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MOVEMENTS OF THE BEET LEAF HOPPER IN 1930 IN SOUTHERN IDAHO

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INTRODUCTION

The beet leaf hopper, *Eutettix tenellus* Baker, is the vector of curly top, a disease of sugar beets, beans, tomatoes, and other crops. It is generally distributed throughout the States west of the Rocky Mountains, except in places where winter temperatures are too severe (as in Montana) or in certain coastal climates in Oregon, Washington, and California. This insect breeds in desert areas, where it completes the early summer brood or broods on the spring annuals. These annuals mature and disappear early in the season, and the leaf hoppers fly to places where green host plants are available, including irrigated sections where certain cultivated crops serve as the summer hosts. These flights may carry the insects many miles from their breeding grounds. In some breeding areas a portion of the insects remain in the desert on summer annuals. This is true in southern Idaho, where Russian thistle (*Salsola pestifer* A. Nels.) maintains large populations in the desert during the summer after the mustards, chiefly *Norta altissima* (L.) Britton and *Sophia parviflora* (Lam.) Standl., have matured and dried.

The important breeding areas surrounding Twin Falls, Idaho, are the result of removal of the native sage cover for farming and later abandonment of the farms, and the overgrazing of native sage by sheep. In both cases the mustards and Russian thistle commonly come in and furnish abundant food for production of the spring

[1] The writers wish to acknowledge their indebtedness to other members of the staff who have assisted in obtaining some of the data here presented, particularly Frieda Hinnenkamp, who assisted most competently in desert surveys and early-spring beet surveys, and R. A. Fulton, who was primarily responsible for the design of the air trap used in detecting insect movements in the air. Acknowledgement is also made of the assistance rendered by D. E. Fox, A. C. Cole, and C. W. Eagleson. Thanks are due to Ray Hagar, of the Amalgamated Sugar Co., for his cooperation in furnishing data and records taken by his company and other assistance which he and members of his staff have freely given. The writers are indebted to Eubanks Carsner, of the Bureau of Plant Industry, whose long experience with curly-top injury was utilized by them during the early part of this dispersal period.

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brood, which in this case is the brood whose flight is of importance in the cultivated area.

For a number of years the Bureau of Entomology has been engaged in an intensive study of the beet leaf hopper in several of the Western States. This work was initiated in 1925 under the immediate direction of Walter Carter and continued under his direction until March, 1930, when the senior author assumed charge, upon the severance of Doctor Carter's connection with the project.

One of the by-products from the project dealing with ecological investigations of the leaf hopper has been the issuance of predictions of leaf-hopper abundance in the Twin Falls area, begun in 1927. Inasmuch as curly top, the disease transmitted by *E. tenellus*, is here the most important limiting factor in sugar-beet production, foreknowledge of probable leaf-hopper abundance has assumed considerable importance in enabling farmers to plan the heaviest planting of beets in the years of lowest leaf-hopper populations, and to avoid the past tendency of increasing acreage in the years of greatest leaf-hopper abundance. The utilization of data obtained by the end of February, collected and made available to the farmers, has offered a means of sustaining the industry and avoiding losses until a satisfactory and permanent solution of the problem can be obtained.

The basis for prediction has been the correlation of type of winter associated with previous good beet and poor beet years; the determination of winter survival of the leaf hoppers in cages, the determination of preceding fall populations, and, when possible, the determination of field survival on the basis of early-spring surveys. It can be readily recognized that accuracy in evaluating these conditions is dependent on comparison with a series of years for which adequate information regarding insect and curly-top conditions is available. Such information is obtainable only for the years since 1926, although the years of serious curly-top injury since 1916 are known from tonnage records and sugar-company observations.

Since 1926 four predictions on leaf-hopper abundance have been issued. (Table 7.) In so far as the leaf hopper was concerned, 1927 was indicated as a favorable beet year, 1928 as unfavorable, 1929 as favorable, and 1930 as favorable. The predictions for 1927, 1928, and 1929 were borne out by the results of the beet season as shown by tonnage results, abandoned acreage, the number of leaf hoppers, and percentage of plants affected by curly top in the field.

The results of the 1927 and 1928 beet years and their correlation with the predictions have already been discussed by Carter.[2] The data for 1929, however, were not available to Carter when his bulletin was in preparation, and are given briefly here for the sake of completeness. Inasmuch as Carter's report of February 18, 1929, issued as a mimeographed sheet and distributed to the beet growers in the affected area, reviews conditions previous to that date, portions of it are quoted below.

> Information accumulated to date as to sugar-beet prospects for the coming season indicates that these prospects are for an excellent beet year as far as the white fly is concerned.
>
> Leaf-hopper populations last fall were high but were not as generally distributed as in the fall of 1927. This uneven distribution was in favor of the grower, since fewer concentration areas existed at the close of the 1928 season.

[2] CARTER, W. ECOLOGICAL STUDIES OF THE BEET LEAF HOPPER. U. S. Dept. Agr. Tech. Bul. 206, 115 p., illus. 1930.

A new standard for a severe winter has been set by the record of the past winter. Prior to the middle of January enough below-zero weather had been encountered to bring the winter into the favorable class. In other words, by the middle of January we had experienced the type of winter which previous records show is followed by a good beet year. Since that time, the minimum temperatures have been so severe that we are now assured beyond a reasonable doubt that the winter has been extremely favorable.

Studies on the hibernation of the leaf hopper fully support the conclusion that a year free from leaf-hopper damage can be expected in 1929. These experiments include the use of over 10,000 leaf hoppers in outdoor cages. The recovery has been the lowest recorded since this investigation began, and we can with reasonable certainty look forward to extremely low leaf-hopper populations on the desert this coming spring.

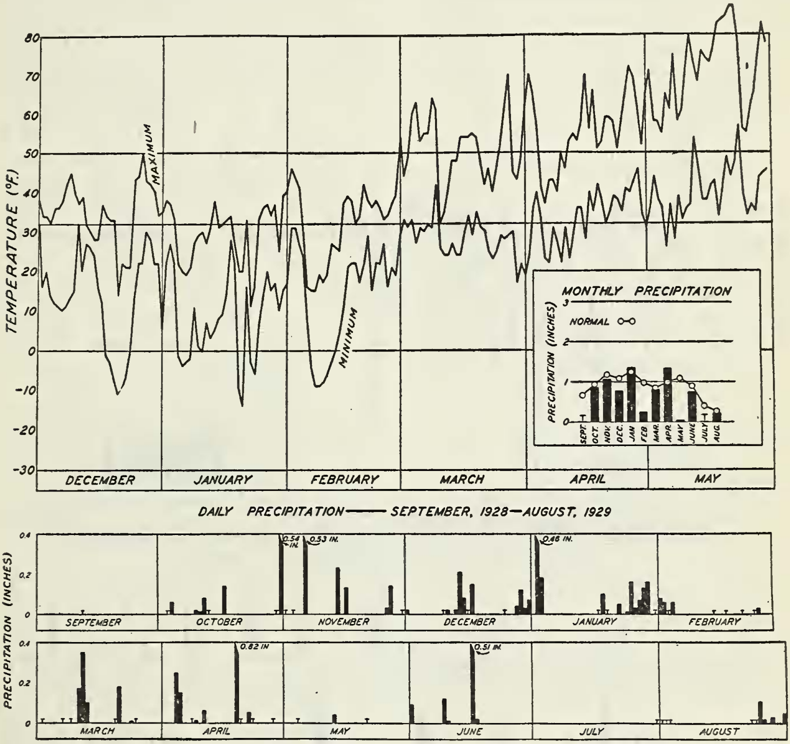

FIGURE 1.—Daily temperatures (December to May) and precipitation (September to August) at Twin Falls, Idaho, season of 1928–29

The winter temperature and rainfall conditions of 1928–29 are shown in Figure 1.

The yields produced in the ensuing season bore out the prediction, as indicated in Table 7. It must be admitted, however, that these were not as high as might have been expected from the extreme winter temperatures and low hibernation-cage survival. Spring conditions that were favorable to black root, and delayed planting due to weather conditions, undoubtedly contributed to this reduced yield.

The results of the 1930 prediction, which were contrary to expectations, will be discussed in this circular.

THE PREDICTION FOR 1930

The prediction for 1930, issued at the end of February, was for a favorable beet year, as far as leaf-bopper damage was concerned, and was based on the data briefly summarized below.

Winter type.—This was in the favorable class, and, although not of the most favorable type, it may be compared, as far as the severe temperature drop is concerned, with 1922, when the average beet tonnage was 13.5 tons per acre and no acreage was abandoned because of leaf-hopper attack. The temperatures occurring in 1921–22 and in 1929–30 are shown in Figures 2 and 3 for the sake of comparison.

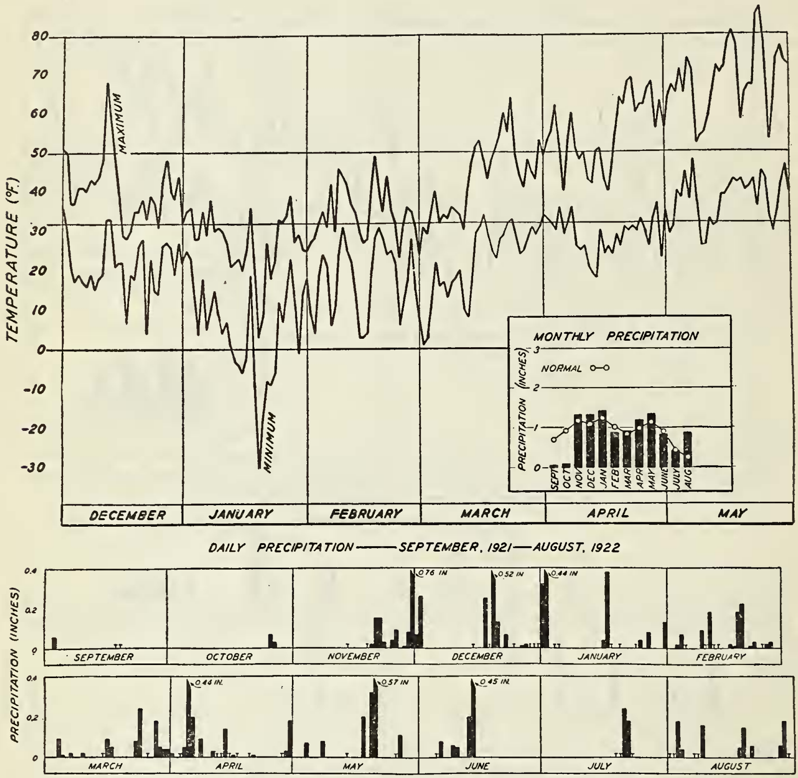

FIGURE 2.—Daily temperatures (December to May) and precipitation (September to August) at Twin Falls, Idaho, season of 1921–22

It will be noted that, although the severe cold weather came at about the same time in January in both years and was of nearly equal severity, the months of December and February in 1921–22 were much colder than in 1929–30. This is particularly true of February, during which the 10° F. line was crossed four times in 1922 while the lowest temperature during the same month in 1930 was 22°.

Fall populations.—Large numbers of insects entered the winter and could readily be taken in the field during the first week in December.

Survival in hibernation cages.—A high survival was obtained in the large hibernation cages; this was definitely higher than the survival in the high-population year of 1928. Small cages, however, showed a relatively low recovery. Figure 4 shows the comparative survival in large hibernation cages in February of 1928, 1929, and 1930, expressed in percentages. The exceptionally high recovery in 1930 may be explained in part by the extremely warm fall, which permitted a very dense matted growth of host plants and also the production of some nymphs.

Spring breeding area survey.—The exceptionally warm, open February made it possible to survey the areas then believed to be

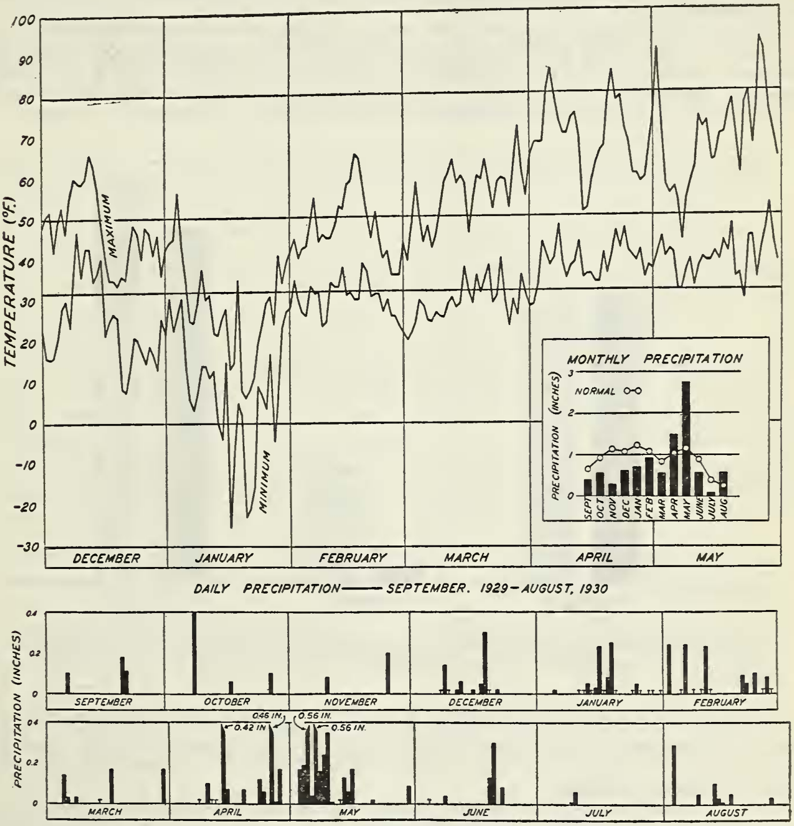

FIGURE 3.—Daily temperatures (December to May) and precipitation (September to August) at Twin Falls, Idaho, season of 1929–30

important in supplying leaf hoppers to the cultivated area. This survey indicated that low populations were present, populations much lower than had been previously associated with poor beet years. It was largely this factor which turned the prediction toward a favorable one. Some points in the Hagerman Valley and along the Hagerman-Wendell Highway northwest of the area under consideration showed rather high leaf-hopper populations, but such had been the case in previous good beet years, according to Carter's observations. Feeling that, in view of the other favorable indications, the high cage recovery could be disregarded, Carter issued the following report on February 28:

Report on Leaf-hopper Conditions for Twin Falls, Jerome, Minidoka, and Cassia Counties, Idaho

This report, which is the fourth annual statement of its kind, is designed to give sugar beet growers in the counties mentioned above, the information available on this date as to sugar beet prospects for the coming season only in so far as leaf hopper is concerned. Such information obviously can not take into consideration any of the numerous other factors that are concerned in the production of a good crop or take into account the climatic conditions of the coming spring and summer.

These prospects are for a good beet year. Hibernation studies showed a high mortality in one type of cage and a low mortality in another, but advantage has been taken of the fine weather prevailing to thoroughly survey the desert breeding grounds. This survey has demonstrated conclusively that desert populations are as low as in the early spring seasons of previous good years.

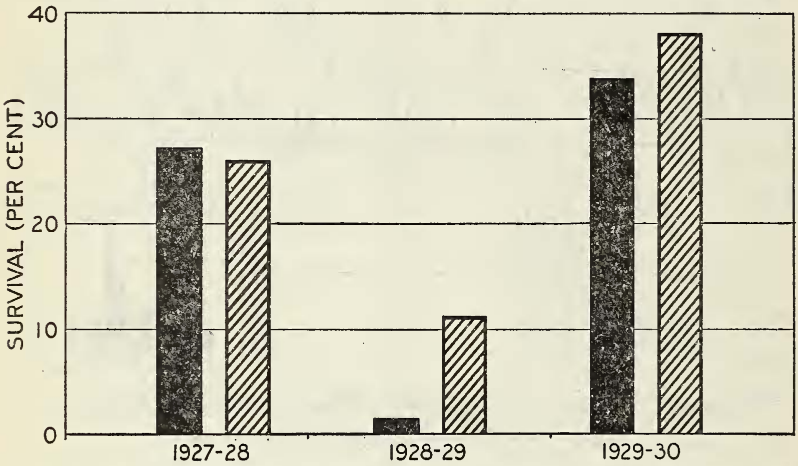

FIGURE 4.—Percentage of beet leaf hoppers recovered from large hibernation cages in 1927–28, 1928–29, and 1929–30. The solid black columns represent recovery from cages containing Russian thistle and the cross-hatched columns represent recovery from cages containing sugar-beet plants

The fall and winter weather chart has been carefully compared with similar charts for the past 11 beet years. This comparison indicates clearly that the past winter has been of a type associated with good beet years having very little leaf hopper damage.

As was stated in the three preceding reports, great emphasis should be placed on planting as early as the season will permit. This is generally true but particularly so in the case of growers whose farms are situated close to the edge of the cultivated area.

If the precaution of planting early is observed and the crop reasonably well cared for, the effect of any leaf hoppers that get to the fields late in the season should be negligible.

The Department of Agriculture is not responsible for any use made of this report in interpreting conditions outside of the limited area mentioned.

The period immediately following the issuance of the report, including March and April, was unprecedented for high temperatures. The rainfall from September to the end of March was far below normal. An accumulated deficiency of 2.63 inches had been reached by the end of March. Beginning with April, however, the rainfall was above normal, and by the end of May the negative accumulation below the normal had been reduced to 0.91 inch. The early high temperatures and concurrent lack of rainfall had two important effects; (1) the development of the insect in the field was extremely early and rapid, and (2) the mustards, on which early development occurs, although getting an early start, were stunted and matured earlier than would ordinarily have been the case. Mustards germinating later in the spring got the benefit of the April and May rains without the stunting effect of drought and in general matured later than the fall and early spring germinated plants. The effect on leaf-hopper populations of early warm weather, as experienced in the spring of 1930, is not definitely known, but it seems probable at least that a larger first generation would be produced and matured than under more nearly normal conditions.

THE FLIGHT IN 1930

On May 24 the leaf-hopper movement into the cultivated districts began. The first survey indicated populations comparable with those of 1929. The flight, as indicated by traps and surveys in the beets, was not completed in a few days, but apparently was a continuous movement, which by June 3 had reached such proportions that it was necessary to warn growers that populations of leaf hoppers were high and that damage was likely to result particularly to late beets and those in poor condition. Individual farmers were visited and given advice according to the populations of leaf hoppers and conditions of their individual fields. By June 13 the infestation was so general that a form letter was sent to all contractors in the Twin Falls district stating the situation. At this date it was possible to plant beans and potatoes in the Twin Falls district and thus prevent what in some cases would otherwise have been an almost total loss. A copy of the letter issued to contractors is given below:

To Sugar Beet Contractors in Territory Tributary to the Twin Falls Factory:

The annual flight of the white fly has been taking place in the Twin Falls territory during the week just passed, and has now reached proportions which can be considered serious.

Populations of white fly in the beets are the heaviest in the western part of the territory, and become lighter toward the east, reaching a minimum at Murtaugh and Milner.

It is unquestionably true that some serious injury will result to beets, the smaller being more susceptible to damage by the curly top disease.

It is probably true that beans will be affected in the territories most seriously invaded.

Burley and Paul territories, according to our most recent surveys, do not have populations which are at present dangerous.

This flight is coming from a northwestern direction, with mustard and thistle areas bordering on the Snake River Valley apparently being responsible for supplying the insects.

The southern areas in the Salmon and Oakley tracts thought to be responsible for previous infestations and which are the areas referred to in the February prediction still have extremely low populations. These areas are not responsible for this infestation. The present flight comes from an area which, according to all information that was available, has not been previously involved in flights into this territory.

It will be noted that at this date Burley did not have populations high enough to warrant removal of beets. The fact that the season is later in that section and that it is not possible to plant either beans or potatoes as late as in the Twin Falls district also argued in favor of keeping the beet acreage unless more severe infestations occurred.

The later date of infestation was also an important consideration in the decision not to include Burley in this general statement, a decision which was borne out by developments as the season progressed, for, although there was little abandonment, the average tonnage was very close to that considered profitable.

The flight continued throughout June, every 5-day period at a conservative estimate showing a large enough number to be by itself of economic significance. By the middle of June the beet area west of Twin Falls was so heavily infested and showed such a high incidence of disease that most of the beets had been plowed out.

The source, direction of movement, and speed of infestation are indicated by data obtained from desert surveys, surveys of beets and beans as to populations and percentage of disease present, and from traps established at strategic points to intercept leaf hoppers in flight. Summaries of the data thus obtained are given below.

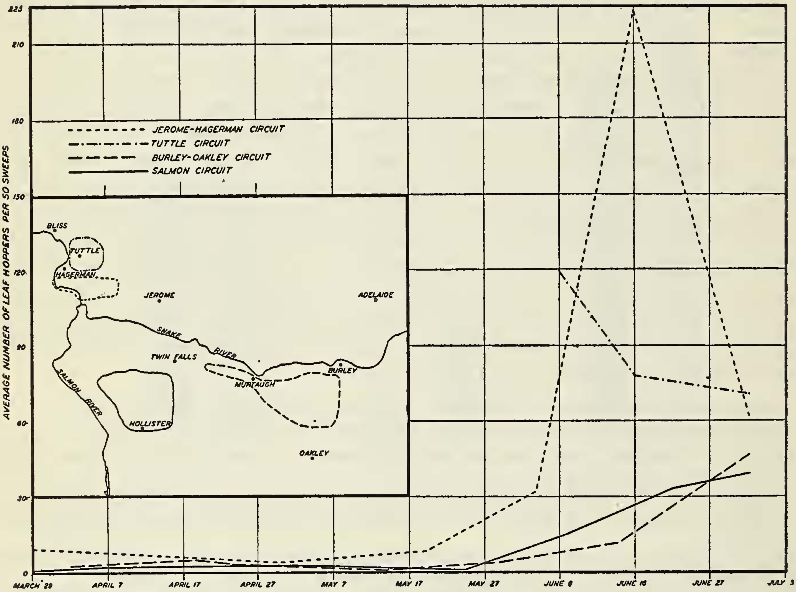

FIGURE 5.—Populations of beet leaf hoppers in the various breeding areas prior to and during the 1930 movement at Twin Falls, as indicated by averages of 50-sweep counts taken at a series of stations on each circuit. The small map shows the approximate area covered by each circuit

DESERT SURVEYS

The leaf-hopper populations of the various breeding grounds throughout the season were ascertained by means of regular observations and sweep counts taken at a representative series of points established in each of the circuits under consideration. Owing to the fact that the Tuttle circuit to the northwest was not suspected until the first actual movement was observed, data prior to the 6th of June were not secured for that circuit.

Clear evidence of the high populations in the Tuttle circuit, as compared with the low initial population in the Salmon and Burley-Oakley circuits, is shown in Figure 5, which gives the number of leaf hoppers present on the various circuits as measured by averages of a series of 50-sweep counts taken at a number of points on each circuit. The data for the Jerome-Hagerman circuit were obtained from a relatively small number of points in the direct path of the Tuttle movement. It will be noted that the tremendous increase in population in this circuit between June 3 and June 16 corresponds with a general decrease in the Tuttle populations. This increase may be accounted for in part by the progressive maturation of the first brood and corresponds with much smaller increases in both the Burley-Oakley and Salmon River circuits. Two other factors are probably responsible for the very great increase, however. The first of these is the probable contribution received from the Tuttle circuit, and the second and probably less important one is the concentration on Russian thistle due to drying of mustard plants along the Jerome-Hagerman circuit. The rapid decrease in population between June 16 and July 1 corresponds with a series of large trap catches and with large increases in beet-field populations and may be explained on the basis of a continuation of flight from this area accompanied by depletion of the Tuttle populations. After the dispersal the desert populations on Russian thistle increased gradually during the summer and by fall had attained a size somewhat larger than any of the four previous fall populations of which there is accurate record.

BEET SURVEYS RELATIVE TO LEAF-HOPPER POPULATIONS AND CURLY-TOP DEVELOPMENT

The 1930 flight was most intensively studied in its relation to leaf-hopper populations in the beet fields and in the consequent incidence of curly top. Prior to May 24 the number of leaf hoppers per 100 feet of unthinned beet row was nearly negligible throughout the territory, say two or three at most. On May 24 and 25 the first indications that a flight was under way were noted in the marked increases in row-count populations approximating 40 to 80 or more leaf hoppers per 100 feet of row in the Tuttle plantings to 10 to 20 per 100 feet in the western end of the Twin Falls-Jerome tract. These populations became steadily greater and the area of infestation gradually moved farther and farther eastward, although with a progressively lower population. By June 5 the distribution was as shown in Figure 6. The data there summarized show that the degree of infestation was greatest in the Tuttle district, very high in the Jerome-Buhl-Filer district, and gradually diminishing thereafter to the east. In correlation with the prevailing westerly and northwesterly winds and the fact that, as already pointed out, the Tuttle district was the only near desert breeding ground of high leaf-hopper population, it became reasonably clear that the dispersal, in so far as it concerned the main cultivated area, had a northwestern origin, with Tuttle contributing significantly to the total population.

The data at hand regarding incidence of curly top in beets, for the period of June 17–22, are clearly a reflection of the insect distribution previously noted. By this time the leaf-hopper populations were extremely high in the sections showing concurrently a high percentage of curly-top disease in the sugar-beet fields, and were dangerously high in even the most easterly sections around Burley and Paul. By August 11 the least seriously affected beets in the entire territory, those around Burley, showed 90 to 95 per cent of the total affected

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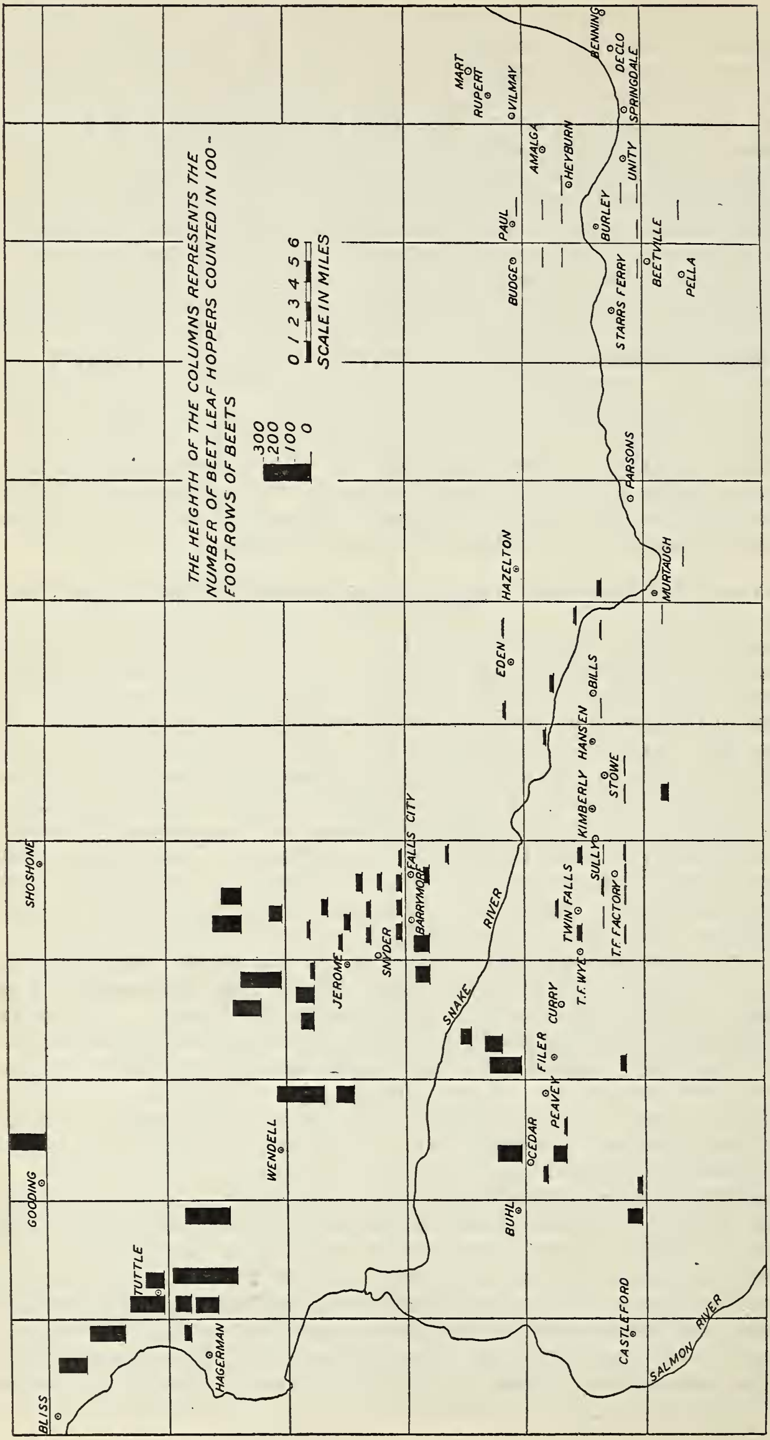

FIGURE 6.—Distribution of the beet leaf hopper in beet fields from May 27 to June 5, 1930, based on the numbers of insects occurring on 100 feet of beet row. The location of the various beet dumps (loading points) is also indicated

by curly top. The date on which a certain percentage had been attained was, as might have been predicted on the basis of the foregoing, a function of the distance of a given territory from the Tuttle breeding area. Thus the Tuttle beet district first showed 85 to 100 per cent of the plants with serious infection by curly top (obvious disease) between June 16 and 20; the Buhl-Filer-Jerome district showed the same percentage between July 1 and 10; the Twin Falls and Eden-Hazelton districts between August 16 and 20; and those from Murtaugh east between August 25 and 27. The amount of injury in the various districts also reflects this difference in time of infestation, the Burley district producing nearly a 10-ton average with little abandonment in spite of the high, late-season incidence of

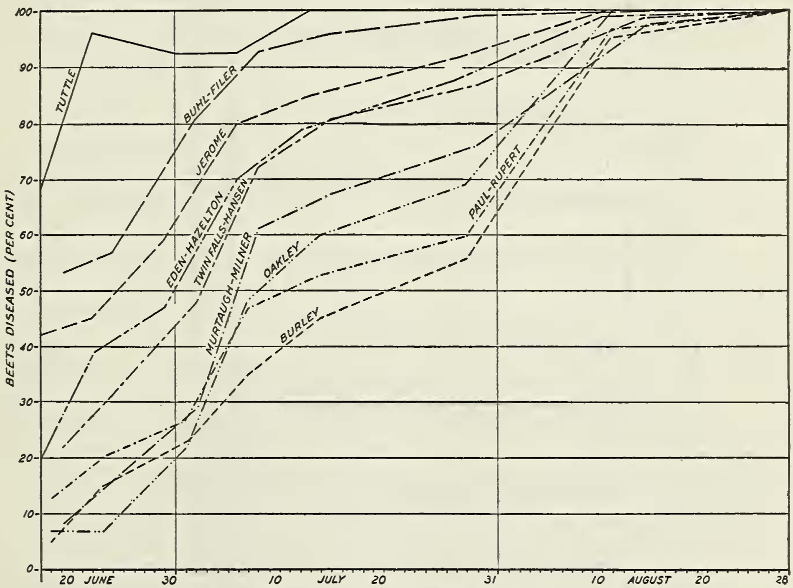

FIGURE 7.—Seasonal development of curly top in beets, showing the progressive decrease of disease from west to east and the final total of disease in all districts late in the season

disease. Figure 7 shows the development of curly top as indicated by weekly surveys. The gradual decrease of disease on a given date from Tuttle on the west to Burley on the east is clearly indicated.

SURVEYS OF CURLY-TOP DISEASE AND THE BEET LEAF HOPPER IN BEAN FIELDS

The incidence of curly top in bean fields offered an excellent opportunity to verify the distribution of *E. tenellus* which had entered the cultivated area at the time of maximum dispersal. Twenty-one fields of Great Northern beans were kept under observation during the summer of 1930. Three rows of 100 plants each were staked off in each field, and on these curly-top counts were taken eight times from June 18 to August 20. Three sets of 50 double-sweep insect samples were taken at each visit on rows adjacent to the ones under observation.

TABLE 1.—*Curly-top percentages*[1] *and beet leaf-hopper counts*[2] *on 21 fields of Great Northern beans*

Locality	Field No.	June 18-27		June 30-July 3		July 7-12		July 14-17		July 21-25		July 29-Aug. 1		Aug. 5-12		Aug. 13-20	
		Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers	Curly top	Leaf hoppers
		Per cent	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*
Buhl	1	1	10	18	29	67	[3] 39	92	26	96	18	96					
	2	7	9	23	12	71	13	85	18	90	6	95	12	93	[4] 20	92	
	3	0	5	8	9	47	2			82	3	81	23	82	[4] 44	85	42
	4	0	2	4	4	19	4	38	5	45	0	44	1	49	[4] 14	48	10
Filer	5	23	2	37	14	50	4	59	4	65	[3] 28	63	13	67	5	63	16
	6	2		12	[3] 3	21	0	22	3	25	2	25	2	25	0	30	1
	7	6	2	6	8	11	1	12	8	15	6	13	[3] 18	26	2	21	2
	8	6	1	13	3	19	[3] 8	23	0	30	0	27	2	27	4	24	5
Hollister	9	7	2	6	[3] 8		1			17	8	15	6	24	1	22	6
	10		1	6	7	16	5	19	[3] 18	26	8	23	17	30	5	26	3
	11	4	0	1	[3] 8	7	3	7	2	9	7	6	8	12	2	13	1
Twin Falls	12	8	[3] 4	6	1	10	0	13	0	14	2	13	3	12.	3	15	4
	13	1	0	4	3	11	4	16	3	17	3	17	[3] 6	17	0	17	3
Kimberly	14	11	1	15	2	15	0	17	0	18	1		1		[3] 9		4
	15	4	[3] 5	6	2	8	1	9	1	10	0	10	2	12	2	14	4
Murtaugh	16	10	[3] 5		4			27	2	27	1	24	3	26	5	24	4
	17	1	[3] 18			7	2	6	2	9	0	8	1	7	2	9	1
	18	1	[3] 5			1	0	3	0	4	1	5	0	5	0	4	0
Burley	19	0	1	0	1	0	0	0	0	0	1	2	0	1	2		
	20	1	2	1	1	3	0	3	1	2	1	2	1	3	0	2	0
	21	3	0	3	0	4	0	5	1	6	1	3	0			1	1

[1] Curly-top percentages based on three rows, of 100 marked plants each, in every field.
[2] Leaf-hopper counts based on counts, each of 50 double sweeps, taken on rows adjacent to the ones under observation for disease.
[3] The peak of leaf-hopper population for the season in the field under consideration.
[4] This increase of leaf hoppers during the period of Aug. 5-12 was apparently local. The trap collection just previous to this period also showed a large increase.

The data pertaining to these fields have been arranged in Table 1, and are listed in order from west to east so as to emphasize the decrease in percentage of disease toward the east. Beans are unfavorable as a host, as indicated by the failure of the insect to build up high populations during the season. In most cases, as shown in the table, there is a marked reduction in populations long before the beans reach maturity. This is quite contrary to the development in beet fields and on other favorable hosts. Only small numbers of nymphs were taken in bean fields at any time during the season.

Figure 8 presents graphically a summary of the data contained in Table 1. The inset includes a summary of the average percentage of diseased plants and numbers of *E. tenellus* found in the 21 fields throughout the season.

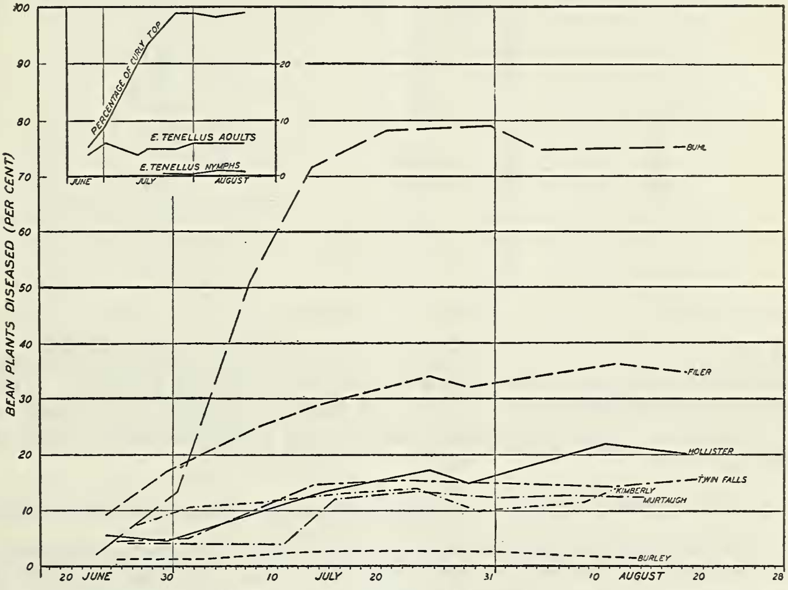

FIGURE 8.—Distribution of curly top by locality and season in 21 Great Northern bean fields extending from Buhl to Burley. The inset gives an average of the percentage of plants affected by the diesase and numbers of *E. tenellus*, adults and nymphs, for these same fields

The Great Northern bean is not a favorable host plant of the beet leaf hopper, as indicated by the fact that the populations reached by June 30 were maintained but not increased throughout the season, and, as shown in Figure 8, nymphs were extremely rare in bean fields as late as August 20. Thirteen of the fields had reached the peak of leaf-hopper abundance by July 17. Only eight fields showed an increase subsequent to this date, and three of these were located near Buhl, where trap collections taken on August 6 showed a great increase, probably indicating a local movement. Curly-top percentages rose steadily from June 23 to July 21, when a level was reached which was maintained until the end of the season. In all probability the majority of the diseased plants were infected early in the season when the movement was at its peak (fig. 10) and before the redistribution of leaf-hopper populations to more favorable host plants had occurred.

A general survey of Great Northern beans was made between July 17 and 22, covering 42 fields (Table 2), in addition to the ones noted above.

TABLE 2.—*Results of a general survey of curly top on beans, 1930*

Range No.	Field No.	Proportion of bean plants diseased		Range No.	Field No.	Proportion of bean plants diseased	
		July 17–22	Aug. 15–18			July 17–22	Aug. 15–18
		Per cent	*Per cent*			*Per cent*	*Per cent*
	1	79	----------		23	17	20
13	2	95	----------	18	24	6	8
	3	88	----------		25	16	20
	4	87	----------		26	17	15
14	5	75	----------		27	10	6
	6	93	----------	19	28	5	5
15	7	88	88		29	15	14
	8	73	79		30	10	----------
	9	56	42	20	31	13	9
	10	44	44		32	1	2
16	11	33	27	21	33	4	4
	12	55	51	22	34	3	----------
	13	56	54		35	9	----------
	14	34	36		36	1	----------
	15	59	62		37	3	----------
	16	18	17	23	38	8	----------
	17	32	34		39	0	----------
17	18	11	13		40	8	----------
	19	31	34	24	41	4	----------
	20	16	17		42	0	----------
	21	17	----------				
	22	15	12				

A second survey, made on August 15 to 18 over many of the same fields, indicated an increase in curly top of only 0.6 per cent. The west-to-east distribution of curly top in beans from July 17 to 22 agrees very closely in percentage and distribution with the beet survey of June 17 to 22.[3]

TRAP COLLECTIONS AND THE 1930 SPRING FLIGHT OF THE BEET LEAF HOPPER

A trap, the construction and operation of which has been described,[4] was devised and set up at strategic points covering in general the western boundary of the Twin Falls–Jerome tract. Each station comprised three traps mounted respectively at 8, 16, and 25 feet above the ground. The traps were not put into really effective operation until after the first dispersal movement into the cultivated area was well under way. After the populations in the field became sufficiently great to mask the daily increment from outside sources, these traps furnished the most accurate measure available as to the duration and magnitude of the movement. The results of the season's work with the traps are given in Tables 3, 4, and 5.

[3] A disease thought to be curly top occurred in potatoes, and its incidence followed the same general distribution as in beets and beans. An investigation of the relation of *E. tenellus* to this disease in potatoes is now in progress and will be reported separately.

[4] FULTON, R. A., and CHAMBERLIN, J. C. A NEW AUTOMATIC INSECT TRAP FOR THE STUDY OF INSECT DISPERSION AND FLIGHT ASSOCIATIONS. Jour. Econ. Ent. 24: 757–761, illus. 1931.

Table 3.—*Trap collections of beet leaf hoppers May 26 to June 30, 1930*

Date [1]	Maximum temperature (°F.)	Prevailing wind direction [2]	Number of leaf hoppers in trap collections at—									
			Station 9, Wendell	Station 1, Thousand Springs	Station 2, Buhl, north rim	Station 3, Buhl, south rim	Station 4, Buhl	Station 5, Castleford farm	Station 6, Hollister desert	Station 7, Hollister	Station 8, Twin Falls	All stations
May 26	77	Variable east to west.	------	0	0	0	0	0	0	0	------	0
27	93	do	------	------	------	------	------	------	------	------	------	------
28	90	Northwest	------	0	1	0	0	0	0	0	------	1
29	73	do	------	------	------	------	------	------	------	------	------	------
30	63	West to northwest	------	1	1	2	0	0	0	0	------	4
31	62	West	------	------	------	------	------	------	------	------	------	------
June 1	68	do	------	0	0	0	0	0	0	0	0	0
2	64	West northwest	------	------	------	------	------	------	------	------	------	------
3	68	Variable, mostly west.	------	1	1	0	2	0	0	0	0	4
4	69	Westerly	------	------	------	------	------	------	------	------	------	------
5	79	Northwest, variable	------	6	3	0	1	0	0	0	2	12
6	91	Light east	1	18	1	4	0	3	0	2	1	30
7	93	West to northwest	5	13	4	2	4	6	0	0	2	36
8	84	West	------	------	------	------	------	------	------	------	------	------
9	86	Northwest	6	23	12	5	9	5	1	0	3	64
10	91	North northwest	4	7	2	2	4	0	0	1	0	20
11	91	West to northwest	20	17	6	7	3	7	1	0	1	62
12	82	do	3	3	3	4	14	1	1	0	4	33
13	75	West	0	3	3	2	3	1	------	------	3	15
14	78	West to northwest	3	3	2	3	9	1	0	0	3	24
15	92	Variable east to west	------	------	------	------	------	------	------	------	------	------
16	98	Northeast to north	26	28	9	15	10	4	5	4	------	101
17	98	West	------	------	------	------	------	------	------	------	------	------
18	77	Northwest	0	2	4	3	8	13	2	1	15	48
19	77	Variable west to east northeast.	------	------	------	------	------	------	------	------	------	------
20	76	West northwest	2	9	2	3	5	1	2	3	1	28
21	84	West	------	------	------	------	------	------	------	------	------	------
22	84	Southwest to south	3	2	4	1	7	2	5	2	2	28
23	81	West northwest	------	------	------	------	------	------	------	------	------	------
24	80	Southwest	0	1	6	1	2	1	1	2	1	15
25	84	Easterly	------	------	------	------	------	------	------	------	------	------
26	91	North	7	8	7	6	21	32	1	5	0	87
27	91	North northwest	------	------	------	------	------	------	------	------	------	------
28	90	West	------	------	------	------	------	------	------	------	------	------
29	81	do	2	7	4	0	5	7	6	9	3	43
30	89	do	------	------	------	------	------	------	------	------	------	------
Total	--------	--------------------	82	152	75	60	107	84	25	29	41	655

[1] In each case the date for which data are given represents the date upon which the collections were taken into the laboratory for counting. The date upon which the traps were first set out is indicated by the date immediately preceding.

[2] Prevailing wind is only an approximation; it represents a rough average of 8 to 10 daily observations at various points and times. There is of course rarely a day in which any major wind direction is unrepresented, for a short time at least, but during June the winds were so dominantly west and northwesterly that a marked shift was cause for comment.

TABLE 4.—*Trap collections of beet leaf hoppers, July 1 to November 10, 1930*

Date	Number of leaf hoppers in trap collections at—										Remarks
	Station 9, Wendell	Station 1, Thousand Springs	Station 2, Buhl, north rim	Station 3, Buhl, south rim	Station 4, Buhl	Station 5, Castleford farm	Station 6, Hollister desert	Station 7, Hollister	Station 8, Twin Falls	All stations	
July 1 to 2	3	1	1	0	3	0	5	5	1	19	Beets plowed out at Castleford farm July 8.
8 to 9	1	1	1	2	2	26	1	1	------	35	
12 to 13	0	1	0	0	1	1	0	0	2	5	
17 to 18	0	3	0	0	0	1	1	5	6	16	
25 to 26	1	0	0	1	0	13	16	11	------	42	
Aug. 1 to 2	2	0	3	5	1	41	4	1	3	60	Severe hailstorm at Castleford, August 3.
7 to 8	0	0	0	0	1	0	4	2	------	7	
14 to 15	0	5	2	0	0	4	1	0	------	12	
19 to 20	1	8	0	2	2	0	3	1	------	17	
21 to 22	0	0	0	0	0	0	0	0	0	0	
23 to 24	0	0	0	0	0	1	2	0	------	3	
25 to 26	0	0	0	2	0	0	1	0	------	3	
Sept. 4	0	1	0	0	0	0	2	0	------	3	
5 to 6	0	0	0	0	0	2	0	0	------	2	
7 to 8	0	0	0	0	0	0	0	0	------	0	
9 to 10	0	2	0	0	1	1	0	1	------	5	Old glue type traps being replaced by new wire maze trap. Collections henceforth refer only to new trap.
11 to 12 [1]	0	0	0	0	0	1	3	6	------	10	
18 to 22	------	------	------	------	------	5	4	6	------	15	
22 to 29	------	------	------	8	2	3	10	1	------	24	
Sept. 29–Oct. 3	------	------	0	0	0	0	0	0	------	0	
Oct. 3 to 7	0	8	0	3	0	2	0	7	------	20	
7 to 10	0	2	1	2	3	0	0	1	0	9	
10 to 11	0	0	0	0	0	1	0	0	------	1	Approximate beginning of beet harvest.
11 to 13	0	0	1	0	0	0	0	0	0	1	
13 to 15	0	1	0	0	0	1	0	1	0	3	
15 to 17	0	0	1	1	2	0	0	0	0	4	
17 to 20	1	2	0	2	10	1	5	3	0	24	Beet harvest well under way.
20 to 23	0	4	1	0	22	2	1	1	0	31	
23 to 27	0	0	1	1	0	2	2	2	0	8	
27 to 30	0	2	0	3	6	1	1	2	0	15	
Oct. 30 to Nov. 3	0	1	0	1	4	0	0	4	0	10	
Nov. 3 to 6	0	4	0	1	8	3	0	7	0	23	Beet harvest nearing end.
6 to 10	0	1	0	1	5	0	1	9	0	17	
Total	9	47	12	35	73	112	67	77	12	444	

[1] The dates given up until Sept. 11–12 refer only to the first two days during which the traps were exposed. This is because it was assumed that the efficiency of the glue was thereafter so impaired as to be relatively noneffective in retaining leaf hoppers. See also the discussion in the text. After this date (the wire maze traps being continuously efficient, regardless of the length of exposure) the dates indicated cover the entire period over which the traps were out.

TABLE 5.—*Trap collections of beet leaf hoppers in single traps at 16-foot elevation, October 8 to November 10, 1930* [1]

Date	Number of leaf hoppers in trap collections at—								
	Station 10, Jerome	Station 9, Wendell	Station 1, Thousand Springs	Station 2, Buhl, north rim	Station 3, Buhl, south rim	Station 4, Buhl	Station 5, Castleford farm	Station 6, Hollister desert	Station 7, Hollister
Oct. 9 or 10	---------	0	0	1	1	2	0	0	0
11	---------	0	0	0	0	0	1	0	0
13	---------	0	0	0	0	0	0	0	0
15	0	0	1	0	0	0	1	0	1
17	0	0	0	0	1	0	0	0	0
20	0	0	2	0	1	3	0	1	1
23	1	0	4	0	0	6	2	1	1
27	3	0	0	0	1	0	1	1	0
30	0	0	---------	0	---------	---------	1	1	1
Nov. 3	0	0	0	0	0	3	0	0	2
6	0	0	2	0	0	2	0	0	2
10	0	0	1	0	1	2	0	0	5
Total	4	0	10	1	5	18	6	4	13

[1] At the beginning of the beet harvest a new series of single-trap stations (traps 16 feet above ground) were set out. (Fig. 9.) This table shows the catches of these new stations for the period of the beet harvest and those of the middle (16-foot) trap only of the old 3-trap stations, so that the catches throughout are comparable.

Table 5.—*Trap collections of beet leaf hoppers in single traps at 16-foot elevation, October 8 to November 10, 1930*—Continued

Date	Number of leaf hoppers in trap collections at—								
	Station 11, South Twin Falls	Station 8, Twin Falls	Station 12, Hansen	Station 13, Murtaugh	Station 14, West Burley	Station 15, Rupert	Station 16, Declo	Station 17, South Burley	All stations
Oct. 9 or 10		0							4
11									1
13		0							0
15	0	0	0	0	1	0	0	6	10
17	0	0	0	0	1	0	0	1	3
20	1	0	1	0	3	1	0	7	21
23	1	0	0	0	10	0	7	0	33
27	3	0	1	0	0	0	0	2	12
30	1	0	0	1	1	1	0	0	7
Nov. 3	0	0							5
6	2	0	0	0	1		0	0	9
10	3	0		1	1		0		14
Total	11	0	2	2	18	2	7	16	119

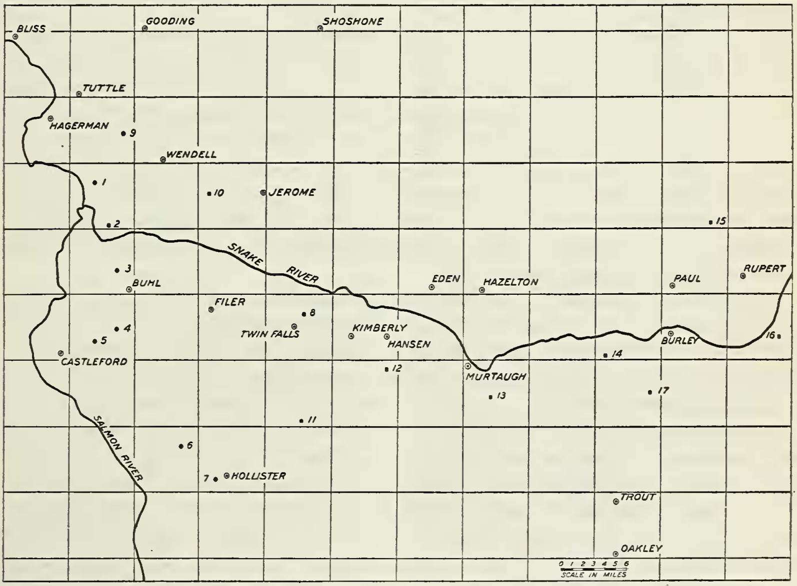

Figure 9.—Sketch map showing locations of trap stations operating during 1930. The circular dots represent stations with three traps at 8, 16, and 25 foot levels; the rectangular dots represent single traps at the 16-foot level

The number of leaf hoppers given for each trap-station collection in Tables 3 and 4 represents the total catch of the three traps exposed, regardless of their elevation above the ground. The position of the various individual stations is referred to by number and a brief descriptive title. Their exact geographical position is indicated in Figure 9. In all cases but one (station 5, near Castleford) the trap stations were located at least an eighth to a quarter of a mile distant from any area which might serve as a local source of leaf-hopper populations, so that, with the exception just noted, local swarming of the insects from host plants at the base of the trap could not affect the catches. Even in case of the Castleford station just noted, local swarming did not seem to occur except when some serious local disturbance provoked it. In this connection two collections from the Castleford station (No. 5) are of interest.

In Table 4 it will be noted that on July 8 to 9 all stations except the one under consideration yielded very small collections. Nearly three times as many *E. tenellus* were caught at the Castleford station as at all the other stations (26 out of a total of 35). This is correlated with the fact that on July 8 a considerable portion of the immediately adjacent and heavily infested beet planting was plowed out, thus stimulating a movement which was reflected in this particular collection.

A similar abnormally large collection was taken at this same station between August 1 and 6. (Table 4.) This time the movement was apparently correlated with the severe hailstorm noted for August 3. This storm severely injured a Russian-thistle area bearing high leafhopper populations, which was situated about 4 miles due west of the trap station and, it is thought, stimulated a local movement recorded by this particular collection. Although the effective collection date for this station is given as August 1 to 2, the collection was actually not taken up until the 6th, so that if the glue of these traps remained efficient beyond the arbitrary 2-day period assigned (as might well be in some cases), it is quite possible that this collection reflected this disturbance in spite of the apparent discrepancy in dates. Actual field inspection a week later showed markedly reduced populations of *E. tenellus* in the area affected by hail as compared with adjacent areas which escaped the storm.

The actual number of leaf hoppers caught in any one trap collection may appear to be rather small. However, a simple calculation will readily show that even the smaller numbers in these collections, considering the ratio between the effective surface area of a given trap or series of traps and the area of the front actually sampled, would in reality represent a large flight of insects. Thus, for example, we may assume a 24-hour collection from the six principal trap stations lying between Wendell and Castleford to have been 37 leaf hoppers. The effective sampling capacity of these trap stations (three traps to the station) is 45 square feet out of a front approximately 30 miles long and an unknown depth. Assuming 30 feet as the upper height of the flight, the actual area of the front in question is, roughly, 1,500,000 square feet. Thus 37 insects from a 45-square-foot sample, if even approximate, would in reality represent a flight of more than a million insects. That these figures are conservative seems certain, for the traps are most certainly not 100 per cent efficient, and it is wholly arbitrary to assume 30 feet as the upper limit of flight. These figures are cited, not as offering a numerical solution to the problem of the actual number of insects passing into the cultivated areas from the desert, but merely as an indication that a catch of from 15 to 100 leaf hoppers daily represents a sample of a really large total.

Owing to its functioning as a vector of the curly-top virus, an economically important population of *E. tenellus* is much lower in absolute number than a destructive population of a similar insect whose ravages depend solely upon feeding capacity.

Unless otherwise noted, all collections are from traps on which the insects were caught by a special glue.[5] Experience showed that the effective period for this type of trap did not ordinarily extend much beyond one or two days following exposure. Dates as given in the accompanying tables therefore arbitrarily indicate the first two and presumably most effective days of exposure rather than the date upon which the traps were actually brought into the laboratory. (See also the footnote under Table 4.)

As will be observed from Table 3, during the period of May 26 to June 7 the leaf hoppers were taken in numbers along the entire western boundary of the cultivated tract extending from Wendell to Castleford. The two stations near Hollister in the southern breeding area yielded very small collections. The largest collections were taken at the station west of Wendell and southeast of Tuttle.

Collections of the week following this period (which of itself, as previously pointed out, supplied enough leaf hoppers to endanger the beet plantings of the Twin Falls and Jerome districts) increased enormously, as shown by the data for the more westerly stations for the period of June 9 to 16. The collection at the Twin Falls station similarly showed a marked increase, indicating the progressively deeper penetration of the insects into the cultivated area. The stations between Wendell and Buhl at this time still maintained their preponderating lead over the more southerly stations.

As clearly shown in Tables 3 and 4, and especially in Figure 10, the movement of the leaf hoppers continued almost unabated until the end of June, showing two pronounced peaks culminating about June 16 and June 26 to 27, respectively. Thereafter the movement declined but continued nevertheless throughout the summer and fall.

In connection with the graphical representation of the season's catch (fig. 10), a word of explanation becomes necessary. With the glue type traps which were used exclusively up to September 18, the glue was effective with somewhat diminishing efficiency over a period of two, three, or, in some cases, more days. Where traps were left exposed longer than two days, as was the case throughout July, August, and early September, the leaf-hopper catch was arbitrarily (in the absence of any basis for more accurate evaluation) considered to represent the catch of the first two days of exposure. Since some averaging was necessary and no data were available for permitting more definite distribution, the catch was merely assigned on an equal basis to each of the two "effective" days. The same consideration of course held for the wire maze traps, which were equally effective during the entire exposure period and were employed after September 18. Here the catches had to be arbitrarily divided by the total number of days over which the catch was made. This accounts for the apparently anomalous equality of the catches of two or more successive days as shown in Figure 10. The actual catches are shown in Table 4.

As the season progressed the northern stations decreased in importance, while the southern stations (Hollister and Castleford) increased in relative importance, although in no case did the catches of the latter ever attain the actual magnitude of the early June collections for the northern group. Throughout June there appeared,

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[5] See footnote 4.

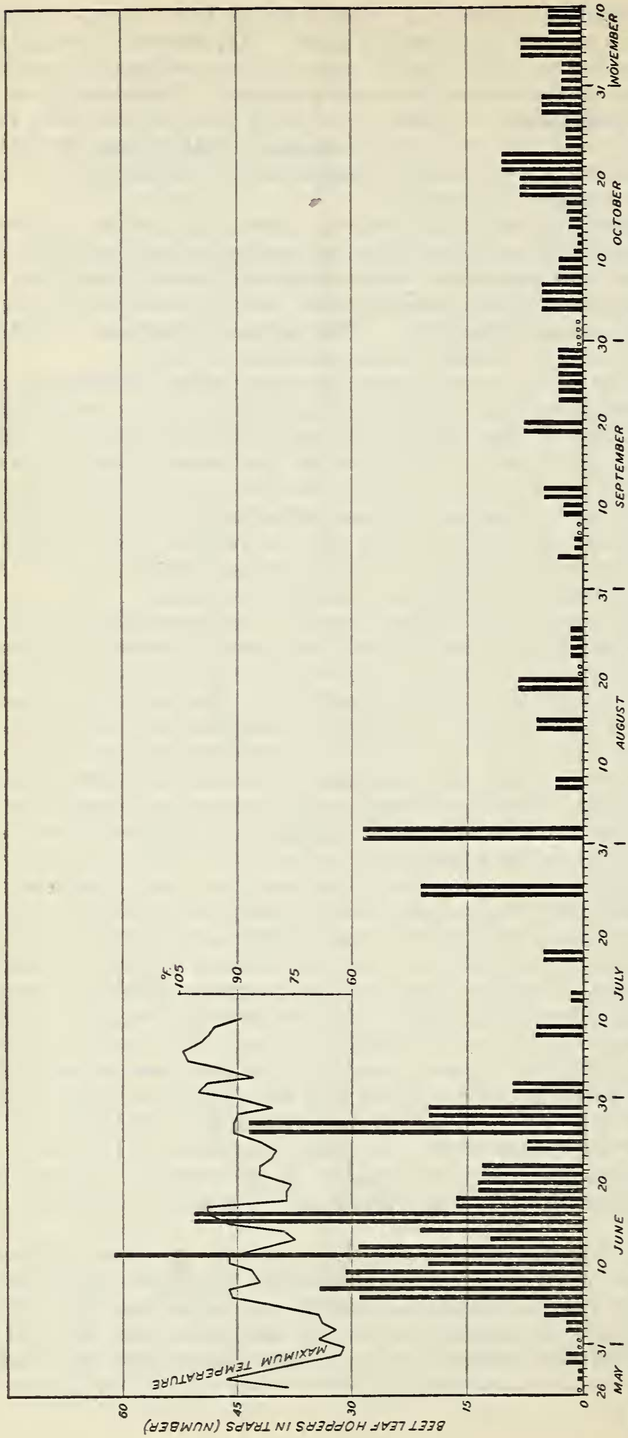

Figure 10.—Graphical summary of trap collections of beet leaf hoppers in 1930. Collections in all cases are totals of the catches of eight trap stations extending from Wendell on the north to Hollister on the south. The continuous line graph represents daily maximum air temperatures at Twin Falls

as might be expected, a correlation between temperature and leaf-hopper catches. High temperatures were apparently favorable to dispersal.

Although the detailed interpretation of these data is obviously difficult and must await further investigations, one important fact stands out. Those traps nearest the Tuttle circuit and southeast and south therefrom showed by far the highest catches. Desert surveys show that there were no near-by breeding areas, of any size, south of the Snake River and west of the Salmon River, while those breeding areas east and south of the western trap line had, as previously shown, very low leaf-hopper populations. These data, in conjunction with the fact that prevailing winds were westerly and northwesterly, seem to indicate that the northwestern area was the source of the movement in 1930 and thus support the conclusions already reached from the data previously discussed.

FALL MOVEMENTS OF THE BEET LEAF HOPPER

Data secured by means of traps indicate two things relative to fall movements. (1) Leaf hoppers are in the air and moving about and may be trapped well up into the harvest period, since significant collections were taken as late as November 10. (Tables 4 and 5.) (2) The average daily catch during the beet harvest, at which time Russian thistle in the desert was also drying rapidly, shows a distinct and probably at least significant increase over collections taken late in the year but prior to the harvest and the drying of Russian thistle.

It is also of interest to note that *E. tenellus* was readily taken during the harvest period in virgin sage 5 miles from the nearest summer host plant at the time when desert Russian thistle was rapidly drying. The extent and size of this movement is not known, but a flight during the fall is quite definitely indicated.

HEIGHT OF THE FLIGHT

Trapping also produced some data of interest regarding the density of the flight at different elevations above the ground. The results for the season show that, of a total of over a thousand leaf hoppers trapped, about 37 per cent were taken 8 feet above the ground, 35 per cent at the 16-foot level, and 28 per cent at the 25-foot level. This percentage varies of course from station to station and time to time, as shown below. At no time did the trap at 25 feet catch as many leaf hoppers as the lower traps.

Of the 655 *E. tenellus* taken during May and June, 169 (26 per cent) were caught at the 25-foot level, 210 (32 per cent) at the 16-foot level, and 276 (42 per cent) at the 8-foot level.

Table 6 shows the numbers and percentages of leaf hoppers trapped at the 8, 16, and 25 foot levels, respectively, for each of the nine regular trap stations over the period of May 26 to June 30, inclusive.

TABLE 6.—*Data showing the vertical distribution of catches of beet leaf hoppers for the nine principal trap stations, May 26 to June 30, 1930*

Trap height (feet)	Beet leaf hoppers caught at trap station—									
	9		1		2		3		4	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
25	22	26.8	32	21.1	27	36.0	21	35.0	30	28.0
16	11	13.4	67	44.1	31	41.3	14	23.3	36	33.6
8	49	59.8	53	34.8	17	22.7	25	41.7	41	38.4
Total	82	100.0	152	100.0	75	100.0	60	100.0	107	100.0

Trap height (feet)	Beet leaf hoppers caught at trap station—									
	5		6		7		8		All stations	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
25	10	11.9	6	24.0	10	34.5	11	26.8	169	25.8
16	31	36.9	7	28.0	9	31.0	4	9.8	210	32.0
8	43	51.2	12	48.0	10	34.5	26	63.4	276	42.2
Total	84	100.0	25	100.0	29	100.0	41	100.0	655	100.0

From these data it is evident that the flight extends somewhat higher than the 25-foot level at least and reaches its maximum abundance somewhere below this, apparently near the 8 and 16 foot levels.

SOURCES OF THE INFESTATION IN 1930

The foregoing data leave little doubt that the general movement was from the northwest and west, the major part of the movement coming from the northwestern area surrounding Tuttle and extending at least as far as Bliss and Gooding. The writers do not have sufficient data to determine the western limits of the contributing breeding area, but there is evidence that the territory west of Bliss contributed to the movement to some extent. Relatively small breeding grounds along the Snake River as far west as Glenns Ferry had high populations and white beans 4 miles west of Bliss were severely diseased. Indications are, however, that the general area surrounding Tuttle was responsible for a significant part of the movement. This area has not been considered of particular importance in the past, and no data were taken for what was apparently the most important breeding ground in 1930. The southern breeding grounds on the Salmon area previously considered most important to the Twin Falls-Jerome area without doubt played little or no part in the 1930 infestation.

YIELDS OF SUGAR BEETS

The results on beets of the heavy dispersal just considered were of a very serious nature. Table 7 gives a comparison of the yields per acre in 1930 with those of the preceding three years.

TABLE 7.—*Yields, in tons per acre, of sugar beets in prediction area for the four years for which predictions have been issued*

Year	Type of year predicted	Average yield based on acres harvested			Average yield based on acres thinned [1]		
		Jerome	Twin Falls	Burley-Paul	Jerome	Twin Falls	Burley-Paul
1927	Good	11.95	16.35	14.46	8.90	15.44	12.95
1928 [2]	Poor	4.63	8.39	11.46	1.39	6.11	10.84
1929	Good	9.92	12.99	12.68	6.18	11.70	12.54
1930	do	7.13	8.70	9.69	4.76	5.14	8.99

[1] These figures are based in some cases on acres measured, which vary slightly from those actually thinned.
[2] Only 358 acres were grown in the Jerome-Twin Falls district in 1928, owing to the prediction of a poor year. This represented to a large extent the better land and growers. In the Burley district only 1,632 acres of the 2,234 acres planted were thinned. The average yield, based on acres planted, was only 7.9 tons per acre.

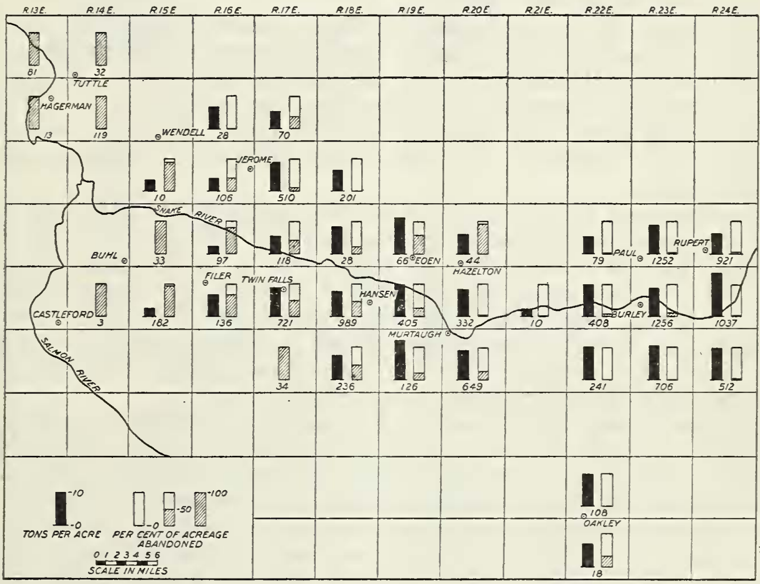

FIGURE 11.—Tons of beets harvested per acre and percentage of acreage abandoned in 1930, averaged by townships. The total number of acres planted in each township is shown numerically. Average yield in tons per acre, based on acres harvested, and percentage of total acreage abandoned, are indicated by the black and crosshatched columns, respectively

As might have been expected, the abandonment of beet acreage followed the same areal distribution as did the distribution of leaf-hopper populations and curly-top disease incidence in beans and beets earlier in the season, as previously shown (figs. 6 and 7, Tables 1 and 2), being greatest in those sections nearest the Tuttle and Buhl districts and least in the Burley-Rupert district to the east (fig. 11). The same holds true of the average beet tonnages obtained, as is also shown in Figure 11.

SUMMARY AND DISCUSSION

The predictions of beet leaf-hopper abundance in southern Idaho for the years 1927 to 1930, inclusive, were based on the assumption that the most important source of infestation was the southern breeding area surrounding Hollister. This was probably true for all years except 1930. Although the flight of 1927 apparently originated in the northwest and may have come from the Tuttle area southeast of Bliss, it was small and economically unimportant, and indicated that when the southern area had low populations infestation would be light.

In 1930 the Tuttle area toward the northwest, not previously associated with poor years, supplied large numbers of leaf hoppers to the cultivated sections. This area was responsible for the severe outbreak of that year, which occurred contrary to expectations as indicated in the favorable report of February. The expectation of low populations indicated by the early spring survey of the southern area, in which high populations had previously occurred in poor beet years, was borne out by later developments, as the spring brood in this area was extremely small.

As a result of the movement of 1930, future predictions will be based on the study of all possible breeding areas and their probable contributions to the infestation of the cultivated sections. Observations during that year have emphasized the variability of seasons and breeding areas with relation to leaf-hopper abundance and the necessity for extensive and thorough surveys of fall-population distribution.

Correlation of a severe drop in winter temperatures with low leaf-hopper populations did not hold during 1930. That one criterion of this sort should occasionally be inaccurate is to be expected, and absolute accuracy can probably only be attained by a correlation of fall and spring conditions with winter type over a period of years, coupled with accurate knowledge of fall populations and their areal distribution and spring survival. The dependability of data of this kind can only be determined by long observation.

A report issued by the end of February can obviously take into consideration only the fall and winter conditions. The early spring weather of 1930 was of unusual type, as has been pointed out, and this undoubtedly was a contributing factor to earliness of attack. It seems improbable that this factor was the determining one so far as high spring populations are concerned, and it is believed that high winter survival in the areas mentioned was more important. Surveys made later in the spring, when new brood individuals can be observed directly in the breeding areas, are feasible and can be used as a check on the data obtained up to March 1. These surveys can further safeguard the interests of the farmer in preventing losses due to cash outlay for thinning in case unforseen factors arise which influence the results.

Past experience indicates that probably the majority of years will fall readily into a clear-cut good or poor year class. Intermediate years will always be difficult to classify, inasmuch as factors of little importance in definitely good or poor years may be of sufficient magnitude to turn the scale in borderline years.

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