.09	1.221	1.505
Thiabendazole	500	dip	11.98[b]	12.63	11.83	1.391	1.763
Thiabendazole	1,500	dip	13.32[b]	13.38[b]	12.42[b]	1.940	2.034[b]
Thiabendazole	5,000	dip	13.71[b]	14.56[b]	13.50[b]	1.864	2.705[b]
Topsin M	500	dip	12.07	13.05	11.94	1.310	1.806
Topsin M	1,500	dip	10.61[b]	12.20	11.97[b]	1.411[b]	1.773[b]
Topsin M	5,000	dip	10.32[b]	13.18	12.78[b]	2.351[b]	2.958[b]
BayDam 18654	500	dip	12.31	12.46	11.87	1.313	1.955
BayDam 18654	1,500	dip	11.70[b]	13.37[b]	12.46[b]	1.923	2.015[b]
BayDam 18654	5,000	dip	13.42[b]	14.00[b]	13.26[b]	1.947	2.422[b]
Sulfur	500	dip	13.63[b]	12.95	12.02	1.502	1.630
Sulfur	1,500	dip	11.47	12.80	11.95	1.466	1.554
Sulfur	5,000	dip	12.45	12.82	11.78	1.770	1.940
Sulfur dioxide	1,000	gas	12.76[b]	12.62[b]	11.83[b]	1.627	2.330[b]
Sulfur dioxide	10,000	gas	12.37	15.10[b]	13.91[b]	1.905	2.531[b]
Ozone	--	gas	11.64	12.57	12.33	1.685	2.422[b]
L.S.D.			1.02	0.76	0.89	0.530	0.551

[a] Invert sugar at harvest = 0.352 g/100 RDS.
[b] Significantly different from check at 0.05.

5000 ppm, sulfur dioxide and ozone increased invert sugar to significant or near significant levels. High invert sugar formation under these conditions may have been caused by tissue damage from the chemicals or by microorganisms which became established as a result of earlier tissue damage. All treatments which significantly increased respiration also significantly increased invert sugar accumulation.

Sucrose losses (initial sucrose - final sucrose adjusted for weight change) were significantly increased by the higher concentration of thiabendazole, Topsin M, BayDam 18654, sulfur dioxide and ozone (Table 5). All treatments

Table 5. Effect of fungicides applied at harvest on sucrose loss during storage.

Treatment			Sucrose Loss-lb/Ton/Day	
Fungicide	Dosage:ppm	Appl. Method	104 Days	133 Days
Check	--	--	0.291	0.327
Water	--	dip	0.293	0.324
Benomyl	500	dip	0.377[a]	0.403
Benomyl	1,500	dip	0.320	0.368
Benomyl	5,000	dip	0.270	0.340
Thiabendazole	500	dip	0.362	0.410
Thiabendazole	1,500	dip	0.404[a]	0.439
Thiabendazole	5,000	dip	0.463[a]	0.631[a]
Topsin M	500	dip	0.341	0.411
Topsin M	1,500	dip	0.318	0.440
Topsin M	5,000	dip	0.483[a]	0.590[a]
BayDam 18654	500	dip	0.360	0.428
BayDam 18654	1,500	dip	0.537[a]	0.501[a]
BayDam 18654	5,000	dip	0.534[a]	0.584[a]
Sulfur	500	dip	0.355	0.472
Sulfur	1,500	dip	0.360	0.410
Sulfur	5,000	dip	0.455[a]	0.463
Sulfur dioxide	1,000	gas	0.337	0.483[a]
Sulfur dioxide	10,000	gas	0.510[a]	0.810[a]
Ozone	--	gas	0.370	0.523[a]
L.S.D.			0.084	0.148

[a]Significantly different from check at 0.05.

were numerically higher in sucrose loss than the controls except 5000 ppm benomyl after 104 days. The sucrose losses associated with chemical treatment are significantly correlated with both respiration ($r=0.58$ for 91 days and $r=0.87$ for 133 days) and invert sugar after storage ($r=0.80$ for 91 days and $r=0.82$ for 133 days).

The treatments had a similar effect on respiration, invert sugar and sucrose loss for both intermediate (104 days) and long term (133 days) storage periods; however, the differences between treatment and control became larger with the longer storage periods. Correlation (r) between intermediate and long term storage periods was 0.92, 0.85, and 0.79 for respiration, invert sugar accumulation and sucrose loss, respectively.

The control beets showed little evidence of rot and mold even after 133 days storage. Without something to control, the chemicals would not be expected to reduce storage loss. Several of the candidates appeared to be toxic at higher concentrations as measured by increased respiration and invert sugar formation. Thiabendazole at 1500 ppm applied as a spray has been used commercially (8). Nearly three times as much liquid can be adsorbed or absorbed by the beet from a dip treatment than from a 2-gal. per ton spray treatment (unpublished data). Thus, more residue would be left with the dip treatment than the spray treatment and so toxicity would be expected to be greater with the former treatment than the latter.

Sucrose and recoverable sucrose losses in Thiabendazole treated beets (1500 ppm with spray application) were compared with non-treated beets in three tests in 1977-78 and 1978-79 (Table 6). Recoverable sucrose losses were significantly higher in thiabendazole treated beets than non-treated beets stored as captive samples in commercial piles at Eaton and Berthoud, Colorado. Recoverable sucrose loss of thiabendazole treated beets averaged 13% greater

Table 6. Effect of thiabendazole treatment on weight, sucrose, and recoverable sucrose loss during storage as captive samples

Storage Location	Year	Storage Days	Treatment	Loss-lb/Ton/Day		
				Weight	Sucrose	Rec. Sucrose
Eaton CO Pile	1977-78	75	Check	2.22	0.527	0.641
			Thiabendazole-1500 ppm	2.17	0.581	0.697[a]
Berthoud CO Pile	1978-79	120	Check	0.83	0.141	0.330
			Thiabendazole-1500 ppm	0.97	0.157	0.401[a]
Longmont CO	1978-79	98[b]	Check	0.32	0.283	0.682
ARC Basement			Thiabendazole-1500 ppm	0.33	0.165[a]	0.540[a]
Average		97.7	Check	1.12	0.317	0.551
			Thiabendazole-1500 ppm	1.16	0.301	0.546

[a]Significantly different from check treatment at 0.05 - paired t test.
[b]Stored at 55°F for 50 days followed by 40°F for 48 days at 100 percent relative humidity.

Table 7. Effect of thiabendazole on quality of beets stored as captive samples.

Storage Location	Treatment	Quality Component							
		Sucrose[b]		C.J. Purity		Invert Sugar		Raffinose	
		In	Out	In	Out	In	Out	In	Out
		- - - % - - -		- - - % - - -		- g/100 RDS -		- g/100 RDS -	
Eaton CO Pile	Check	17.03	16.43	92.39	89.74	0.511	1.097	0.572	0.246
	Thiabendazole-1500 ppm	17.03	16.17	92.39	89.57	0.511	0.811	0.572	0.284
Berthoud CO Pile	Check	15.11	15.11	91.36	86.67	0.522	0.771	0.365	1.131
	Thiabendazole-1500 ppm	15.11	15.06	91.36	86.42	0.522	0.752	0.365	1.101
Longmont CO	Check	16.76	15.63	93.91	86.64	0.497	1.230	0.462	0.402
ARC Basement	Thiabendazole-1500 ppm	16.76	16.32[a]	93.91	87.42[a]	0.497	0.831[a]	0.462	0.572
Average	Check	16.30	15.72	92.55	87.68	0.510	1.033	0.466	0.593
	Thiabendazole-1500 ppm	16.30	15.85	92.55	87.80	0.510	0.798	0.466	0.652

[a]Significantly different from check treatment at 0.05 - paired t test.
[b]Sucrose content was not corrected for weight loss.

than non-treated beets in the two tests. No significant differences existed in sucrose loss between the two treatments in the Eaton and Berthoud tests, but in each case, the purity was slightly lower in the treated beets after storage (Table 7). Little, if any, mold was observed on the beets in either test. Losses of beets in the Eaton test were higher than normal which may have been caused by crown frost two days before harvest. Temperature and moisture conditions in the third test were set up to encourage mold growth. The sucrose and recoverable sucrose losses in treated beets were significantly less than in non-treated beets. Purity was also significantly better in treated beets after storage than in non-treated beets. Visual observations showed thiabendazole reduced mold in the third test. These data show that thiabendazole reduced storage losses by reducing rot and mold in beets stored under conditions which promote mold growth, as would occur in canopy covered piles. The treatment gave no benefit and may actually increase losses relative to the non-treated beets under conditions where little mold occurs. These conditions would exist under short and intermediate term storage periods in piles which are not covered with a canopy.

The following conclusions have been made from the studies reported in this paper:

1) Some chemicals increase respiration, invert sugar formation, and sucrose loss in stored beets. The toxicity increased with increasing dosage of the chemical and with the chemicals applied just prior to or after harvest.
2) None of the herbicides or nematicides applied at recommended rates and times gave detectable increases in respiration, invert sugar formation, or sucrose loss. These materials applied early in the season would have little residue left at harvest to produce toxic effects in roots. New pesticide candidates, however, should be evaluated for their effect upon storage loss before being put into commercial use.

3) Fungicides are useful in reducing rot and mold under some storage conditions (8, 9), but their use should be limited to areas of known potential problems (such as long term storage, canopy covered piles, or a known history of problems). If no mold problems exist, the fungicides may increase storage losses.
4) Cultivars differ widely in respiration rate, invert sugar accumulation, and sucrose loss (1, 5, 11). Cultivars could likewise vary in their storage loss reaction to chemical treatment, but we have no evidence to indicate this is true.

SUMMARY

The chemicals applied early in the season such as herbicides or nematicides had no adverse effect on respiration, invert sugar formation, or sucrose loss during sugarbeet storage; however, many chemicals applied prior to or after harvest significantly increased storage loss, no doubt because of toxicity to the beets. The losses increased with increasing rate of application.

Certain fungicides applied to the roots after harvest reduced storage losses in situations where rot and mold problems exist; however, they may increase losses where little or no mold problems exist.

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