Seed Treatments for the Control of Insects and Diseases in Sugarbeet

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ABSTRACT

Insect feeding and vectoring of viruses cause serious problems in sugarbeet (*Beta vulgaris* L.) production worldwide. In order to ameliorate insects and diseases on sugarbeet, two seed treatments, Poncho Beta (60 g a.i. [active ingredient] clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds) and Cruiser Tef (60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds) were investigated in a series of five field trials from 2006 to 2009. The two seed treatments and an untreated check were tested on commercial sugarbeet cultivars in a randomized complete block design with eight replications. Insect incidence and curly top symptoms were evaluated. Both Poncho Beta and Cruiser Tef provided significant reduction in curly top symptoms and incidence of leafminers (Pegomya spp.), black bean aphid (Aphis fabae Scopoli), and sugarbeet root aphid (Pemphigus betae Doane). In the two trials conducted under curly top pressure, Poncho Beta and Cruiser Tef had more root yield than the untreated check by 3.4 to 15.1 t/ha. In the three trials without curly top pressure, Poncho Beta and Cruiser Tef resulted in root yield increases of 3.1 to 6.7 t/ha over that of the untreated check. Neonicotinoid seed treatments play an important role in early season disease and insect management in sugarbeet production, but should be viewed as a supplement to host plant resistance rather than a substitute for it.

Additional key words: *Beta vulgaris*, curly top, *Curtovirus*, clothianidin, thiamethoxam, neonicotinoid

Insect pests cause serious problems in sugarbeet (*Beta vulgaris* L.) production worldwide by inflicting feeding injury and vectoring virus diseases. Curly top caused by *Curtovirus* species is transmitted by the beet leafhopper (*Circulifer tenellus* Baker). In the western United States, *Beet severe curly top virus* (BSCTV) and *Beet mild curly top virus* (BMCTV) are frequently associated with curly top in sugarbeet, while *Beet curly top virus* (BCTV) is only rarely found (Strausbaugh et al., 2008b). These virus species can lead to severe yield losses and even kill plants if susceptible plants are infected at an early growth stage. Host plant resistance is the primary strategy for curly top management, but resistance does not provide complete control. The neonicotinoid seed treatment, clothianidin (Poncho), has shown promise as another tool to ameliorate curly top problems in sugarbeet (Strausbaugh et al., 2006).

Black bean aphid (*Aphis fabae* Scopoli), cutworms (*Agrotis* spp. and *Euxoa* spp.), sugarbeet root aphid (*Pemphigus betae* Doane), sugarbeet root maggot (*Tetanops myopaeformis* Röder), leafminers (*Pegomya hyoscyami* Panzer and *Pegomya betae* Curtis), and wireworms (*Limonius* spp.) also lead to production problems in sugarbeet. Host plant resistance also would be an attractive management tool for these problems, but insecticides also are frequently needed to reduce losses.

The neonicotinoid class of insecticides has proven to be an invaluable tool for managing some of the world's most important crop insects (Jeschkle and Nauen, 2008). Neonicotinoids represent the most effective chemical class for the control of sucking insects such as aphids, whiteflies, leafhoppers, and planthoppers, as well as thrips, some microlepidoptera, and a number of coleopteran insect species (Elbert et al., 2008). Their combination of broad spectrum efficacy, systemic and translaminar action, pronounced residual activity, and alternative mode of action as competitive inhibitors of nicotinic acetylcholine receptors, make neonicotinoids a rapidly expanding insecticidal class (Elbert et al., 2008; Wang et al., 2008). Seven neonicotinoids (i.e., imidacloprid, acetamiprid, nitenpyram, thiamethoxam, thiacloprid, clothianidin, and dinotefuran) are marketed as 530 products in 123 countries (Nauen et al., 2008). When neonicotinoids are utilized as seed treatments, very little active ingredient is used to protect the plant. Since these products are systemic, only target pests are affected. Thus, negative impacts on beneficial insects are typically avoided. In an effort to develop improved and more environmentally friendly disease and insect control measures, studies were conducted to evaluate the influence of host plant resistance and neonicotinoid-based insecticidal seed treatments to manage curly top and insect problems in sugarbeet.

MATERIALS AND METHODS

Treatments.

Five trials were conducted to assess the efficacy of seed treatments for disease and insect control in sugarbeet. The trials involved two insecticidal seed treatments plus an untreated check and four sugarbeet cultivars. In Trials 1-3, four cultivars with differing levels of host plant resistance to curly top (HM070021 = high, B-16 = high-intermediate, HH005 = intermediate-low, and SX003 = highly susceptible; Camp et al., 2005) were evaluated. HH005 also contains resistance to rhizomania, while the other three cultivars do not. In Trials 4 and 5, four cultivars with resistance to glyphosate and rhizomania (B-13, B-22, C-12, and HM070002) were evaluated. The seed treatments for all trials except Trial 1 included an untreated check (no insecticide), Cruiser Tef (60 g a.i. thiamethoxam + 8 g a.i. tefluthrin /100,000 seeds), and Poncho Beta (60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds). In Trial 1, Cruiser (60 g a.i. thiamethoxam/100,000 seeds) was tested without Tef. The seed in all trials were treated with a fungicide package as well. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to limit the influence of soil-borne fungal pathogens and allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package. All seed treatments were applied to large raw conditioned seed by Astec Seed Technology (Sheridan, WY) for the 2006 and 2007 trials. In 2008 and 2009, the untreated checks and Poncho Beta treatments were applied by Bayer CropScience (Research Triangle Park, NC) and the Cruiser Tef treatment was applied by Syngenta Seeds, Inc. (Stanton, MN).

The experimental design for all trials was a randomized complete block with eight replications. There were a total of 12 treatments in each trial. The trial location and dates for planting, thinning, disease and insect evaluation, and harvest are presented in Table 1. All plots were planted to a density of 352,123 seeds/ha, and thinned to 117,374 plants/ha. Plots were four rows wide (56-cm row spacing) and 10.4 m long except for Trials 4 and 5, which were 7.3 m long. Trials were managed using standard crop production practices described previously (Strausbaugh et al., 2006), except no insecticides were used other than the seed treatments.

Ratings.

Surviving plant stand counts were conducted when the untreated checks were approaching 100% seedling emergence and plants had reached cotyledon (i.e., no true leaves emerged) stage. Stand counts represent the percentage of emerged plants within 3 m of a center row prior to thinning. In Trials 1 and 2, curly top ratings were recorded in mid-September (Table 1) from the center two rows using a disease index of 0 to 9 described by Strausbaugh et al. (2006). The index was applied in a quantitative manner with all non-whole numbers between 0 and 9 possible. In Trials 2-5, the percentage of plants with leafminer in the center two rows was determined at the four- to six-leaf growth stage. In Trials 1, 4, and 5, the percentage of plants with black bean aphid colonies was assessed from the center two rows in mid-August. In Trial 4, ten plants were dug from an outside row and the percentage of plants with root aphids on the main tap root and lateral rootlets was determined on 8-9 September. In Trial 1, one viruliferous beet leafhopper per two plants was released to support curly top development. All other trials relied on natural infestations of all insects. The viruliferous beet leafhoppers came from a colony maintained by the Beet Sugar Development Foundation in Twin Falls, ID. The beet leafhopper population contains all three curly top virus species (Strausbaugh et al., 2008b).

Yield.

The center two rows were mechanically topped and a two-row plot harvester was used to harvest the plots on the dates mentioned in Table 1. Two eight-beet samples per plot were collected for sugar analysis during harvest and were submitted to the Amalgamated Tare Lab in Paul, ID for percent sugar and quality analysis. Percent sugar was determined by using an Autopol 880 polarimeter (Rudolph Research Analytical, Hackettstown, NJ), a half-normal weight sample dilution, and aluminum sulfate clarification method [ICUMSA Method GS6-3 1994] (Bartens, 2005). Conductivity was measured using a Foxboro conductivity meter Model 871EC (Foxboro, Foxboro, MA) and nitrate was measured using a multimeter Model 250 (Denver Instruments, Denver, CO) with Orion probes 900200 and 9300 BNWP (Krackler Scientific, Inc., Albany, NY). Recoverable sucrose yield per ton of roots was estimated using [(extraction)(0.01)(gross sucrose/ha)]/(t/ha), where extraction = 250 + [[(1255.2)(conductivity) – (15000)(percent sucrose - 6185)]/[(percent sucrose)(98.66 – [(7.845)(conductivity)])]] and gross sucrose = [[(t/ha)(percent sucrose)](0.01)](1000 kg/t).

Table 1. Planting, harvest, and assessment dates for five sugarbeet trials conducted to assess the efficacy of insecticidal seed treatments for insect and disease control in Idaho.

				Dates for rating					
Trial	**Location**	**Year**	**Planted**	**Stand**	**Curly top**	**Leafminer**	**Black bean aphid**	**Root aphid**	**Harvest**
1	Kimberly, ID	2006	12 Jun[†]	29 Jun	12 Sep	NR[‡]	21 Aug	NR	17 Oct
2	Kimberly, ID	2007	1 May	24 May	17 Sep	7 Jun	NR	NR	9 Oct
3	Kimberly, ID	2008	6 May	27 May	NR	18 Jun	NR	NR	20 Oct
4	Declo, ID	2008	16 Apr	2 Jun	NR	19 Jun	21 Aug	9 Sep	7 Oct
5	Declo, ID	2009	21 Apr	13 May	NR	10 Jun	17 Aug	NR	13 Oct

† This trial was originally planted on 11 May but was hailed out on 8 Jun and replanted on 12 Jun.

‡ NR = no rating conducted due to lack of natural infestation.

Data analysis.

Data were analyzed in SAS (SAS Institute Inc., 2008) using the Proc Mixed procedure. The Tukey-Kramer multiple comparison test ($P < 0.05$) was used for mean comparisons.

RESULTS

Stand.

Cotyledon-stage plant stands in the untreated checks were uniform in all trials (Table 2). Cruiser Tef was applied improperly in 2007 (Trial 2), so we did not present 2007 data for this treatment. There was no seed treatment by cultivar interaction in Trials 1-4 (P = 0.184, 0.125, 0.066, and 0.443, respectively). In Trial 5, the interaction was significant (P = 0.008) with all four cultivars, but when analyzed with just three cultivars (B-22, C-12, and HM070002) there was no interaction (P = 0.469). In Trial 5, cultivar B-13 emerged very poorly (45% emergence) and there were no differences among treatments (P = 0.622). Seed treated with Poncho Beta produced stands similar to the untreated check in all trials. Seed treated with just Cruiser in Trial 1 resulted in a better stand than the untreated check. Stand was 14, 11, and 17% lower in Trials 3, 4, and 5, respectively, when Cruiser Tef was compared to the check. Significant differences were evident among cultivars but varied from trial to trial.

Curly top.

In Trials 1 (natural infestation + one viruliferous beet leafhopper per two plants) and 2 (natural infestation), there was moderate to low uniform curly top pressure with untreated checks averaging 4.1 (most leaves moderate curling but more than 50% of the upper leaf surface visible) and 3.0 (slight leaf curl on center whorl and pimpling of veins) by mid-September, respectively (Table 3). The checks responded as expected with HM070021 expressing the most resistance followed by B16. In Trial 1 there was no seed treatment by cultivar interaction (P = 0.988) and Cruiser and Poncho Beta reduced curly top symptoms by 24 and 32%, respectively. Results from Cruiser and Poncho Beta were not significantly different in Trial 1. In Trial 2 the interaction between seed treatment and cultivar was significant (P = 0.014), so seed treatments were compared within each cultivar. The interaction appeared to be related to low disease pressure which made it difficult to always separate the untreated check from the treated seed in all replications. Nevertheless in Trial 2, Poncho Beta significantly reduced curly top symptoms on all cultivars. Overall curly top symptoms were reduced

Table 2. Stand establishment at the cotyledon growth stage (prior to thinning) as influenced by insecticide seed treatments with sugarbeet grown in five Idaho trials from 2006 to 2009.

	Emergence (%)				
Variable	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Seed treatment[†]					
Untreated check	53 b	81 a	68 a	51 a	76 a
Cruiser Tef	59 a	ND	54 b	40 b	59 b
Poncho Beta	57 ab	81 a	73 a	50 a	78 a
$P > F$[‡]	0.027	0.849	<0.001	<0.001	<0.001
Cultivar[§]					
B-16	64 a	87 a	70 a	ND	ND
HH005	53 b	75 b	78 a	ND	ND
HM070021	52 b	70 b	69 a	ND	ND
SX003	55 b	93 a	43 b	ND	ND
B-13	ND	ND	ND	45 ab	ND
B-22	ND	ND	ND	46 ab	62 b
C-12	ND	ND	ND	44 b	81 a
HM070002	ND	ND	ND	52 a	69 b
$P > F$[d]	<0.001	<0.001	<0.001	0.015	<0.001

[†] Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. In Trial 1, Cruiser (60 g a.i. thiamethoxam/100,000 seeds) was tested without tefluthrin. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package. ND = no data.

[‡] $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at P = 0.05. There were no significant seed treatment by cultivar interaction for Trials 1-4 (P = 0.184, 0.125, 0.066, and 0.443, respectively). In Trial 5, poor emergence of cultivar B-13 lead to a significant (P = 0.008) treatment by cultivar interaction; however, there was no interaction (P = 0.469) when B-13 was excluded. Thus, data for three of the cultivars are reported in the table and the data for B-13 were analyzed and reported separately in the results.

[§] For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

Table 3. Curly top ratings as influenced by host resistance and insecticide seed treatments with plants from commercial sugarbeet cultivars grown in Kimberly, ID during 2006 and 2007.

	Curly top rating‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	*P* > *F*§
Trial 1				
HM070021	3.7	2.8	2.5	
B16	4.0	2.9	2.7	
HH005	4.5	3.5	3.2	
SX003	4.3	3.1	2.9	
Overall mean	4.1 a	3.1 b	2.8 b	<0.001
Trial 2				
HM070021	0.6	ND	0.0	0.019
B16	2.5	ND	1.0	<0.001
HH005	4.0	ND	3.3	0.004
SX003	4.7	ND	3.4	0.001
Overall mean	3.0	ND	1.9	

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex. Expected levels of host resistance to curly top varied among the cultivars (HM070021 = high, B16 = high-intermediate, HH005 = low-intermediate, and SX003 = highly susceptible).

‡ The curly top disease index scale ranged from 0 = no symptoms to 9 = dead plant (Plant Disease 90:1539-1544). Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. In Trial 1, Cruiser (60 g a.i. thiamethoxam /100,000 seeds) was tested without tefluthrin. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ *P* > *F* is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at *P* = 0.05. In Trial 1, there was no seed treatment by cultivar interaction (*P* = 0.988). In Trial 2, there was a seed treatment by cultivar interaction (*P* = 0.014), so seed treatment data were analyzed within each cultivar. ND = no data.

by an average of 37% with Poncho Beta. Curly top was either not evident or present in trace amounts (1% or fewer plants infected) in Trials 3, 4, and 5. No damping off, root diseases, or foliar diseases other than curly top (Trials 1 and 2 only) were evident on plants in these trials.

Leafminer.

Natural leafminer infestations in the untreated checks of Trials 2, 3, 4, and 5 were 92, 2, 18, and 76%, respectively (Table 4). The seed treatment by cultivar interaction was not significant in Trials 2, 3, and 5 (P = 0.654, 0.512, and 0.060, respectively), but was significant in Trial 4 (P = 0.035). The interaction appeared to be associated with differences in magnitude, when the untreated and treated were compared. At the four- to six-leaf growth stage, Cruiser Tef and Poncho Beta had reduced leafminer incidence to zero in three trials and 5% or less in the other trial, which were all significantly different from the untreated check. No data were taken in Trial 1 because of the lack of a natural infestation.

Black bean aphid.

In Trials 1, 4, and 5, plants in the untreated checks averaged 18, 15, and 5% natural infestations of black bean aphids, respectively (Table 5). The seed treatment by cultivar interaction was not significant in Trials 4 and 5 (P = 0.267 and 0.563, respectively), but was significant in Trial 1 (P = 0.008). The interaction appeared to be associated with differences in magnitude, when the untreated and treated were compared. In Trial 1 (replanted 12 June) seed treatments provided aphid control into mid-August, while in Trial 4 (planted 16 April) and Trial 5 (planted 21 April) only suppression was evident in mid-August. In Trial 4, aphid infestations on Cruiser Tef and Poncho Beta plants were 9 and 10% lower, respectively, compared to the untreated check. In Trial 5, which had less pest pressure, only the Poncho Beta treatment had significantly lower aphid counts than the check. There was no difference between seed treatments based on black bean aphid numbers in these three trials. No data were taken in Trials 2 and 3 because of the lack of natural aphid pressure.

Sugarbeet Root aphid.

No seed treatment by cultivar interaction for either main roots or lateral rootlets (P = 0.783 and 0.834, respectively) was present in Trial 4, so overall means were compared. In Trial 4, incidence of root aphid on the main root was 10 and 16% lower in Cruiser Tef and

Table 4. Leafminer (*Pegomya* spp.) ratings at the four- to six-leaf growth stage as influenced by insecticide seed treatments with plants from commercial sugarbeet cultivars grown in Kimberly and Declo, ID from 2007 to 2009.

	Plants infested with leafminer (%)‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	$P > F$§
Trial 2				
HM070021	91	ND	0	
B16	89	ND	0	
HH005	96	ND	0	
SX003	90	ND	0	
Overall mean	92	ND	0	<0.001
Trial 3				
HM070021	2	0	0	
B16	2	0	0	
HH005	0	0	0	
SX003	2	0	0	
Overall mean	2 a	0 b	0 b	<0.001
Trial 4				
B-13	17 a	0 b	0 b	<0.001
B-22	20 a	0 b	0 b	<0.001
C-12	14 a	0 b	1 b	<0.001
HM070002	21 a	0 b	0 b	<0.001
Overall mean	18	0	0	
Trial 5				
B-13	72	1	0	
B-22	69	5	1	
C-12	82	2	5	
HM070002	79	4	5	
Overall mean	76 a	3 b	3 b	<0.001

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

‡ Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at $P = 0.05$. In Trials 2, 3, and 5 there was no seed treatment by cultivar interaction ($P = 0.654$, 0.512, and 0.060, respectively) so the overall means were compared. In Trial 4, there was a seed treatment by cultivar interaction ($P = 0.035$), so seed treatment data were analyzed within each cultivar. ND = no data.

Table 5. Black bean aphid (*Aphis fabae* Scopoli) infestation as influenced by host resistance and insecticide seed treatments with plants from commercial sugarbeet cultivars grown in Kimberly and Declo, ID during 2006, 2008, and 2009.

	Plants infested with black bean aphid (%)‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	$P > F$§
Trial 1				
HM070021	29.8 a	0.4 b	0.6 b	<0.001
B16	17.4 a	0.2 b	0.5 b	0.012
HH005	17.3 a	0.1 b	0.4 b	0.002
SX003	8.7 a	0.1 b	0.5 b	<0.001
Overall mean	18.3	0.2	0.5	
Trial 4				
B-13	18.1	5.6	3.9	
B-22	10.2	3.9	2.6	
C-12	10.8	4.9	5.2	
HM070002	19.8	7.0	5.9	
Overall mean	14.7 a	5.3 b	4.4 b	<0.001
Trial 5				
B-13	2.3	1.4	1.0	
B-22	4.3	1.0	0.2	
C-12	2.7	2.1	1.6	
HM070002	11.7	5.6	1.9	
Overall mean	5.2 a	2.5 ab	1.2 b	0.041

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

‡ Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin /100,000 seeds. In Trial 1, Cruiser (60 g a.i. thiamethoxam/100,000 seeds) was tested without tefluthrin. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at $P = 0.05$. In Trial 1, there was a significant ($P = 0.008$) seed treatment by cultivar interaction, so seed treatment data were analyzed within each cultivar. In Trials 4 and 5, there was no seed treatment by cultivar interaction ($P = 0.267$ and 0.563, respectively) so the overall means were compared. ND = no data.

Poncho Beta plots, respectively (Table 6). On lateral rootlets in Trial 4, both seed treatments reduced root aphid incidence compared to the check (Table 7). Also, Poncho Beta (32% lower than check) was better than Cruiser Tef (16% lower than check). No data was taken in the other trials because of the lack of natural root aphid pressure.

Yield.

In Trials 1, 3, 4, and 5 there was no seed treatment by cultivar interaction (*P* = 0.740, 0.365, 0.273, and 0.883, respectively) with root tonnage, so the overall means were compared. In Trial 2, there was a seed treatment by cultivar interaction (*P* = 0.011) with root tonnage, so seed treatment data were analyzed within each cultivar. Poncho Beta yielded 18, 8, 9, and 4% more root tonnage than the untreated check in Trials 1, 3, 4, and 5, respectively (Table 8). In Trial 2, Poncho Beta averaged 16% more root tonnage with three of the four cultivars (Table 8). Cruiser

Table 6. Sugarbeet root aphid (*Pemphigus betae* Doane) infestation on main tap root as influenced by host resistance and insecticide seed treatments with plants from commercial sugarbeet cultivars grown in Declo, ID during 2008.

	Plants infested with sugarbeet root aphid on main root (%)‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	$P > F$§
Trial 4				
B-13	20	10	8	
B-22	19	14	1	
C-12	20	14	4	
HM070002	20	4	2	
Overall mean	20 a	10 b	4 b	<0.001

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

‡ Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at $P = 0.05$. In Trial 4, there was no seed treatment by cultivar interaction (P = 0.783) so the overall means were compared. ND = no data.

Tef yielded 17, 6, and 5% more root tonnage than the untreated check in Trials 1, 4, and 5, respectively (Table 8). Root tonnage for Cruiser Tef was not different from the untreated check in Trial 3 (Table 8).

In Trials 1, 3, 4, and 5 there was no seed treatment by cultivar interaction (P = 0.416, 0.155, 0.162, and 0.916, respectively) with estimated recoverable sucrose, so the overall means were compared. In Trial 2, there was a seed treatment by cultivar interaction (P = 0.022) with estimated recoverable sucrose, so seed treatment data were analyzed within each cultivar. Poncho Beta yielded 20, 15, 9, 11, and 4% more estimated recoverable sucrose than the untreated check in Trials 1-5, respectively (Table 9). Cruiser Tef yielded 18, 9, and 4% more estimated recoverable sucrose than the untreated check in Trials 1, 4, and 5, respectively (Table 9). Estimated recoverable sucrose for Cruiser Tef was not different from the untreated check in Trial 3 (Table 9).

Table 7. Sugarbeet root aphid (*Pemphigus betae* Doane) infestation on lateral rootlets as influenced by host plant resistance and insecticide seed treatments with plants from commercial sugarbeet cultivars grown in Declo, ID during 2008.

	Plants infested with sugarbeet root aphid on lateral rootlets (%)[‡]			
Cultivar[†]	Untreated check	Cruiser Tef	Poncho Beta	$P > F$[§]
Trial 4				
B-13	74	68	48	
B-22	95	80	58	
C-12	89	62	49	
HM070002	82	65	58	
Overall mean	85 a	69 b	53 c	<0.001

[†] For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., and HM = Hilleshog.

[‡] Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

[§] $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at P = 0.05. In Trial 4, there was no seed treatment by cultivar interaction (P = 0.834) so the overall means were compared. ND = no data.

Table 8. Sugarbeet root yield as influenced by host plant resistance and insecticide seed treatments in five trials conducted in Idaho from 2006 to 2009.

	Yield (t/ha)‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	$P > F$§
Trial 1				
HM070021	51.0	65.1	62.6	
B16	59.9	66.1	69.4	
HH005	53.8	62.5	64.6	
SX003	46.0	51.9	53.1	
Overall mean	52.7 b	61.4 a	62.4 a	<0.001
Trial 2				
HM070021	84.3	ND	87.7	0.222
B16	75.8	ND	89.6	<0.001
HH005	73.3	ND	88.6	0.003
SX003	63.7	ND	68.8	0.030
Overall mean	74.3	ND	83.7	
Trial 3				
HM070021	84.1	93.8	98.0	
B16	78.1	83.0	87.0	
HH005	81.3	81.7	83.5	
SX003	74.4	73.0	76.3	
Overall mean	79.5 b	82.9 ab	86.2 a	0.008
Trial 4				
B-13	67.1	76.0	73.8	
B-22	64.2	68.4	68.6	
C-12	63.2	63.7	71.3	
HM070002	61.7	64.2	65.3	
Overall mean	64.1 b	68.1 a	69.8 a	0.001
Trial 5				
B-13	88.4	90.3	92.0	
B-22	80.8	84.3	82.7	
C-12	84.0	89.9	87.6	
HM070002	79.0	82.6	82.2	
Overall mean	83.0 b	86.8 a	86.1 a	<0.001

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

‡ Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. In Trial 1, Cruiser (60 g a.i. thiamethoxam/100,000 seeds) was tested without tefluthrin. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at $P = 0.05$. In Trials 1, 3, 4, and 5 the seed treatment by cultivar interaction was not significant ($P = 0.740$, 0.365, 0.273, and 0.883, respectively) so the overall means were compared. In Trial 2, the seed treatment by cultivar interaction was significant ($P = 0.011$), so seed treatment data were analyzed within each cultivar. ND = no data.

Table 9. Estimated recoverable sucrose for commercial sugarbeet cultivars as influenced by host plant resistance and insecticide seed treatments in five trials conducted in Idaho from 2006 to 2009.

	Estimated recoverable sucrose (kg/ha)‡			
Cultivar†	Untreated check	Cruiser Tef	Poncho Beta	$P > F$§
Trial 1				
HM070021	6,354	8,486	8,135	
B16	7,215	7,917	8,451	
HH005	6,016	7,061	7,186	
SX003	5,635	6,403	6,568	
Overall mean	6,305 b	7,467 a	7,585 a	<0.001
Trial 2				
HM070021	11,444	ND	12,221	0.013
B16	8,331	ND	10,843	0.000
HH005	9,018	ND	10,603	0.015
SX003	8,455	ND	9,206	0.026
Overall mean	9,312	ND	10,718	
Trial 3				
HM070021	11,199	12,299	12,935	
B16	9,490	10,426	11,266	
HH005	10,682	10,682	11,013	
SX003	10,301	9,819	10,241	
Overall mean	10,419 b	10,838 ab	11,364 a	0.005
Trial 4				
B-13	7,985	9,394	8,974	
B-22	8,766	9,221	9,178	
C-12	7,867	8,408	9,368	
HM070002	7,751	8,201	8,465	
Overall mean	8,092 b	8,806 a	8,996 a	<0.001
Trial 5				
B-13	13,211	13,340	13,608	
B-22	12,874	13,518	13,284	
C-12	12,526	13,283	12,996	
HM070002	12,248	12,895	12,818	
Overall mean	12,715 b	13,260 a	13,177 a	0.008

† For more information on the coded cultivars contact the respective seed companies: B = Betaseed, C = ACH Seeds Inc., HH = Holly Hybrids, HM = Hilleshog, and SX = Seedex.

‡ Untreated check = no insecticide seed treatment, Poncho Beta = 60 g a.i. clothianidin + 8 g a.i. beta-cyfluthrin/100,000 seeds, and Cruiser Tef = 60 g a.i. thiamethoxam + 8 g a.i. tefluthrin/100,000 seeds. In Trial 1, Cruiser (60 g a.i. thiamethoxam/100,000 seeds) was tested without tefluthrin. Untreated checks and Poncho Beta treated seed had an Allegiance FL (15.6 g a.i. metalaxyl/100 kg seed) plus Thiram 42S (250 g a.i. thiram/100 kg seed) fungicide package to allow for good stand establishment. Seed treated with Cruiser or Cruiser Tef had Apron XL (7.5 g a.i. mefanoxam/100 kg seed) + Maxim 4FS (2.5 g a.i. fludioxonil/100 kg seed) as the fungicide package.

§ $P > F$ is the probability of observing a greater value in the F test. Means within a variable and trial sharing a letter did not differ significantly based on Tukey's test at $P = 0.05$. In Trials 1, 3, 4, and 5 there was no seed treatment by cultivar interaction ($P = 0.416$, 0.155, 0.162, and 0.916, respectively) so the overall means were compared. In Trial 2, there was a seed treatment by cultivar interaction ($P = 0.022$), so seed treatment data were analyzed within each cultivar. ND = no data.

DISCUSSION

Protection of sugarbeet with either Cruiser Tef or Poncho Beta as insecticidal seed treatments reduced curly top pressure and provided control or suppression of all major insect pest infestations in five trials conducted over four years. Both seed treatments controlled leafminer at the four- to six-leaf growth stage. Poncho Beta provided suppression of black bean aphid in data sets from three trials, while Cruiser Tef was only significantly different from the untreated check in two of three trials. Both seed treatments provided suppression of sugarbeet root aphid incidence till late August/early September but were only evaluated in one trial. Root aphid evaluations in other trials (data not shown) led to similar results. Poncho Beta yielded more than the untreated check for both root tonnage (all trials except for one cultivar in Trial 2) and recoverable sucrose (all trials). Cruiser Tef-treated plants produced similar yields to those protected by Poncho Beta. Commercial fields with pest pressure similar to these five trials could potentially rely only on the seed treatment for pest control, thus reducing negative impacts on beneficial insects and overall environmental footprint associated with foliar insecticide applications. Even in the absence of curly top pressure, yields can be increased with the neonicotinoid seed treatments at rates used in this study.

Although both Cruiser Tef and Poncho Beta looked promising for disease and insect control as well as yield, Cruiser Tef plots incurred stand reductions of 14, 11, and 17% in Trials 3, 4, and 5, respectively. Cruiser when tested without Tef did not reduce stand in Trial 1, but was evaluated only once. Since growers plant to stand and typically do not thin to stand, this stand reduction could be problematic. Any delay in seed germination or plant emergence carries with it the increased risk of attack by disease-causing organisms or plant-feeding insects. Four days after sowing in corn studies, emergence with Cruiser-treated seed was 42%, while Poncho was 80% compared to the untreated check (Jonitz and Leist, 2003). By day 5 or 6, there was no difference in emergence with these treatments compared to the untreated check (Jonitz and Leist, 2003). Poncho Beta had similar or increased stand compared to the untreated check in these trials (Table 2) and a previous study (Strausbaugh et al., 2006).

In trials conducted in 2005 and 2006, Poncho Beta was shown to reduce curly top symptoms, increase yield, and improve storability (Strausbaugh et al., 2006; Strausbaugh et al., 2008a). The previous study that established the efficacy of Poncho Beta for curly top control was based on two trials conducted in 2005 (Strausbaugh et al., 2006). Subsequent to these initial trials, additional data has been collected over multiple years with varying curly top pressure (Table 3), which confirms the efficacy established in the 2005 trials. Previous studies have shown that for every unit decrease in disease rating, there is an approximate increase in yield of 5.76 to 6.93 t/ha (Strausbaugh et al., 2007). The curly top ratings and yield results in Tables 3, 8, and 9 support these findings. Previous work showed root yield was increased by 20 to 22% with Poncho Beta with sugarbeet under moderate curly top pressure (Strausbaugh et al., 2006). Under moderate pressure, the susceptible cultivar had curly top ratings of 7.3 and 5.6 in their respective studies (Strausbaugh et al., 2006). Data for the two trials reported in Table 3 show that the same susceptible check cultivar, SX003, had ratings of 4.3 to 4.7, indicating curly top pressure was low. When compared over these two trials with low curly top pressure the untreated checks averaged 63.5 t/ha while the Poncho Beta plots averaged 73.0 t/ha, a 13% increase. However, the yield increase with Poncho Beta can likely be attributed to more than curly top control, since insect problems (black bean aphid in Trial 1 and leafminer in Trial 2) were also considerably influenced by Poncho Beta. Yields in plots protected with Cruiser were similar to those treated with Poncho Beta.

Leafminers typically do not cause serious damage to sugarbeet in Idaho, but some infestations have been severe enough to require treatment (Hirnyck and Downey, 2005). They typically produce two to three generations per year, but the first generation is the most important since young sugarbeet plants have little foliage. Control of the first generation can be achieved with foliar and systemic soil insecticides or seed treatments. A 2005 trial showed 99.6% reduction of the first generation of the leafminer with Poncho Beta at four- to six-leaf growth stage with 82 % natural incidence in the untreated check, but the trial was not repeated (Strausbaugh et al., 2006). The current study confirms this observation with complete or nearly complete control of the first generation at the four- to six-leaf growth stage across four trials with one trial having a high (92%) infestation in the check. Both the Cruiser Tef and Poncho Beta seed treatments provided similar control. Observations suggest that control transitions to suppression by late July (data not shown).

The black bean aphid is most common on beans, spinach, cucumber, corn, and sugarbeet but only sporadically reaches damaging levels, most often late in the season (Hirnyck and Downey, 2005; Cammell et al., 1989). The first six to eight weeks after emergence is the most important time to protect sugarbeet from black bean aphids (Hirnyck and Downey, 2005). Yields can be substantially reduced if the aphids are not controlled (Hirnyck and Downey, 2005; Hurej and van der Werf, 1993). A diverse community of naturally occurring predaceous (e.g., lady beetles, green lacewing larvae, and syrphid fly larvae) and parasitic insects, can contribute to aphid suppression (Hirnyck and Downey, 2005; Summers et al., 2005). However, the foliar application of non-systemic, neurotoxic insecticides is especially hazardous to these natural enemies (Hirnyck and Downey, 2005.). Thus, the use of seed treatments to obtain early season control is inviting. Based on data in Trials 1, 4, and 5, growers should be able to expect black bean aphid control for at least the first 70 days after planting with Poncho Beta and Cruiser Tef, but control declines to only suppression by 118 to 127 days after planting (Table 5). Along with seed treatments and natural enemies, host resistance should also be considered in a management program.

Sugarbeet root aphids feed on the roots and secrete a white, waxy material frequently mistaken by growers to be fungal growth. Feeding on the lateral rootlets interferes with nutrient and water uptake, which can lead to yield losses of up to 50% (Hutchinson and Campbell, 1994). Good host resistance exists in commercial cultivars such as Monohikari, but is not present in all cultivars (Campbell and Hutchinson, 1995). While host resistance may be the most beneficial long term strategy, utilizing systemic insecticides may be the best alternative with susceptible cultivars (Campbell and Hutchinson, 1995). Based on September ratings in the present study, seed treatments appear only to provide suppression of sugarbeet root aphid and not control. Poncho Beta apparently provided better sugarbeet root aphid suppression than Cruiser Tef in Trial 4. These data need to be repeated before conclusions concerning root aphid can be made.

Use of either neonicotinoid insecticide seed treatment reduced curly top pressure and provided early season control or suppression for a number of important insects on sugarbeet in these trials. Poncho Beta and Cruiser Tef generally gave similar responses for the variables assessed. The neonicotinoid seed treatments look very promising on sugarbeet, but we should also maintain our focus on improving host resistance to these insects and diseases as well. The neonicotinoids are marketed as 530 products in 123 counties making this chemistry one of the most widely utilized ever, which raises the question of whether insect resistance problems could develop (Nauen et al., 2008). Some resistance issues have arisen with using neonicotinoids to control the rice brown planthopper (*Nilaparvata lugens* Stål), Colorado potato beetle (*Leptinotarsa decemlineata* Say), tobacco whitefly (*Bemisia tabaci* Gennadius), and green peach aphid (*Myzus persicae* Sulzer); however, most reported cases of resistance are relatively manageable and/or geographically localized and most targeted insects are currently without resistance problems (Alyokhin et al., 2007; Foster et al., 2008; Gorman et al., 2008; Jeschke and Nauen, 2008; Nauen and Denholm, 2005; Nauen et al., 2008; Wang et al., 2008). However, given the potential for resistance to neonicotinoid insecticides, resistance management strategies should be considered as suggested by the Insecticide Resistance Action Committee (www.irac-online.org).

Neonicotinoids are used in all major cropping systems, urban insect control, and animal health (Nauen et al., 2008). They are widely used as seed treatments on cotton, corn, cereals, and oilseed rape (Elbert et al., 2008). The Poncho seed treatment is effective on corn against Coleoptera, Lepidoptera, Diptera, Hemiptera, and Hymenoptera (Elbert et al., 2008). On sugarbeet, Poncho Beta and Cruiser Tef were effective against beet leafhopper, black bean aphid, sugarbeet root aphid, and leafminer in the research presented, but other investigations indicate some efficacy exists against other insects such as sugarbeet root maggot (data not shown), wireworms (data not shown), and springtail (Thorsness et al., 2007). In Idaho, the broad spectrum of pest control provided by these seed treatments may serve as the only insecticide needed for pest control during the growing season in some fields, therefore greatly reducing the environmental footprint of the pest control in sugarbeet production. Although the Poncho Beta and Cruiser Tef where shown to provide effective pest management, host plant resistance should continue to be improved and incorporated into cultivars whenever possible.

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