Insecticidal Prevention of Curly Top in Beets *

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INTRODUCTION

Curly top (CT), a virus disease of beet (*Beta vulgaris* (L.)) transmitted only by the beet leafhopper (BLH) (*Circulifer tenellus* (Baker)), was a serious problem of sugarbeet production in the western United States until the development and widespread use of highly resistant varieties in the 1940's. Beginning in 1976, interest developed in varieties with less CT resistance because of yield advantages in the absence of CT (3). This situation created renewed interest in the use of systemic insecticides to kill viruliferous BLH before they could transmit the virus. We report here the results of tests conducted in southern Idaho on sugarbeets in 1978, 1979, 1980, and 1981, and on fodder beets in 1980.

Literature Review

Insecticidal control of the BLH in desert breeding areas before their migration to cultivated crops has been conducted in Idaho, Wyoming, and California. The program of survey and control conducted by the U.S. Department of Agriculture in Idaho has been discontinued (3). The program conducted in California by the California Department of Food and Agriculture is continuing (14). The program in Wyoming started in 1963 and is continuing (personal communication, Walter H. Patch, Wyoming Department of Agriculture). Early efforts to control the BLH in individual fields with sprays applied to the growing crop were of little value.

The earliest promising attempts to prevent CT in sugarbeets in individual fields using systemic insecticides, were by

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applying the materials as emulsions or in carbon dust to the seed immediately before planting (5, 10, 11, 17). Incorporation of systemic insecticides in the pellet coating around the seed was reported to be effective (6, 7, 12), but no further reports of this method were found. Placing systemic insecticides in the soil prior to or at the time of seeding has proven effective in terms of BLH mortality, reduction of CT symptoms, and/or increased yield (2, 3, 4, 7, 8, 9, 11, 13, 14, 15, 16, 18). Most of these tests involved placement of insecticides from 3-8 inches below the seed row, but a few involved side-dress and over-the-row applications after plant emergence.

Methods

The major conditions of our tests and the treatments applied are given in Tables 1 and 2. Three sugarbeet varieties were chosen to represent the range in susceptibility to CT; highly resistant AH10 (The Amalgamated Sugar Co.), intermediate Mono-Hy D2 (Great Western Sugar Co.), and highly susceptible Betaseed 1345 (Betaseed, Inc.). Three systemic insecticides (aldicarb, carbofuran, and phorate) were chosen because they are

Table 1. Treatments[1/] used in insecticide tests for prevention of curly top in sugarbeets and fodder beets. Idaho, 1978-1981.

	Method of application[2/]			Sugarbeet varieties		
	aldicarb 2 lb. AI/A	phorate 1.33 lb. AI/A	carbofuran 2 lb. AI/A	AH10	D2	1345
1978	SI[3/], IBS	OR[3/], IBS		✓	✓	✓
1979	SI			✓	✓	✓
	R	SI, R	SI, R		•	✓
1980	R	R	R	✓	✓	✓
1981			IBS, SI, R		✓	
				Fodder beet varieties		
				Monara	Solanka	Peroba
1980	R			✓	✓	✓

[1/] Untreated check plots were included in all comparisons.

[2/] IBS = injected below seed; SI = side dress injection; R = Rusken; OR = over the row.

[3/] Post emergence; all others were at planting.

Table 2. Conditions of insecticide tests for prevention of curly top in sugarbeets and fodder beets.[1] Idaho, 1978-1981.

	1978	1979	1980	1981
Planted	4/14	4/17	4/18	4/16
Thinned	5/24-25	5/16-18	5/29-30	5/27-28
Beet leafhopper[2]/release date	6/12	5/25	6/13	6/9
No. BLH per plant	1.2	2.0	0.5, 1.0	1.1
Plant size at release	6-8 leaf	4 leaf	6-8 leaf	8-10 leaf
No. days from treatment to release	59, 17	37	55	54
Rainfall 4/16-6/15 (inches)	1.73	1.02	4.02	2.90
No. irrigations[3]/prior to BLH release	3	3	2	1
Plot size (rows x feet)	4 x 30	4 x 30	4 x 30	4 x 30
No. replicates	4	12	5 (0.5 BLH) 6 (1.0 BLH)	6
Feet of row harvested[4]/per plot	50	120	60	60

1/ Conditions for fodder beets were the same except that they were lifted and hand topped with 6 replicates and BLH rate of release was 0.5 per plant.

2/ Beet leafhoppers remained on plots for the full season except in 1980 when they were sprayed on July 8 to prevent possible movement to nearby beets.

3/ All tests were furrow irrigated except in 1979 when half of the replicates were sprinkler irrigated.

4/ All tests were lifted and hand topped except in 1980 when the sugarbeets were harvested by machine.

currently registered for soil application to sugarbeets for control of one or more insects. All were applied in granular formulations at rates of active ingredient per acre (AI/A) of 1.33 lb. phorate and 2.0 lb aldicarb and carbofuran.

Methods and times of application varied from test to test. In 1978, materials were applied in accordance with label directions and recommendations of chemical company representatives. Because smaller plants are more susceptible to CT infection than larger plants, and because the migration of the BLH is unpredictable, it is necessary to provide protection from CT beginning with beet emergence. Thus, in 1979, 1980, and 1981, all applications were made at planting. Injection of materials below the seed is considered undesirable by most growers (in the southern Idaho area) since mechanical disturbance of soil at planting tends to dry it out and interfere with stand establishment. Also, in some fields, the presence of rocks interferes with injection equipment. In areas where the crop is normally irrigated for germination, and rocks are not a factor, injection below the seed is a feasible procedure. However, in 1979, injection 3-4 inches to the water side of the seed row was used with the assumption that this would have less effect on soil drying than injection below the seed. In 1980, all applications were made with a Rusken applicator, which lays a band of insecticide 4-5 inches wide and about 1 inch deep over the seed row. Post-emergence or over-the-row application of phorate in 1978 consisted of dribbling the material in a 4-to 5-inch band over the row followed by a looped drag chain for light incorporation in the soil surface. All injections utilized an injector that placed a very narrow band either 4-6 inches below the seed or 2-4 inches deep and 4-5 inches from the seed or plant row on the water furrow side. In 1981, the 3 methods of application at planting were compared directly on the variety D2.

In 1979, insecticide treatments under furrow and sprinkler irrigation were compared in adjacent areas of the same field. In 1978, 1980, and 1981, all plots were furrow irrigated.

Viruliferous BLH were furnished by Betaseed, Inc. These were placed in small cages for transport to the field, released at equal rates among plots, and then scattered further by dragging sacking material twice over the rows in an attempt to achieve uniform distribution. In 1978, 1979, and 1981, the test areas were somewhat isolated and released BLH populations remained undisturbed for the growing season. In 1980, BLH populations were sprayed with malathion 25 days after their release to minimize the possibility of migration to nearby beets. The 1979 release was made at the rate of 2 leafhoppers/plant and to smaller beets than in the other 3 years resulting in a very severe infection. In 1978, the release rate was 1.2 leafhoppers/plant, and release rates were 0.5 and 1.0/plant in adjacent areas of the same field. In 1981, the rate was 1.1 leafhoppers/plant.

Plots were thinned prior to BLH release to plant spacings of approximately 1/ft. of row. Plots were 30 feet long by 4 rows wide and all data were taken from the 2 center rows. Final CT ratings were made in early to mid-August on individual plants using a scale of 0 = none to 9 = severe. Root yields were obtained each year. In 1978, 1980, and 1981, percent sugar and percent tare were also obtained. Root yields given in the tables are field weights corrected for percent tare except as noted. Sugar yields are root yields multiplied by percent sugar.

In 1980, in addition to the tests with sugarbeets, 3 varieties of fodder beets were planted adjacent to the sugarbeet test. Treatments were aldicarb applied at planting by Rusken, and no insecticide. Treatments were randomized in 6 replicates. The BLH infestation rate was 0.5/plant. Evaluations were made for CT infection and root yield.

Treatments were established in a restricted randomized fashion within replicates. Most data were examined by analysis of variance and means separated by Duncan's multiple range test. Correlations and regressions were made between some data sets.

Results and Discussion

Treatment means for the 1978, 1979, and 1980 tests are

Table 3. Effect[1]/ of two insecticides applied[2]/ to three sugarbeet varieties on curly top rating, percent tare, percent sugar, and yield. Kimberly, Idaho, 1978.

Measurement	Variety	Aldicarb 2 lb. AI/A AP, IBS	Aldicarb 2 lb. AI/A PE, SI	Phorate 1.33 lb. AI/A AP, IBS	Phorate 1.33 lb. AI/A PE , OR	Untreated check	x̄
Curly top rating	AH10	0.12 a	0.10 a	0.37 a	0.60 ab	0.67 ab	0.37
(8/11)	D2	.75 ab	.75 ab	.57 ab	2.58 de	2.07 cd	1.34
	1345	1.27 abc	1.35 abc	1.65 bcd	3.72 e	3.67 e	2.33
	x̄	.71	.73	.86	2.30	2.14	
Percent tare	AH10	7.30	7.62	8.18	8.00	9.08	8.04
	D2	5.48	6.28	6.75	5.88	6.85	6.25
	1345	7.42	7.00	8.32	6.92	9.12	7.76
	x̄	6.73	6.97	7.75	6.93	8.35	
Percent sugar	AH10	16.63	16.33	16.35	16.24	16.40	16.39
	D2	16.86	16.43	16.27	16.33	16.75	16.52
	1345	17.79	17.04	16.69	16.17	16.71	16.88
	x̄	17.09	16.60	16.44	16.25	16.62	
Root yield (T/A)	AH10	28.97 abc	28.64 abc	25.04 bc	28.02 abc	23.58 c	26.85
	D2	28.78 abc	29.43 ab	30.72 a	23.98 bc	25.30 abc	27.64
	1345	27.89 abc	27.00 abc	24.25 bc	17.72 d	18.53 d	23.08
	x̄	28.55	28.36	26.67	23.24	22.47	

Table 3. continued.

Measurement	Variety	Aldicarb 2 lb. AI/A AP, IBS	Aldicarb 2 lb. AI/A PE, SI	Phorate 1.33 lb. AI/A AP, IBS	Phorate 1.33 lb. AI/A PE, OR	Untreated check	$\bar{x}$
Sugar yield (lb. /A)	AH20	8928 ab	8638 ab	7563 ab	8365 ab	7090 bc	8117
	D2	9139 a	9079 a	9318 a	7401 abc	7896 ab	8566
	1345	9171 a	8608 ab	7369 abc	5313 d	5706 cd	7234
	$\bar{x}$	9079	8775	8083	7026	6897	

1/ Values for individual treatments are means of 4 replicates. Treatment means within sets followed by the same letter do not differ significantly at the 5% levelof probability.

2/ AP = at planting, PE = post emergence, IBS = injected below seed, SI = side injection, OR = over the row.

Table 3. continued.

Measurement	Variety	Aldicarb 2 lb. AI/A AP, IBS	Aldicarb 2 lb. AI/A PE, SI	Phorate 1.33 lb. AI/A AP, IBS	Phorate 1.33 lb. AI/A PE, OR	Untreated check	x̄
Sugar yield (lb. /A)	AH20	8928 ab	8638 ab	7563 ab	8365 ab	7090 bc	8117
	D2	9139 a	9079 a	9318 a	7401 abc	7896 ab	8566
	1345	9171 a	8608 ab	7369 abc	5313 d	5706 cd	7234
	x̄	9079	8775	8083	7026	6897	

1/ Values for individual treatments are means of 4 replicates. Treatment means within sets followed by the same letter do not differ significantly at the 5% levelof probability.

2/ AP = at planting, PE = post emergence, IBS = injected below seed, SI = side injection, OR = over the row.

Table 4. Curly top ratings and root yield as affected by three insecticides applied two ways[1]/at planting[2]/ to sugarbeets. Twin Falls, Idaho, 1979.

	Variety	Carbofuran 2 lb AI/A SI	Carbofuran 2 lb AI/A R	Aldicarb 2 lb AI/A SI	Aldicarb 2 lb AI/A R	Phorate 1.33 lb AI/A SI	Phorate 1.33 lb AI/A R	Untreated
Curly top rating	AH10			3.4				3.2
6/20-21	D2			4.4				4.2
	1345	4.8	4.4	5.0	4.8	5.0	4.7	5.0
Root yield (T/A)[3]/	AH10			5.24a				3.81 b
	D2			2.68b				1.40 c
	1345	1.06cd	.30d	.28d	.16d	.33d	.06d	.18 d

[1]/SI = side injection; R = Rusken.

[2]/Data are for 6 replicates under furrow irrigation and 6 replicates under sprinkler irrigation combined.

[3]/Values both horizontally and vertically followed by the same letter do not differ significantly at the 5% level of probability. Yields are not corrected for percent tare.

given in Tables 3, 4, and 5. The results with fodder beets in 1979 are summarized in Table 6. The results comparing methods of application in 1981 are given in Table 7.

Table 5. Effect[1]/ of three insecticides applied by Rusken at planting to three sugarbeet varieties on curly top rating, percent tare, percent sugar, and yield. Kimberly, Idaho, 1980.

Variety	carbofuran 2 lb. AI/A	phorate 1.33 lb. AI/A	aldicarb 2 lb. AI.A	Untreated	$\bar{x}$
		Curly top rating, August 6-7			
AH10	0.80 a	1.33 ab	2.53 de	2.97 ef	1.91
D2	1.11 a	2.03 cd	2.37 cde	3.96 h	2.37
1345	1.84 bc	3.28 fg	3.72 gh	5.01 i	3.46
$\bar{x}$	1.25	2.21	2.87	3.98	
		Percent tare			
AH10	7.2 c	5.3 abc	6.7 bc	5.6 abc	6.2
D2	5.5 abc	4.7 ab	4.5 a	4.3 a	4.8
1345	5.7 abc	5.0 ab	4.4 a	4.3 a	4.8
$\bar{x}$	6.1	5.0	5.2	4.7	
		Percent sugar			
AH10	16.35 abc	15.84 bcde	15.61 de	15.84bcde	15.91
D2	16.48 ab	16.22 abcd	15.99 abcde	15.74 cde	16.11
1345	16.56 a	16.29 abc	16.30 abc	15.38 e	16.13
$\bar{x}$	16.46	16.12	15.97	15.65	
		Root yield T/A			
AH10	28.22 ab	27.05 abc	24.22 c	19.46 d	24.74
D2	29.92 a	28.18 ab	25.84 bc	16.47 d	25.10
1345	27.23 abc	19.86 d	19.48 d	8.24 e	18.70
$\bar{x}$	28.45	25.02	23.19	14.72	
		Sugar yield lb./A			
AH10	8569 ab	8078 bc	7092 cd	5797 ef	7384
D2	9357 a	8732 ab	7896 bc	4950 f	7734
1345	8486 ab	6154 de	6023 de	2427 g	5772
$\bar{x}$	8804	7655	7004	4391	

1/ Values for individual treatments are means of 11 replicates. Values both vertically and horizontally within sets of treatments followed by the same letter do not differ significantly at the 5% level of probability.

The differences in severity of CT infection among years on untreated sugarbeets is shown in Figure 1. Ratings show that CT in 1978 was moderate, in 1980 and 1981 moderately severe, and in 1979 very severe. Initial CT damage ratings and the rate of CT buildup during the season was greatest for variety 1345, intermediate for D2, and least for AH10.

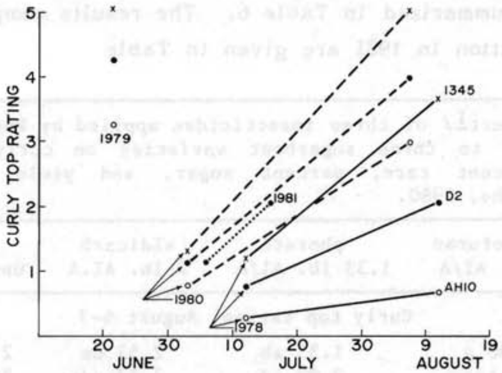

Figure 1. Curly top ratings in untreated plots of 3 sugarbeet varieties during 4 years of testing.

Table 6. Effect of aldicarb (2 lb. AI/A) applied by Rusken at planting to three fodder beet varieties on curly top ratings and yield. Kimberly, Idaho, 1980.

Variety	CT rating August 6-7 aldicarb	CT rating August 6-7 check	Yield[1], gross T/A hand dug on Oct. 10 aldicarb	Yield[1], gross T/A hand dug on Oct. 10 check
Monara	4.42	5.17	14.51	6.69
Solanka	4.13	4.88	16.63	5.54
Peroba	4.18	4.68	15.19	5.44
$\bar{x}$	4.24	4.91	15.44	5.89
$\bar{x}$ for variety				
1345	3.72	5.01	19.53	8.25

[1] Yield not corrected for tare. No significant differences among varieties, but highly significant differences between treated and untreated for all three varieties.

CT damage ratings were very closely associated with percentage of plants with CT symptoms as shown in Figure 2. The association is slightly curvilinear, but the linear r values were 0.98** for 1978, 0.97** for 1980, and 0.94** for the 2 years combined. The data for 1978 and 1980 were taken in early August by the same observer. In 1980, 9-12% more plants were infected for the same rating than in 1978. The 1979 data are not strictly comparable since observations were made on June 7 for percent infected, and on June 20 and 21 for damage

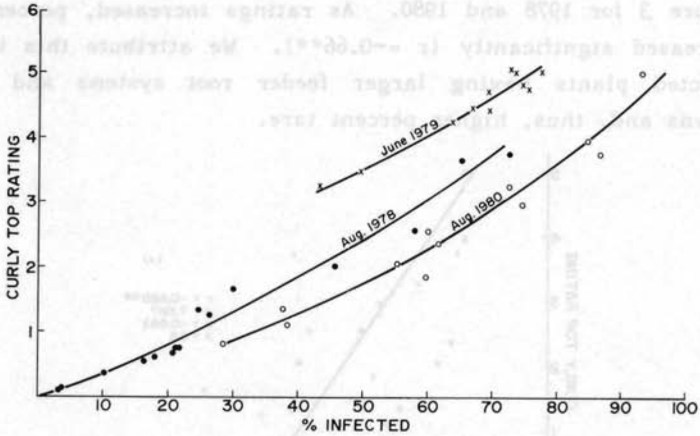

Figure 2. Relationship between curly top ratings and percent of plants infected using treatment means of 3 varieties during 3 years; curves are drawn by eye.

Table 7. Effect[1] of carbofuran (2 lb. AI/A) applied at planting by three methods to variety GW-D2 on curly top and yield. Kimberly, Idaho, 1981.

Treatment[2]	7/6	7/16	Yield T/A field wt.	% sugar	% tare	Sugar lb/A
SI	0.77 a	1.56 a	27.15 a	13.58	2.80	7165 a
IBS	.72 ab	1.54 a	25.23 ab	13.46	2.53	6597 a
Rusken	1.07 bc	2.10 b	20.01 b	13.56	2.78	5252 b
Untreated	1.13 c	2.04 b	20.49 b	13.53	2.83	5316 b

[1] Values in columns followed by the same letter do not differ significantly at the 5% level of confidence. Means separated by Duncan's multiple range test.

[2] SI = side injection, IBS = injection below the seed.

ratings. By early August, all plants were infected and the damage ratings were much higher. Since damage ratings more truly reflect plant condition, we prefer it to percent infected, although at lower CT infections either would serve equally well as a measurement. Because the 2 measurements were so closely correlated, percent of plants infected were omitted from the tables.

Effect of Curly Top on Tare, Percent Sugar, and Yield

The effect of CT infection on percent tare is shown in

Figure 3 for 1978 and 1980. As ratings increased, percent tare decreased significantly (r =-0.66**). We attribute this to non-infected plants having larger feeder root systems and larger crowns and, thus, higher percent tare.

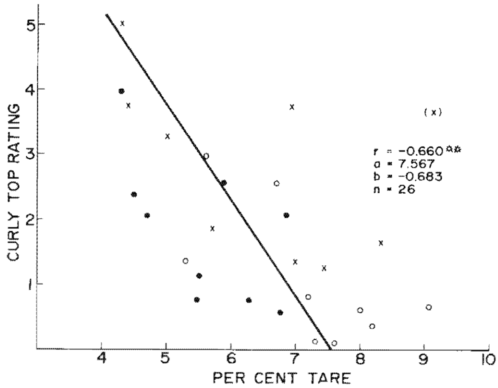

Figure 3. Effect of curly top infection on percent tare using treatment means of 3 sugarbeet varieties; 1978 and 1980 combined. Correlations for individual varieties were not significant at the 5% level of probability. Varieties are designated as: O = AH10, ● = D2, and X = 1345. Ratings were made in early August.

The effect of CT infection on percent sugar is shown in Figure 4 with 1978 and 1980 data combined for each variety. For each variety, as CT increased, percent sugar decreased significantly; r = -0.875** for AH10, -0.668* for D2, and -0.844** for 1345. This is in contrast to other reports where no significant differences in percent sugar were found due to insecticide treatments (18, 7, 8, 15). The regressions show AH10 with comparatively low sugar, 1345 with high sugar, and D2 intermediate.

The effect of CT infection on root yield is shown in Figure 5. In 1978, at low infection levels, the relationship is linear. At higher infection levels in 1980, a curvilinear relationship is suggested for all 3 varieties. AH10 had the lowest root yield, D2 the highest, and 1345 was intermediate.

Percent tare and percent sugar, as indicated above, tended to offset one another in arriving at the net sugar yield.

The effect of CT on sugar yield is shown by correlation

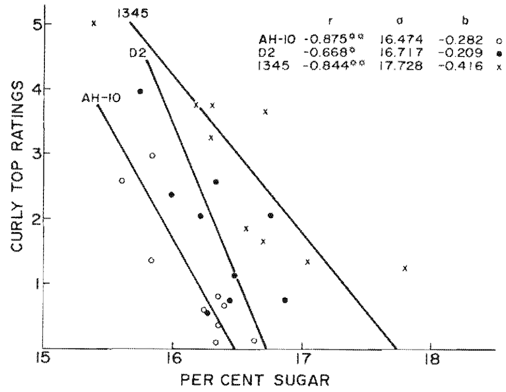

Figure 4. Effect of curly top infection on percent sugar for 3 sugarbeet varieties using treatment means; 1978 and 1980 combined. Ratings were made in early August.

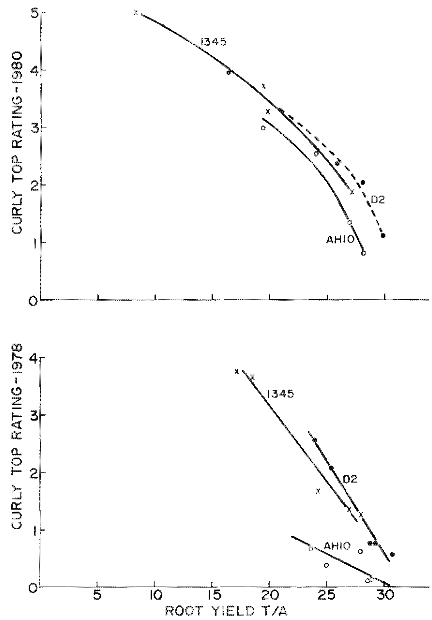

Figure 5. Effect of curly top infection on root yield for each of 3 varieties in 2 years.

and regression in Table 8 for each variety for 1978, 1980, and for the 2 years combined in 2 ways--unadjusted data and 1978 yield data adjusted upward by 11.5% for all 3 varieties. The adjustment was made since the calculated potential yields were higher in 1980 than in 1978, and averaged about 11.5% higher at equal CT ratings. All but one of the correlations were significant or highly significant. For years combined (and 1978 yield adjusted), r values ranged from -0.931** for AH10 to -0.969** for D2. In all cases, calculated potential yields (no CT) were least for AH10 and greatest for 1345, but the rate of decrease in yield per unit increase in CT rating was also least for AH10 and greatest for 1345. The regression of sugar yield (1978 yields adjusted) on CT rating is shown for each variety in Figure 6.

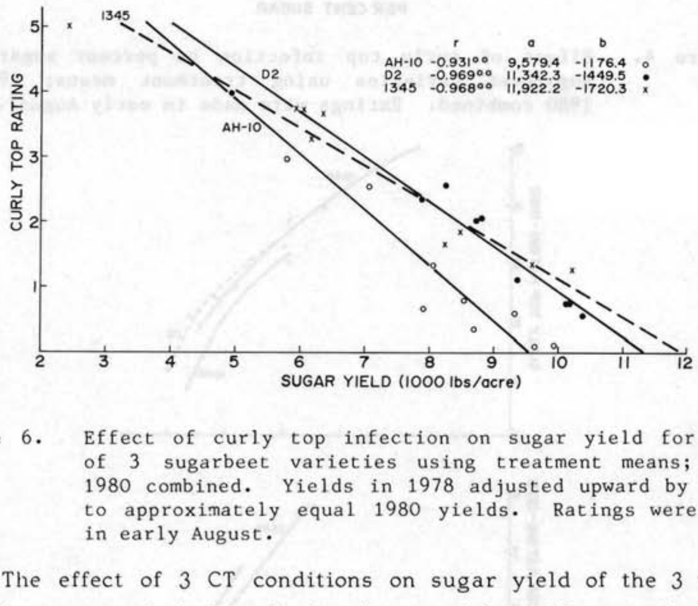

Figure 6. Effect of curly top infection on sugar yield for each of 3 sugarbeet varieties using treatment means; 1978 1980 combined. Yields in 1978 adjusted upward by 11.5% to approximately equal 1980 yields. Ratings were made in early August.

The effect of 3 CT conditions on sugar yield of the 3 varieties in terms of their calculated potential yield, actual yield, and increase over untreated is presented in Table 9 for insecticide treatments applied a planting. In most cases (7 of 9 comparisons), AH10 produced closer to its potential than the other 2 varieties. Untreated AH10 produced 80, 60, and 12.3% of its potential under moderate, moderately severe, and extremely severe CT conditions, respectively. Protection by insecticides decreased regularly (as a percentage of potential) from AH10 to D2 to 1345 under all 3 conditions. These interactions among varieties and treatments are more clearly seen in Figure 7. Essentially, the reverse is shown when data are presented as percent increase in yields over untreated checks with increase least for AH10 and most for 1345.

Table 8. Correlation and regression values for three varieties in two years between curly top ratings (X) in August and sugar yield (Y). Kimberly, Idaho.

Year[1]/	Variety	Correlation r	Calculated potential sugar yield (lb/A) a	Slope b
1978	AH10	-0.735	8,912	-2136
	D2	- .999**	9,828	- 939
	1345	- .959**	10,285	-1308
1980	AH10	- .964*	9,604	-1164
	D2	- .980*	11,545	-1610
	1345	- .977*	12,246	-1870
1978 and 1980	AH10	- .803**	8,610	- 777
	D2	- .944**	10,347	-1196
	1345	- .959**	10,856	-1507
1978 and 1980 adjusted[2]/	AH10	- .931**	9,579	-1176
	D2	- .969**	11,342	-1450
	1345	- .968**	11,922	-1720

[1]/ Four replicates and five treatment means in 1978; 11 replicates and four treatment means in 1980.

[2]/ 1978 yields adjusted upward 11.5%.

Efficacy of Insecticide and Method of Application

The important consideration is whether the potential yield advantage of varieties intermediate in resistance, such as D2, or highly susceptible, such as 1345, can be maintained with insecticides under CT pressure as compared to highly resistant varieties such as AH10. The data in Tables 3 and 5 indicate that both D2 and 1345 maintained yields comparable to AH10 under the most effective insecticide treatments when subjected to moderate and moderately severe CT conditions even though less of their potential yield was realized (Table 9). In 1978 under moderate CT pressure, the 2 aldicarb treatments on D2 and 1345 increased sugar yield significantly over untreated AH10. In 1980 under moderately severe CT pressure, the best insecticide treatment, carbofuran, on D2 and 1345 again in-

Table 9. Sugar yield as percent of the calculated potential, and as percent increase over untreated, for three varieties treated at planting under three curly top conditions.

Variety	Sugar yield lb/A		Percent increase over untreated			Percent of potential			
	Potential	Untreated	Carbofuran 2 lb	Phorate 1.33 lb	Aldicarb 2 lb	Carbofuran 2 lb	Phorate 1.33 lb	Aldicarb 2 lb	Untreated
Moderate curly top, 1978, 4 replicates, insecticides injected below seed									
AH10	8,912	7090		7	26		85	100	80
D2	9,828	7896		18	16		95	93	80
1345	10,285	5706		29	61		72	89	55
Moderately severe curly top, 1980, 11 replicates, insecticides applied by Rusken									
AH10	9,604	5797	48	39	22	89	84	74	60
D2	11,545	4950	89	76	60	81	76	68	43
1345	12,246	2427	250	154	148	69	50	49	20
Moderately severe curly top, 1981, 6 replicates, insecticides injected below seed									
D2	10,900	5316	24			60			49
Extremely severe curly top, 1979, 12 replicates, insecticides side injected									
AH10	9,000[1/]	1109			37			17	12
D2	10,000[1/]	407			92			8	4
1345	11,000[1/]	52	214	85	56	1.5	0.9	0.7	0.5

[1/] Potential yield arbitrarily selected as a rough average of 1978 and 1980. Sugar yield estimate based on field weights, 3% tare and 15% sugar.

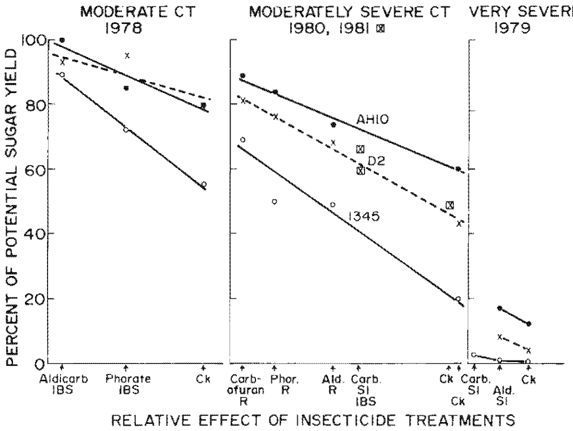

Figure 7. Relationship between insecticide treatments and beet varieties under 3 curly top conditions in terms of potential sugar yield. Insecticide treatments show relative effect by positioning horizontally to most closely approximate a straight line. Methods of application are IBS = injected below seed, R = Rusken, and SI = side injection.

creased sugar yield significantly over untreated AH10. Thus, we can say that the most effective insecticide treatments under these conditions more than replaced the effect of plant resistance to CT in untreated AH10. However, the increase in yield would be at the cost of insecticide application. In 1979 under very severe CT pressure, none of these varieties were adequately protected by chemical treatment (Table 4).

Two other publications discuss the relative performance of varieties differing in resistance to CT when treated with insecticides. Burtch (4) in California, used phorate 1.0 lb. AI/A 5 inches under the seed on 5 varieties varying from highly resistant to highly susceptible. The plants of the most susceptible variety were 83.6 percent infected with CT late in the season compared to 9.1 percent of the most resistant variety. Although he found no significant differences in yield under treatment, yield tended to be less for the more susceptible varieties. Finkner and Scott (8) in New Mexico in 1968 and 1970, applied phorate and disulfoton to a resistant and a susceptible variety. The materials were "banded into the soil approximately 8 inches" at rates of 1.0 lb AI/A 1 day before planting. CT infections were light reaching only 15% in 1968 and 30% in 1970 for the untreated susceptible variety. They concluded that phorate was effective in reducing the percentage of CT and increasing the yield of the susceptible cultivar, and that there was no advantage to using phorate with the resistant cultivar.

The performance of fodder beets treated with aldicarb by Rusken in 1980 is summarized in Table 5. In comparison to the susceptible sugarbeet Betaseed 1345 in an adjacent test, they are also highly susceptible to CT, and yielded even less gross tonnage than 1345 in both treated and untreated plots.

Comparison of the effectiveness of insecticide treatments can be made in Tables 3, 4, 5, and 9. As shown in Table 9 where only at-planting applications are compared, aldicarb injected below the seed was better than phorate in 1978. In 1980, carbofuran applied by Rusken was more effective than phorate or aldicarb, and in 1979, carbofuran injected to the side of the seed row was more effective than aldicarb or phorate. It is probable that excessive rainfall in 1979 diluted the more soluble aldicarb in the soil so that it was less available than the less soluble carbofuran and phorate.

Most of the literature cited deals with phorate, several also include disulfoton, but only 2 make comparisons of the materials used in our tests. Mumford and Griffin (16) compared aldicarb, carbofuran, and phorate all at 2.0 lb AI/A applied in the seed furrow 3-4 inches deep and side dressed in furrows 1-2 inches alongside the row of seedlings 16 days after planting. They determined the length of time of effectiveness by caging BLH on plants at intervals and observing 24-hour mortality. Below-the-seed applications were superior to side-dress applications. For below-the-seed applications, phorate and carbofuran were essentially equal giving 86-100% mortality 40 days after treatment as compared to aldicarb which declined rapidly from 100% mortality 19 days after treatment. Malm and Finkner (15) in New Mexico, applied 4 systemic insecticides (including aldicarb, carbofuran, and phorate) each at 1.0 and 2.0 lb AI/A at planting approximately 8 inches below the soil surface in each of 2 years using a CT susceptible variety. In 1966, the plants infected by mid-August in untreated plots reached only 8.16% and in 1967 plants infected reach 24.5%. They concluded that phorate and carbofuran gave the best control and the highest yield, that aldicarb was intermediate in effectiveness, and that disulfoton was the least effective. Though no significant differences were detected for rates, the 2.0-lb. rate consistently gave better results.

Since the 3 methods of application at planting were not compared directly in 1978, 1979, 1980, they were tested together in 1981 using carbofuran on the variety D2 at planting. The data are presented in Table 7. Injection below the seed or to the side of the seed row did not differ significantly in any respect, but both differed significantly from the Rusken application and the untreated check. Both reduced CT symptoms about 34% on July 6 and about 24% on July 16, and increased sugar yield about 29% (1,565 lb./A). This lack of difference between the 2 injection methods is in contrast to the findings of Mumford and Griffin (16) described above. The Rusken method of applying carbofuran to variety D2 was highly effective in preventing CT in 1980 (Table 5), but was totally ineffective in 1981 (Table 7). The major difference between the 2 years was moisture from time of planting to BLH release (Table 2). In 1980 there was 1.1 more inches of rainfall and 1 more irrigaton during this period. It is possible that the increased moisture in 1980 moved carbofuran down to the root zone, whereas this did not happen in 1981.

The frequency of years of severe CT damage to sugarbeets in southern Idaho has been summarized (3). Before the development and widespread use of highly resistant varieties (1912-1934), severe to extreme CT damage occurred in 1919, 1921, 1924, 1926, 1930, 1931, and 1934, or 7 times in 23 years. During those years, area yields averaged from 4.89-8.53 T/A, the percentage of planted sugarbeet acres abondoned (mostly due to CT) varied from 15.6-87.1, and descriptions of CT injury varied from "serious, severe, 100 percent infected," to "extreme" and "disastrous." The infections of, and damage to, the variety 1345 in our 1979 and 1980 tests, would be fairly representative of many fields during those outbreak years. Our 1978 test was fairly typical of moderate CT damage. The fact that a moderate CT year occurred naturally in 1977 in southcentral Idaho is evidence that a potential problem continues to exist. In 1977, 1 field suffered severe yield loss with the variety D2 producing 6.0 T/A and AH10 producing 12.2 T/A (3), and a similar situation occurred in 1981.

Conclusions

We conclude that all 3 insecticides tested (carbofuran, aldicarb, and phorate) placed under the seed or injected to the side of the seed row at planting will maintain yields of varieties with moderate or no CT resistance in most years at an acceptable level. None of the insecticides would adequately protect any variety under early and very severe CT infection. Carbofuran appeared to be the most effective of the 3 materials tested. The effectiveness of aldicarb appeared to be decreased by excessive moisture. Banding over the row at planting was indicated as an acceptable method of application in 1980 under moderately severe conditions but gave no protection in 1981 (possibly due to differences in moisture), and was not as effective as side injection in 1979. Our data in 1981 show that injetion below the seed and side injection were equally effective methods of application.

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