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THE BEET LEAFHOPPER AND ITS CONTROL ON BEETS GROWN FOR SEED IN ARIZONA
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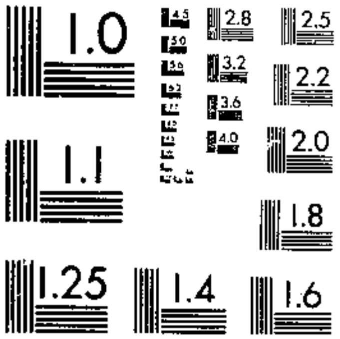

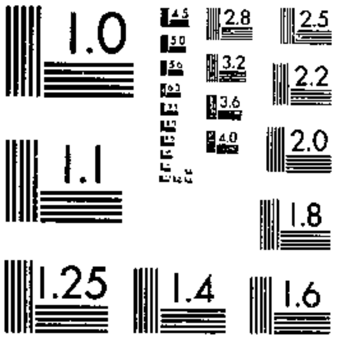

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The Beet Leafhopper and Its Control on Beets Grown for Seed in Arizona and New Mexico[1]

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INTRODUCTION

The commercial production of sugar-beet seed on a large scale is a relatively new agricultural industry in the western part of the United States. Commercial plantings for beet-seed production by the method of overwintering the plants in the field were first made in Mesilla Valley, N. Mex., during the fall of 1927, as reported by Overpeck et al. (*8*) [3] and since that time the industry has expanded to various other agricultural districts.

A limitation of major importance to the production of sugar-beet seed in some districts is damage from curly top, a virus disease transmitted by the beet leafhopper (*Eutettix tenellus* (Bak.)). The intensity of infestation by the leafhopper and severity of curly top damage vary from year to year, frequently resulting in a sharp reduction in the yield of seed. The variety of beet, its resistance to curly top disease, the density of plant stand, and the rate of growth in the fall are factors which influence the activities of the leafhopper in the beet fields and the subsequent prevalence and severity of the curly top disease which it transmits.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 24.

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By 1935 the indications were that in order to continue the profitable production of beet seed on a commercial basis year after year a control of the beet leafhopper would be necessary in some of the main seed-producing districts. Preliminary experiments conducted during August, September, and October of that year served as a basis for the application of control measures against the beet leafhopper on large acreages of beets in Arizona, New Mexico, and Texas during November and December 1935. This bulletin reports the results of experiments conducted during the period 1935 to 1941 which were designed to determine the effectiveness of a pyrethrum-in-oil spray and of cultural measures for the control of the beet leafhopper on beets grown for seed in the Salt River Valley of Arizona and in the Mesilla Valley of New Mexico.

Since the existence and survival of the sugar-beet industry in the United States is dependent at present on the production of sugar-beet seed in this country, it necessarily follows that the insects and insect-borne diseases that affect the sugar-beet seed crop must be considered as affecting attainment of crop production goals.

SOURCE AND TIME OF THE FALL INFESTATIONS

The more important areas in which the seed is now produced include the Salt River Valley in Arizona, the Mesilla Valley in New Mexico, valleys near Hemet and Perris in southern California, Shasta Valley in northern California, Virgin Valley in southern Utah, several mountain valleys in north-central Utah, an area near Klamath Falls and the Rogue River and Willamette Valleys in Oregon, and the Puget Sound area in Washington. In most of these areas beet seed is planted from August to late in September, and the unthinned plants are overwintered in the field. Under these conditions they bolt during the following spring and develop a crop of seed that is ready to be harvested by July. This method of seed production is locally known as the "annual method" to distinguish it from the older and more laborious method involving transplanted stecklings.

The beet seed growing districts in southern Arizona and southern New Mexico are surrounded by semidesert breeding areas of the beet leafhopper as shown in figure 1. The black areas indicate agricultural districts where the seed beets are grown, and the shaded areas indicate territory where the beet leafhopper reproduces during the summer and fall and from which the seed-beet field infestations arise. Summer rains, which usually occur from July to September, germinate desert annuals which serve as host plants for the leafhopper. The young beet plants become infested with the beet leafhopper in the fall, in both Arizona and New Mexico, by influxes from the nearby semidesert areas containing summer-fall host plants.

In Arizona

In Arizona the beet leafhoppers that infest the beets grown for seed in the Salt River Valley come from semidesert areas completely surrounding the valley, as shown in figure 1. The leafhopper breeds on extensive stands of chinchweed (*Pectis papposa* A. Gray), *Tidestromia lanuginosa* (Nutt.) Standl., *Trianthema portulacastrum* L., and occasionally on *Atriplex elegans* (Moq.) D. Dietr., beginning in

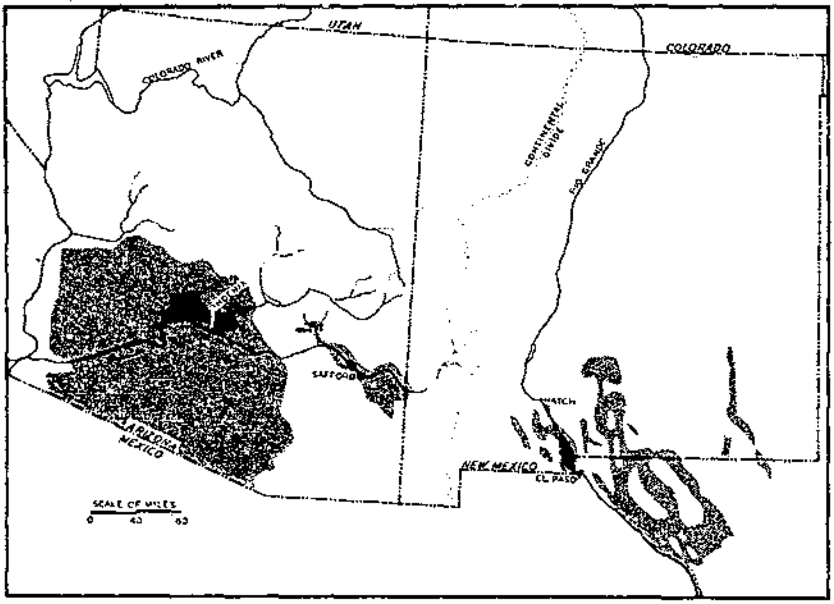

FIGURE 1.—Cultivated districts in Arizona and New Mexico in which beets are grown for seed where curly top is a problem in some seasons (black areas), and summer-fall breeding areas of the beet leafhopper (shaded) which serve as the source of fall movements into the beets.

July and continuing until late in the fall. Figure 2, *A*, shows an area where 62 percent of the ground is covered with foliage of chinchweed and 1 percent with *Tidestromia*, as these plants occurred 12 miles northwest of Phoenix, October 16, 1939. In this environment at that time, there were, on an average, 6 adult beet leafhoppers and 11 nymphs per square foot of solid coverage. Figure 2, *B*, shows 80 percent of the ground covered with *Tidestromia* and 8 percent with *Pectis* at this same time and in the same vicinity. In this environment there were, on an average, 7 adults and 13 nymphs per square foot of solid coverage on *Tidestromia* compared with 5 adults and 9 nymphs on *Pectis*. Such stands are common over the semi-desert areas, although usually more plants occur along the washes.

The numbers of leafhoppers produced are governed largely by the abundance of the summer plants, which in turn depends on the amount of rainfall during July, August, and September, and on the stand of *Atriplex elegans*, which germinates in the winter. Two generations of the leafhoppers usually have been produced over the semidesert areas by the time the beet leafhopper moves into the cultivated areas and infests the beets. When heavy rains occur in September, as they did in 1939 and 1940, as many as two additional generations may be produced in the semidesert areas. October and November rains, which germinate winter annuals in these areas, are important also in governing the number of leafhoppers that infest the seed-beet fields, because when these winter annuals germinate before the summer plants become dry they serve as hosts in the breeding grounds for the leafhoppers which otherwise would be forced into the agricultural districts to find favorable food plants.

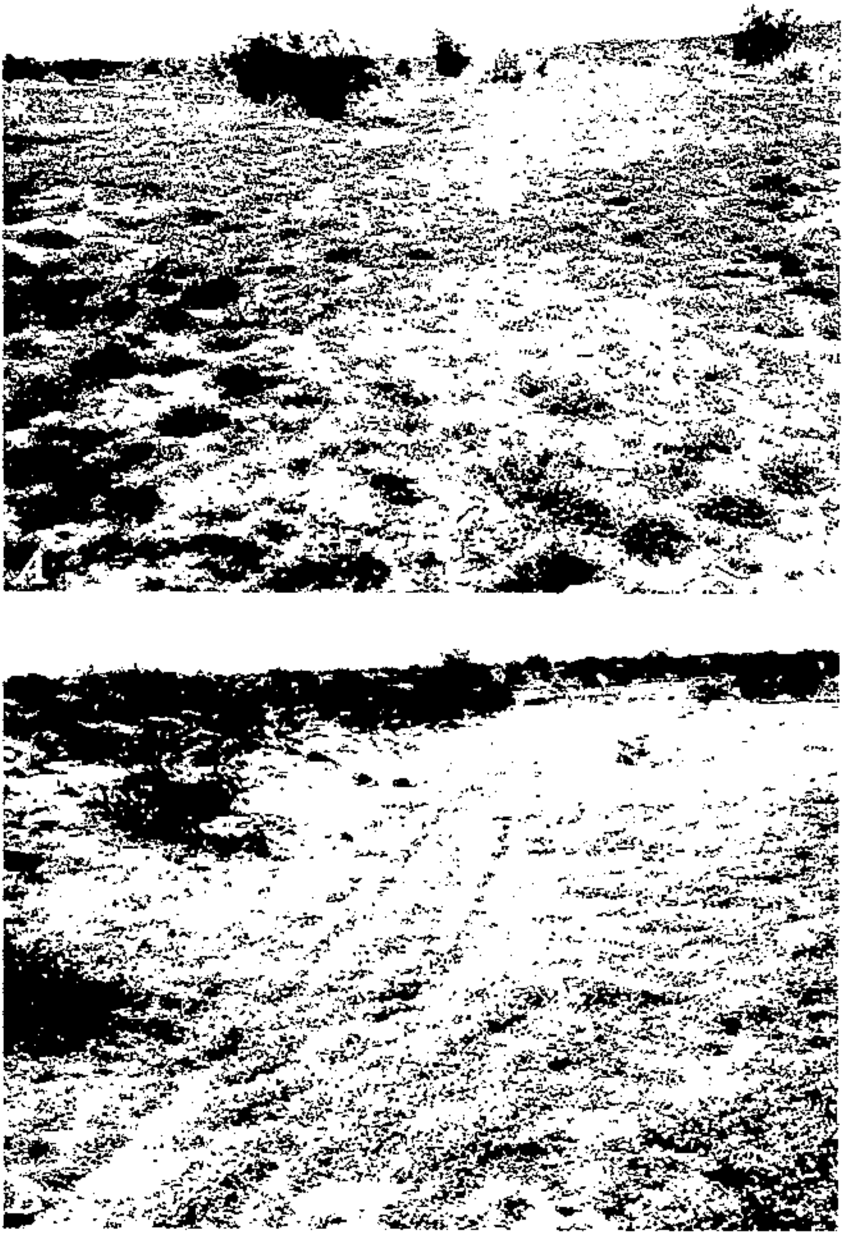

FIGURE 2.—Summer-fall host plants of the beet leafhopper: *A*, where 62 percent of the ground is covered by foliage of chinchweed (*Pectis papposa*) and 1 percent by *Tidestromia lanuginosa*; *B*, where about 80 percent of the ground is covered with *Tidestromia* and 8 percent with *Pectis*.

Beets planted from the middle of August to the early part of September in the Salt River Valley have been infested to a certain extent by the beet leafhopper as soon as they have germinated, and the numbers of the beet leafhopper in such fields have gradually increased until the middle of September. The numbers of leafhoppers at this time of year, however, have thus far not been considered injurious, except in the instance of fields with poor stands of plants. From the middle of September to late in October the leafhopper populations usually do not increase in the fields, although during the 1941 season an influx occurred October 4 to 6, principally from *Atriplex elegans*. This plant has been important as a host in only one season during the period 1935–41. The largest infestations in the seed-beet fields occur about October 25, with occasionally additional influxes late in November.

Beet leafhopper populations often increase in Arizona seed-beet fields during April and May, as a result of spring movement from winter annuals in the surrounding semidesert areas. These leafhoppers cause some damage, but not so much as that caused by an equal infestation in the fall when the beets are small.

The desert foothill areas around Safford also contain stands of chinchweed and some *Tidestromia* which are responsible for beet leafhopper infestations in beets grown for seed in that valley. Population counts were made during only two fall seasons in that area. In 1940 and 1941 moderate numbers of beet leafhoppers infested the beets by late September, but later increases did not occur.

In New Mexico

In New Mexico the foothill areas on both sides of the Mesilla Valley and portions of the Deming Plain are known to be important as a source of the beet leafhoppers that infest sugar beets grown for seed in that valley. Important host plants for the beet leafhopper in these areas during the summer include *Pectis papposa*, *Tidestromia lanuginosa*, *Trianthema portulacastrum*, and *Acanthochiton wrightii* Torr. Two generations of the beet leafhopper usually develop on these summer annuals, but it is principally the second-generation leafhoppers from this source that infest the seed beets in the valley late in September. Later infestations depend on food-plant conditions in the breeding source. In addition to the four summer plants just mentioned, a perennial peppergrass, or mustard, *Lepidium alyssoides* A. Gray, usually grows throughout the summer-breeding areas in New Mexico and Texas (fig. 1). This plant usually does not support large numbers of the beet leafhopper during September, although leafhoppers from it contributed to the infestation in the seed-beet fields along with those from other summer annuals late in September 1941. *L. alyssoides* in the breeding areas has been found to be more beneficial than detrimental to the seed industry in Mesilla Valley, since in its capacity as a host plant it holds more leafhoppers in the breeding source than it contributes to the cultivated areas. During the seasons when summer host plants were abundant and droughts had eliminated the stands of *L. alyssoides*, severe leafhopper infestations occurred in the beet fields, and influxes of this insect into the cultivated areas extended over a much longer period.

Spring infestations of the beet leafhopper in seed-beet fields occur also in New Mexico from late in April to the middle of June, but these infestations in the spring, like those discussed for Arizona, have been considered of minor importance in injuring the beet-seed crop with the curly top disease.

NUMBERS OF BEET LEAFHOPPERS REQUIRED FOR INJURY TO SEED BEETS

The density of the beet stands, the rate at which the soil becomes covered by beet leaves, and the degree of shading are important factors in determining the amount of curly top injury that will result from a given number of beet leafhoppers. It has been found that in thin stands of plants a reduction in the yield of seed may be caused by fewer leafhoppers than are necessary to cause this in dense stands. If a stand is so thin that the soil will not be completely covered by the plants as the result of their growth during the fall, it will be subject to injury by curly top. This will be especially so under the influence of warm fall and winter seasons which provide favorable conditions for leafhopper reproduction in the beet-seed fields. Another advantage enjoyed by thick stands of beet plants as compared with thin stands is that the shade and relatively low temperatures created by such stands among the plants provide unfavorable environmental conditions for the beet leafhopper, which typically and preferably inhabits situations where it is exposed to direct sunlight and relatively high temperatures. Furthermore, there are many varieties of beets considered to be resistant to curly top, and all these differ somewhat in their degree of susceptibility to the disease. The variety will also affect the growth of the plants and the degree of shading that will result.

These factors contribute greatly to the difficulty of designating any definite number of beet leafhopper adults and nymphs per unit length of row as being required before injury would be expected. Studies made during a 6-year period, however, have furnished the basis for an estimate of potentially injurious numbers. In a stand of 700 to 1,000 beets per 100 feet of row in the Salt River Valley of Arizona a fall infestation of from 125 to 150 leafhopper adults or nymphs per 100 feet of row will result, by the following April or May, in about 20 percent of the plants becoming infected with curly top. At least this percentage of affected plants is apparently required before the yield of seed is measurably reduced in stands of this density, but thin stands cannot tolerate such an infestation without a loss in yield. Observations made during two seasons in the Safford, Ariz., district indicate that somewhat similar numbers would be required to induce injury in that area. A fall infestation of only 75 to 100 beet leafhoppers per 100 feet of row in stands of 600 to 800 beets per 100 feet of row has caused sufficient injury in the Mesilla Valley, N. Mex., to warrant insecticidal control measures. In Arizona more growth takes place in the fall and winter than in New Mexico, and the average stands in New Mexico are thinner than in Arizona. The resulting difference in soil coverage in the two areas is probably largely responsible for the difference in numbers of beet leafhoppers required to cause conspicuous injury.

TYPE OF INJURY

The injury by the beet leafhopper to sugar beets as grown for either sugar or seed is in the transmission of the curly top virus. This virus causes a disease which reduces the yield of seed by preventing the more severely diseased plants from producing seed and by proportionately reducing the yield of less severely affected plants. The disease also retards the maturity of the seed, and in some instances there are indications that the viability is also affected.

The mechanical injury caused by the feeding or oviposition of the insect is negligible. Stahl and Carsner (*10*) showed that newly hatched nymphs did not carry the curly top virus, and that other nymphs did not carry it until after they had fed on a diseased plant. This may be either a wild desert host plant or a cultivated plant such as the sugar beet. The Bureau of Plant Industry at their Riverside, Calif., laboratory cooperated in obtaining information which would indicate that about 5 to 10 percent of the leafhoppers that infest the beets from the Arizona semidesert areas in the fall are capable of transmitting the disease at the time they come into the fields. This percentage increases rapidly, however, because of the feeding on diseased beets by leafhoppers not previously carrying the virus.

Wallace and Murphy (*11*) state that beets planted for sugar in Idaho are much more susceptible to curly top infection in the seedling stage than later and that resistance to curly top develops with age. This same phenomenon has been observed in connection with seed production in the Southwest. The prospects for seed production from a plant are increased as the beet increases in size before its infection by curly top, although infection occurring as late as April may reduce the yield. Figure 3 illustrates the effect of curly top on sugar-beet

FIGURE 3.—A healthy sugar-beet plant beginning to flower (right) compared with three plants (left) which are affected with curly top in varying degrees.

plants grown for seed. The plant on the left, which appears as a rosette clump on the ground, is so severely diseased with curly top that no seed stalk is being produced. The second beet from the left has a seed stalk, but is so severely diseased that it will probably produce no seed. The third plant from the left is also diseased but it will produce seed, although the amount will probably be much less than that yielded by the healthy or fourth plant from the left, which is 2 feet 8 inches high.

Figures 4, 5, and 6 illustrate the appearance of different amounts of curly top in stands of sugar beets grown for seed. The stakes shown in each figure are 3 feet high and are 3 feet 4 inches apart at the ground. The 3 photographs were taken in close proximity to one an-

FIGURE 4.—Portion of sugar-beet seed row with all 14 plants between the stakes affected with curly top.

other on the Snow Ranch in Mesilla Valley, N. Mex., May 9, 1941, on the variety U. S. 200×215. The 14 beet plants between the stakes in figure 4 were all diseased with an average severity of 2.9, according to the method of rating described by Giddings (*4*). Although records were not taken, the yield of 4 or 5 of the 14 plants in the group obviously would be much below that of healthy plants, and the remaining 9 or 10 plants would not produce any seed owing to the severity of the curly top disease. There were 21 beet plants between the stakes in figure 5, and 9 of them were diseased, with a severity rating of 3.0. Approximately one-third of the plants in this group would likely produce little or no seed. Only 1 of the 25 beets between the stakes in figure 6 was diseased with curly top and this plant is not visible in the photograph.

FIGURE 5.—Portion of sugar-beet seed row with 9 of the 21 plants between the stakes affected with curly top.

[illegible] 6.—Portion of sugar-beet seed row with 21 of the 25 plants between the stakes [illegible]. The diseased plant is not visible in the photograph.

EXPERIMENTS ON INSECTICIDAL CONTROL OF THE BEET LEAFHOPPER

DEVELOPMENT OF A SUITABLE INSECTICIDE AND SPRAY EQUIPMENT

In 1933 Cook (*1*) reported the use of pyrethrum-in-oil sprays for control of the beet leafhopper on fall host plants in California. It is known that the oils he used were not highly refined and that plant injury resulted, but large reductions were obtained in leafhopper numbers. The same year Lamiman (*7*) reported the use of refined white oil sprays against the grape leafhopper in California, stating that they were very effective but costly.

The first problem as it appeared in August 1935 was to develop a spray suitable for use on beet foliage that would not cause too much injury, since the proprietary pyrethrum-in-oil sprays available at that time burned the plants to some extent. During August and September 1935 undiluted kerosene and combinations of kerosene and highly refined white oils were applied with hand sprayers to beet foliage in a field near Phoenix, Ariz., to determine the degree of injury caused by these materials to the plants.

The undiluted kerosene seemed to cause varying degrees of injury in accordance with variations in weather conditions, but through the addition of a white oil the tendency to plant injury was reduced. The injury to the plants decreased in severity as the percentage of unsulfonated residue of the oils was increased. By October 1935 the following pyrethrum-in-oil spray was developed, and it has since proved to be satisfactory as an insecticide against the beet leafhopper:

	Parts
White oil (a highly refined petroleum oil having a viscosity of 90 to 100 seconds Saybolt at 100° F., and an unsulfonated residue of 94 percent)	10
Kerosene (a good grade of commercial kerosene complying with Federal Specification VV-K-211)	20
Pyrethrum extract (an extract of pyrethrum flowers in petroleum oil having a pyrethrin content of not less than 2.0 gm. pyrethrins per 100 cc.)	1

By November and December 1935 this insecticide was being commercially applied on seed-beet fields at the rate of 6 gallons per acre with the machine illustrated in figure 7, *A*. A machine of this type was first used for control of the beet leafhopper on sugar beets grown for seed at Litchfield Park, Ariz., October 21 to 25, 1935, and since that time it has been used for both commercial and experimental spraying. This insecticide and equipment were used in all experiments reported in this bulletin, except those on table beets during the 1935–36 season. Later work showed that the 6-gallon rate was sufficient at temperatures ranging from 50° to 75° F., but that at higher temperatures more insecticide must be used, until at temperatures above 95° as much as 9 gallons per acre was necessary to obtain satisfactory reductions in leafhopper numbers. Wind velocities of from 8 to 10 miles per hour 4 feet above the ground did not interfere with spray operations, but if the rate of application is increased both temperature and wind velocity should be considered.

Two types of spray machines were available, in one (fig. 7, *A*), the use of which was described in the previous paragraph, a small jet of pyrethrum-in-oil was injected at low pressure into a rapidly moving air stream, whereas the other (fig. 7, *B*) atomized the oil at about 60 pounds' pressure through a paint-gun type of nozzle. This machine also gave good results through application of 6 gallons per acre at the

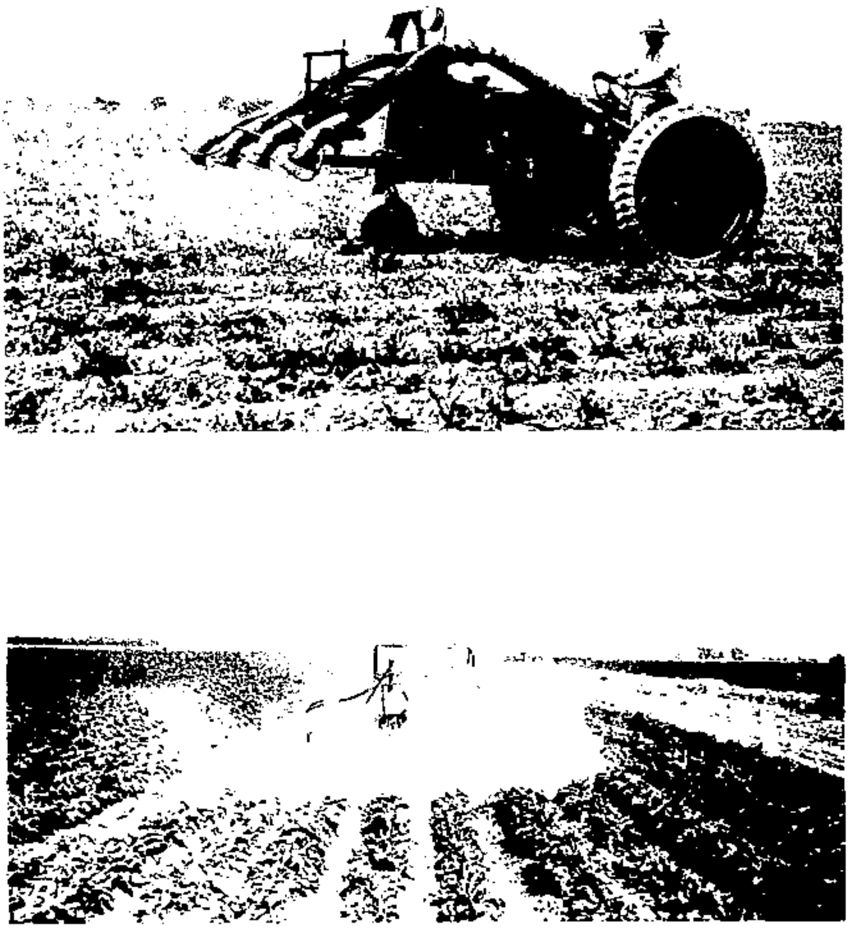

FIGURE 7.—*A*, Low-pressure machine spraying a poor stand of beets for the control of the beet leafhopper in the Salt River Valley of Arizona September 25, 1940; *B*, high-pressure machine spraying table beets at Rittenhouse, Ariz., November 15, 1936.

lower temperatures. Both types of sprayers were satisfactory for applying pyrethrum-in-oil sprays, although the acreage capacity of the low-pressure machine was greater.

Campbell (2) used pyrethrum-in-oil sprays in 1936 and showed that substantial reductions in the number of beet leafhoppers were obtained by use of both airplane and ground equipment. Douglass, Wakeland,

and Gillett (3) conducted experiments in 1936 and 1937 in which pyrethrum-in-oil sprays were found to be very effective against the beet leafhopper but did not appreciably reduce curly top injury or increase the yield in the experimental plots. The latter results were partly attributed to the redistribution of the leafhoppers over the plots after each spray application.

Experimental Methods

The effectiveness of the spray treatments was judged by the reduction in numbers of leafhoppers, the percentage of plants having curly top, the yield of the beet seed, and the percentage of germination of the seed. The plot arrangements varied from year to year, as will be described in the discussions of the individual experiments.

The numbers of beet leafhopper adults and nymphs that survived the treatments were obtained by sampling with the aid of a cage described by Hills (5) or with a similar cage with shorter sides and a removable lid which was found to be more convenient for counting nymphs. Counts were made in 1-square-foot unit areas of beet row located at random. Approximately 50 such sampling units were examined per acre before application and 100 after application.

Plots sprayed in the fall together with the unsprayed plots were sampled the following April or May to determine the plant stand and the percentage of plants affected by curly top. All plants within sampling units of 1 or 2 linear feet of row in the different experiments were counted and examined for curly top symptoms. The sampling units were located systematically in such a manner as to be well distributed over the central one-third to one-half of each plot.

The yield of beet seed per plot was obtained either by systematic sampling or by harvesting all seed from a definite central portion. The seed was threshed and cleaned by use of mechanical equipment.

The percentage of seed balls having viable seed was determined by a commercial concern, and for this purpose the sample for each plot was 400 seed balls.

Temperature data were obtained by a thermometer the bulb of which was placed in the shade at half the height of the plants. Wind velocity was measured by a portable anemometer placed 4 feet above ground.

Field Experiments, 1935 to 1941, Inclusive

PRELIMINARY EXPERIMENTS

Preliminary experiments were conducted at Litchfield Park, Ariz., October 21 to 25, 1935. The low-pressure machine (fig. 7 *A*) was used to apply various pyrethrum-in-oil sprays at the rate of about 6 gallons per acre. The temperature during the applications ranged from 80° to 90° F., and the reduction in adults of the beet leafhopper ranged from 71 to 84 percent. On the basis of these results commercial applications were undertaken on beets grown for seed in Arizona and New Mexico. During the progress of these applications data were obtained to determine the percentage of reduction in leafhoppers by sampling just before and again 24 hours after the spraying. These data are given in table 1.

TABLE 1.—*Reduction in beet leafhopper numbers obtained by commercial applications of pyrethrum-in-oil with the low-pressure machine at varying temperature ranges and rate of application in New Mexico and Arizona, 1935*

Date of application	Temperature during application	Rate of application per acre	Beet leafhopper adults per 100 feet of row		Reduction of leafhoppers
			Before application	24 hours after application	
	° F.	*Gallons*	*Number*	*Number*	*Percent*
Nov. 12	58-60	5.3	119	17.5	85
Do.	61-62	5.3	120	16.0	87
Nov. 13	50-52	6.0	203	16.4	92
Nov. 18	70-71	6.2	148	5.4	96
Nov. 19	67-68	6.2	105	5.3	97
Nov. 20	64-66	6.2	115	3.5	97
Nov. 23	65-67	6.0	70	4.0	94
Nov. 26	55-56	6.0	137	5.0	96
Dec. 6	52-54	6.2	282	0	100
Dec. 11	60-62	6.0	279	5.7	98
Dec. 12	58-60	5.7	390	31.6	92

The pyrethrum-in-oil was applied at an average rate of 5.9 gallons per acre at a time when there was little or no wind. The average reduction in the adult beet leafhopper population under these conditions was 95 percent. Later experiments showed a slightly higher percentage of reduction of nymphs than adults obtained by a given application.

Six experiments with a high-pressure type of machine (fig. 7, *B*) applying a proprietary pyrethrum-in-oil spray at the rate of about 6 gallons per acre to table beets in Texas showed an average reduction in adult leafhoppers of 96 percent during this same period.

SEASON OF 1935-36

During November and December 1935 commercial spraying with a pyrethrum-in-oil spray was done on large acreages of sugar beets in the Mesilla Valley of New Mexico and in fields of table beets southeast of El Paso in Texas. Arrangements were made to have an unsprayed strip left in a number of fields to study the effect of the spraying. The unsprayed strips ranged from ½ to 1¼ acres in area depending on the size of the field. In the sugar-beet fields, Nos. 1, 2, and 3 in table 2, only one spray application was made. In the table-beet fields, Nos. 4, 5, and 6, a second spray application was made in such a manner that a strip sprayed twice and a strip sprayed once could each be compared with the untreated plot. The plot sprayed once in field 6 was ruined by root rot. Observations for curly top were made late in April by examining 22 to 66 1-foot strips of row located at random in each plot. The yield of seed was obtained in from 30 to 60 4-foot strips of row in each plot.

TABLE 2.—*Results obtained by commercial applications of pyrethrum-in-oil for control of the beet leafhopper, as indicated by strip-plot experiments in New Mexico and Western Texas*

Field No.	Variety	Dates of spraying	Beets per 100 feet of row	Beet leafhopper adults per 100 feet of row: Dec. 8-16, 1935	Beet leafhopper adults per 100 feet of row: Feb. 1-2, 1936	Plants showing evidence of curly top	Plants severely affected by curly top per 100 feet of row	Yield of cleaned seed per acre	Increase in yield over untreated check	Viable seed balls
			No.	*No.*	*No.*	*Pct.*	*No.*	*Lb.*	*Pct.*	*Pct.*
1	U. S. 217	Dec. 14, 1935	885	16	28	57.7	180	1,173	44.5	35.0
		Check	895	166	182	80.7	533	812	----	32.5
2	Standard Great Western.	Nov. 22, 1935	608	----	66	57.7	222	507	22.5	40.8
		Check	582	223	300	91.7	372	463	----	35.8
3	Standard Great Western.	Nov. 29, 1935	438	28	42	53.7	186	777	28.9	36.3
		Check	456	123	145	78.2	246	603	----	34.8
4	Detroit Dark Red	Dec. 8, 1935	286	4	506	----	131	721	28.5	----
		Dec. 8, 1935, and Feb. 22, 1936.	325	----	----	----	122	1,022	82.5	35.0
		Check	333	297	825	----	261	500	----	31.0
5	Early Wonder	Dec. 9, 1935	494	10	280	----	74	583	39.8	----
		Dec. 9, 1935 and Feb. 23, 1936	510	----	----	----	89	607	45.6	27.0
		Check	462	150	440	----	136	417	----	15.0
6	Crosby's Egyptian	Dec. 10, 1935, and Feb. 22, 1936.	683	26	550	92.1	186	372	78.8	20.8
		Check	584	391	750	98.5	441	208	----	17.5

Shortly after the first spray application, during the period December 8 to 16, fewer beet leafhoppers were found in the sprayed than in the unsprayed plots. An influx of beet leafhoppers occurred between December 15 and 23, and examinations on February 1 and 2 showed that the number of leafhoppers had increased in all plots. The marked increase of leafhoppers in fields 4, 5, and 6 after the first application made a second application seem advisable, but it was not applied until late in February. A survey made in March showed that the number of leafhoppers had decreased in all plots. Notwithstanding the shifting of leafhoppers from plot to plot and the late applications, the treatments resulted in marked reductions in leafhopper numbers, accompanied by reductions in curly top incidence, and increases in the yield of seed. The average yield of plots receiving one application was 34 percent greater than it was for the untreated plots and for two applications it was 69 percent greater. There was a great deal of curly top damage, even in the sprayed strips, and yields were poor in all cases.

The extremely low percentage of germinating seed produced is undoubtedly largely due to factors other than curly top. Hills (6) later showed by cage experiments that *Lygus* bugs reduce the percentage of viable seed. These insects were abundant in the fields that season and they were probably a factor in causing the low germination. There was little difference in the percentage of seed balls having viable seed in the sprayed and unsprayed plots.

SEASON OF 1936-37

The planting for seed of beet varieties which were nonresistant to curly top was discontinued in the Mesilla Valley, N. Mex., in the fall of 1936, and beet leafhopper infestations were very light in Arizona where the susceptible varieties were still planted. A rather isolated field of beets near Buckeye, Ariz., contained a moderate infestation by late October. The variety was Great Western No. 5, and at that time its degree of resistance to curly top was not known although later it was found to be approximately as resistant as U. S. 33. A randomized block experiment consisting of 12 one-half-acre plots with 3 replicates of 4 treatments was placed in the northwest corner of the field. The treatments consisted of plots sprayed twice, November 6 and 30; plots sprayed once, November 6; plots sprayed once, November 30; and the unsprayed checks. The quantity of insecticide used in this experiment and those of subsequent seasons, except those connected with commercial applications, was sufficiently high to insure a large percentage of reduction in beet leafhopper populations, since it was recognized that some shifting of the leafhoppers occurred between these comparatively small plots. Six plots were sprayed November 6, 1936, with pyrethrum-in-oil at the rate of slightly over 9 gallons per acre with the low-pressure machine (fig. 7, *A*). Temperatures during the application ranged from 68° to 78° F., and wind velocities ranged from a slight breeze up to 15 miles per hour. The average reduction in adult beet leafhoppers under these conditions was 93.8 percent. On November 30 six plots were sprayed with the same rate of application as was given November 6. The temperature ranged from 61° to 62° with no wind and under cloudy and high-humidity conditions. The average reduction in beet leafhopper numbers under these conditions was 93.7 percent. The results from these treatments are given in table 3.

TABLE 3.—*Results obtained by spraying curly top resistant beets with pyrethrum-in-oil near Buckeye, Ariz., for control of the beet leafhopper, as indicated by 3 replications of 4 treatments made during November 1936*

Dates of spraying	Beet leafhopper adults per 100 feet of row on—			Plants showing evidence of curly top[1]
	Nov. 7	Dec. 1	Dec. 14	
	Number	*Number*	*Number*	*Percent*
Nov. 6 and 30	9	3	45	0.017
Nov. 6	10	141	166	.055
Nov. 30	138	3	49	.071
Checks	157	274	282	.224
Difference required for significance				.079

[1] Observations of Apr. 29 to May 1, 1937.

The number of leafhoppers recorded for November 7, 24 hours after the first application, demonstrated that large reductions had occurred. Counts were made on December 1, 24 hours after the second application, and much larger reductions were found owing to more favorable weather at the time of application. Beet leafhoppers averaged 151 per 100 feet of row on November 6 for all 12 plots. The 6 plots as yet untreated on November 30 contained an average of 225 adults per 100 feet of row, which showed that there had been an increase. During the 2 weeks following the second application additional increases occurred.

The percentages of plants affected with curly top were obtained by examining the plants in 75 2-foot lengths of row in each plot during the period from April 29 to May 1, 1937. This involved from 1,700 to 2,000 plants per plot. There was a reduction in the percentage of diseased plants even though less than 1 percent of the unsprayed plants were diseased. Owing to the small percentage of diseased plants in the unsprayed checks, seed yields were not taken. A factor contributing to the small percentage of diseased plants, aside from the plants being moderately resistant to curly top, was the thickness of the stand, there being more than 12 plants per linear foot of row in the field. Obviously it was not worth while, under the conditions of this experiment, to spray for the control of the beet leafhopper.

SEASON 1937–38

Two experiments were conducted near Buckeye, Ariz., during the 1937–38 season on sugar beets of the variety Standard Great Western. Each experiment comprised 4 treatments on plots of one-half acre arranged in a Latin square. The 4 treatments planned were 1 early spraying, 1 late spraying, 2 sprayings (1 early and 1 late), and the unsprayed check. After the first application in experiment 1 it was found that the numbers of beet leafhoppers were rapidly decreasing owing to the unfavorable environment caused by dense beet foliage, so this experiment was left with 8 plots sprayed once, October 30, 1937, and 8 plots unsprayed. The pyrethrum-in-oil spray was applied with the low-pressure machine at the rate of 10 gallons per acre. The temperature during the application ranged from 88° to 89° F., and the wind velocity from 7 to 8 miles per hour 4 feet above the ground. The average reduction of beet leafhoppers under these conditions was 94 percent for adults and 99 percent for nymphs. Curly top data were obtained by the examination of all the plants in 15 2-foot lengths of row in each plot. The yield of seed per acre was determined by harvesting the seed from 32 3-foot lengths of row in each plot. The results from experiment 1 are given in table 4.

TABLE 4.—*Results from spraying with pyrethrum-in-oil for control of the beet leafhopper in experiment 1, October 30, 1937, near Buckeye, Ariz.*

Treatment	Beet leafhopper adults and nymphs per 100 feet of row on—			Plants showing evidence of curly top [1]	Plants severely affected by curly top	Yield of cleaned seed per acre	Viable seed balls
	Nov. 1, 1937	Dec. 21, 1937	Jan. 21, 1938				
	Number	*Number*	*Number*	*Percent*	*Percent*	*Pounds*	*Percent*
Sprayed	9	26	34	41.1	10.8	1,011	78.0
Not sprayed	401	96	77	62.5	25.3	852	75.9
Difference required for significance				8.5	4.9	144	(2)

[1] Curly top counts by systematic samples made May 23–25, 1938.
[2] Difference not significant.

Owing primarily to dense leaf growth, the numbers of leafhoppers in the unsprayed plots decreased from 401 per 100 feet of row on November 1 to 96 on December 21 and to 77 by January 21. Leafhopper numbers in the sprayed plots increased slightly during this same period. On November 1 the beet leaves covered about 40 percent of the soil surface; on November 30 they covered about 80 percent.

and by December 21 approximately 95 percent. The smaller number of leafhoppers in the sprayed plots as compared with the unsprayed plots resulted in a significantly lower percentage of plants developing curly top, and a significant increase in the yield of cleaned seed. Curly top counts made May 23 to 25, 1938, showed a 34.2-percent decrease in the total disease and a 57-percent decrease in severely diseased plants in the sprayed plots as compared with the unsprayed plots. The average yield of cleaned seed from the sprayed plots exceeded that produced by the unsprayed plots by 55.1 percent. More seed stalks were produced in the sprayed than in the unsprayed plots, owing presumably to the denser shade and therefore lower temperatures in the sprayed plots. This agrees with the findings of Owen, Carsner, and Stout (*9*). Seed stalks late in May averaged 230 per 100 feet of row in the sprayed plots, and 192.9 per 100 feet of row in the unsprayed plots. The plots contained an average of 1,031 plants per 100 feet of row. The percentage of viable seed did not appear to be affected by the treatment.

The average seed increase of 359 pounds per acre due to the one spray application was worth $30. The cost of the treatment at the 10-gallon rate was approximately $5 per acre, showing a net gain of $25.

In experiment 2 of the 1937–38 season eight plots were sprayed November 5 with an average of 10 gallons of pyrethrum-in-oil spray per acre. The temperature range during the application was 76° to 89° F., and there was a slight breeze. Beet leafhopper reduction under these conditions averaged 92 percent for adults and 98 percent for nymphs. Eight plots were sprayed November 27 with an average of 6¾ gallons of the insecticide per acre. The temperature range during the application was 66° to 74° and there was a slight breeze. The average reduction was 89 percent for adults and 93 percent for nymphs. The curly top data were obtained from a central portion of each plot, measuring 33 by 97 feet, by examining all beets in 56 sampling units of 2 feet of row each. The yield of seed was obtained by harvesting all seed from the same central portions in each plot, as were staked for curly top counts.

The results from the treatments in experiment 2 are given in table 5.

TABLE 5.—*Results from spraying with pyrethrum-in-oil for control of the beet leafhopper during the 1937–38 season, as indicated by experiment 2 near Buckeye, Ariz.*

Dates of spraying (1937)	Beet leafhopper adults and nymphs per 100 feet of row on—			Plants showing evidence of curly top [1]	Plants severely affected by curly top	Yield of cleaned seed per acre	Viable seed balls
	Nov. 6, 1937	Nov. 29, 1937	Jan. 18, 1938				
	Number	*Number*	*Number*	*Percent*	*Percent*	*Pounds*	*Percent*
Nov. 5 and 27	17	7	78	40.2	9.9	143	50.3
Nov. 5	19	55	128	50.1	15.7	142	52.1
Nov. 27	632	47	126	50.5	18.1	115	50.7
Check	578	529	531	76.7	32.8	79	50.7
Difference required for significance				12.7	8.4	(2)	(2)

[1] Curly top counts by systematic samples made May 10–20, 1938.
[2] According to the *F* test these differences were not significant.

Within the plots there were, on an average, 1,267 beets per 100 feet of row. Fewer leafhoppers survived in the 4 plots sprayed twice than in any of the other plots, although the single-application treatment gave fair control. Only 4 or 5 percent of the beets produced seed stalks, consequently the yield in all plots was extremely low. Production of seed stalks was depressed by various factors unfavorable for growth and reproduction besides curly top, including infestation of the soil by root-knot nematodes, low soil fertility, and high temperatures accentuated by incomplete shading of the soil by the leaves.

SEASON OF 1939–40

During the winter of 1939–40 a single randomized block experiment was conducted with 10 replicates of 2 treatments in a field of reasonably uniform fertility west of Coldwater, Ariz. The variety of beet was American No. 1, and the plots measured 100 by 123 feet. The yield data were obtained by harvesting from each plot all seed from an area in the central portion measuring 27½ by 32 feet. On November 6 and 7, 1939, 10 plots were sprayed with an average of 6 gallons of pyrethrum-in-oil per acre. The temperature during the application ranged from 68° to 76° F., and there was no wind. The average adult beet leafhopper reduction was 92 percent, and at that time nymphs were scarce. The results of this experiment are shown in table 6.

TABLE 6.—*Results obtained by spraying with pyrethrum-in-oil for control of the beet leafhopper, as indicated by 10 replications of 2 treatments made November 6 and 7, 1939, near Coldwater, Ariz.*

Treatment	Approximate soil coverage by beet leaves on—		Beet leafhopper adults and nymphs per 100 feet of row on—		Plants showing evidence of curly top[1]	Plants severely affected by curly top	Yield of cleaned seed per acre	Viable seed balls
	Nov. 8	Dec. 20	Nov. 8	Dec. 20				
	Percent	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Pounds*	*Percent*
Sprayed	45	70	28	72	43.5	23.2	1,208	69.6
Not sprayed	45	70	332	213	71.9	48.6	989	69.6
Difference required for significance					5.0	4.5	102	

[1] Curly top counts by systematic samples made April 19–20, 1940.

Curly top counts made April 19 and 20, 1940, showed a 39.5-percent decrease in total curly top and a 52.3-percent decrease of severely diseased plants in the sprayed plots as compared with the unsprayed plots. The average yield of clean seed from the sprayed plots exceeded that from the unsprayed plots by 22.1 percent. The sprayed plots contained an average of 319 seed stalks per 100 feet of row compared with 210.5 in the unsprayed plots. There were, on an average, 580 plants per 100 feet of row in the plots. There was no difference in the percentage of seed balls having viable seed.

The average seed increase of 219 pounds per acre due to the one spray application was worth $18.62. The cost of the treatment at the 6-gallon rate was approximately $3.50 per acre, which showed a net gain of $15.12.

Photographs were taken of all plots April 18, 1940, from the same position with respect to each plot. Figure 8, *A*, depicts an unsprayed

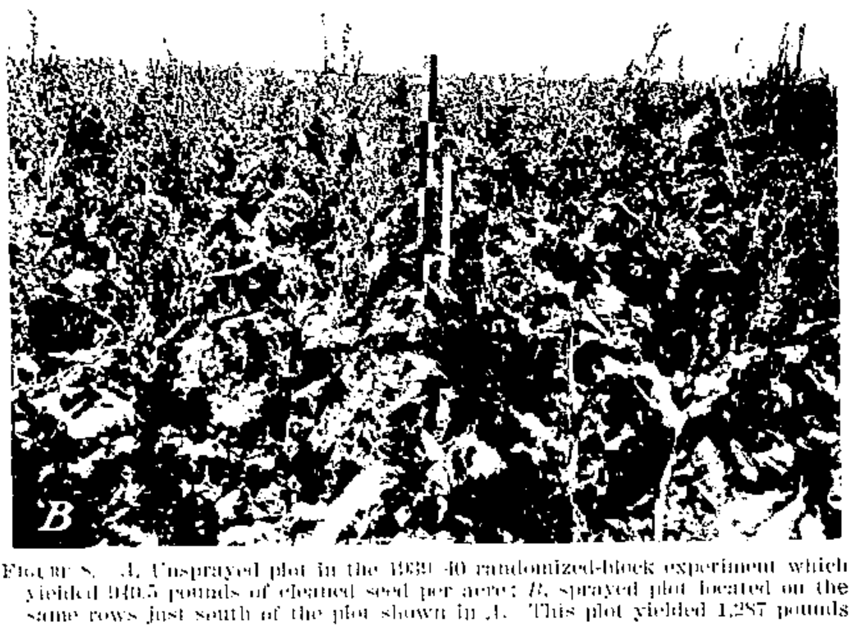

FIGURE 8. *A*, Unsprayed plot in the 1939–40 randomized-block experiment which yielded 940.5 pounds of cleaned seed per acre; *B*, sprayed plot located on the same rows just south of the plot shown in *A*. This plot yielded 1,287 pounds of clean seed per acre.

plot in the 1939–40 randomized-block experiment which yielded 940.5 pounds of cleaned seed per acre. An average of 66.7 percent of the plants in the plot showed obvious curly top disease at this time. Figure 8, *B*, depicts a sprayed plot which was located on the same rows of beets just south of the unsprayed plot shown in figure 8, *A*. The sprayed plot yielded 1,287 pounds of cleaned seed per acre. An average of 31 percent of the plants in this plot showed obvious curly top disease on April 18. More seed stalks are apparent in the photograph of the sprayed plot, and they are taller than those shown in the picture of the unsprayed plot.

SEASON OF 1940–41

A moderate beet leafhopper infestation was found to exist in the seed-beet fields of Mesilla Valley late in September 1940. This was the earliest in the season that injurious infestations had been found. About 500 acres of nonresistant beets grown for seed (variety U. S. 200×215) were sprayed commercially during the period October 4 to 25, 1940, in this valley. Leafhopper numbers at the time of treatment ranged from 50 to 184 per 100 feet of row. The rate of application, with a low-pressure machine, averaged about 6 gallons of pyrethrum-in-oil spray per acre and the temperatures during the applications were comparatively high. Limited examinations of the leafhopper populations after spraying indicated that reductions ranged between 70 and 80 percent.

A pair of experimental plots was provided in each of 5 fields by arranging for the spray operators to leave unsprayed a 24-foot strip across each field. During the period May 8 to 12, records were made of the stand of plants and of the incidence of curly top by examining 30 sampling units in each plot. The sampling units for this purpose included 25 consecutive plants each. The results as presented in table 7 indicate that spraying reduced considerably the percentage of plants showing evidence of curly top as well as the percentage of plants severely affected. The injury to the unsprayed plots by curly top was sufficient to warrant a spray application in the Black Mesa and Snow Ranch fields where the plant stand was relatively thin. In the Santo Tomas fields, however, there was a thicker stand of plants, and the injury was not sufficient to have warranted the application of insecticides.

TABLE 7.—*Curly top incidence in sugar beets as affected by plant stand and by the commercial application of pyrethrum-in-oil spray for the control of the beet leafhopper, Mesilla Valley, N. Mex., 1940–41*

Field	Beets per 100 feet of row		Plants showing evidence of curly top		Plants severely affected by curly top	
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Black Mesa	208	214	25.3	46.8	18.5	34.0
Snow Ranch No. 1	400	472	21.5	33.1	17.1	27.2
Snow Ranch No. 2	487	448	18.4	33.7	12.5	25.5
Santo Tomas No. 1	747	627	3.6	11.2	2.1	7.3
Santo Tomas No. 2	648	798	2.0	3.6	1.2	1.9

CULTURAL CONTROL

Beet leafhopper control by cultural methods has been found effective in reducing curly top injury in nonresistant varieties of beets. Early planting, good stands, and care conducive to rapid growth until the leaves almost completely shade the soil have greatly reduced curly top in seed-beet fields of the Salt River Valley, Ariz. Under favorable conditions in this locality beets planted from the middle of August to the early part of September may almost completely cover the soil by late in October when large leafhopper influxes sometimes occur. Damaging numbers rarely infest fields in that valley before late October, except in those fields with thin stands. The field shown in figure 9, *A*, was first irrigated on September 2, 1940, a few days after it was planted in dry soil. On October 25, or 53 days later, the beet leaves shaded about 98 percent of the soil surface. Such fields as this have been found to be unfavorable en-

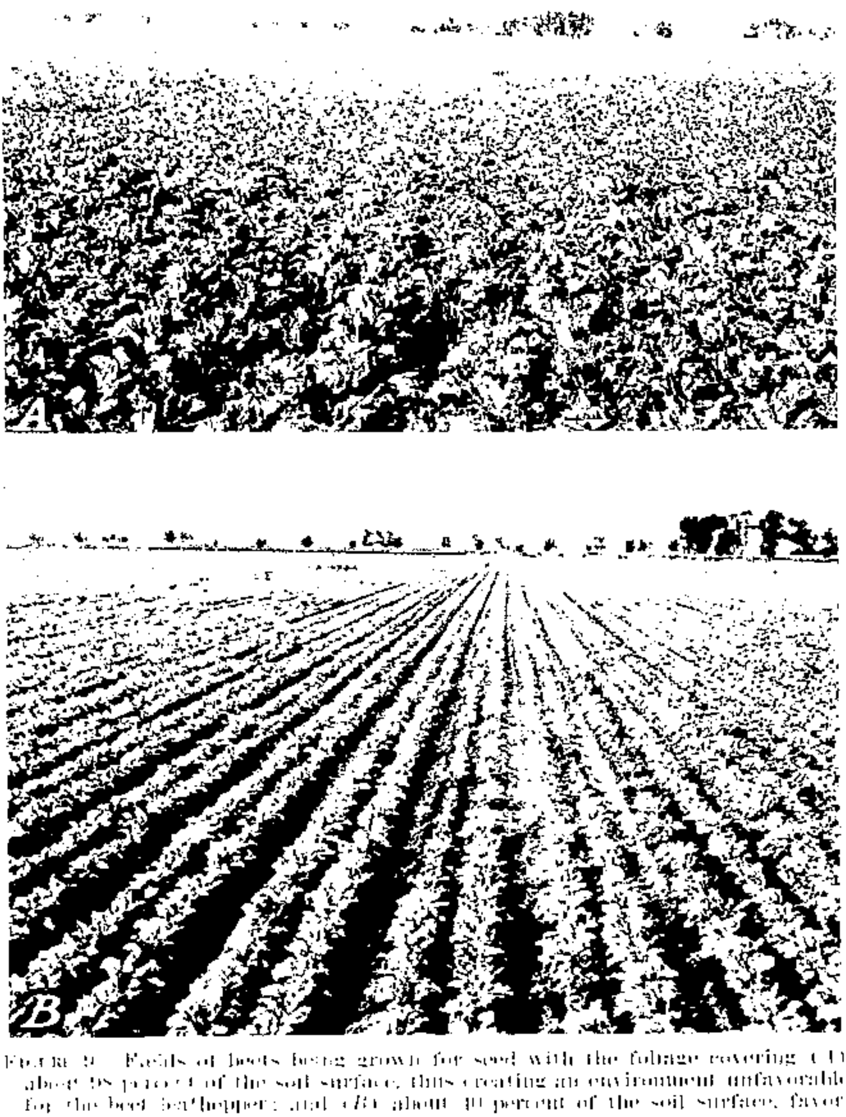

FIGURE 9.—Fields of beets being grown for seed with the foliage covering (*A*) about 98 percent of the soil surface, thus creating an environment unfavorable for the beet leafhopper; and (*B*) about 40 percent of the soil surface, favorable for leafhopper infestations.

vironments for the beet leafhopper. By the time the foliage covers about 80 percent of the soil in the fields, beet leafhopper adults begin to leave them, and fields with 90 to 98 percent of the soil covered with leaves have invariably been found to contain small numbers of leafhoppers. Furthermore, leafhopper reproduction does not occur in fields where the foliage is dense. Fields with poor stands or poor growth (fig. 9, *B*), or both, are subject to October and November infestations, and there may be late fall and late winter reproduction in them during exceptionally warm winters such as that of 1939–40. Fields with considerable soil surface exposed during the winter months may, under such conditions, be severely damaged.

A number of fields with different degrees of soil coverage by beet leaves were sampled in the Tolleson, Ariz., district early in November 1939 to determine the number of beet leafhoppers in them. Seven fields with an average estimated soil coverage of 38 percent contained an average of 137.1±2.8 beet leafhoppers per 100 feet of row, compared with 4.3±0.02 leafhoppers per 100 feet of row in the same number of fields with an average estimated soil coverage of 98 percent.

Several examples showing the effect of foliage cover on beet leafhopper populations should bring out its importance. The beet leafhopper population data in table 4 for the unsprayed plots showed a drastic decrease in leafhopper numbers between November 1 and December 21, and a smaller but definite further decrease from December 21 to January 21. These decreases in leafhopper numbers were probably due to an increase in the density of the foliage, since on November 1 the foliage covered about 40 percent of the soil surface, on November 30 about 80 percent, and about 95 percent on December 21. The beet foliage in experiment 2 (table 5) did not cover more than 75 percent of the soil surface during the winter, and leafhopper numbers in this field remained relatively constant in the unsprayed plots between November 6 and January 18. A third field studied this same season, with a maximum of 40 percent coverage during the winter, contained an average of 246 beet leafhopper adults and nymphs per 100 feet of row on October 26, and by late January the numbers had increased to an average of 610 per 100 feet of row. This increase was due principally to adults coming into the field and not as a result of reproduction.

Good cultural practices will also reduce losses from curly top in nonresistant varieties in the Mesilla Valley of New Mexico, but they have not been so effective in reducing leafhopper populations there as in the Salt River Valley of Arizona. Moderate leafhopper infestations have occurred in the Mesilla Valley as early as the middle of September, when the beets were still small, and under such conditions insecticidal control measures are needed. Owing to a colder climate in New Mexico than that in Arizona, it is more difficult to obtain the rapid growth of the beets necessary for early soil coverage. In some seasons the seed-beet fields in the Mesilla Valley are subject to large leafhopper infestations during late October and later; therefore every effort should be made to obtain a dense leaf growth by that time in order to avoid the necessity of insecticidal control.

Data from the Safford, Ariz., district are limited, but the indications are that control of curly top by cultural practices in that district will be a little more difficult than in the Salt River Valley, since beets in that area make slower fall growth and are subject to damaging beet leafhopper infestations in September while the beets are still small.

SUMMARY

Beets grown for seed in the Salt River and Safford Valleys of Arizona and in Mesilla Valley, N. Mex., are subject to fall infestations of the beet leafhopper (*Eutettix tenellus* (Bak.)). This insect transmits from plant to plant a virus disease known as curly top. The source of the leafhoppers that infest the fields is principally from adjacent semi-desert areas where summer rains germinate such plants as chinchweed (*Pectis papposa*), *Tidestromia lanuginosa*, *Trianthema portulacastrum*, and *Acanthochiton wrightii*, which serve as host plants from July to September or later. The second generation of leafhoppers from these plants usually infest the beets, although in Arizona when September rains are heavy the third and fourth generations of leafhoppers produced on summer host plants may also infest beets in the Salt River Valley.

The variety of beet, the stand of plants, the rate at which the soil surface becomes covered by beet foliage, and the degree of shading are important factors in determining the number of beet leafhoppers a field of seed beets can tolerate without noticeable damage from curly top. Observations made on nonresistant varieties indicate that in Arizona, with from 700 to 1,000 plants per 100 feet of row, 125 to 150 beet leafhoppers per 100 feet of row are required to cause appreciable damage, since such stands can tolerate about 20 percent of the plants being affected by curly top. An infestation of only 75 to 100 beet leafhoppers per 100 feet of row in stands of 600 to 800 beets per 100 feet of row has caused sufficient injury in the Mesilla Valley, N. Mex., to warrant insecticidal control measures. In both districts it has been found that in thin stands of plants a reduction in the yield of seed may be caused by fewer leafhoppers than are necessary to cause similar injury in dense stands.

The curly top disease reduces the seed yield of beets grown for seed somewhat in proportion to the severity of the disease. Plants severely diseased by late April do not usually produce seed, whereas others less severely diseased produce seed but less of it than do healthy plants. The disease apparently does not materially reduce the viability of the seed.

Experiments conducted during a 6-year period (1935–41) have shown that significant reductions in the incidence of curly top and increases in the seed yields occurred when the seed-beet fields were sprayed in the fall with pyrethrum-in-oil for control of damaging infestations of the beet leafhopper. Applications made at the rate of 6 to 9 gallons per acre caused satisfactory reductions in beet leafhopper numbers in the fields. The 6-gallon rate was found to be sufficient at temperatures from 50° to 75° F. As the temperature rises above 75° the rate should be increased until at about 95° as much as 9 gallons per acre may be necessary to obtain large reductions. Wind velocities above 8 to 10 miles per hour also limit the effect of the insecticide, and both temperature and wind velocity should be considered when deciding on the rate of application. The spray should be applied as soon as possible after damaging beet leafhopper infestions occur in the seed-beet fields, such as were usually found in September, late October, or late November; the time coinciding with leafhopper brood development or host-plant drying in the semidesert breeding areas.

The more severe infestations of the beet leafhopper have occurred in late October or later in both Arizona and New Mexico. Beets planted from the middle of August to the early part of September and given good cultural care can usually be made practically to cover the soil surface in the fields with foliage within about 50 days. Fields with over 95 percent of the ground covered with beet foliage have been found to provide an unfavorable condition for the beet leafhopper, and if this condition is attained by late October or sooner, such fields will apparently not be subject to subsequent infestations and injury by the leafhopper. Such cultural practices are highly recommended as an aid to the reduction of injury by the beet leafhopper.

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