Effect of DDT on Beet Leafhoppers, Curly Top, and Yields of Sugar Beet Varieties[1]

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Introduction

Since 1897, curly top, a virus disease affecting beets, beans, tomatoes, cantaloup and many garden crops, has been a disease of major economic importance in intermountain areas subject to infestation by the beet leafhopper *(Circulifer tenellus* (Bak.)) , the only known agent of transmission. Xhe geographic distribution of the disease is, therefore, the same as that of the insect, which is sporadic in its appearance; hence, the severity of curly-top injury fluctuates from year to year.

For a period of years, various investigators have conducted experiments to reduce curly top damage by controlling its vector. Romney (5)[3] was the first to show any significant reduction in curly top and increases in seed yields when the seed-beet fields were sprayed in the fall with pyrethrum-in-oil for the control of the beet leafhopper. Hills et al. (4) showed that DDT applied at dosages of from two to three pounds of toxicant per acre gave as good an initial kill as the recommended pyrethrum-in-oil spray and that the residual effect was sufficient to hold leafhopper populations at a low level for at least one to two weeks after application. Smith (6) showed that a highly refined petroleum oil containing 4.5 percent DDX spray applied at six gallons per acre gave control of the beet leafhopper for 15 days. Douglass et al. (1) , working with several chlorinated hydrocarbon compounds, HEPT, and pyrethrum, found that DDT was the most effective insecticide tested against the beet leafhopper. Douglass et al. (2) showed that curly-top-susceptible R. and O. Old Type beets could be protected from curly top infection by controlling the beet leafhopper under conditions of extreme exposure. Giddings (3) showed that resistance of the sugar beet to curly top increases rapidly with the size and age of the plant.

Over a four-year period (1948-1951) the authors investigated the effect of spraying with DDT on sugar beet varieties which varied in their resistance to curly top.

Methods and Materials

To increase the curly top exposure by obtaining a high natural infestation of beet leafhoppers, the plots were located near a desert breeding area of the insect, and the planting date was delayed about five weeks from the normal planting date for the area. An attempt was made to plant the sugar beet seed each year so that the plants would be in the seedling stage, the period of greatest susceptibility, when the spring movement of the leafhoppers was expected to reach its peak. The planting dates for the four years of the experiment varied from May 18 to 29. Four sugar beet varieties of varying degrees of curly top resistance were used each year, and these varieties were selected so that at least one variety represented each of

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[3] Numbers in parentheses refer to literature cited.

the three main types of resistance, namely 1. high resistance, 2. intermediate resistance, and 3. susceptible.

Two experimental designs were used. For the first three years (1948, 1949 and 1950) the experimental area was equally divided—one-half being treated and one-half left untreated. Within the treated and untreated areas the varieties were replicated. This design, however, was not suitable to evaluate statistically the effect of treatment. Therefore, the 1951 test was enlarged and treatments were replicated as well as varieties. The experimental design, which permitted the evaluation of the effects of the spray treatments as precisely as possible, was prepared by Dr. D. D. Mason, Biometrician, B.P.I.S.A.E., taking into consideration the limitation of the size of the area, the problem of spray drift, and the activity of the beet leafhopper. The varieties and treatments were replicated eight times. This split plot design provided for eight guard rows between each of the spray treatments. The four guard rows associated with each test plot were planted to the same variety as the adjacent test plot and were sprayed or unsprayed according to the treatments of the adjacent whole plot. In other words, the area was planted as if each subplot was eight rows wide and 60 feet long and was sprayed as if each whole plot was 16 rows wide and 120 feet long.

For all years, the spray applications were begun as soon as the seedlings emerged and the treatment repeated three more times at weekly intervals, except in 1949 when five applications were made. Generally, the treatments were applied at seven-day intervals, but rains or high winds on two occasions prevented the spray schedule.

The DDT emulsion was applied with power equipment at a dosage of 1.5 pounds of toxicant per acre-application in 100 gallons of spray at about 400 pounds pressure.

The formula used for the spray treatment was 1.5 pounds of technical DDT; 1,200 milliliters of a non-volatile solvent, chiefly di- and tri methylnapthalenes, and 100 milliliters of a proprietary emulsifier of polyethyl aryl alcohol per 100 gallons of spray.

The effectiveness of the DDT spray material was determined by comparing pre- and post-treatment numbers of adult beet leafhoppers, by curly top counts and by yield data from the sprayed and unsprayed plots. The leafhopper counts were made with the square-foot sampler. The samples, which were taken at random along the beet rows, included more than one plant before thinning but single plants after thinning. Counts were made just before each application and seven days after the last treatment. Since counts show that better than 95 percent control of this leafhopper is obtained with a similar spray one day after treatment, the increase in population is, therefore, a result of reinfestation from incoming migrants or from redistribution over the plots after each spray application.

Experimental Results

In the 1948 and 1949 tests, difficulty was encountered with irregular beet stands as a result of wireworm injury, which made it difficult to evaluate the effect of treatment. However, yield data showed that the susceptible variety and the one of intermediate resistance made a higher yield when treated than did the untreated plots. For the highly resistant variety S. L. 72 (U. S. 22/3) in these tests, treatment had little influence on the yield. The leafhopper population in 1948 reached a peak of 212 leafhoppers per 100

Table 1.—The Effect of a DDT Spray Applied June 9, 16, 23 and 30, 1950, on Adult Beet Leafhopper Populations in Sugar Beets.

Date	Average leafhoppers per 100 square feet in plots		
	Treated	Untreated	Reduction
1950	Number	Number	Percent
June 9	74	76	.....
June 16	92	218	57.6
June 23	200	240	41.2
June 30	348	632	44.9
July 7	184	304	39.5

samples in the untreated plots, while in 1949 there were 264 leafhoppers at the peak. The leafhopper population for these two years is, therefore, quite comparable and can be regarded as of moderate intensity in relation to the tests of 1950 and 1951.

The leafhopper infestation in 1950 was the highest of any of the four years since the population reached a peak of 632 leafhoppers per 100 square feet, as shown in Table 1, while the infestation in 1951 was the lowest, reaching a peak of 144 leafhoppers per 100 square feet. The effect of four sprays of DDT applied June 9, 16, 23 and 30, 1950, on adult beet leafhopper populations is given in Table 1. There were 74 and 76 leafhoppers per 100 square-foot samples on the treated and untreated plots before the first application of DDT was applied on June 9. June 30, when the peak was reached, the number of leafhoppers increased to 348 and 632 in the treated and untreated plots. The seven-day post-treatment differences in populations between the sprayed and unsprayed plots on June 16, 23, 30 and July 7 were 126, 140, 284 and 120 adults. Table 1 also gives the percentage decrease in adult population in the sprayed and unsprayed plots.

Table 2.—A Comparison of Yield as Affected by Four Applications of a DDT Spray for the Control of the Beet Leafhopper and Curly Top in 1950.

Variety and S. L. number	Treated			Untreated		
	Beets[1]	Yield	Curly top July 10	Beets[1]	Yield	Curly top July 10
	Number	Tons	Percent	Number	Tons	Percent
U. S. 22/3 (S. L. 72)	82	19.6	1.1	79	14.8	1.9
U. S. 56/2 (S. L. 859)	84	14.0	10.1	87	10.1	17.4
R. and G. Old Type (1-500)	58	3.8	92.8	11	.6	100.0
S. L. 742	5	.3	99.2	1	.1	100.0

[1] Per 108 feet of row at harvest.

A summary of the average percent curly top on July 10 and yield per acre for the different varieties in the 1950 test is given in Table 2. The differences in yield between the treated and untreated plots were 4.8, 3.9, 3.2 and 0.2 tons per acre for varieties U. S. 22/3, U. S. 56/2, R. and G. Old Type, and S. L. 742. The variety S. L. 742 is much more susceptible to curly top than R. and G. Old Type, and the purpose of including it in at least one test was to get a better measure as to the extent of control than could be expected on the most susceptible variety available. Under the

conditions of the 1950 test, four applications of DDT did not afford this variety enough protection to make much of a showing.

In 1950 the sprayed block gave increased yields over that of the unsprayed block, but neither the difference in percent of curly top nor the difference in stand seemed to account for the large increase in yield (4.8 tons per acre) in the case of U. S. 22/3. However, the treatment effect was confounded with place effect, and it was not possible to determine whether the increase in yield was statistically significant. Since the results of the 1950 test were at variance with the similar 1948 and 1949 tests, it indicated the necessity for additional work with a different experimental design. To obtain statistical evaluation of the effect of treatment, both treatment and varieties were replicated in the 1951 test in order to separate possible soil location effects from treatment effects.

By the year 1951, a variety more resistant to curly top than S. L. 72 (U. S. 22/3) had been developed. This was the male sterile hybrid S. L. 92 HI, which represents a fourth backcross to the inbred CT9 x SL 92, a highly resistant mass selected line.

In the 1951 test there was considerable spray injury to the young seedlings. Spray injury had been noted before and in every previous instance had been followed by light rains. However, spray injury was more severe in the 1951 test than in any of the previous tests and probably depressed yields to some extent. This may help to explain why the highly resistant male sterile hybrid 92 HI yielded 1.73 tons per acre more in the untreated plots than in the treated plots. It was difficult to evaluate the extent of spray injury as to varieties, but it is possible that 92 HI was more susceptible to injury of this type or else recovery was slower than in the case of the other varieties. Injury consisted of burning, which produced a pitting effect on the leaves where the spray droplets had dried, and an inward rolling of the leaves. Some leaves dropped off the plants which were the most severely injured.

Table 3.—The Effect of a DDT Spray Applied June 11, 19, 25 and July 3, 1951, on Adult Beet Leafhopper Populations on Sugar Beets.

Date	Average leafhoppers per 100 square feet in plots		
	Treated	Untreated	Control
1951	Number	Number	Percent
June 11	144	132	—
June 19	22	66	66.7
June 25	24	100	76.0
July 3	18	35	48.6

The effect of DDT on the beet leafhopper in the treated and untreated plots for the 1951 test is given in Table 3. This table shows that the pretreatment population was 144 and 132 leafhoppers per 100 square-foot samples. This population decreased to 22 and 66 adults on June 19, increased to 24 and 100 on June 25, and then decreased to 18 and 35 leafhoppers on July 3 in the treated and untreated plots.

The post-treatment difference in population between the treated and untreated plots (Table 3) on June 19, 25 and July 3 and 44, 76 and 17 adults or 66.7, 76.0 and 48.6 percent.

A summary of the average percent curly top on June 30, curly top grade on October 1, and yield per acre for the different varieties in the 1951 test is given in Table 4. The data presented in the table show that there was little difference in the percentage of curly top for the two most resistant varieties on June 30 but there was a difference in favor of the treatment in the less resistant and susceptible varieties.

Xable 4.—A Comparison of Curly-top Infection, Plant Stand and Yield of Sugar Beet Varieties as Affected by Four Spray Applications of DDT for the Control of the Beet Leafhopper in 1951.

Treatment	Beet varieties	Curly top		Stand of beets per 100 feet of row at		Mean yield of beets per acre
		June 30	October 1	Thinning	Harvest	
		Percent	Grade	Number	Number	Tons
DDT	92 HI	1.6	0.4	92	95	18.22
Untreated	92 HI	.9	.4	102	101	19.95
DDT	S. L. 72	1.7	.8	95	92	17.01
Untreated	S. L. 72	1.8	1.0	99	89	17.29
DDT	S. L. 859	10.8	1.7	118	103	15.01
Untreated	S. L. 859	17.1	2.0	119	93	14.26
DDT	R. and G. (1-800)	87.6	3.6	104	66	8.51
Untreated	R. and G. (1-800)	97.2	4.0	97	42	4.87
Difference required for significance (19:1)						1.16
Difference required for significance (99:1)						1.54

There was practically no loss in plant stand between thinning and harvesting of the more resistant varieties of beets, but in the intermediate and susceptible varieties there was a loss. A comparison of this loss between the treated and untreated plots will show that 9.1 and 20.2 percent more plants were lost in the untreated than in the treated plots for varieties S. L. 859 and R. and G. Old Type. A study of yields of beets per acre shows that the untreated outyielded the treated plots 1.73 tons for the male sterile hybrid 92 HI, which possessed the highest degree of curly-top resistance. However, it will be noted from Table 4 that the stands were better in the untreated than in the treated plots. There was little difference in yield between the treated and untreated plots for S. L. 72. In the variety of intermediate resistance, S. L. 859, there was a gain of 0.75 tons per acre in favor of the treatment, but this increase was not great enough to be statistically significant. The treatment of susceptible variety R. and G. Old Type gave an increase in yield of 3.64 tons over the untreated plots, which was statistically significant.

The results of the 1951 spray treatment did not show an increase in the yield of the two most resistant varieties. Possibly this was because the leafhopper populations and, hence, the curly top exposure did not reach a level where the spray treatment would have shown an effect.

The 1951 experimental design, while an improvement over the other three years of the test, was not entirely satisfactory. With an insect as active as the beet leafhopper, disturbances such as cultivation, weeding, etc., cause the insect to move and when relatively small plots are used they redistribute themselves more or less over the entire experimental area. This movement of the causal agent of the disease makes the treatment less effective. However, the control of drift with respect to spray material and of insects was

relatively good. Otherwise all effects would have been equalized and the large differences between treated and untreated plots for the susceptible variety R. and G. Old Type would not have been apparent.

Summary and Conclusions

Field tests with DDT spray treatments were investigated over a four-year period for four sugar beet varieties ranging from susceptible to highly resistant. The planting date was delayed five weeks to increase the curly top exposure. Spray treatments were begun as soon as the seedlings emerged and were repeated at weekly intervals for four or five weeks.

The highest leafhopper population occurred in 1950, and the difference in yield between the treated and untreated plots was 4.8, 3.9, 3.2 and 0.2 tons per acre for varieties U. S. 22/3, U. S. 56/2, R. and G. Old Type and S. L. 742. However, because of the experimental design used in the 1950 test, it was impossible to determine whether this difference was due to treatment or to location of unreplicated plots. Under the drastic curly top exposure in the 1950 test four applications of DDT did not afford sufficient protection to the susceptible varieties to produce a commercial crop.

During years of comparatively low leafhopper populations, sprays gave gains in yield for only the susceptible varieties, since the curly top exposure was not sufficient to decrease the yields of resistant varieties. In 1951, a statistically significant gain as a result of treatment was obtained for R. and G. Old Type, which showed an increase of 3.64 tons per acre over the check.

Because of the complexity of the problem, the effectiveness of a DDT spray treatment is difficult to measure accurately, but the evidence seems to indicate that in the case of varieties intermediate in resistance some benefit can be expected under certain conditions from spraying.

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