Beet Leafhopper Control in Sugar Beets by Seed or Soil Treatment

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Experiments by the senior author in 1955 indicated that treatment of sugar beet seed with phorate (Thimet) or other systemics was of value in controlling beet leafhoppers (*Circulifer tenellus* (Baker)) on plants being grown for seed in the Salt River Valley of Arizona (1)[3]. Reynolds et al. (2) tested various materials as seed and soil treatments on several crops, including sugar beets, and reported good control on beets up to the 4 to 6-leaf stage of development. In 1956 and 1957 field-plot and greenhouse tests were conducted by the authors at Phoenix, Arizona, to compare various methods of seed or soil treatment in the control of the beet leafhopper[4]. The effectiveness of some of the treatments on lepidopterous larvae was also determined.

Small Field Plot Tests

Materials and Methods

These tests were made on field plots adjoining commercial plantings of sugar beets for seed. Each plot consisted of four rows of beets 50 feet long. The plots were arranged in randomized blocks planted August 30 and 31. All treatments were replicated six times.

In 1956 all treatments were with phorate, but in 1957 both phorate and Di-Syston were used. They were applied as seed and soil treatments and as granules under the seed.

Seed treatments were based on the amount of active ingredient on 15 pounds of seed, since this is the average planting rate per acre. Both dusts and emulsions were used. The dusts were carbon impregnated with the insecticide. The seed balls were coated with this material by tumbling them in a cement mixer for about 20 minutes. For the emulsion-treated seed, a 90-percent concentrate of phorate was diluted with water to make a total of 38 ounces of emulsion per 15 pounds of seed. This emulsion was poured over the seeds as they were being tumbled in a cement mixer. They were then air-dried overnight before planting.

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[1] Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Phoenix, Arizona.

[2] Western Seed Production Corporation, Phoenix, Arizona.

[3] Numbers in parentheses refer to literature cited.

[4] The field plots were provided by the Western Seed Production Corporation, Phoenix, Arizona.

Spray-in-seed-row treatments were accomplished by placing a spray nozzle between the planting shoe and the cover wheel of the planter. A 3X cone-type T-jet nozzle was used with the whirl plate removed to produce a jet of liquid. Either 2 or 4 pounds of the insecticide was used in 21 gallons of water per acre. Granules were applied by drilling them into the seed row ½ to 1 inch below the seed just before planting. Commercial granules containing 2 percent of phorate or 2.5 percent of Di-Syston were used.

The effectiveness of the treatments against beet leafhoppers was determined by caging the insects on various parts of plants in different stages of development. From 5 to 10 clip cages (Figure 1) each containing 5 to 7 leafhoppers were used for each date of infestation. After the cages had remained on the plants 48 hours, they were removed and leafhopper mortalities determined. Leafhoppers for this work were collected from Russian-thistle and placed in stock cages. The clip cages were protected from the sun by shingles, and the stock cages were kept under an umbrella while they were in the field (Figure 2).

Figure 1.—Clip cage used to confine beet leafhoppers on test plants. (Actual size ¾ inch diameter.)

Figure 2.—Small plots of seed beets for tests of seed and soil treatments against the beet leafhopper. Shingles protected the caged leafhoppers from the summer sun; the umbrella protected the leafhoppers in the colony cage.

To determine the effectiveness of the treatments against lepidopterous larvae that attack seedling beets, one foot of row samples were taken in each plot and all worms counted. This was done when the plants were in the late cotyledon stage and again when they were in the 2 to 4-leaf stage.

To determine the presence of the toxicant in the beet plants at different stages of development, plant samples from plots given the higher dosage of each treatment in 1956 were sent on five dates to the American Cyanamid Company's laboratory at Stamford, Connecticut, for chemical analyses. These samples were quick-frozen, held in cold storage overnight, and shipped the next day by air freight in dry ice.

To determine the location and amount of the toxicant in the plants, samples of parts of plants grown from seed treated with phorate dust at both ½ and 1 pound per acre were obtained when they were in the six-leaf stage of development and sent to the American Cyanamid Laboratory for residue analyses. Similar samples from plots grown from seed receiving the one-pound dosage of impregnated carbon dust were also sent to the Entomology Research Division Laboratory at Yakima, Washington, for chemical analysis.

Effect on Plants

Plant stand counts in 1956 showed drastic reductions for the phorate emulsion seed treatments, 62 percent for the ½-pound and 97 percent for the 1-pound dosage. Some reductions were also indicated for the dust seed treatments, but these are attributed to the seeding rate rather than the effect of the phorate. The dust-treated seed did not flow through the planter as readily as did the untreated seed.

Effects on Insects

In 1956 leafhopper mortalities were high on the cotyledons in all stages of plant development for all treatments except the granules under seed (Table 1). Later analysis of this material showed that the phorate content of the granules was considerably below the required 2 percent. The higher dosages were usually superior to the lower dosages, especially when sprayed in the seed row. Mortalities on the first pair of true leaves were not significantly different from the check except in the 1-pound emulsion seed treatment.

Table 1.—Percent Mortality of Beet Leafhoppers After 48 Hours on Plants in Various Stages of Development in Small Phorate-Treated Plots of Sugar Beets Grown for Seed, 1956.

Treatment	Pounds of Phorate per Acre	2-Leaf (14 days)[1]	2 to 4 Leaf (20 days)		4 to 6 Leaf (26 days)		6 to 8 Leaf (33 days)
		Cotyledons	Cotyledons	First Pair of Leaves	Cotyledons	Second Pair of Leaves	Cotyledons
Seed:							
Dust	½	88	96	19	74	11	50
	1	99	100	32	100	6	92
Emulsion	½	98	100	22	98	8	----
	1	100	95	66	100	15	----
Soil:							
Spray in seed row	2	71	72	16	64	7	34
	4	97	100	31	94	20	88
Granules under seed	3	20	50	16	30	7	----
Untreated check	----	8	58	13	19	12	16
LSD at 5% level	----	11	14	20	14	[2]	17

[1] Days after emergence of seedlings.
[2] Not significant by F test at 5% level.

The effectiveness of the various treatments on lepidopterous larvae is shown in Table 2. The first count was made on September 17, at which time the plants were in the cotyledon stage. At this time 92 percent of the larvae were beet armyworms (*Laphygma exigua* (Hbn.)) and 8 percent garden webworms (*Loxostege similalis* (Guen.)). At the second count, made on September 24 when the beets were in the 2-leaf stage, 87 percent were beet armyworms, 9 percent garden webworms, and 4 percent cutworms. There was a tendency toward a reduction in numbers of lepidopterous larvae in all the treatments except the granules under the seed, but the differences from the untreated checks were significant only for the emulsion seed treat-

Table 2.—Number of Lepidopterous Larvae per 10 Feet of Row in Small Phorate-Treated Plots of Sugar Beets Grown for Seed, 1956.

Treatment	Pounds of Phorate per Acre	Cotyledons	2 Leaf
Seed:			
Dust	½	5.7	8.6
	1	5.2	9.4
Emulsion	½	5.8	6.9
	1	1.2	1.4
Soil:			
Spray in seed row	2	3.8	10.9
	4	3.0	7.4
Granules under seed	3	14.0	19.2
Untreated check	—	11.2	10.7
LSD at 5% level		7.8	[1]

[1] Not significant by F test at 5% level.

Table 3.—Percent Mortality of Beet Leafhoppers on 4-Leaf Plants from Small Plots of Sugar Beets Grown for Seed, 1957.

Treatment	Pounds of Toxicant per Acre	Cotyledons	First Pair of Leaves
Seed with dust:			
Phorate	½	98	34
Di-Syston	½	86	42
Granules under seed:			
Phorate	4	71	29
Di-Syston	4	77	35
Untreated check	—	53	20
LSD at 5% level	—	23	[1]

[1] Not significant by F test at 5% level.

ment and the spray-in-seed-row at the higher dosage when the plants were in the cotyledon stage.

In 1957 leafhopper mortalities were high for all treatments when the insects were caged on the cotyledons, but there were no significant differences due to treatment when they were on the first pair of true leaves (Table 3). Mortalities from the seed treatment with phorate dust were significantly higher than from granules placed under the seed, but this was not true of Di-Syston.

Residue Analyses

Results of residue analyses by the American Cyanamid Company are expressed as the sulfone analogue, while those of the Entomology Research Division are expressed as total phorate. Elton L. Clark, of the American Cyanamid Company pointed out in correspondence that in plants, phorate goes through a series of oxidation steps to yield several metabolites, all of which are more potent inhibitors of cholinestrase, and that the final oxygen sulfone analogue is about 1000 times as active as phorate.

Analyses of tops from sugar beet plants receiving the higher dosages of the various 1956 treatments (Table 4) showed the greatest amount of toxicant in 10-day-old cotyledon plants grown from dust-treated seed. By the time the plants were 17 days old and in the 2-leaf stage, those grown from dust-treated seed contained less than half as much toxicant as plants from the sprayed seed rows. Thereafter, the rate of decline was about the same until at the 10-leaf stage no phorate could be recovered from the beet tops. These plants were 12- to 14-inches tall.

Table 4.—Parts per Million of the Sulfone Analogue of Phorate in Tops of Sugar Beets in Various Stages of Development Grown from Seed Treated in Different Ways, 1956.

Treatment	Pounds of Phorate per Acre	Cotyledon (10 days)	2 Leaf (17 days)	4 Leaf (24 days)	6 to 8 Leaf (31 days)	10 Leaf (52 days)
Seed dusted	1	2.590	0.581	0.474	0.082	<0.002[1]
Spray in seed row	1	1.160	1.190	.384	.027	< .002
Granules under seed	3	0.110	.043	< .002	< .002	

[1] Sensitivity of the method is 0.002.

Analyses of various parts of plants in the 6-leaf stage (Table 5) showed by far the greatest amount of the toxicant in the cotyledons. There was also about twice as much of the toxicant in cotyledons of plants receiving the 1 pound as in those receiving the ½ pound dosage. Only the higher dosage showed some toxicant in the first pair of leaves. There was some phorate toxicant in the roots of the 6-leaf plants, but samples dug 7 months later from plots receiving the 1-pound dosage showed no phorate residue.

Greenhouse Tests

Tests were made in the greenhouse to determine beet leafhopper mortalities resulting from short periods of feeding on sugar beets grown from phorate-treated seed. Since separate tests

Table 5.—Parts per Million of Phorate Toxicant in Various Parts of 6-Leaf Plants of Sugar Beets Grown from Seed Dusted at Different Rates, 1956.

	Phorate Application per Acre		
	½ lb.	1 lb.	1 lb.
Plant Parts	Sulfone Analogue		Total Phorate
Cotyledons	0.257	0.556	660.0
First pair of leaves	<0.002[1]	0.085	100.0
Second pair of leaves	<0.002	0.022	20.0
Roots	0.004	0.023	48.0

[1] Sensitivity of the sulfone analogue analysis is 0.002.

were run on cotyledons and first and second pairs of leaves, the data also give information on the position of the toxicant in the young plants.

Tests during November and December were run with leafhoppers collected in the field from Russian-thistle and later in the season with leafhoppers from reared colonies. Test plants were sugar beets grown in greenhouse flats from seed treated at the rate of ½ pound of phorate on 15 pounds of seed.

Insects were confined on the plants by clip cages, as in the field-plot tests, except that only one leafhopper was placed in each cage, and they were starved for 3 to 4 hours before being placed on the plants. After they had been on the treated plants for 1 hour to insure feeding, mortality readings were taken and the live insects transferred to untreated plants for 24 hours after which mortality readings were again taken. Percent mortality was also determined on untreated check plants. As shown in Table 6, feeding periods of 1 hour or less produced high mortalities. Mortality was much higher on the cotyledons than on either the first or second pair of true leaves, which is in agreement with data from the small field-plot tests.

Table 6.—Beet Leafhopper Mortalities in Greenhouse Cages on Leaves of Sugar Beets in Various Stages of Development Grown from Phorate-Treated Seed, 1956.

Stage of Plant Development	Leaves Tested	Number of Leafhoppers	Percent Mortality over Untreated Check	
			1 hour	24 hours
Cotyledon	Cotyledons	100	42	92
2 to 4 Leaf	Do	50	—	86
	First pair	150	15	47
4 to 6 Leaf	Do	50	—	47
	Second pair	150	—	35

Large Field-Plot Tests

Materials and Methods

These tests were on commercial plantings with seed treated with phorate-impregnated carbon dust. In 1956 all the seed was treated at the rate of ½ pound of phorate on 15 pounds of seed (or per acre). Strips of 8-11 acres each were planted with treated seed in five fields; three other fields ranging in size from 6 to 34 acres were grown entirely from treated seed.

In 1957 practically the entire acreage of seed beets in the Salt River Valley was grown from seed treated at the same rate as in 1956. In each of seven fields a strip of approximately 10 acres was planted with seed having no treatment and another strip with seed treated with 1 pound of phorate per 15 pounds of seed. All the seed was treated by a local company a few days before planting.

As far as possible beet leafhopper populations were measured weekly in all strips until the plants had reached the 10 to 12-leaf stage and were approaching 75 percent foliage cover. This was about 4 to 6 weeks after they emerged. Leafhopper populations in the fields at this time are normally on the decline. Counts were made with a square-foot counting cage (3) 25 square feet constituting a sample.

In 1957 stand counts and counts of lepidopterous larvae were made when the plants were in the late cotyledon to 2-leaf stages; 50 units of 1 foot of row each constituted a sample.

When the plants were in the 6 to 8-leaf stage or larger, curly-top counts were made to determine the effect of treatment on the disease. Counts were made in units of 5 feet of row; 20 such units, taken at random, constituted a sample.

Effect on Plants

Plant stands were not taken in 1956 but stands in all plots were considered satisfactory. In the 1957 plots, seed treated with 1 pound of phorate per acre produced 177 plants, seed treated with ½ pound per acre 167 plants, and untreated seed 144 plants per 10 feet of row. Some difficulty was encountered in getting the treated seed through the planters. A larger opening was therefore used and the planting rate increased, which undoubtedly accounts for the difference in stand counts. In some of the higher dosage plots a slight burning was noted on the tips of the cotyledons, but this did not affect the growth of the plants.

Effect on Insects and Curly Top

Beet leafhopper population during the fall of 1956 were too low to measure differences due to treatment. The average

population for all plots during September and October was 2.4 per 100 feet of row. Populations of 2.0 per 100 feet of row or less are not considered high enough to cause a measurable amount of curly top.

In 1957 phorate treatment reduced the beet leafhopper population on plants in the cotyledon and 2 to 4-leaf stages far below the check; on older plants the differences were not significant (Table 7). Beet leafhopper populations were not high even in the untreated checks, although 50 or more per 100 feet of row on small plants are of economic concern.

Table 7.—Numbers of Beet Leafhoppers per 100 Square Feet on Plants in Various Stages of Development Grown from Phorate-Treated Seed in Large Field-Plot Tests on Commercial Plantings of Sugar Beets Grown for Seed, 1957.

Pounds of Phorate per Acre	Cotyledon (7 days)[1]	2 to 4 Leaf (14 days)	4 to 6 Leaf (21 days)	6 to 8 Leaf (28 days)	10 Leaf (35 days)
1	1	9	30	11	12
½	4	10	34	8	21
Untreated check	37	49	57	15	27
LSD 5%	22	20	[2]	[2]	[2]
1%	31	29	[2]	[2]	[2]

[1] Days after emergence of seedlings.
[2] Not significant by F test at 5% level.

Lepidopterous larvae occurring in the plots were primarily the beet armyworm and the yellow-striped armyworm (*Prodenia ornithogalli* Guen.). Plots grown from seed treated with 1 pound of phorate contained 16 larvae per 10 feet of row, those grown from seed treated with ½ pound 13 larvae, and untreated checks 9 larvae.

Curly top readings showed an average of 3 curly top plants per 100 feet of row for the 1-pound treatment, 5 for the ½ pound, and 10 for the untreated checks. These readings show a very low curly top incidence and under the conditions of this experiment differences due to treatment are not significant.

Discussion

The most important fact demonstrated by these experiments is the concentration of toxicants from seed treatment with phorate or Di-Syston in the cotyledons of the sugar beet plants. This concentration of toxicants in the cotyledons does not mean that beet leafhopper control by this method is confined to seedlings. The cotyledons ordinarily remain in good condition until the plants are past the 6 to 8-leaf stage, at which time they are 10 to 12 inches tall. The beet leafhopper is a very active insect

and in moving about over the plants may feed on the cotyledons as long as they are present. Figure 3 shows the condition and prominence of cotyledons on sugar beets in the 4 to 6-leaf stage. These experiments also show that beet leafhoppers are rapidly killed by one feeding on the cotyledons of plants grown from treated seed. This is an important point in preventing the spread of curly top.

Figure 3.—Cotyledons on sugar beet plants in the 4-6-leaf stage of development.

Summary

In 1956 and 1957 tests were conducted in field plots and in the greenhouse on sugar beets grown for seed to determine the comparative effectiveness against the beet leafhopper (*Circulifer tenellus* (Baker)), of various methods of seed and soil treatment with phorate and Di-Syston. The seed treatments were with impregnated carbon dusts or emulsions and the soil treatments with emulsion sprays in the seed row at planting time or granules under the seed. Dust seed treatments gave as good results as other treatments, were easier to use, and did not damage plant stands as did emulsion seed treatments. Good results were obtained with both insecticides at ½ and 1 pound on 15 pounds of seed or per acre. Cage tests with beet leafhoppers as well as analyses of plant parts showed a concentration of phorate in the cotyledons. Some control of lepidopterous larvae was indicated on young plants.

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