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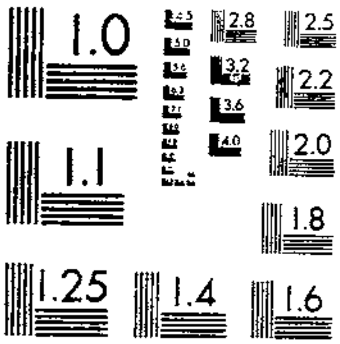

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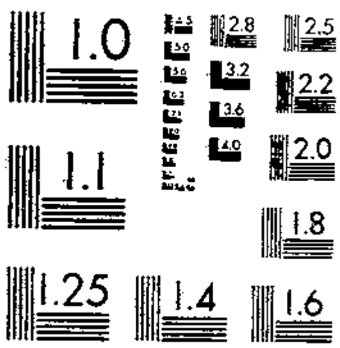

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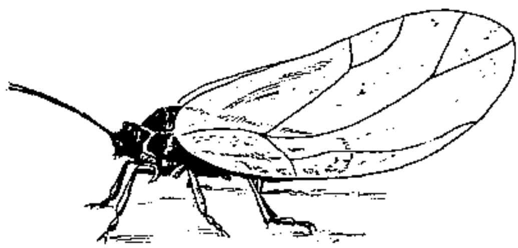

By R. L. Wallis

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U. S. DEPARTMENT OF AGRICULTURE

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ECOLOGICAL STUDIES ON THE POTATO PSYLLID AS A PEST OF POTATOES[1]

By R. L. Wallis,[2] *entomologist, Entomology Research Branch, Agricultural Research Service*

Potatoes in certain Western States are subject to psyllid yellows, a disease caused by the potato psyllid (*Paratrioza cockerelli* (Sulc)) (*14*). Sudden outbreaks of this inconspicuous insect are accompanied by epidemics of the disease. Such an epidemic in 1938 caused complete crop loss to many growers in Colorado, Wyoming, Nebraska, Montana, and New Mexico. At the request of the agricultural experiment stations of these States, the Bureau of Entomology and Plant Quarantine began ecological studies to determine the cause and source of such outbreaks.

The lack of satisfactory evidence that the potato psyllid overwintered in the affected areas had indicated that large populations developed somewhere in the South during the winter, possibly on wild host plants. It seemed, therefore, that the chief problems were to locate the wild hosts of the psyllid, to establish its overwintering quarters, and to determine the factors causing its development in outbreak numbers and its movement to potato fields. The ultimate objective was to establish surveys to provide information that would be useful as a guide to control measures. These studies were made during the period 1939–52 from headquarters at Scottsbluff, Nebr.

ECONOMIC IMPORTANCE

The injury by psyllids or psyllid yellows disease to potatoes results in the production of a large number of tubers of small size and poor quality. On tomatoes there is a similar reduction in yield and quality of fruit. The writer has observed as many as 100 tubers per plant in severely damaged potato fields, none of them of marketable size. The presprouting period of the tubers is shortened so that they may sprout in the ground before harvest or early in the storage period.

It is difficult to estimate the losses of potatoes and tomatoes from damage by the psyllids, because the severity of attack varies greatly from year to year and from one locality to another. Without control measures total crop failures will occur nearly every year in the cool climate of the higher elevations, or in the plains areas during the cooler part of the year.

The literature indicates that there were psyllid epidemics in 1911–12, 1926–27, 1929–33, 1938–39, and 1949, with moderate to light infestations in the intervening years. Although the recent literature deals almost

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[1] Submitted for publication August 9, 1954.

[2] Staff members of the Agricultural Experiment Stations of Nebraska, Wyoming, Colorado, Montana, and New Mexico gave advice and assistance in the course of these studies.

entirely with populations on potatoes, it may be presumed that epidemics on tomatoes occurred at the same times. The epidemics affected Utah, Montana, Wyoming, Colorado, and the western part of Nebraska.

Daniels (*3*) reported that in Colorado in 1931 many fields of early potatoes were never dug and that the reduction in yield below the 1930 crop was 7,895,000 bushels, representing a loss of 2,763,200 dollars. Richards and Blood (*15*) estimated that in Utah in 1927 from 25 to 30 percent of the potato crop was destroyed, the losses amounting to approximately 750,000 dollars. The most severe losses over all the Western States occurred in 1938, according to many investigators. According to Pletsch (*13*), damage to the potato crop in that year was 50 to 75 percent in most of the southeastern counties of Montana, considerably less in the northeastern part of the State, and none in the western section. Edson and Wood (*4*) estimated the losses to the potato crop in several of the affected States in 1938 as follows: Colorado 1,502,000 bushels, or 8 percent of the crop; Wyoming 1,392,000 bushels, or 50 percent; and Montana 605,000 bushels, or 25 percent.

During the years 1939–52 estimates were made of the psyllid infestations on early, medium, and late plantings of potatoes in the North Platte Valley in eastern Wyoming and western Nebraska. In this area an early crop is planted about May 1, and the commercial late crop from May 25 to June 30. For the purpose of this study, however, potatoes planted from May 25 to June 5 are called the medium crop.

Ten fields for each crop were located at random over the valley, and two to four 100-sweep samples were taken at weekly intervals during the growing seasons. As shown in table 1, few psyllids were present in 1943, 1945 to 1947, and 1950 to 1952. Outbreaks occurred in 1939 and 1949. The heaviest populations were on the early crops, where there were 3 or more adults per 100 sweeps in 7 of the 14 years.

Table 1.—*Average numbers of adult potato psyllids per 100 sweeps in potato fields in the North Platte Valley, 1939–52*

Year	Early crop	Medium crop	Late crop
1939	16.1	1.1	2.3
1940	1.3	2.4	.5
1941	5.1	1.9	2.6
1942	3.6	2.6	1.4
1943	.5	.1	.1
1944	3.0	3.0	2.9
1945	.8	--------	.2
1946	2.5	.6	.3
1947	.5	.2	.3
1948	3.9	1.7	1.3
1949	15.9	4.7	3.4
1950	3.6	.7	.7
1951	0	0	0
1952	.5	0	0

Studies were also made to determine the effect of psyllids on potato yields. Population and yield records were made on four plots in each planting. Each plot consisted of 6 rows 90 feet long. The early planting was made on May 1, the medium planting on June 1, and the late one on June 25. Three of the plots were dusted with sulfur one, two, or three times in order to vary the population so that its effect on the yield could be measured. At four intervals during the growing period the nymphs and adults on each plot were counted. Counts of nymphs were made on 50 leaflets collected at random and counts of adults in two 100-sweep samples. Yield records were taken at harvest. All population and yield samples were taken from the 2 middle rows of each plot.

In these experiments the correlation of psyllid population with yield was particularly good in 1942, when the population was high and the growing season was uninterrupted by adverse weather (fig. 1).

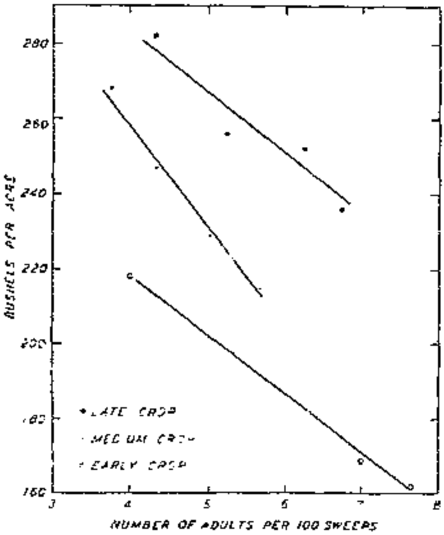


FIGURE 1.—Correlation of psyllid population with yield of potatoes, 1942.

The average reductions in yield for each additional psyllid per 100 sweeps were 16, 27, and 16 bushels per acre for the early, medium, and late crops, respectively. It is realized that these values are based on limited studies, but they seem to be fairly accurate for populations up to 7 or 8 psyllids per 100 sweeps. When these values are applied to the infestation data in table 1, a general idea is obtained of the damage caused by the insect.

DISTRIBUTION

The potato psyllid is generally distributed in North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and all States west of them except Washington and Oregon (fig. 2). Psyllid yellows is found only in these States. It is also found in Mexico and the Canadian Provinces of British Columbia, Alberta, and Saskatchewan.

Since psyllids occur in diminishing numbers eastward from the 100th meridian, the approximate dividing line between the humid and dry areas of the United States, high humidity may be the factor preventing their spread to the Eastern States. There are many reports of their occurrence east of the 100th meridian in the lower Rio Grande River Valley of Texas, but surveys have shown that they are present only in small numbers, particularly where the humidity is high.

Richards and Blood (*15*) reported the psyllid yellows disease from Idaho Falls and Twin Falls, Idaho, in 1927, but there is no record of the collection of the potato psyllid at these points. Swenk and Tate (*18*) stated that, "In Nebraska the potato psyllid is of greatest economic importance in the commercial potato growing sections of the western part of the state. It occurs, however, throughout the entire state, and in 1938 some damage was definitely recorded on tomatoes and potatoes as far east as Lancaster county."

Glick (*6*) reported collection of the insect in airplane flights in the vicinity of Tlahualilo, Durango, Mexico. Adults were taken at an altitude of 4,000 feet and in considerable numbers up to 2,000 feet. None were taken in similar flights at Tallulah, La.

NATURE OF INJURY

The first symptom of psyllid yellows on potatoes is an upward curling of the basal portions of the leaflets near the top of the plant. As the disease progresses, the curling becomes more pronounced and nearly reaches the petioles and extends toward the tips of the leaflets. The edges of the leaflets turn slightly yellow or purple in some varieties. In advanced stages of the disease the entire plant has a yellowish or purplish appearance,

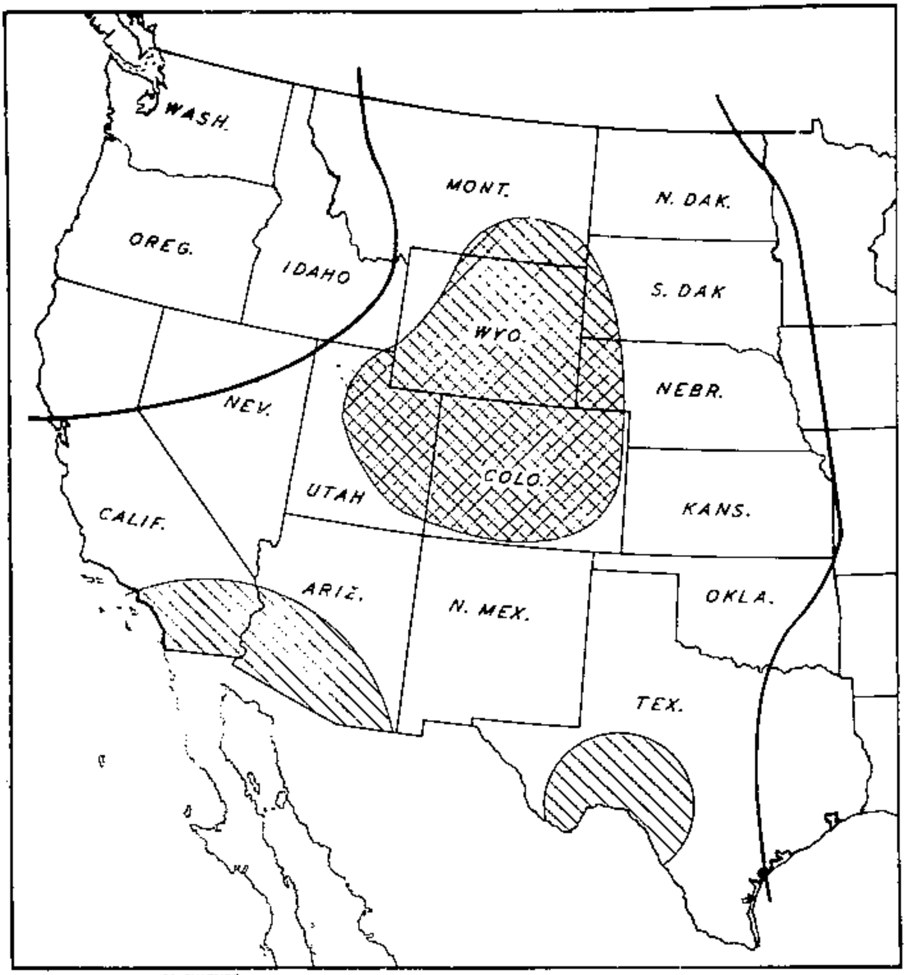
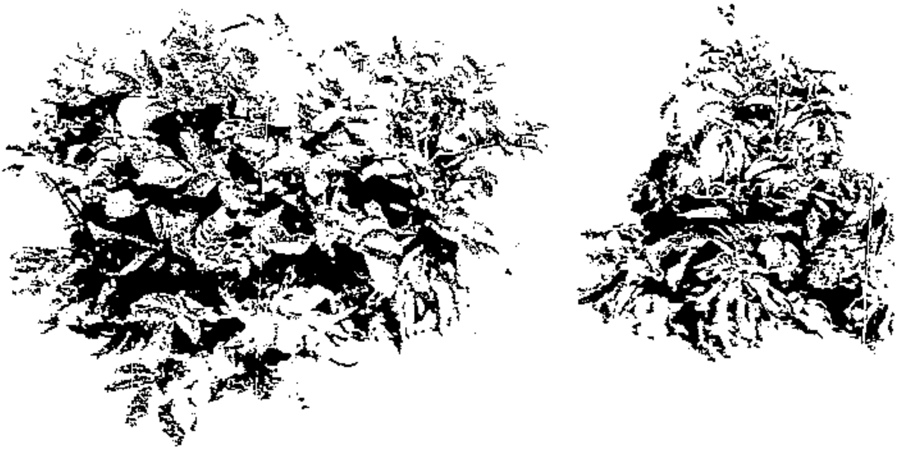


FIGURE 2.—Distribution of the potato psyllid in the United States. The crosshatching indicates the area of greatest injury, the diagonal lines the approximate overwintering areas, and the heavy lines the eastern and western limits of occurrence.

and the leaves on the lower portion curl upward and become discolored and leathery. During the progress of the disease the nodes enlarge and the buds in the axils begin growth, resulting in the formation of short shoots each with a small cluster of abnormally shaped leaves or small aerial tubers bearing tiny leaves. Finally the top of the plant is composed mostly of secondary shoots and leaves attached to the primary stems, which give it a dwarfed appearance. Thus the plant has a pyramidal shape, with larger leaves at the base. Normal and psyllid-injured plants are shown in figure 3.

Potato plants that are affected early in their growth produce few if any tubers. On plants attacked later, after the tubers begin to set, tubers stop growing and mature before they become of marketable size. Some of them sprout and produce secondary stolons, which may in turn set additional tubers. The crop is reduced not only in size but



[illegible]

[illegible] storage and the sprouts [illegible] When affected [illegible] However, these [illegible] psyllids [illegible] period.

Psyllids [illegible] plants at the edge of the [illegible]

FIG. 3.—Left, diseased tubers from a field heavily infested with potato psyllids; right, normal tubers.

progresses [illegible] toward the center. [illegible] the psyllids migrating from [illegible] of the [illegible] and seek suitable host plants. This accounts for the greater [illegible] at the edge of the field. [illegible] toward the center of the field. [illegible] stage of [illegible] formerly [illegible] of abnormal shape. [illegible] such as leaf roll, [illegible] symptoms.

The true nature of psyllid yellows has never been fully understood. [illegible] suggested that the disease [illegible] caused by [illegible] rather than [illegible] feeding of the psyllid nymphs, but that it is not transmitted through the psyllid eggs. However, Richards and Blood [illegible] showed that the severity of the symptoms is in proportion to the nymphal population, and supported the theory that it is caused by a toxin injected by the nymphs while feeding. These workers were able to obtain disease symptoms in 5 days with 15 nymphs per plant and in 3 days with 30 nymphs per plant in the field. They also showed that the symptoms do not appear in a plant infested with as many as 1,000 adults and concluded that adults do not cause the disease. They were unable to transmit the disease through inoculation by various standard methods used for the transfer of virus diseases and with a large number of plants in different stages of development as sources of inoculum. Neither were they able to transmit it through the tubers from diseased parents to the progeny in the field or greenhouse.

The writer has observed in small-plot tests that severe psyllid yellows on potato plants can be checked and that the plants recover when psyllids are removed from them. This indicates that the material injected into the plants by the nymphs is a toxin and not a virus.

The effect of psyllid yellows on tomatoes is similar to that on potatoes, i. e., a heavy set of fruit that fails to develop in size, quality, and color. The fruit is light green to yellowish instead of the normal red. It is coarse and tough and contains little juice. Infestations that are so light as to cause no plant symptoms may reduce the quality of the fruit.

DESCRIPTION, LIFE HISTORY, AND HABITS

The Adult

The adult psyllid (fig. 5, *A*) is about 1/12 to 1/10 inch long to the tip of the wings. It is a clear-winged insect resembling a miniature cicada in shape. The adult is light green when newly emerged, but after 2 or 3 days becomes black with white markings, which give it a gray appearance. These white markings are distinguishing characteristics of the psyllid, particularly the broad,

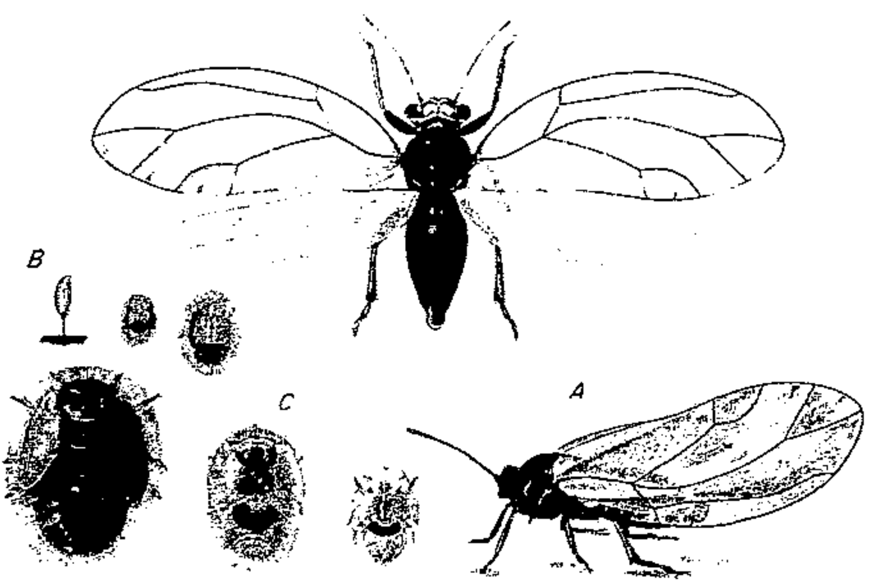


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FIGURE 5.—The potato psyllid in different stages of development: *A*, Adult; *B*, egg; and *C*, nymphs. (Enlarged.)

transverse white band on the first abdominal segment and the inverted V-shaped white mark on the last abdominal segment. When at rest the wings are held in a rooflike position over the abdomen.

The adult is very active, and when disturbed it jumps quickly into the air and takes flight. Its movement in the upper air currents is probably caused more by the wind than by its own force. Apparently it may be transported long distances by the wind. When the adult is in a resting position on a leaf, it will swing the abdomen from side to side at the least disturbance or on exposure to strong light.

The eggs are deposited usually on the edge or under side of the leaves on the upper part of the plant. Studies in 1946 indicated that only about 12 percent of the eggs are laid on the upper surface of the leaves.

One female deposits about 300 eggs, averaging 15 per day over a period of about 21 days. Eggs are deposited most freely at about 80° F., although oviposition at 60° and 100° has been reported. A temperature above 95° shortens the life of the females.

The Egg

The egg (fig. 5, *B*) is about 1/32 inch long, oval, and bright yellow to orange. One end of the egg shell is prolonged into a stalk by which it is attached to the leaf.

The incubation period varies considerably with the temperature but averages about 7 days. The greatest number of eggs hatch at 80° F. Very few hatch when the temperature reads 100° for a few hours each day and about 40 percent at a constant temperature of 60°.

The Nymph

The nymph (fig. 5, *C*) is flat and scalelike with a row of short hairs or spines around the entire margin of the body. It is orange to yellow when newly hatched and becomes pale green when mature. In their development nymphs pass through five instars, which average about 2½ days for each of the first four and about 5 days for the last. The developmental period varies with the temperature from about 13 days in July to 17 days in May and October.

It is difficult to see the nymphs on the leaves, owing to their minute size, green color, and flat bodies. They hold themselves close to the leaf surface, and the hair around the edge of the body makes contact with the leaf surface. They are usually found on the under sides of the leaves on the upper half of the plant. They probably do not move far from the leaf on which they hatched except to obtain food.

HOST PLANTS

The food plants, both wild and cultivated, are important in facilitating the breeding, overwintering, and distribution of the potato psyllid. The relative importance of the various host plants has never been fully determined. The importance of a given host plant is undoubtedly influenced by its abundance, the insects' preference for it, and its proximity to the cultivated areas.

The principal host plants of the potato psyllid belong to the Solanaceae, but they are not restricted to this family. Host-plant lists have been published by Knowlton and Thomas (*10*), Pletsch (*13*), Crawford (*2*), and Essig (*5*). The following list has been compiled from the literature and the writer's record of collections:

Solanaceae

- *Atropa belladonna* L. (belladonna)
- *Capsicum frutescens* L. (pimiento pepper)*
  - *frutescens* var. *conoides* (Mill.) (tabasco pepper)*
  - *frutescens* var. *grossum* (L.) (bell pepper)*

*Asterisk indicates plants on which the author has observed psyllids breeding.

Solanaceae—Continued
Datura fastuosa L.
innoxia Mill.
metel L. (entire leaf thornapple)
meteloides DC.
sanguinea Ruiz and Pavon
stramonium L. (jimsonweed)*
Hyoscyamus albus L.
niger L.
Iochroma tubulosum Benth.
Lycium andersonii Gray*
californicum Nutt.
carolinianum Walt.
exsertum Gray*
fremontii Gray*
halimifolium Mill. (matrimony-vine)*
pallidum Miers*
parishii Gray*
quadridichum (Moe. and Sesse) C. L. Hitchcock*
torreyi Gray*
Lycopersicon esculentum Mill. (tomato)*
pimpinellifolium (Jusl.) Mill.
Nicandra physalodes (L.) Gaertn. (apple-of-Peru)*
Nicotiana affinis Moore (flowering tobacco)*
glauca Graham (tree tobacco)*
glutinosa L.
tabacum L. (tobacco)*
texana Hort.
Nierembergia hippomanica Miers*
Petunia sp. (ornamental petunia)
Physalis angulata L. (cutleaf groundcherry)*
comata Rydb. (wild groundcherry)*
crassifolia Benth. (wild groundcherry)
franchetii Mast. (Chineselantern)*
heterophylla Nees (clammy groundcherry)*
ixocarpa Brot. (cultivated groundcherry)*
lanceolata Michx.*
lobata Torr. (purple groundcherry)*
longifolia Nutt. (longleaf groundcherry)*
mollis Nutt. (longleaf groundcherry)*
peruviana L.
pruinosa L. (husk tomato)*
rotundata Rydb. (longleaf groundcherry)*
Physalodes pubescens L. (husk tomato)
Salpiglossis sp.
Solanum aviculare Dunal
ballisii Dunal

*Asterisk indicates plants on which the author has observed psyllids breeding.

Solanaceae—Continued
Solanum aviculare Dunal—Continued
capsicastrum Link. (Jerusalem-cherry)*
carolinense L. (horsenettle)*
citrullifolium A. Br.
elaeagnifolium Cav. (white horsenettle)*
flavum Kit.
gracile Otto
jamesii Torr. (wild potato)*
marginatum L.
melongena L. (eggplant)*
mexicanum Dunal
nigrum L. (wonderberry)*
pyracanthum Jacq.
racemigerum (Lange) Zodda
rostratum Dunal (buffalo-bur)*
saniticongsei Craib
sisymbrifolium Lam. (viscid nightshade)
triflorum Nutt. (wild tomato)*
triquetrum Cav.
tuberosum L. (potato)*
umbelliferum Eschsch.
verbascifolium L.
villosum Mill.
Convolvulaceae
Convolvulus arvensis L. (field bindweed)*
Ipomoea batatas (L.) Lam. (sweetpotato)*
purpurea (L.) Roth (morning-glory)*
Asteraceae
Chrysothamnus paniculatus (A. Gray) Hall (rabbitbrush)
nauseosus (Pall.) Britt.
Helianthus annuus L. (sunflower)
Lactuca sativa L. (garden lettuce)
Taraxacum officinale Weber (dandelion)
Zygophyllaceae
Larrea tridentata (DC.) Coville
Fabaceae
Lathyrus sp.
Medicago sativa L. (alfalfa)
Phaseolus vulgaris L. (bean)
Brassicaceae
Brassica sp. (mustard)
Descurainia pinnata (Walt.) Britt.
Lepidium scopulorum Jones (peppergrass)
Raphanus sp. (radish)
Chenopodiaceae
Atriplex rosea L.
Atriplex sp. (orache)
Bassia hyssopifolia (Pall.) Kuntze
Beta vulgaris L. (beet)
Salsola kali var. *tenuifolia* Tausch (Russian-thistle)
Salicaceae
Salix sp. (willow)
Rosaceae
Purshia sp.
Polygonaceae
Eriogonum trichopes Torr.
Polygonum sp. (knotweed)

Pinaceae
- *Juniperus* sp. (redcedar)
- *Picea* sp. (spruce)
- *Pinus monophylla* Torr. and Frém. (singleleaf pine)
- *Thuja occidentalis* L. (arborvitae)

Malvaceae
- *Hibiscus trionum* L. (flower-of-an-hour)
- *Malva* sp. (mallow)

Asclepiadaceae
- *Asclepias* sp. (milkweed)

Amaranthaceae
- *Amaranthus* sp. (redroot)

Lamiaceae
- *Mentha spicata* L. (spearmint)
- *Nepeta cataria* L. (catnip)

Violaceae
- *Viola* sp. (wild pansy)

Poaceae
- *Avena fatua* L. (wild oats)
- *Dactylis glomerata* L. (orchardgrass)

Ranunculaceae
- *Delphinium* sp. (larkspur)

Scrophulariaceae
- *Antirrhinum majus* L. (snapdragon)

Menthaceae
- *Micromeria chamissonis* (Benth.) Greene

The literature did not always indicate the stage of the insect collected. It may be presumed that adults were collected in most cases, since nymphs and eggs are rarely taken with a sweep net. There is therefore no indication whether the host is a true host, as shown by feeding and the presence of immature stages, or a casual host, on which adults can be taken without evidence of feeding or breeding.

The writer has found psyllid eggs and nymphs on all the many solanaceous host plants observed, and it is probable that all species of this family may be *true* hosts wherever they occur in the psyllid-infested area.

Several workers have recorded few plants other than Solanaceae as true host plants. Knowlton and Thomas (*10*), in greenhouse and laboratory tests, found that psyllids will breed on *Convolvulus arvensis* and *Micromeria chamissonis*. List (*12*) reported that they had developed on the common garden morning-glory. He also reported the occurrence of nymphs on bindweed, and that he was able to transfer them from potatoes and tomatoes to bindweed and vice versa with no unusual mortality. The writer found psyllids in all stages in abundance on bindweed and sweetpotato near a heavily infested field of tomatoes in 1949.

Among the wild or noneconomic host plants buffalo-bur (fig. 6) and the several species of perennial groundcherry (fig. 7) are the most common and widely distributed. The writer (*19*) found matrimony-vine and potato sprouts growing in cull piles by far the most important noneconomic host plants of the psyllid.

Since they begin growth in April, ahead of other hosts, they have a long time in the spring to receive incoming adults from overwintering sources and for breeding before cultivated crops are growing. The several species of wild groundcherry do not start growth in Nebraska and Wyoming until about May 1, and are not large enough to attract adult psyllids until June, and then only in

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FIGURE 6.—Buffalo-bur, a wild host plant of the potato psyllid.

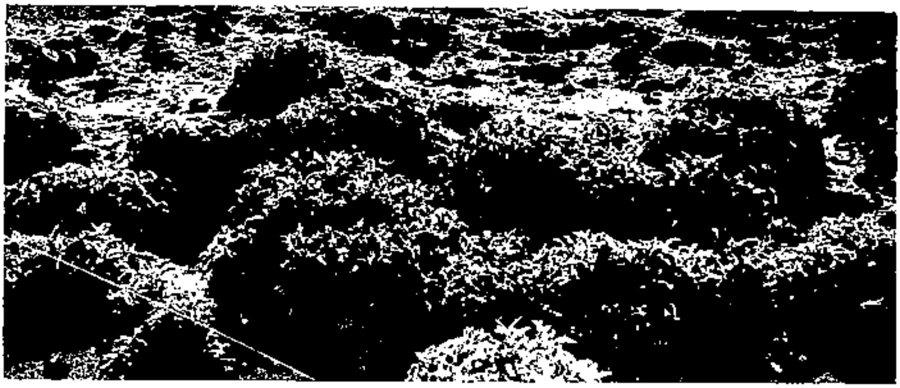

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FIGURE 7.—Groundcherry, a wild host plant of the potato psyllid.

small numbers. Buffalo-bur, an annual, does not usually start growth until about June 1, and therefore is too late for spring infestations, which may move to and damage cultivated crops.

Potato plants growing in dumps from discarded cull tubers provide ideal spring breeding quarters for psyllids. The large number of psyllids that develop in neglected cull dumps before potato plants are available in the fields constitutes a serious menace to the potato crop. The cull potato sprouts die during the hot, dry weather in July.

Matrimony-vine (fig. 8) is a cultivated ornamental frequently found around the older city and rural residences. It reproduces by rootstocks. Abandoned plantings spread to considerable size and make ideal early spring breeding grounds for psyllids.

In the southern part of the psyllid-infested area several species of wild matrimony vine serve as breeding plants of the psyllid in the winter and the spring. According to Hitchcock (*9*), the center of dispersal of *Lycium* in this country is Arizona, and of the 14 native North American species, 10 are found in southern Arizona, 10 in northern Mexico, 9 in southern California, 5 in Lower California, 5 in Texas, 4 in New Mexico, 3 in Utah, 2 in southern Nevada, 1 in Colorado, and 1 in the Gulf States. Most wild species of *Lycium* are part of the typical desert flora. They become defoliated during periods of drought or low temperature and quickly revive upon the return of favorable conditions.

Several species of wild groundcherry occur in the Southern States. White horsenettle is widespread, but few psyllids are found on it except in cool weather.

The host plant preference of the potato psyllid in the Northern States has been studied by the writer (*20*). Egg counts were made on 14 wild and cultivated host plants. Significantly more eggs were laid on Chineselantern and horsenettle than on the other plants, and more on cultivated and wild groundcherries than on the remaining plants, including potatoes and tomatoes. Chineselantern is an ornamental grown to a limited extent, and therefore will never be an important psyllid-breeding plant. Horsenettle, a wild plant, is abundant in many sections of the potato- and tomato-growing area, and therefore will be an important host in these sections. Wild groundcherries are widespread over the psyllid-infested area, but their late growth reduces their importance as psyllid-breeding plants.

FIGURE 8.—Matrimony-vine, an important spring breeding source of potato psyllids.

OVERWINTERING

In Northern Potato Areas

The manner in which the potato psyllid overwinters and reinfests the fields in the spring has long been questioned. The numbers found in the winter in the northern potato-growing areas have never been sufficient to account for the spring infestations.

Daniels (*3*) reported that overwintering psyllids were found in the cedar areas in southwestern Nebraska in the winter of 1936, but they were later determined as *Aphalara loca* Cald., a species rarely found on potatoes.

Experiments were conducted at Scottsbluff, Nebr., during the winters of 1939–40 and 1940–41 to determine whether potato psyllids could be overwintered on cedar, pine, and spruce trees. Cages consisting of muslin bags 15 by 18 inches were tied over twigs of these trees in various situations and slope exposures. Cages on cedars were removed at weekly intervals and examined for mortality. One hundred adults were introduced into each cage in late October and examination of them was started on November 20. In the winter of 1939–40, 53 percent of the psyllids were dead by November 20, and all were dead by January 2. Subzero temperatures did not occur until the last week in December. The cages on the other trees were examined in April and all psyllids were found dead. In the winter of 1940–41, all the psyllids in cages on cedar trees were dead on December 2. Subzero temperatures had occurred in early November and again in early December. These tests show that psyllids can survive on evergreen trees for short periods but cannot withstand the subzero temperatures that occur every winter at this latitude.

The possible overwintering of psyllids in greenhouses and their movement to outdoor crops in the spring is suggested by Strickland (*17*), who doubts whether they can overwinter in the open in southern Alberta, Canada. This may occur in some areas, but it does not explain spring infestations in areas where greenhouses are remote from cultivated fields.

In the springs of 1940 and 1941 the writer surveyed psyllid infestations in greenhouses in the North Platte Valley in western Nebraska. In 1940 only a few psyllids were found in any of the greenhouses and most greenhouses were entirely free of them. In 1941 no psyllids were found in any greenhouse. These observations indicate that greenhouses are not the source of spring infestations in this area.

In the Southwestern States

To obtain information as to the source of the spring infestations, the writer began a study of the overwintering areas east of the Rocky Mountains and of the movement of psyllids northward during the spring months. Surveys were made in southern Texas and New Mexico in mid-November, mid-January, and late March or early April from the fall of 1946 to the spring of 1952.

Counts of adults were made with a 15-inch insect net where the host plants were in foliage. From one to four 100-sweep samples were taken at 10 to 35 points selected at random over each area surveyed. Counts of eggs and nymphs were made on 100-leaf samples taken at the same points. Counts of immature stages were made with the aid of a magnifying glass.

The areas used were selected where host plants were most abundant in the vicinity of Crystal City, Del Rio, San Angelo, Marathon, Big Spring, and El Paso in Texas (fig. 9).

Figure 9.—Places in the breeding areas of the potato psyllid where surveys were made, 1946–52. Arrows indicate the prevailing wind direction at the time of the spring movement.

The principal host plants and the ones used in the study were species of *Lycium* (fig. 10), 5 of which occur in Texas and 4 in New Mexico. Other host plants included several species of wild groundcherry and white horsenettle, but few psyllids were found on them.

Lycium plants grow wild on range and waste land. They reproduce mainly by underground rootstocks and are able to withstand long periods of drought or low temperatures. They have woody stems and grow ordinarily to heights of 3 or 4 feet, but under favorable conditions may reach 7 or 8 feet. During droughts they become defoliated, but quickly leaf out again when moisture becomes sufficient. They are generally dormant in winter in the areas surveyed except at San Angelo, Del Rio, and Crystal City. However, host plants were dormant at San Angelo in January 1947, and they were in foliage at Marathon in January 1950, a mild winter.

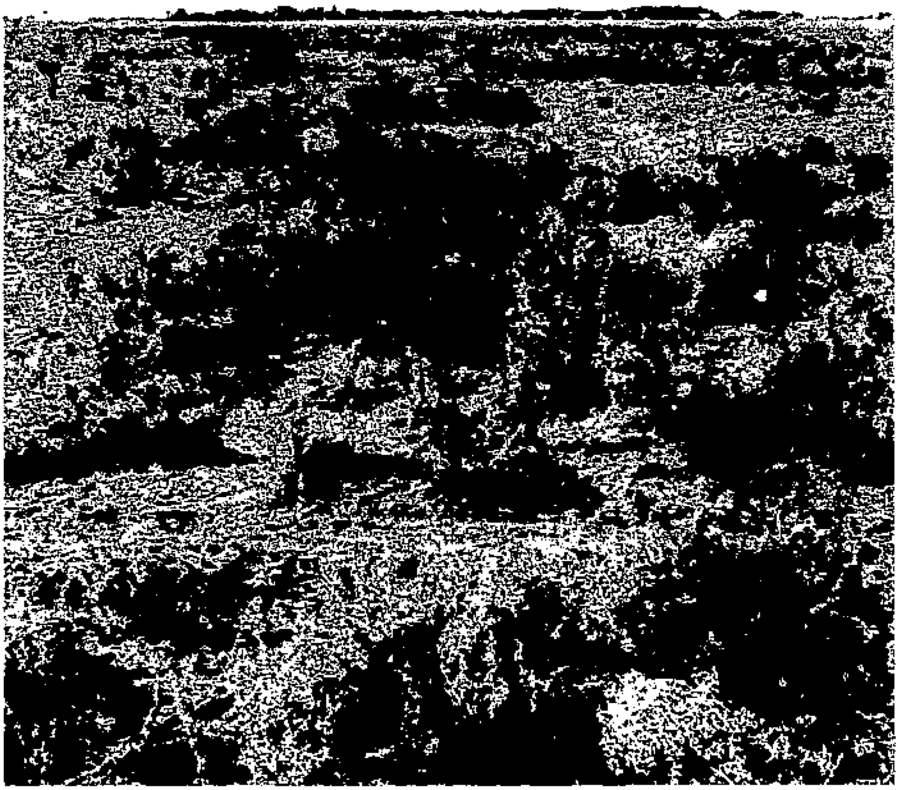

FIGURE 10.—A typical growth of wild *Lycium* near Estancia, N. Mex.

The average adult, egg, and nymph population counts each year from the winter of 1946–47 to 1949–50 for each area surveyed are given in table 2. Only a trace of psyllids was found in the winters of 1950–51 and 1951–52.

Psyllid populations in November were small and fall breeding had just begun. Temperatures averaged approximately the same in November as in March, when breeding was more rapid.

The source of these fall populations is still in question. Although no summer survey has been made in that area, it is doubtful whether potato psyllids can exist in the high summer temperatures there.

According to Romney (16), they move from breeding areas in southern Arizona by the middle of June, and it is not possible to find psyllids there again until late October or early November, when there is an influx from an unknown source. A similar movement may occur in southern Texas, where the climate is similar. It is possible that potato psyllids move from northern areas or from southern mountainous sections where summer temperatures and host plant conditions are such that they can survive the summer.

Adult populations increased by January (table 2), but breeding had practically ceased, as indicated by

TABLE 2.—*Potato psyllids found on wild* Lycium *spp. at survey points in southern Texas and New Mexico, 1946–50. Numbers of adults per 100 sweeps and of eggs and nymphs per 100 leaves*

Locality and year	Fall			Winter			Spring		
	Adults	Eggs	Nymphs	Adults	Eggs	Nymphs	Adults	Eggs	Nymphs
1946–47									
Crystal City				1	0	0	0	0	0
Del Rio	6	T[1]	T	12	T	0	11	T	T
San Angelo	2	T	0				101	8	5
Marathon	1	0	0				125	4	2
El Paso							21	T	0
1947–48									
Crystal City	0	0	0	2	1	0	0	0	0
Del Rio	2	T	0	17	5	0	2	T	T
San Angelo	T	0	0	2	T	0	2	T	T
Marathon							26	2	1
Big Spring	0	0	0				17	1	0
El Paso							9	T	0
1948–49									
Crystal City	0	0	0				0	0	0
Del Rio	1	0	0	10	2	0	12	1	1
San Angelo	1	0	0	4	T	0	23	4	2
Marathon							49	4	3
Big Spring	2	0	0				6	0	0
El Paso	1	0	0				2	T	0
1949–50									
Crystal City				1	T	0	0	0	0
Del Rio				48	1	1	4	0	T
San Angelo				105	3	2	12	T	T
Marathon				3	0	0	3	0	1
Big Spring							45	38	11
El Paso							30	1	0

[1] Trace.

the small number of eggs and the absence of nymphs. Apparently a few eggs were deposited during periods of warm weather, which were too short to complete incubation of the eggs. However in 1950, when the temperatures for January averaged 6.4° F. above normal, a small nymph and large adult population occurred over a more widespread area than in the previous years.

From 1947 to 1949 the January population of adults centered in the vicinity of Del Rio, but during the above-normal temperature of January 1950 it centered near San Angelo, approximately 150 miles north of Del Rio. Although January temperatures are normally higher at Crystal City, which is approximately 100 miles southeast of Del Rio, few psyllids are found there. Greater humidity is apparently the factor limiting the spread of psyllids eastward. Crystal City is east of the 100th meridian, which is the approximate dividing line between the humid and dry areas of the Western States. Psyllids rarely cause noticeable injury to winter crops in the lower Rio Grande Valley, although temperatures and host-plant conditions are favorable for winter breeding. Likewise during the summer few psyllids are found east of the 100th meridian in areas farther north.

Psyllid populations increased greatly during the spring and spread to areas where host plants were dormant in January. Spring weather and host-plant conditions apparently have a greater effect on the spring population than the size of the winter population. The largest spring population was recorded in 1947 following the lowest winter population. In 1950 only average spring populations followed the highest winter population, but the spring infestation was more widespread than in previous years.

In most years the spring population centered in the vicinity of Marathon and San Angelo, to the north and west of the overwintering area. However in 1950, when temperatures averaged above normal, it had moved as far north and west as Big Spring and El Paso.

THE SPRING MOVEMENT

The movement of psyllids from southern breeding areas to northern potato-growing areas has been suggested by Romney (*16*), who stated that psyllids breed on *Lycium* for several hundred miles along the Rio Grande drainage above Laredo, Tex., and believed that this may be the main source of spring infestations east of the Divide and as far north as Colorado. Richards and Blood (*15*) stated that the insect is so minute that it might readily be transported long distances by the air currents. Glick (*6*) has shown that large numbers of psyllids do occur in the air currents. Wallis (*19*) has shown that May and June temperatures affect the size of initial spring populations and the movement of psyllids is greatest at temperatures between approximately 60° and 70° F.

To determine the movement of psyllids, spring populations in Texas and New Mexico were studied by the author in relation to early-summer populations in potato- and tomato-growing areas in Colorado, Wyoming, and Nebraska.

Samples of adults were taken with a sweep net on wild matrimony-vine in the spring breeding areas near San Angelo, Marathon, Big Spring, and El Paso (fig. 9). A single survey was made each spring near the first of April, since populations were found to be largest at about this time. Samples were taken in a similar manner in the summer breeding areas on cultivated matrimony-vine, an ornamental related to the wild species found in Texas. Surveys were made at weekly intervals during May and June in the Arkansas Valley in southern Colorado, the Greeley district in northern Colorado, and in the North Platte Valley in eastern Wyoming and western Nebraska (fig. 9). The average populations in the spring breeding areas and the peak populations and time of their occurrence in the summer breeding areas are given in table 3.

A low population in the spring breeding areas, such as occurred in 1951 and 1952, was followed by a low population in the summer breeding areas, indicating that the spring breeding areas are the source of the summer infestations in the Northern States. However, a high population in the spring breeding areas does not mean that a heavy infestation will always occur in the Northern States, since the highest population, which occurred in 1947, was not followed by the highest population in the Northern States. Therefore, certain factors, probably unfavorable wind currents and temperatures, may inhibit the movement of psyllids from the spring to the summer breeding areas.

Psyllids begin moving into the summer breeding areas during the first week in May. At first the largest numbers arrive in the Ar-

TABLE 3.—*Potato psyllid populations in the spring breeding areas and at the peak of their movement to the summer breeding areas, 1947–52. Numbers of adults per 100 sweeps*

Year	Spring breeding areas	Summer breeding areas					
		Arkansas Valley		Greeley district		North Platte Valley	
		Number	Time of peak	Number	Time of peak	Number	Time of peak
1947	52	34	June 10	43	June 24	4	July 8
1948	11	11	May 27	62	July 1	10	July 1
1949	18	97	May 20	194	July 1	81	July 1
1950	19	168	May 27	166	July 1	3	July 1
1951	1	3	(1)	2	(1)	2	(1)
1952	2	2	(1)	3	(1)	1	(1)

[1] Numbers were so small that no definite peaks were observed.

kansas Valley, which is in the most southern part. They increase, reaching a peak from May 27 to June 10.

Although the movement into the Greeley district and the North Platte Valley begins at approximately the same time as that into the Arkansas Valley, it is slower and the peak populations are not reached until about July 1. Apparently part of this movement is from the Arkansas Valley. Fewer psyllids reach the North Platte Valley than the Arkansas Valley and the Greeley district.

The factors affecting the movement of psyllids from the spring to the summer breeding areas have not been completely determined. Apparently the most important are temperature and wind movements. Psyllids begin moving from the spring breeding areas in May when temperatures are above 70° F. They begin arriving in the summer breeding areas when the temperatures are from approximately 55° to 60°, but the greatest movement occurs when the temperature is between 60° and 70°. Psyllids are so small that they should be affected by wind currents after they start moving. The prevailing winds during May and June are from the south as far north as northern Colorado and from the northwest in eastern Wyoming and western Nebraska (fig. 9). This would favor a movement of psyllids as far north as the Greeley district and may account for the smaller numbers in the North Platte Valley. Although the prevailing winds favor a northward movement, there will be some days when the winds will be from the wrong direction. If many of these days should occur during the time of movement, it might account for the comparatively low numbers in the summer breeding areas after high populations in the spring breeding areas.

MOVEMENT WITHIN THE SUMMER BREEDING AREAS

The rapid decrease in psyllid populations in the lower elevations (Arkansas Valley, Greeley district, and North Platte Valley) of the summer breeding areas during July, when the host plants are in excellent condition and the temperatures are highest, indicates that psyllids move away from these areas. To determine whether this movement is toward the mountains, where lower temperatures prevail, surveys were made in both high and low altitudes in the summer breeding areas (fig. 9). Population counts were made on cultivated matrimony-vine in the Greeley district at an elevation of 4,600 feet and at Laramie, Wyo., at 7,200 feet. Counts were made at 1- to 2-week intervals during the growing period each year from 1947 to 1950. Table 4 shows the results of these counts and the average weekly temperatures at each location.

Each year except 1950 there was a rapid increase in psyllids at Laramie at the same time that a rapid decrease occurred in the Greeley district (table 4). In July weekly

TABLE 4.—*Relationship between summer populations of psyllids and temperatures at low (Greeley) and high (Laramie) elevations, 1947–50*

Date	1947		1948		1949		1950	
	Psyllids per 100 sweeps	Temperature	Psyllids per 100 sweeps	Temperature	Psyllids per 100 sweeps	Temperature	Psyllids per 100 sweeps	Temperature
	Number	°*F.*	*Number*	°*F.*	*Number*	°*F.*	*Number*	°*F.*
GREELEY								
May 6						56	2.0	43
May 13					65.2	52		42
May 20			4.5		102.0	56	14.4	52
May 27			8.8	65	100.4	59	18.8	47
June 3			4.8	67	59.8	61	10.8	53
June 10	0.8	66	3.6	75	20.3	59	6.4	64
June 17		57	40.3	74	30.0	54	6.8	72
June 24	13.2	62	54.0	62	197.5	70	96.5	68
July 1		68	62.5	68	293.6	72	165.5	71
July 8	9.2	74		75	30.3	75	74.8	69
July 15		74	11.5	75		70		71
July 22	8.0	71		71	6.7	73	17.8	68
July 29	3.5	74	6.8	75		74	11.3	70
Aug. 5	2.0	78		71	22.0	73		70
Aug. 12	12.5	76	5.8	71	24.7	74	13.3	71
Aug. 19		71		72		72		69
Aug. 26		70	10.0	73		72	30.0	67
LARAMIE								
May 6						47		39
May 13						47		41
May 20						49		40
May 27				55	2.4	50	0	45
June 3			0	58	2.4	51		49
June 10	0	55		63		52	0	57
June 17		50	1.0	63	5.2	59	0	62
June 24	.5	52	.5	52	6.8	62	0	61
July 1		57	2.4	60		63	1.3	62
July 8	5.6	65		67	26.4	64	0	62
July 15		66	10.8	66		62		64
July 22	6.5	61		64	146.4	64	0	58
July 29	7.0	68	24.8	64		66	0	59
Aug. 5	30.8	68		63	98.4	66		61
Aug. 12	37.0	67	10.0	64	49.6	65		61
Aug. 19		63		67		64		61
Aug. 26		61		64		65		59

temperatures at Greeley went above 70° F., which is the optimum for psyllid population increases, whereas at Laramie temperatures were between 60° and 70°. Since psyllids do not overwinter at Laramie, it appears that they moved into the area from Greeley. Apparently some of the decrease on matrimony-vine in the Greeley district may be attributed to a movement to the early potato crop. This crop is approaching maturity in July, and small increases in adult psyllids have been observed at this time. The plants are large enough to protect psyllids from high temperature. There is apparently a return movement from early potatoes to matrimony-vine in August after the crop has been harvested.

In 1950, when the average temperature in July at Greeley did not go much above the optimum for psyllids, the decrease in adults was less than in other years. There was no corresponding increase at Laramie that year, although temperatures were suitable. Apparently this was a movement largely to the early potato crop in the Greeley district rather than to higher elevations. The temperature was not high enough to force psyllids to move to the cooler area.

FACTORS AFFECTING POPULATIONS IN THE SUMMER BREEDING AREAS

The factors affecting psyllid populations in the potato-growing areas of the Northern States appear to be equally important as those in the spring and winter breeding areas.

Daniels (*3*) reported that the size of an infestation depends largely upon the type of season—that a moderately warm spring with low rainfall is conducive to a psyllid outbreak. He believed that the serious outbreak of 1931 might have been attributed to favorable spring conditions, which allowed the groundcherries to appear in the plains sections early in April, thus enabling a generation or two of psyllids to breed before early potatoes were up. According to Hartman (*7*), high temperatures in late June and early July reduce psyllid damage. List (*11*) has shown by laboratory tests that psyllids thrive best at about 80° F.; that oviposition, hatching, and survival are reduced at a constant temperature of 90°; and that 100° for only 1 or 2 hours a day is lethal to eggs and nymphs. Werner (*21*) reported that high temperatures are conducive to a low incidence of psyllid yellows. Pletsch (*13*) found that average temperatures from 70° to 76° caused psyllids to complete development in 20 to 27 days, temperatures from 60° to 70° in 25 to 37 days, and at 52° they failed to complete development in 55 days. Wallis (*19*) has shown that the principal factors affecting psyllid populations after July 1 in the North Platte Valley in Wyoming and Nebraska are the initial infestation, the size of the host plants, and maximum temperatures during July. He found that above-normal temperatures in July will so reduce populations that the subsequent buildup is very slow, except on early-potato plants that are large enough in July to protect the psyllids from the hot sun. Hill (*8*) reported an unusual weather condition in 1938, a year of high psyllid populations, when July was very wet with few hot days and August and September were exceptionally warm. According to Hill, such weather conditions are favorable for the development of summer populations of psyllids and they occurred only in 1 other year (1922) from 1921 to 1946.

Temperature

From 1941 to 1950 weekly surveys were made of adult psyllid populations on matrimony-vine, which has the longest growing period of any of the host plants. Table 5 shows the relationship between June and July temperatures, the peak populations, occurring about July 1, and the average July population in each year.

TABLE 5.—*Relationship between June and July temperatures, the peak summer populations of psyllids on matrimony-vine, and the subsequent July populations, 1941–50*

Year	Average temperature		Date of population peak	Population per 100 sweeps	
	June	July		At peak	Average in July after peak
	°F.	°F.		*Number*	*Number*
1941	65	73	June 24	74	27
1942	65	73	July 1	384	64
1943	65	75	July 15	4	3
1944	64	71	July 8	27	8
1945	59	73	July 8	31	9
1946	67	76	June 24	7	2
1947	61	75	July 8	4	3
1948	66	73	July 1	10	4
1949	66	75	July 1	81	10
1950	66	70	July 1	3	4

These records show that the early-summer peak is not influenced by the temperature in June, when the population is building up. Populations build up to a peak during June temperatures ranging from 59° to 67° F. From 1941 to 1949, when average July temperatures ranged from 71° to 76°, there were great reductions in population from the early-summer peak. However in 1950, when the average July temperature was 70°, populations continued to build up through July. The upper limit of the optimum range for their development therefore seems to be near 70°.

Noneconomic Host Plants

Certain noneconomic host plants serve as reservoirs for incoming adult psyllids from overwintering sources and provide spring breeding places for populations that later move to cultivated hosts. For a host plant to be of importance as a spring breeding source, its growth, as well as the occurrence of psyllids on it, must precede that of the cultivated host.

Matrimony-vine and potato sprouts in cull piles are the host plants having the greatest influence on psyllid abundance. Matrimony-vine puts out leaves in April, in warm seasons by the first of that month. Potato sprouts in cull piles also start growing in April. Groundcherries, wild perennial plants that reproduce by rootstock, do not come up until after the first of May and are too small to attract psyllids until June. Buffalo-bur, a wild annual, does not generally sprout until after the first of June. Early potatoes are planted in April and are usually up by the middle of May. Medium potatoes, which are the earliest plantings of the commercial late crop, are planted from May 25 to June 10. The late crop is planted from June 20 to 30, and few of these plants are up before July.

Surveys of the spring populations of adult psyllids on these host plants in the North Platte Valley were made from 1941 to 1950. The average spring populations prior to July 1 are shown in table 6.

Matrimony-vine and cull potatoes were by far the most important as spring reservoirs and breeding sources of psyllids. These plants started growth ahead of all other host plants and were therefore available to receive psyllids from overwintering sources. Considerable variation in populations from one season to another was noted with cull potatoes. This was due

TABLE 6.—*Average numbers of adult potato psyllids per 100 sweeps on different hosts prior to July 1 in the North Platte Valley, 1941–50*

Year	Noneconomic hosts				Cultivated hosts [1]		
	Matrimony-vine	Cull potato sprouts	Groundcherries	Buffalo-bur	Early potatoes	Medium potatoes	Tomatoes
1941	36	52	3	1	2	1	4
1942	68	42	2	1	2	0	1
1943	0	1	0	0	0	0	0
1944	10	52	1	1	2	0	1
1945	3	3	1	0	0		0
1946	4	1	0	0	0	0	0
1947	1	2	0	0	0	0	0
1948	4	3	0	0	2	0	1
1949	26	331			15	3	13
1950	2	3			0	0	0
Average	15	49	1	T	2	1	2

[1] No psyllids found on late potatoes.

to spring frosts, which killed the sensitive potato plants in some years. Matrimony-vine was not injured by frost, and the other hosts were not growing during the frost period. It may be concluded that groundcherries and buffalo-bur were not important psyllid host plants in this area.

Much benefit could be obtained by eliminating the cultivated matrimony-vine and potato sprouts in cull piles, on which the psyllids collect and breed in the spring. It is impractical to attempt to control wild *Lycium* in the winter and spring breeding areas, since it is so abundant and widespread.

Cultivated matrimony-vine can be easily killed with 2,4-D. If grubbed out, new plants will appear from rootstocks remaining in the soil; so it is difficult to kill in this manner.

Potato sprouts that grow in cull piles are excellent breeding places for psyllids because the dense growth protects them from high temperature. These sprouts die in July from lack of moisture, forcing the psyllids to move to other plants. The growth of these sprouts can be easily prevented by spreading the tubers in a single layer when they are dumped, so that they are exposed to the sun's rays. Killing the sprouts with chemicals is too expensive and slow to be of much benefit.

Time of Planting Potatoes

Field observations have indicated that early-planted potatoes are more subject to attack by psyllids than later plantings, and further that the influence of high temperature on reducing populations is minimized on early plantings, the plants of which are large at the time maximum summer temperatures occur.

To determine the difference in susceptibility to psyllid attack between early, medium, and late plantings of potatoes, population counts were made on these crops in the North Platte Valley from 1939 to 1952. Counts of adults were made by the sweep-net method at fixed observation points at 1-week intervals during the growing period. The average seasonal population for each crop each year is given in table 1.

Over a period of 14 seasons psyllid populations on early potatoes averaged considerably higher than on later plantings and slightly higher on the medium crop than on the late crop. Populations on the medium plantings were only 34 percent and those on the late crop only 28 percent as high as on the early crop. On the late crop they were 83 percent as high as on the medium crop.

There seem to be two reasons for the higher populations on early potatoes. This crop is growing in the spring when the psyllids are most abundant, and by July the plants are so large that the foliage protects the insects from the hot summer temperatures.

In 1941, 1942, and 1943 tests were made to determine the relationship between the temperature in the foliage of various-sized potato plants and the air temperature. Thermocouples were placed in the foliage 2 to 3 inches above the soil and protected from the sun's rays by the leaves. Three thermocouples were placed 20 feet apart in each plot, and readings were made daily at 2 p. m., near the time of the maximum air temperature. Air temperatures were taken from a thermograph near the plots.

Several factors were found to affect the foliage temperature. Irrigation, which caused a higher rate of evaporation from the soil surface, had a cooling effect. High wind velocities increased the circulation of air, causing foliage and air temperatures to be closer together. The greatest differences occurred on days of maximum air temperatures above 90° F. When air temperatures were below 70°, foliage temperatures were sometimes even higher. The most important factor was the size of the plants.

For plants of different height the average reduction of foliage temperature below the maximum air temperature when it was above 90° F. was as follows:

Inches	*°F.*	*Inches*	*°F.*
4	3	16	10
6	5	18	10
8	5	20	11
10	6	22	11
12	9	24	13
14	9		

This greater temperature reduction in large potato plants accounts for the fact that psyllid populations show the greatest increase on early-planted potatoes, which are large in July.

VALUE OF SURVEYS

The potato psyllid can occur in outbreak numbers and cause a complete crop loss before it is recognized by the grower. Since the insect is inconspicuous and its outbreaks are independent of the previous year's infestation in potato fields, there is no warning buildup. It is therefore essential that growers be informed each spring of psyllid conditions and warned of any possible outbreaks. To obtain the necessary information surveys must be made to follow the development of the insect in its distant overwintering and spring breeding areas as well as in the potato-growing areas.

Surveys in the overwintering areas of southwestern Texas late in January or early in February show how widespread the infestation is and how successfully the psyllid has overwintered. Surveys during March and April will show how rapidly populations are building up and spreading to the north and northwest and whether host plants are in favorable condition for the development of outbreak numbers. In short they will give some indication of the numbers of psyllids that will be available to move into the potato-growing areas in May. In the potato- and tomato-growing areas it is important that the abundance of the insect on matrimony-vine be determined as well as on other early hosts such as potato sprouts in neglected cull piles.

Surveys in the spring breeding areas during the course of these studies have made it possible to warn growers of the need for applying insecticides in outbreak years. For example, in 1949 psyllid populations in outbreak proportions in Colorado, Wyoming, and Nebraska were foreseen from the results of surveys made in May, and growers were warned that rigid control measures would be needed. Throughout this entire region in fields where control measures were not applied crop losses were almost complete. According to the 1950 Census of Agriculture approximately 126,000 acres of potatoes are grown in the psyllid-infested area with a total production of approximately 33 million bushels. However, on about three-fourths of this acreage growers apply control measures each year whether or not an infestation occurs. The remainder, producing approximately 10 million bushels, with a farm value of approximately 10 million dollars, would be a complete loss in outbreak years without an appropriate warning to the growers.

The surveys in the spring breeding areas should be followed by local surveys in the potato fields. With the aid of such surveys growers need apply insecticides only when control is needed. For example, in Laramie County, Wyo., where 6,000 acres of potatoes are not usually damaged by insects other than the psyllid, growers were advised not to apply insecticides during 6 years of this study. The saving of insecticides and labor in this county was estimated at 60,000 dollars per year.

SUMMARY

An ecological study of the potato psyllid (*Paratrioza cockerelli* (Sulc)), which causes psyllid yellows of potato and tomato plants, was made during the period 1939–52 to determine the cause of psyllid outbreaks.

The potato psyllid occurs in North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and all States west of them except Washington and Oregon. High humidity apparently prevents it from moving east of these States.

Psyllid yellows appears first on plants at the edge of the field and progresses toward the center. The first symptoms in potato plants are an upward curling of the basal portions of leaflets near the top of the plants and a purpling of the curled portions. As the disease advances, the tops of the plants become dwarfed and the affected leaves become thick and leathery and eventually turn yellow or purplish. Underground there is a heavy set of small tubers close to the main stem. These tubers mature early, sprout, and produce secondary stolons, which may set additional tubers. The tubers are usually unmarketable.

The host plants are confined almost entirely to the family Solanaceae. The only other plants on which it is known to breed are field bindweed, morning-glory, and sweetpotato.

The potato psyllid overwinters in Texas and southern New Mexico, feeding mostly on wild *Lycium*. Development nearly stops during January because of low temperatures, but is resumed in February. In the spring the adults spread to the north or northwest with the prevailing winds.

The psyllids move from the spring breeding areas in Texas and New Mexico into the potato-growing areas of Colorado, Wyoming, and Nebraska. This movement occurs during May and June, when temperatures in the potato-growing

areas are between 60° and 70° F. The greatest movement is in June, reaching a peak near July 1. Psyllid populations in the plains areas decrease rapidly in July, when temperatures average above 70°. There is a corresponding increase in the mountainous areas, where temperatures are lower.

Summer populations of psyllids in the potato-growing areas are also affected by the size of the host plants when maximum temperatures occur. Large plants, such as early potatoes, protect psyllids from high temperatures in July.

In potato-growing areas the ornamental plant matrimony-vine and piles of sprouting cull potatoes are important sources of psyllid infestations to cultivated crops. Much benefit can be obtained by destroying these host plants. Matrimony-vine may be easily killed by spraying with 2, 4-D. Sprouts in cull piles may be prevented by scattering the cull tubers when dumped, so that they are not more than one layer in depth.

Groundcherries and buffalo-bur, which are abundant in the potato-growing areas, are not important sources of infestation since they do not begin growth until potato plants are available.

A preseason survey each year of adult psyllid populations on noneconomic host plants will indicate the expected population on potatoes for the growing season. Such a survey will save up to 10 million bushels of potatoes in the psyllid-infested area in outbreak years and will spare the farmer the expense of treating with insecticides when light attacks are indicated.

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