THE BEET LEAFHOPPER IN THE CENTRAL COLUMBIA RIVER BREEDING AREA [1]

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INTRODUCTION

The Yakima Valley in Washington is a potential sugar-beet-producing area, but production is limited by the prevalence of curly top disease, caused by the beet leafhopper, *Eutettix tenellus* (Baker). Three sugar factories built before the severity of this disease was realized have now been dismantled. An attempt to produce white pea beans commercially in the vicinity of Walla Walla in 1930 was abandoned, apparently for the same reason, and tomato growers there suffer heavy losses almost every year. In fact, susceptible crops in vegetable gardens throughout this section are severely damaged.

Surveys conducted by the Bureau of Entomology from 1927 to 1929 [3] indicated that there is a large breeding area of the leafhopper in the central Columbia River Valley, in south-central Washington and northeastern Oregon, from which populations are dispersed to the Yakima Valley and other surrounding territory (fig. 1).[4]

In 1930 ecological studies of the beet leafhopper were undertaken in this area. A laboratory was established at Hermiston, Oreg., and 24 stations were set up for the purpose of making observations on this insect. These stations were so placed as to include the more important host plants and were widely enough separated to be representative of the entire breeding area. To determine the host-plant sequence, brood occurrence, and population fluctuations throughout the season, observations were made at these stations as nearly as possible every 10 days from spring to fall over the period 1930 to 1933. Population sampling was accomplished the first year by means of the sweep net, supplemented by square-yard counts in the spring and late in the fall, when the temperature was so low and host plants were so small as to make sweeping impracticable. The square-yard counts were made by covering a definite area on hand and knee and counting the insects disturbed. The square-foot sampler,[5] a cylindrical cage with a 5-foot handle and covering 1 square foot of soil surface, was devised in the spring of 1931, and was used exclusively after that time.

LIFE HISTORY

The beet leafhopper overwinters in the central Columbia area only as the fertilized female. During the year there are at least three broods. The spring brood appears in May, the summer brood about

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[2] The writer's thanks are due P. N. Annand, formerly in charge of this project, for guidance and suggestions in the study of this problem; and to W. C. Cook for helpful suggestions in the preparation of the manuscript.

[3] These surveys were conducted by H. E. Wallace, C. H. Griffith, and the writer.

[4] Wallace, H. E., and Hills, O. A. DISTRIBUTION OF THE BEET LEAFHOPPER, EUTETTIX TENELLUS (BAKER), IN OREGON. (Manuscript in preparation.)

[5] Hills, O. A. A NEW METHOD FOR COLLECTING SAMPLES OF INSECT POPULATIONS. Jour. Econ. Ent. 26: 906–910, illus. 1933.

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the first of July, and the fall brood late in August (fig. 2). The spring and summer broods overlap, causing the peak of populations for the

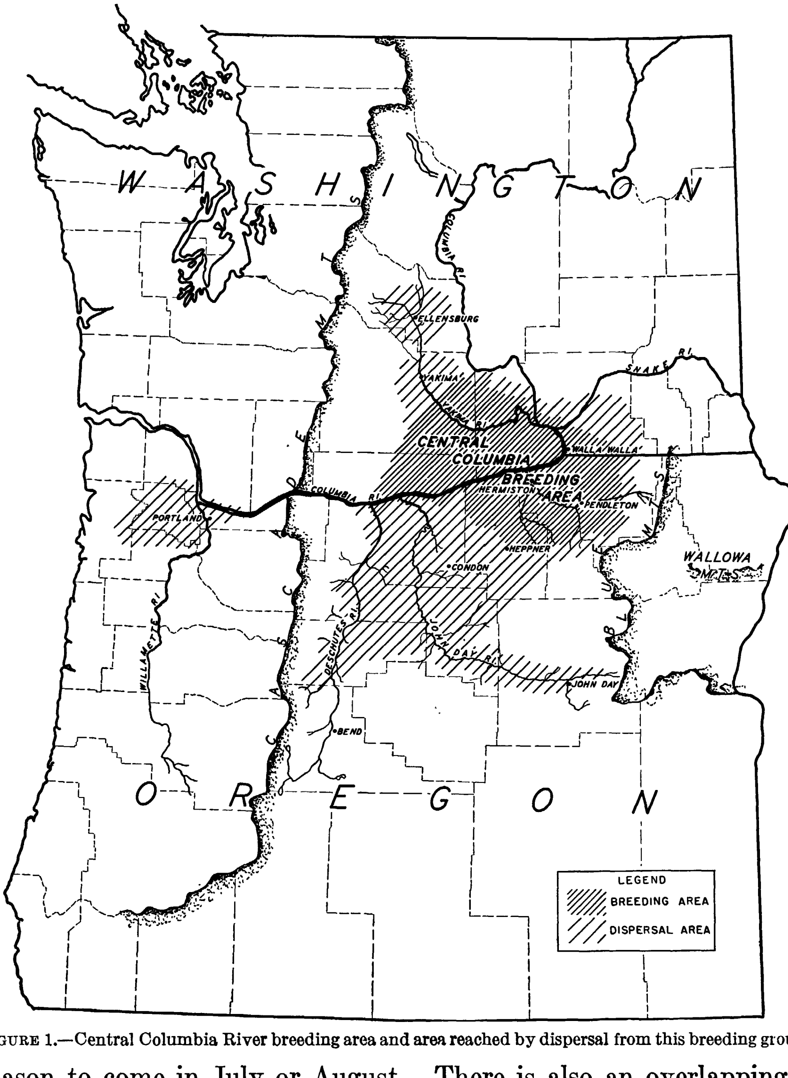

FIGURE 1.—Central Columbia River breeding area and area reached by dispersal from this breeding ground.

season to come in July or August. There is also an overlapping of the summer and fall broods, but host-plant and weather conditions

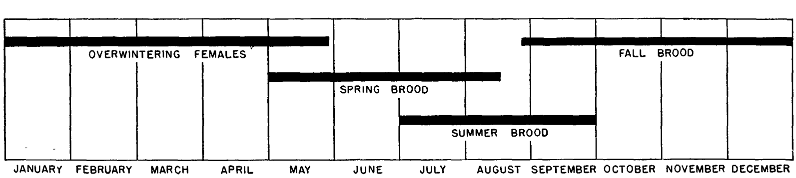

FIGURE 2.—Occurrence of the different broods of the beet leafhopper in the central Columbia breeding area.

at this time are such that populations are not so high as during the summer months.

HOST PLANTS

The principal overwintering host plants of *Eutettix tenellus* in this area are alfileria (*Erodium cicutarium*) and tumblemustard (*Norta altissima*). This mustard is also the most important host of the spring brood. Russian-thistle (*Salsola pestifer*) is by far the most important host of the summer brood. The fall brood matures on Russian-thistle, but the drying of this plant forces the insects to shift to the young fall-germinated plants of mustard and alfileria.

HOST OF THE SPRING BROOD

Spring-brood nymphs hatch and develop largely on tumblemustard and alfileria. These plants germinate in the fall and are usually abundant early in the spring. The tumblemustard usually lives longer than the alfileria, but since the two occur in close proximity or in intermixed stands the insects easily shift from alfileria to tumblemustard. Ordinarily neither plant dries before most of the spring brood matures, and many of the eggs are deposited in the mustard. Each year summer nymphs have hatched from the mustard just as it dried.

Tumblemustard is subject to considerable competition by downy bromegrass (*Bromus tectorum*). Much of the area in which tumblemustard was dominant in 1930 was entirely replaced by bromegrass in 1933. Alfileria is not so easily crowded out by the bromegrass, since it grows much faster late in the fall and early in the spring than does either tumblemustard or bromegrass. Moisture is sufficient for both plants at these times, and alfileria usually matures by the time the bromegrass becomes large enough to crowd it out. The tumblemustard, maturing later, comes into direct competition with the bromegrass at a time when moisture is scarce.

Large acreages of tumblemustard were noted to have succumbed to drought since 1929. In the summer of 1929 this mustard was abundant over much of the area between the Columbia and the Yakima Rivers. In 1930 young plants were observed the middle of March, but they had dried by the middle of April. Very few plants were seen in 1931, and most of these dried before reaching maturity. As a result the area was almost barren of tumblemustard during 1932 and 1933.

In 1932 *Pectocarya penicillata* harbored large populations of spring-brood nymphs and adults. Previously the plant had not been noticed. Its distribution was limited, and it was found to be relatively short-lived. In 1932 its seeds germinated late in February and the plants were mature and dry by May; in 1933 the seeds germinated the first week in March and the plants had matured and dried by the first week in June. In most places many large nymphs of the spring brood were present at the time the plants dried.

Bassia hirsuta, though of limited distribution, harbors rather large populations of the spring brood. It germinates either in the fall or spring and remains green until the following fall. Germination was noted on October 27, 1930, November 18, 1932, March 7, 1931, and March 14, 1933.

Chenopodium leptophyllum is a host of minor importance. Prior to 1933 population counts had not been made on this plant owing to its limited distribution. In 1933 it was slightly more abundant, but spring-brood populations on it were comparatively small.

HOSTS OF THE SUMMER BROOD

Russian-thistle, the most important summer host, has germinated in March every year, but it has not harbored large populations until after the spring dispersal. The entire life cycle of the summer brood is spent on this plant.

Gilia minutiflora is primarily a host of the summer and fall broods. The seeds usually germinate in April and the plants do not dry until late in October. Where *Gilia* is intermixed with tumblemustard, as it often is, populations on it are small until the mustard becomes unsuitable; where it occurs away from spring hosts, populations prior to dispersal are small. Populations have never been known to be large on this host, but in some years its abundance has made it important. In 1930, when it first attracted attention as a host of *Eutettix tenellus*, it was very abundant. That summer it was completely defoliated by the larvae of *Heliothis* sp. Later the plants leaved out and bloomed to a limited degree, but before they could set seed they were again defoliated, this time by a second brood of *Heliothis*. The plants were so completely prevented from setting seed by these two broods of *Heliothis* that *Gilia* was not again abundant until 1933, and even then it was less so than in 1930.

Chenopodium leptophyllum is a minor host of the summer as well as of the spring brood, since it does not usually dry until September.

HOSTS OF THE FALL BROOD

Host plants of the fall brood are of three distinct types: (1) Those on which the brood hatch and develop, (2) those on which the females overwinter, and (3) those that furnish food and a medium for oviposition the following spring. Of the first group Russian-thistle is by far the most important, with some breeding occurring on *Gilia minutiflora*, *Chenopodium leptophyllum*, and *Bassia hirsuta*. Alfileria is the most important in the second group owing to its abundance, while tumblemustard is the most important in the third group. This mustard germinates early in March and large spring populations of nymphs indicate that it is preferred for oviposition by the overwintered females.

SEASONAL OCCURRENCE

The magnitude of the spring brood of *Eutettix tenellus* depends upon the numbers of overwintered gravid females present in the spring. Thus, fall drought, type of winter, or any other factor that affects the overwintering of the fall-brood females has a marked effect on spring-brood populations. The time of appearance of this brood depends largely upon the temperature.

As will be seen from figure 3, spring-brood nymphs appeared each year about the first of May [6] and reached the peak of abundance the latter part of May. The low level the middle or latter part of June represents the end of that brood. The curves did not reach zero in June because of the hatching of the summer-brood nymphs and consequent overlapping of broods.

In 1931 an abundance of spring nymphs was expected because of the relatively large populations of overwintered females (fig. 3) and

[6] The data for 1930 were obtained by sweep-net sampling and are in terms of insects per 50 sweeps of a 14-inch net. They are not comparable to those obtained from the square-foot samples and are therefore not presented in figure 3.

the early egg development (fig. 6). Such is not indicated in the curve for that year. This inconsistency was probably due to imperfections in the technique of removing and counting small nymphs, since it was the first spring the counting cage was used. Sweep-net samples and the early appearance of large numbers of spring-brood adults indicated that nymph populations were comparatively large during May 1931.

In 1930 and 1931 spring-brood adults appeared from the middle to the latter part of May, populations reaching their peaks in June and declining after July 1, but in 1932 and 1933 they did not appear until about June 1, reaching their peaks the last of July. In figure 3 disappearance of the spring-brood adults cannot be determined, since the summer brood appeared about the first of July and caused overlapping.

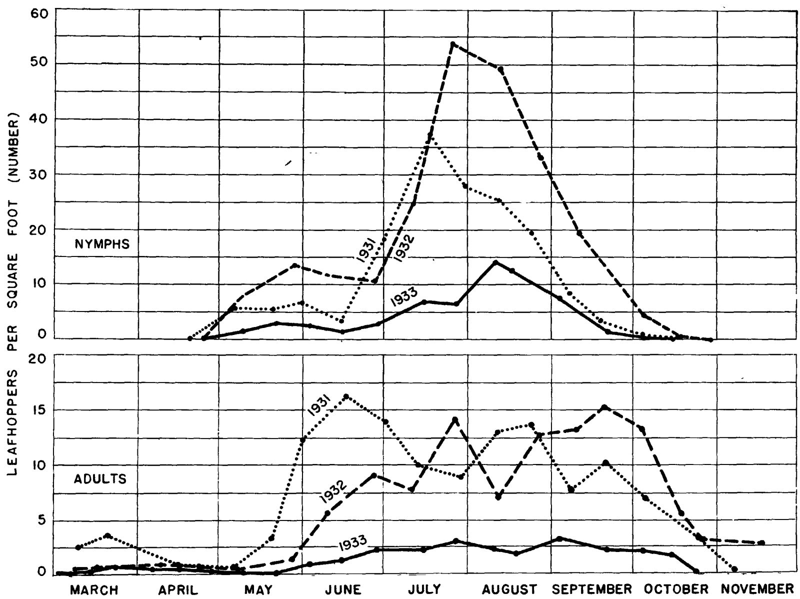

FIGURE 3.—Mean populations of the beet leafhopper in the breeding grounds.

Each year there has been a sudden increase in nymph populations and an appearance of very small nymphs late in June, which probably denotes the hatching of the summer brood. The summer and fall broods greatly overlap, so that figure 3 scarcely shows where one leaves off and the other begins. The slight decrease toward the end of July probably represents the beginning of the decline of the summer-brood nymphs. The time of appearance of the summer-brood adults is masked by the presence of the spring-brood adults. The peak of summer-brood adults came in August in 1930 and 1931, and the first of September in 1933. In all probability the 1932 peak also came the first of September, although this is not shown in figure 3, because the early appearance of large numbers of fall-brood adults undoubtedly prevented a drop in September populations.

The time of hatching of the fall-brood nymphs cannot be determined from figure 3, but it is undoubtedly the hatching of this brood that prevents the curve from dropping to zero in August, as the trend the latter part of July would indicate. Figure 3 shows a peak in September for fall-brood adults in 1931 and 1932. In 1933 populations were small, and in September fall-brood emergence scarcely replaced summer-brood mortality. Therefore, no fall-brood peak is shown for this year. The definite drop in adult populations in October is caused by the drying of the summer hosts, principally Russian-thistle. The last point in the 1931 curve for adults and the last two points in the 1932 curve represent collections on newly germinated mustard and

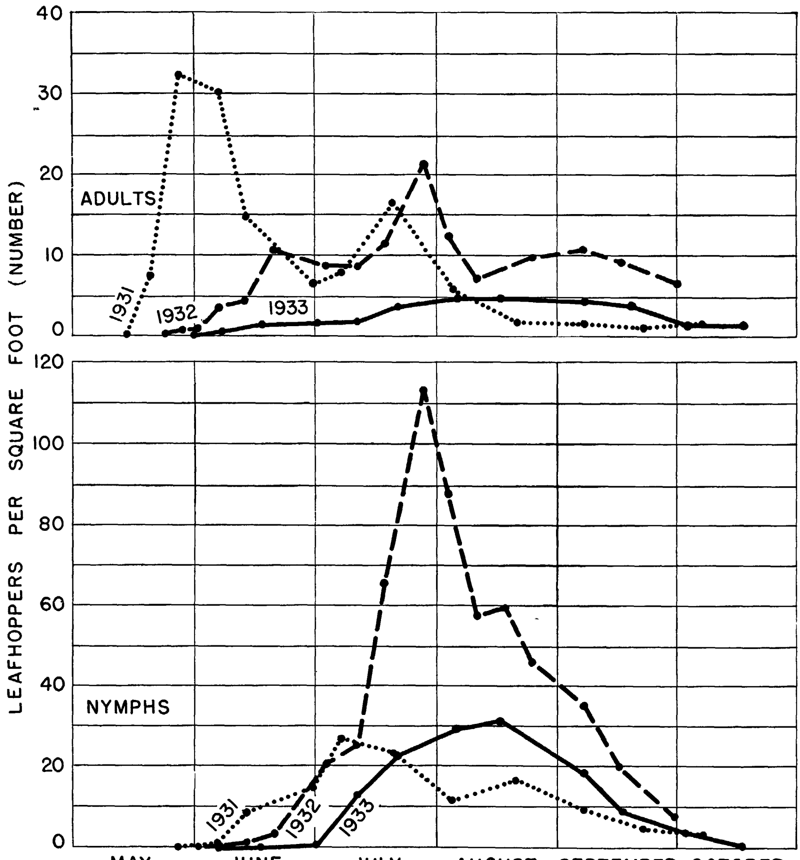

FIGURE 4.—Mean populations of the beet leafhopper in the beet plots.

alfileria. As fall hosts cover a much larger area than summer hosts, the shift results in a decreased population density, but there is probably a real mortality due to the forced shifting. The small fall populations shown are a resultant of both these causes.

DISPERSALS

Movements or dispersals of the spring brood have been studied by observations in beet plots and by catches in insect traps. Since no sugar beets are grown in the central Columbia area, one-fourth-acre plots were planted to beets in cooperation with the farmers for the purpose of studying *Eutettix tenellus* populations as well as disease conditions. Three were planted in 1931, three in 1932, and four in 1933. Prior to the spring dispersals the beet plots contained only a few overwintered females, which had no doubt come from adjoining wild hosts. Therefore, the increase in adult populations during May and June (fig. 4) was due entirely to an influx from the breeding ground. The curves for adults in figure 4 indicate both the time and the relative magnitude of the dispersals for these years.

A comparison of figures 3 and 4 shows that while adult populations are large in the breeding grounds at the time of migration, the peak is not reached until migration is over. It is possible that migration is so closely associated with brood maturity in the breeding grounds that the peak of adult populations is prevented until after migrations are over.

Approximate dates of spring dispersals as determined by windvane trap [7] collections and beet-plot population studies are as follows:

1931	May 19–20, 25–30. June 1–12. July 6–15 (slight).
1932	May 25 and 31. June 1–25. July 1–5 (slight).
1933	June 1–19 (slight).

In 1931 four traps were placed on the city water tower at Stanfield, Oreg., at heights of 38, 74, 108, and 127 feet above the ground, to determine the relative numbers of insects at those heights. During the season 18 *Eutettix tenellus* were caught in the trap at 38 feet, 12 at 74 feet, 6 at 108 feet, and 10 at 127 feet. Although these data are meager, they indicate that the flying insects are most numerous close to the ground.

The records obtained indicate that large populations in the breeding ground precede heavy dispersals, and since it is the spring brood that disperses to the cultivated area, the magnitude of this brood in the breeding ground is of prime importance. Figure 3 shows that the spring-brood populations in the breeding grounds were much larger in 1931 than in 1932 and 1933. Likewise, figure 4 shows a much larger spring-brood population in the beet plots in 1931 than in either 1932 or 1933. Curly top was severe in the plots in 1931, but not in 1932 and 1933. Curly top injury to tomatoes over the Umatilla irrigation project was also more severe in 1931 than in either 1932 or 1933. The magnitude of the summer brood in the beet plots, as indicated by the July peaks in figure 4, is of comparatively little importance, since the older plants are more resistant to the disease.

FALL AND WINTER SURVIVAL

Survival of the fall brood may be divided into two periods, fall and winter. Fall survival is largely dependent upon proper host-plant sequence. A change of host is necessitated by the maturation of Russian-thistle, which usually occurs from September 15 to October 15. High fall survival is favored when rainfall is sufficient to germinate winter hosts before Russian-thistle matures. Fall survival is low when fall rains are late and germination is delayed until after

[7] FULTON, F. 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. 1931.

Russian-thistle reaches maturity. When this occurs the insects are forced to feed on unfavorable food plants until winter hosts germinate.

In the period covered by these studies four distinct types of winter were represented. During January of the winter 1929–30 there were 16 days of subzero weather with a minimum temperature of −38° F., accompanied by 15 inches of snow. Snow was on the ground 5 days during December and 19 days during January. During the winter of 1930–31 there was no snow and the minimum temperature was 15°. The winter of 1931–32 set in early. The temperature dropped to 8° on November 21 and was consistently low from then to the middle of December, with a minimum of 2° on November 28. There were 5 inches of snow on the ground during this period. Temperatures during the last half of December and all of January were moderate, but from February 1 to 5 they were below 0°, with a minimum of −20° on February 2. The soil-surface temperature on this date was 26°. These low temperatures were accompanied by 8 inches of snow. From November 25 to February 10 snow was on the ground for 52 days. During the winter of 1932–33 there were 7 days of subzero temperature, with a minimum of −9° in December; there was no snow cover during this period, and the soil-surface temperature dropped to 2°. On February 9 the minimum air temperature was −5° and, with no snow cover, the soil temperature dropped to 5°.

The winter of 1932–33 is the only one of the four which had any apparent effect on leafhopper survival. Field counts taken in fall and spring, as well as hibernation-cage results, show that the winters of 1929–30, 1930–31, and 1931–32 had little if any effect on the insects, whereas only 4 percent of the insects survived the winter of 1932–33. The extremely low soil-surface temperatures affected the insect not only directly but indirectly by limiting the food supply, since practically all alfileria and tumblemustard were killed.

SEASONAL COLORATION

Severin [8] mentions certain differences in color patterns of *Eutettix tenellus* in California. These seasonal color patterns have been found to occur in Oregon. In general there are three color types, the dark forms, which are the usual overwintering type, and the green and straw-colored forms, which occur during the spring and summer. In 1931 and 1932 *E. tenellus* adults taken in the regular population counts were classified according to color (fig. 5). The difference in coloration between the green and the straw-colored forms during the spring and summer is not always clear-cut, but there is always a noticeable difference between the spring and summer forms and the dark overwintering forms. This difference in coloration may or may not be associated directly with brood occurrence, but it will be noted from figure 5 that early in the spring, when only overwintered females are present, only the dark forms occur. The sudden increase in May or June is due entirely to the green forms. The peak of the summer brood is caused largely by the straw-colored forms, and the fall populations are made up almost entirely of straw-colored and dark forms. The fall and winter mortality of the straw-colored forms is very high, so that by spring the populations consist almost entirely of dark forms.

[8] SEVERIN, H. H. P. LIFE-HISTORY OF THE BEET LEAFHOPPER, EUTETTIX TENELLUS (BAKER), IN CALIFORNIA. Calif. Univ. Pubs. Ent. 5 (4): 37–88, illus. 1930.

EGG DEVELOPMENT

A special technique was devised for studying seasonal ovule development. About every 10 days samples of females were taken from a locality in which the host-plant sequence was adequate to maintain the insect throughout the year. These samples were preserved in a 5-percent aqueous solution of chloral hydrate. Twenty-five females for each date of collection were dissected under a binocular microscope, and then measurements were made by substituting a sliding-scale ocular micrometer for one of the oculars. Comparative development was determined by measuring the developing ovules within the female, and egg length was taken as an indication of the degree of development. Only ovules over 0.20 mm in length were recorded, smaller ovules being considered unimportant for this work. Results were expressed in terms of total length of all eggs over 0.20 mm for each female, and the mean total length of eggs for each sample was taken to represent

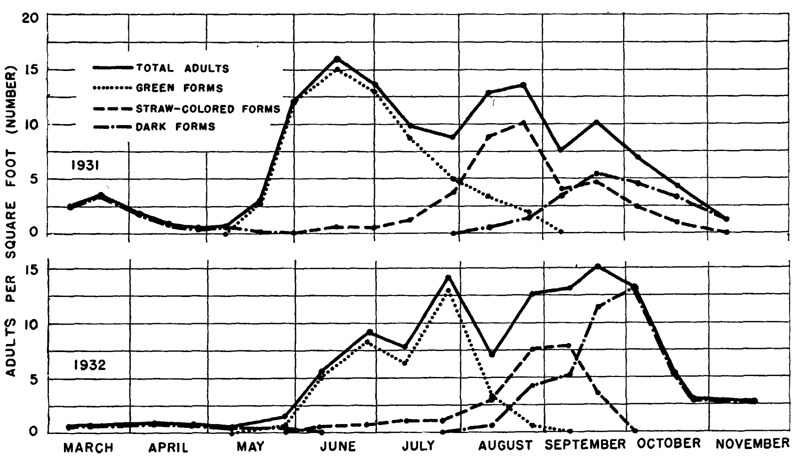

FIGURE 5.—Seasonal coloration of the adult beet leafhopper in the central Columbia breeding area.

the relative egg development for that date. It was later found, however, that almost identical results could be obtained by simply counting the number of mature eggs present in each female on given dates.

The results of these measurements are presented in figure 6. The data indicate a total absence of developing ovules from mid-September until the latter part of February or the first of March of the following year. During April and May the number of developing ovules is much greater than throughout the summer. The decline in May is probably due to exhaustion of the egg supply of the overwintered females and is followed by maturing of spring-brood females.

A peak of ovule development is shown near the end of June 1931 for the spring brood and another the first part of August 1931 for the summer brood. In 1930 a peak is shown for the spring brood the latter part of June. Other peaks for the spring and summer brood do not show in figure 6. They are in all probability masked by overlapping of broods. The abrupt ending of development in September is due largely to the dying of the summer brood, leaving only the fall females, whose ovaries do not develop until the following spring.

Comparison of figures 6 and 7 indicates that the number of ovules present in the spring females that moved into the beet plots was considerably larger than in those that remained in the breeding grounds.

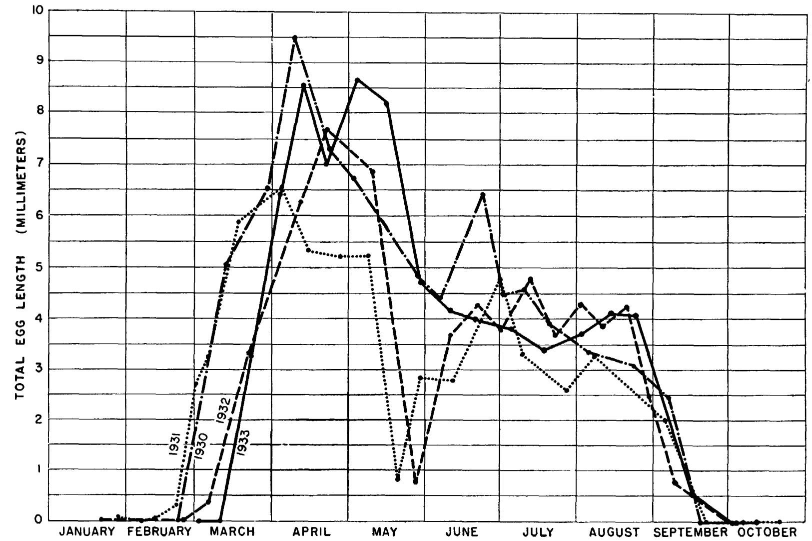

FIGURE 6.—Egg development of the beet leafhopper in the breeding grounds.

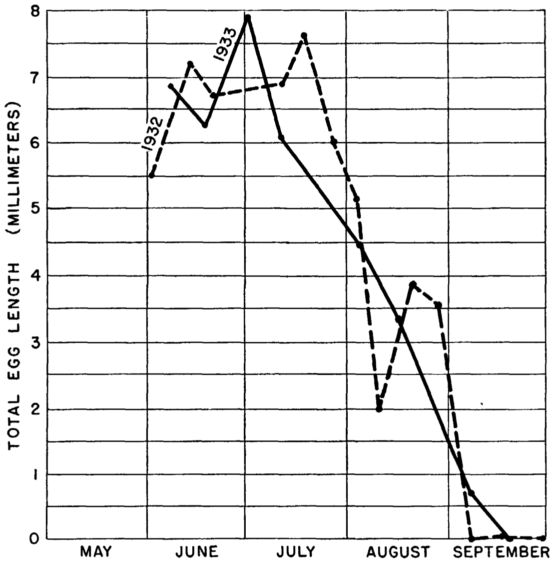

FIGURE 7.—Egg development of the beet leafhopper in the beet plots.

SUMMARY

Ecological studies of the beet leafhopper, *Eutettix tenellus* (Baker), were made in the breeding area in the central Columbia River valley, in south-central Washington and northeastern Oregon. In this area there are three broods of this insect. The more important host plants are tumblemustard, alfileria, and Russian-thistle.

The leafhopper usually disperses from this breeding area between May 20 and June 30, movements being more or less continuous during this period. Return to the fall and winter hosts, tumblemustard and alfileria, occurs during October and is largely a forced movement caused by the drying of the summer

hosts, principally Russian-thistle. If germination of the fall hosts is delayed by drought until after Russian-thistle has dried, a high mortality is likely to result.

High percentages of curly top are directly correlated with large spring-brood populations of the leafhopper. Large populations of the summer and fall broods are relatively unimportant in this respect, except as they affect the magnitude of the spring brood the following year.

Winter mortality is usually of comparatively little importance in this area. In only one winter of the four observed was there severe mortality, and this was due to subzero weather without snow cover, which not only subjected the insects to intense cold but killed their food plants as well.

Seasonal variations in color patterns of the beet leafhopper have been observed in this area. In general, dark forms predominate during winter, greenish forms during spring, and straw-colored forms during summer.

Studies have been made of seasonal ovule development in this breeding area. Development drops to zero in September and does not begin again until late in February or early in March of the following season.