Influence of Curly Top and Poncho Beta on Storability of Sugarbeet

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ABSTRACT

Sucrose losses during postharvest storage of sugarbeet (*Beta vulgaris* L.) maybe exacerbated by field diseases. This study investigated the influence of curly top (causal agent *Beet severe curly top virus* and related viruses) on storability of sugarbeet roots during the 2005 and 2006 growing seasons. Three sugarbeet cultivars varying for resistance to curly top were evaluated both with and without the insecticide seed treatment Poncho Beta (60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seed). At harvest, 8-beet samples from each cultivar were collected and placed inside an outdoor pile. Samples were removed at 40-day intervals beginning on 31 October in 2005 and 1 November in 2006. Sucrose concentration, frozen and discolored root area, and root weight were evaluated. By mid-September plants from Poncho Beta treated seed had curly top ratings that were 37 and 31% lower ($P < 0.01$) than plants from the untreated seed in 2005 and 2006, respectively. After 124 and 131 days in storage, roots from Poncho Beta treated seed had 8.5 and 5% more sucrose than roots from untreated seed in 2005 and 2006, respectively. Resistant cultivars and insecticide seed treatments not only limit losses to curly top in the field, but also in long term storage.

Additional key words: *Curtovirus*, geminivirus, *Beta vulgaris*, clothianidin

Storage of sugarbeet in piles is common in production areas with mild climates, which allows the factory campaigns to be longer and more productive. However, sucrose loss occurs during this storage period. Harvest practices, respiration rates, storage rots, and weather conditions during and after harvest influence the storability of sugarbeet (Bugbee, 1993; Jaggard et al., 1997). The respiration required to maintain a viable root, may account for 50-60% of the total sucrose loss (Wyse and Dexter, 1971). On the outer 60 cm of piles, dehydration is a major cause of sucrose loss (Bugbee, 1993). Once weight loss in a beet exceeds 25-30%, the root can no longer resist microbial development (Bugbee, 1993). Storage rot pathogens such as *Phoma betae* Frank, *Botrytis cinerea* Pers. ex Fr., and *Penicillium claviforme* Bainier also cause important sucrose losses in storage (Bugbee, 1982). In Moorhead, MN, a survey of beet coming into the factory from storage piles determined that 1.2% of the tissue was rotted (Bugbee and Cole, 1976). This amount of rot may seem small but led to a loss of 500 t of sucrose daily and another 800 t lost indirectly because of impurities (Bugbee and Cole, 1976). Air flow and temperature control are also important in managing sucrose losses in storage piles (Bugbee, 1993; Peterson et al., 1980; Wyse, 1978). Diseases in the field may also influence storability (Campbell and Klotz, 2006; Campbell et al., 2008; Kenter et al., 2006; Smith and Ruppel, 1971; Strausbaugh et al., 2008).

Curly top is a widespread problem in sugarbeet in semi-arid areas of the United States. Curly top on sugarbeet is caused by *Beet severe curly top virus* or a number of closely related species transmitted by the beet leafhopper, *Circulifer tenellus* (Baker) in a circulative-nonpropagative manner (Soto and Gilbertson, 2003; Stenger, 1998; Strausbaugh et al., 2007). Curly top nearly eliminated the sugarbeet industry in the western U.S. until cultivars with resistance became generally available (Bennet, 1971; Blickenstaff and Traveller, 1979). Control of this disease is still largely based on host resistance. Insecticides including seed treatments such as clothianidin may also reduce curly top damage (Strausbaugh et al., 2006). However, even the combination of host resistance and insecticidal seed treatment (Strausbaugh et al., 2006; Strausbaugh et al., 2007) does not keep plants virus free. Therefore, studies were conducted to investigate the influence of curly top, host resistance, and insecticide seed treatments on the storability of sugarbeet.

MATERIALS AND METHODS

Treatments.

The study contained six treatments consisting of three commercial sugarbeet cultivars with and without Poncho Beta (clothianidin 60 g a.i./100,000 seed + beta-cyfluthrin 8 g a.i./100,000 seed). The study was conducted with roots from the 2005 growing season and repeated using roots from the 2006 growing season. The field in the 2005 growing season was exposed to natural leafhopper and virus for infection. In the 2006 growing season, the natural infestation was not adequate for good disease pressure. Therefore, 0.5 viruliferous leafhoppers per plant were released on 10 July when the plants were getting their first or second set of true leaves. The three sugarbeet cultivars used in the study were; HM PM21 which had high resistance to curly top, Beta 8600 which was intermediate, and HH Phoenix R which was intermediate to susceptible. The cultivar HM PM21 was not available in 2006 and thus we included HM PM90 in place of HM PM21, since it had a similar level of resistance to curly top in previous work (Strausbaugh et al., 2007).

The six treatments were arranged in a randomized complete block design with four replications as four-row plots 10.4 m long with rows 0.6 m apart. The fields were managed using standard commercial cultural practices (Strausbaugh et al., 2006). At harvest, six 8-beet samples from each plot were harvested and placed in nylon mesh onion bags. Two of the six samples were submitted to the Amalgamated Tare Lab for sugar analysis. The remaining four samples were stored outdoors in a shaded area until they were placed inside the Twin Falls commercial ventilated pile. The storage samples were piled inside a round metal corrugated ventilation pipe (0.9 m diameter) on top of plywood in the same experimental design and blocks as they were arranged in the field.

The sample bags inside the pipe covered a 6 m^2 area starting 6.1 m in from the end of the pipe. The end of the pipe was covered with straw bales. The pipe was located on top of a 30 cm layer of beet to keep it off the ground and was covered with 6.1 m of roots. The pile was ventilated using the same type of pipe placed 3.7 m on center. The storage pipe with the samples was not ventilated and was placed in between the pipes used for ventilation. The samples were retrieved at 40 day intervals beginning on 31 October in 2005 and 1 November in 2006. Temperature inside the storage tube was recorded on a Hobo temperature sensor (Onset Computer Corp., Bourne, MA) at 1 h intervals (Fig. 1).

2005 Field Samples. The field was located on the USDA-ARS Research Farm near Kimberly, ID. Wheat had been grown on the field the previous year. Sugarbeet cultivars were planted on 6 May 2005. The field was mechanically topped and harvested on 27 October with a small plot harvester and the roots were placed inside the pipe in the Twin Falls ventilated pile on 28 October.

2006 Field Samples. The field was located on the USDA-ARS

Research Farm near Kimberly, ID. The field had been in field corn in 2005 and was planted on 11 May. The field got hailed out on 8 June and was replanted on 12 June. The sugarbeet plants were hand topped and harvested on 17 October. The storage samples were stored outdoors in a shaded area until they were placed inside the Twin Falls ventilated pile on 19 October.

Curly Top, Rot, and Freeze Damage Ratings. The plants were evaluated for curly top symptoms using a disease index of 0 (= no disease) to 9 (= dead plant) (Strausbaugh et al., 2006) on 7 and 12 September in

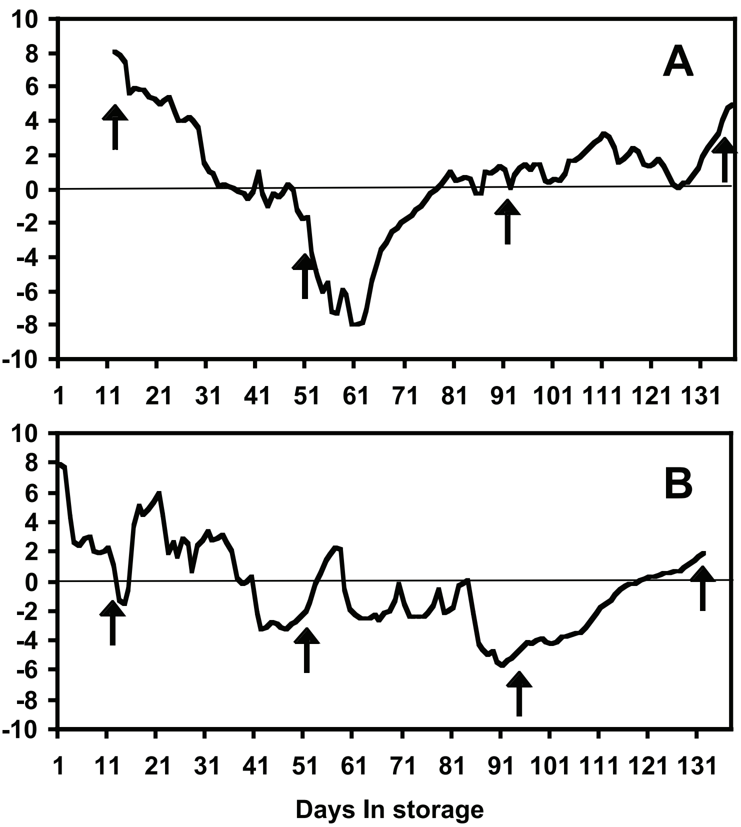

Figure 1. Average daily temperature (°C) next to sugarbeet storage samples inside the storage tube from 27 October 2005 to 28 February 2006 (A) and from 19 October 2006 to 26 February 2007 (B) in an outdoor pile in Twin Falls, ID. Arrows designate when storage samples were retrieved.

2005 and 2006, respectively. At the time of retrieval from the storage pile, root rot was assessed by estimating the percentage of root surface area with dry black rot, wet bacterial rot, and/or covered with fungal growth. The roots were also visually evaluated to establish the percentage of root surface area with freeze damage (frost on root surface, tissue translucent, etc.). No freeze data were taken on the first samples because no freezing had occurred by this date. There was no evidence of insect damage on the roots either at harvest or after storage. Prior to storage, there was no evidence of root rot .

Weight Analysis. Prior to placing the storage samples in the pile, each sample was weighed. The samples were reweighed when retrieved from the storage pile. A comparison of these weights was used to estimate reduction in root weight.

Sugar Analysis. Two of the six samples collected from each plot were submitted to the Amalgamated Tare Lab in Paul, ID at the time of harvest. Percent sucrose was determined using an Autopol 880 polarimeter (Rudolph Research Analytical, Hackettstown, NJ) and a half-normal weight sample dilution and aluminum sulfate clarification by the method generally described in ICUMSA Method GS6-3 [1994] (Bartens, 2005). Percent sucrose for samples coming out of storage was determined by Amalgamated Research Inc. in Twin Falls, ID using gas chromatography. The gas chromatographic method was similar to ICUMSA Method GS4/7/8/5-2 [2002] with the following modifications: the internal standard used is D(-)- salicin [2-(hydroxymethyl)phenyl-ß-D-glucopyranoside] and equal volumes (to ± 0.01 ml) of a solution of internal standard in dimethylformamide were dispensed into weighed samples and standards using a volumetric dispenser (Bartens, 2005). Previous work comparing the two sampling techniques determined that the gas chromatography analysis averaged 1.395% higher than the polarimeter (Strausbaugh et al., 2008). To establish percent reduction in sucrose at harvest versus storage, only samples from within the same plot were compared. Percent sucrose reduction was established using the following equation: % reduction in pounds of sugar = $(1-[((\%\ \text{Sugar}_{\text{storage sample}} - 1.395) \times \text{Weight}_{\text{storage sample}})/(\%\ \text{Sugar}_{\text{harvest sample}} \times \text{Weight}_{\text{harvest sample}})]) \times 100$.

Data Analysis. Data were analyzed using the general linear models procedure of SAS (SAS Institute Inc., 1999), and Fisher's protected least significant difference was used for mean comparisons. Mean comparisons across treatments were conducted using single degree-of-freedom contrast statements. Bartlett's Test was used to evaluate homogeneity of variance.

RESULTS

Temperature. During the 2005/2006 storage season temperatures dropped below 0°C on 3 December 2005 and stayed below zero for the next 29 days (Fig. 1). The lowest temperature during the cold period was -7.9°C. Temperatures then remained above 0°C for all but two days until the end of the storage season. During the 2006/2007 storage season temperatures dropped below 0°C for 2 days at the end of October and then not again until 25 December 2006. Temperatures fluctuated above and below freezing until mid February when they remained above freezing until the end of the storage season. The coldest temperature recorded was -5.7°C on 17 January 2007.

Curly top ratings. During the 2005 growing season moderate curly top disease pressure was present based only on natural leafhopper movement. By 7 September the mean curly top ratings for HM PM21, Beta 8600, and HH Phoenix R without Poncho Beta were 2.7, 3.7, and 5.3, respectively [LSD ($P < 0.05$) = 0.5]. With Poncho Beta, the same three cultivars had ratings of 1.5, 2.1, and 3.8, respectively (Strausbaugh et al. 2006). When analyzed across cultivars, the Poncho Beta treatment readings averaged 1.97 lower ($P < 0.01$) than treatment without the insecticide. During the 2006 growing season there was moderate disease pressure based on inoculation with viruliferous leafhoppers. By 12 September the mean curly top ratings for HM PM90, Beta 8600, and HH Phoenix R without Poncho Beta were 3.7, 4.0, and 4.5, respectively [LSD ($P < 0.05$) = 0.4]. With Poncho Beta, the same three cultivars had ratings of 2.5, 2.7, and 3.2 respectively. When analyzed across cultivars, the Poncho Beta treatment readings averaged 1.3 lower ($P < 0.01$) than treatments without the insecticide.

Surface rot. There was no apparent surface rot in the November sampling during either year. December data for surface rot from 2005 and 2006 were analyzed together since they were not significantly different ($P = 0.15$) and variances were homogeneous ($P = 0.08$). January data for surface rot did not differ between years ($P = 0.12$), but variances were not homogeneous ($P = 0.03$). Thus, these data were analyzed individually. February data for surface rot differed between years ($P < 0.01$). Roots from the 2005 growing season did not differ in surface rot throughout the storage season (Table 1). In roots from the 2006 growing season, treatments differed for surface rot in January. HH Phoenix

Table 1. Percentage of root surface exhibiting rot on sugarbeet roots harvested in 2005 and 2006 from curly top infested plots with untreated and Poncho Beta treated seed stored in an outdoor commercial pile at Twin Falls, ID.

		Surface rot[†]				
Cultivar	**Treatment**	**9 Dec 2005/2006**	**18 Jan 2006**	**28 Feb 2006**	**22 Jan 2007**	**26 Feb 2007**
HM PM21[¶]	Poncho Beta	4.1	15	14	0.9 b	1.0 b
HM PM21	Untreated	4.2	16	18	0.8 b	0.9 b
Beta 8600	Poncho Beta	2.6	4	8	2.6 b	2.0 b
Beta 8600	Untreated	4.5	4	18	2.9 b	8.6 ab
HH Phoenix R	Poncho Beta	4.9	15	20	5.0 b	10.8 ab
HH Phoenix R	Untreated	2.6	16	29	13.8 a	14.6 a
$P > F$[§]		0.8802	0.1312	0.2302	0.0125	0.0595
LSD ($P < 0.05$)		NS	NS	NS	7.1	10.6

† Surface rot = percentage of root area covered by fungal growth or dark tissue discoloration. Sugarbeet were harvested and put into storage on 31 October 2005 and 19 October 2006. December data from 2005 and 2006 were analyzed together since they were not significantly different ($P = 0.1500$) and variances were homogeneous ($P = 0.0832$).

¶ HM PM90 was used in 2006 instead of HM PM21, since HM PM21 was no longer available.

§ $P > F$ was the probability associated with the F value. LSD = Fisher's protected least significant difference value. NS = not significantly different. Means followed by the same letter did not differ significantly based on Fisher's protected least significant difference, with $P < 0.05$.

R without Poncho Beta had more surface rot than the other treatments. The February sampling was borderline for significance (P = 0.0595). When data were analyzed across cultivars using contrasts, there were no significant differences in surface rot with or without Poncho Beta (Table 2).

Frozen root area. There was no frozen root damage evident in either of the November samplings. December data for frozen tissue for both years were not different (P = 0.20), but variances were not homogeneous (P < 0.01). Transformation did not create homogeneous variances and thus these data were analyzed individually. January and February data for frozen tissue differed between years (P < 0.01 and <0.01, respectively). In the 2005 roots, there were no significant differences in frozen root area for any of the sampling dates (Table 3). In the 2006 roots, the only treatment difference in frozen root area was for the February sampling. Beta 8600 without insecticide had more frozen root tissue than the other treatments. When comparing across cultivars, the only difference was in February 2007 when roots in the untreated check treatment had more frozen root tissue than the Poncho Beta treatment (Table 2).

Root weight reduction. Data for weight loss for both years were significantly different (P < 0.01) in December, January (P < 0.01), and February (P < 0.01) and therefore were analyzed individually. Regardless of sampling date, cultivar, or year, there were no root weight reduction differences between treatments (Tables 2 and 4).

Sucrose reduction. With the 2005 roots, no attempt was made to determine reduction in sucrose on 31 October since harvest and sampling date were only 4 days apart. Thus these data were not compared with the 2006 November data. December data from 2005 and 2006 for sucrose reduction were analyzed together since they were not significantly different (P = 0.20) and variances were homogeneous (P = 0.30). January data from 2005 and 2006 for sucrose reduction were not significantly different (P = 0.37) but the variance was not homogeneous (P < 0.01) and transformation did not create homogeneous variance. Thus, these sucrose reduction data were analyzed by year. February data from 2005 and 2006 for sucrose loss based on harvest data and GC were not significantly different (P = 0.24) and variances were not homogeneous (P < 0.01). Thus, these sucrose reduction data were analyzed by year. There were no differences in sucrose reduction among treatments for November, December, or January either year (Table 5). In February both years there were differences in sucrose reduction among treat-

Table 2. Single degree of freedom contrasts to investigate the influence of curly top on sugarbeet roots harvested from plots with untreated and Poncho Beta treated seed and stored in an outdoor pile in Twin Falls, ID.

		Contrast (mean)			
Variable[†]	**Date**	**Un-treated**	**Poncho Beta**	***F***	***P > F***
Surface rot (%)	Dec 2005/2006	3.8	3.9	0	0.9519
	18 Jan 2006	12.0	11.3	0	0.8162
	28 Feb 2006	21.7	14.0	3	0.1230
	22 Jan 2007	5.8	2.8	2	0.1439
	26 Feb 2007	8.0	4.6	1	0.2486
Frozen root area (%)	9 Dec 2005	5.7	12.5	1	0.2909
	18 Jan 2006	1.3	0.6	0	0.6330
	28 Feb 2006	0.0	0.0		
	12 Dec 2006	0.0	1.7	1	0.3332
	22 Jan 2007	98.3	97.3	3	0.1130
	26 Feb 2007	3.9	0.0	34	<0.0001[§]
Weight loss (%)	9 Dec 2005	4.5	5.1	1	0.3667
	18 Jan 2006	6.5	7.2	1	0.4385
	28 Feb 2006	7.6	6.4	1	0.3814
	1 Nov 2006	9.6	7.3	2	0.1395
	12 Dec 2006	10.9	13.6	3	0.0876
	22 Jan 2007	15.1	13.8	1	0.3106
	26 Feb 2007	16.5	14.8	1	0.3036
Sucrose reduction (%)	1 Nov 2006	6.8	4.3	1	0.2935
	Dec 2005/2006	8.4	8.2	0	0.9252
	18 Jan 2006	6.6	8.7	4	0.2635
	28 Feb 2006	17.6	9.1	5	0.0503
	22 Jan 2007	12.5	12.0	0	0.7864
	26 Feb 2007	22.8	17.8	6	0.0249

[†] Surface rot = percentage of root area covered with fungal growth or rotted tissue. Frozen root area = percentage of outside area of the root frozen based on frost or tissues with wet water soaked appearance. Weight loss = reduction in weight of stored roots in relation to that determined at harvest. Sucrose loss = reduction in sucrose of stored roots in relation to that determined at harvest.

[§] Frozen root area data analysis was conducted using the square root transformation to account for zero data.

Table 3. Percentage of frozen root tissue in sugarbeet roots harvested in 2005 and 2006 from curly top infested plots with untreated and Poncho Beta treated seed were stored in an outdoor pile in Twin Falls, ID.

		Frozen root area (%)†						
							26 Feb 2007	
Cultivar	**Treatment**	**9 Dec 2005**	**18 Jan 2006**	**28 Feb 2006**	**12 Dec 2006**	**22 Jan 2007**	**Normal**	**Transformed§**
HM PM21‡	Poncho Beta	0.0	1.2	0.0	0.0	95.0	0.0	0.7 b
HM PM21	Untreated	5.0	0.0	0.0	0.0	100.0	0.0	0.7 b
Beta 8600	Poncho Beta	12.5	0.5	0.0	5.0	97.5	0.0	0.7 b
Beta 8600	Untreated	11.2	0.0	0.0	0.0	95.0	11.0	3.3 a
HH Phoenix R	Poncho Beta	25.0	0.0	0.0	0.0	99.5	0.0	0.7 b
HH Phoenix R	Untreated	0.8	3.8	0.0	0.0	100.0	0.8	1.0 b
$P > F$¶		0.2482	0.5843		0.4509	0.2613		<0.0001
LSD ($P < 0.05$)		NS	NS	NS	NS	NS		0.6

† Frozen root area = percentage of root frozen based on frost or tissues with wet water soaked appearance. Sugarbeet were harvested and put into storage on 31 October 2005 and 19 October 2006.

§ Analysis was conducted on square root transformed data because of zeros in the data set.

‡ HM PM90 was used in 2006 instead of HM PM21, since HM PM21 was no longer available.

¶ $P > F$ was the probability associated with the F value. LSD = Fisher's protected least significant difference value. NS = not significantly different. Means followed by the same letter did not differ significantly based on Fisher's protected least significant difference, with $P < 0.05$.

Table 4. Percent reduction in root weight in sugarbeet roots harvested in 2005 and 2006 from curly top infested plots with untreated and Poncho Beta treated seed were stored in an outdoor pile in Twin Falls, ID.

		Root weight reduction[†]						
Cultivar	**Treatment**	**9 Dec 2005**	**18 Jan 2006**	**28 Feb 2006**	**1 Nov 2006**	**12 Dec 2006**	**22 Jan 2007**	**26 Feb 2007**
HM PM21[¶]	Poncho Beta	5.3	6.4	5.7	8.4	10.2	14.3	17.8
HM PM21	Untreated	4.1	6.8	8.1	12.4	12.2	14.5	14.7
Beta 8600	Poncho Beta	4.9	7.3	7.1	6.0	8.2	12.6	12.7
Beta 8600	Untreated	5.2	7.3	6.4	11.0	10.5	15.1	16.6
HH Phoenix R	Poncho Beta	5.0	8.0	6.5	7.5	8.8	14.4	14.0
HH Phoenix R	Untreated	4.1	5.3	8.3	5.4	10.0	15.7	18.3
$P > F$[§]		0.8088	0.6936	0.8347	0.0843	0.3189	0.7985	0.3240
LSD ($P < 0.05$)		NS	NS	NS	NS	NS	NS	NS

† Percent reduction in root weight in relation to that determined at harvest. Sugarbeet were harvested and put into storage on 31 October 2005 and 19 October 2006.

¶ HM PM90 was used in 2006 instead of HM PM21, since HM PM21 was no longer available.

§ $P > F$ was the probability associated with the F value. LSD = Fisher's protected least significant difference value. NS = not significantly different.

ments. In 2005 roots, HM PM21 lost more sucrose when untreated. In 2006, Beta 8600 lost more sucrose when not treated, but the difference was not present in the 2005 roots. HH Phoenix R with Poncho Beta lost more sucrose than the other cultivars with Poncho Beta both years. When compared across cultivars, roots with Poncho Beta retained 8.5 (P = 0.05) and 5% (P = 0.02) more sucrose in 2005 and 2006, respectively (Table 2). Regression analysis revealed a significant relationship between curly top ratings and sucrose reduction in both 2005 (r^2 = 0.28, P < 0.01) and 2006 (r^2 = 0.22, P = 0.02).

DISCUSSION

Curly top of sugarbeet can lead to sucrose reduction in beet stored more than 100 days in outdoor piles. The Poncho Beta seed treatment reduced curly top symptoms in the field and subsequently was associated with reduced sucrose loss of 5 to 8% in long-term storage. The reduction in curly top symptoms associated with Poncho Beta had almost no measurable influence on surface rot, freeze damage, and weight loss in storage. Cultivar selection had a greater impact on storability and these data emphasize the importance of resistant cultivars in reducing storage losses.

Recently, the influence of disease problems in the field have been studied using Rhizoctonia root rot (Kenter et al., 2006), Cercospora leaf spot (Kenter et al., 2006; Smith and Ruppel, 1971), Aphanomyces root rot (Campbell and Klotz, 2006), and rhizomania (Campbell et al., 2008; Strausbaugh et al., 2008). Based on these recent publications, it could be argued that some disease problems can rival if not exceed sucrose loss associated with inherent differences in respiration. The reduced sucrose loss in storage and reduction in symptoms associated with the Poncho Beta treatment suggest that curly top negatively influenced the storability of sugarbeet.

Curly top on sugarbeet can be caused by BSCTV or two other closely related species *Beet mild curly top virus* [BMCTV] and *Beet curly top virus* [BCTV] (Stenger, 1998; Strausbaugh et. al., 2006). Surveys from plants in adjacent studies indicate that BSCTV and BMCTV were likely to have been present both years (Strausbaugh et al., unpublished data). BCTV was also likely to be present in 2006. A previous survey also established that BSCTV (formerly known as the CFH strain) was present in Idaho (Stenger and McMahon, 1997). Thus, the virus strains and disease pressure reported here should be typical of commercial fields under moderate curly top infestation.

The clothianidin in Poncho is a second generation neonicotinoid

Table 5. Percent reduction in sucrose in sugarbeet roots harvested from curly top infested plots with untreated and Poncho Beta treated seed were stored in an outdoor pile in Twin Falls, ID.

		Sucrose reduction (%)[†]					
Cultivar	**Treatment**	**9 Dec 2005/2006**	**18 Jan 2006**	**28 Feb 2006**	**1 Nov 2006**	**22 Jan 2007**	**26 Feb 2007**
HM PM21[¶]	Poncho Beta	6.0	5.4	0.9 c	4.0	9.8	14.2 b
HM PM21	Untreated	6.9	2.4	15.8 ab	9.1	12.4	20.7 ab
Beta 8600	Poncho Beta	6.1	6.8	4.7 bc	0.8	11.2	14.8 b
Beta 8600	Untreated	11.3	6.9	14.0 abc	5.4	9.5	24.0 a
HH Phoenix R	Poncho Beta	12.5	16.8	21.8 a	8.0	14.9	24.5 a
HH Phoenix R	Untreated	6.9	10.6	23.1 a	5.8	15.7	23.8 a
$P > F$[§]		0.1728	0.0801	0.0314	0.4009	0.3837	0.0219
LSD ($P < 0.05$)		NS	NS	14.6	NS	NS	7.4

† Percent reduction in sucrose in relation to that determined at harvest. Sugarbeet were harvested and put into storage on 31 October 2005 and 19 October 2006. December data from 2005 and 2006 for sucrose reduction were analyzed together since they were not significantly different ($P = 0.2041$) and variances were homogeneous ($P = 0.3010$). There is no data for the first sampling date in 2005 since harvest and sampling were almost simultaneous.

¶ HM PM90 was used in 2006 instead of HM PM21, since HM PM21 was no longer available.

§ $P > F$ was the probability associated with the F value. LSD = Fisher's protected least significant difference value. NS = not significantly different. Means followed by the same letter did not differ significantly based on Fisher's protected least significant difference, with $P < 0.05$.

which is a systemic insecticide seed treatment that provides control of beet leafhoppers (vector for BSCTV) and subsequent reduction in curly top (Strausbaugh et al., 2006). The beta-cyfluthrin component is a non-systemic insecticide that should have had no influence on beet leafhoppers or curly top. Although Poncho Beta reduces curly top symptoms, the plants still become infected and some symptom development occurs even with the most resistant commercial cultivars. Thus, the storage data presented represent a comparison between more symptomatic and less symptomatic plants.

The influence of disease problems in the field on the ability of sugarbeet tissue to resist freezing is poorly studied. A previous study with roots from a rhizomania infested field showed that *Beet necrotic yellow vein virus* could lead to considerable freeze damage (Strausbaugh et al., 2008). Curly top seemed to have relatively little influence on the risk of roots freezing as there were no consistent differences in the data shown in Table 3. In December 2005 and January 2006 there was freeze damage but subsequent sampling data revealed very little damage. The risk of roots freezing in relation to curly top infection in the field may not need to be investigated further.

Curly top in sugarbeet is a widespread important disease problem in semi-arid areas of the western United States from Nebraska to California. Curly top almost eliminated sugarbeet production until resistance was incorporated into commercial cultivars (Bennet, 1971). The primary control measure for curly top is host resistance. However, even the most resistant commercial cultivars allow for considerable disease development (Strausbaugh et al., 2007). Seed treatments such as Poncho Beta reduce curly top damage, but should be viewed as a supplement to host resistance and not a substitute for host resistance (Strausbaugh et al., 2006). Even combining our best host resistance with insecticide seed treatments does not eliminate virus from the plants, leaving room for further improvement to both host resistance and control measures. The storage data indicate Poncho Beta also has the potential to reduce storage losses in roots stored for more than 100 days in storage. Sugar companies that store sugarbeet roots need to take into consideration the influence that cultivar selection can have on sucrose losses. Companies operating in areas with curly top and long-term storage need to encourage the use of systemic insecticides as seed treatments to reduce or minimize sucrose loss in storage.

ACKNOWLEDGMENTS

These data support the objectives for the United States Department of Agriculture CRIS project 5368-21220-002-00D. We acknowledge the Amalgamated Sugar Co., Amalgamated Research Inc., Beet Sugar Development Foundation, and Snake River Sugarbeet Growers for supporting our research work. We also wish to acknowledge the efforts of the following technical support staff: Diane Patterson, Paul Foote, Jodi Smith, Mindie Funke, Dustin Kenney, and Terry Brown.

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