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The Potato and Tomato Psyllid and Its Control on Tomatoes

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MANY injurious Colorado insect pests are introduced species that have adapted themselves to local food supplies and climatic conditions. However, there are outstanding examples of native insects attacking introduced cultivated plants and becoming serious problems. The best known example of this type in the region is the Colorado potato beetle, *Leptinotarsa decemlineata* Say, an insect of local prevalence that accepted the potato, brought in by the early settlers of Colorado, as its host. It has spread on this host until it has become a major pest over much of the world.

A similar problem, and one of even more importance when judged on the basis of losses in the Rocky Mountain region, has arisen through the acceptance by the potato and tomato psyllid, *Paratrioza cockerelli* (Sulc), of both the tomato and potato as favorite food plants. This destructive insect is often more numerous on these introduced hosts than on its native food plants, the growing of large acreages of the hosts favoring multiplication of the insect. Studies on the problem have been made by the Colorado Experiment Station at various times over a number of years. Work on the psyllid as a pest on potatoes has been published previously (1, 2, 7, 8).† The purpose of this bulletin is to summarize the information that has been gained through studies of the insect as a Colorado tomato pest.

Economic Importance

Tomato growing is limited by climatic factors to the irrigated portions of the lower altitudes and more protected areas of Colorado. The acreage is not large in comparison with that of some other states, yet tomatoes make up a crop of importance to the canners, market gardeners, and home gardeners. Losses from psyllid injury vary from complete crop failures to unrealized reduction in yield and quality. The most consistent losses probably occur in the truck gardens and home gardens in the region near the foothills from Littleton north to Fort Collins. Production for canning is carried on only in parts of

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†Numbers in parentheses refer to bibliography, p. 32.

the Arkansas Valley, in the Grand Valley, and in a rather limited area near Denver. The failure of the psyllid to do serious annual damage in these limited regions has probably been an unrecognized factor that has permitted the development of the industry there. Other regions sufficiently large to support a factory have the other favorable factors for commercial production, but the psyllids have made production uncertain. Greenhouse growers of tomatoes have at times suffered heavy losses from psyllids in both their winter and spring crops.

History and Distribution

The psyllid is not a new pest in Colorado. As a native of the Rocky Mountain area, it undoubtedly began to feed upon the cultivated crops that were to its liking soon after these crops were introduced. Large acreages of these crops, together with favorable growing conditions for the psyllid's wild hosts brought about by irrigation and cultivation of large areas, apparently have favored the insect. Its appearance in Colorado was first recorded in 1894. Early correspondence from the Entomology Section indicates that serious damage to tomatoes was noted in 1898, 1904, 1906, 1911, 1912, 1915, and 1916. Damage has been reported almost every season in recent years. During the early years the full significance of psyllid injury to tomatoes was not recognized. It was not until 1927 that Richards (12), in Utah, found the psyllid to be responsible for a condition in potatoes which he termed "psyllid yellows."

The insect has been reported in North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, and all states west of these, as well as in western Canada. Its prevalence in Colorado is quite general, although the severity of outbreaks appears to be closely associated with certain climatic factors, with the result that losses vary greatly in different localities.

Food Plants

Most of the preferred food plants are members of the *Solanaceae,* or the nightshade, family. The most important cultivated plant hosts are the tomato and potato, although the insects have been found in injurious numbers on peppers, eggplant, Jerusalem cherry, and cultivated groundcherry. Daniels (2), after studying the hosts in the state, reports that the several species of groundcherries are probably the most important wild food plants. Potato and tomato psyllids are frequently found on the buffalo-bur, *Androcera-rostrate* Rydb., and on the wild tomato, *Solanum triflorum* Nutt. They have been reared on the common garden morning glory. In addition they have been taken in numbers from bindweed, *Convolvulus arvense,* the nymphs having been transferred from the tomato and potato to the bindweed, and vice versa, with no unusual mortality. Essig (3) gives arborvitae and spruce as hosts, stating that the insects hibernate in pine trees wherever possible. Daniels (2) reports finding them during the winter on native red cedars at Gering, Nebr., and Lusk, Wyo. Little has been published in regard to the hosts in the southern part of the range, but correspondence indicates that several native plants of wide distribution are important in the building up of large populations of psyllids.

Nature of Injury

The tomato psyllid is a sucking insect but the punctures it makes in the food are not visible to the naked eye. The insect's piercing mouth parts consist of four needle-like stylets which, after being forced into the plant tissue, so fit together that two tubes are formed, one for the sucking of plant juices and the other for the injection into the plant of certain secretions. Secretions from the immature insects have a more serious effect upon the plant than does the actual rupturing of cells and the loss of plant juices; they produce the condition known as psyllid yellows. The exact cause of this definite plant reaction is not known, but the best evidence supports the theory that the insect secretions carry substances that are toxic to the plant. The fact

Figure 1.—The leaf on the left is a normal tomato leaf. The one in the center shows the upward rolling of the leaflets, an early symptom of psyllid injury. The leaf on the right shows a well developed case of psyllid yellows. Note the curled leaflets, twisted petioles and the angular leaf stem. Such a leaf is thickened and breaks readily. All are older leaves from fruiting plants.

that the plant shows a definite tendency to recover after the insects are removed indicates that the abnormal condition is not brought about by a virus.

It appears that only the nymphs poison the plant. The number that will bring about noticeable symptoms of injury in the tomato plant varies with the size, the stage of maturity, and the variety of the plant. From two to five nymphs may seriously affect a tomato plant that is only from 3 to 6 inches tall, while a mature plant may support several hundred or even thousands of nymphs without showing many of the more characteristic symptoms.

The symptoms of psyllid injury to the tomato plant have been described previously (9).

Characteristic early diagnostic symptoms of psyllid yellows of tomatoes are a thickening of the older leaves, often the twisting of their petioles, and the upward rolling of the basal portion of these leaves. There is usually a slight purpling of the veins and margins of the younger leaves. Their basic color usually becomes a light or yellowish green. There is a slight puckering of terminal leaves and a tendency for them to stand upright. They never attain normal size, the leaflets being narrow and the petioles slender. The stem diameter of the growing tips becomes greatly reduced, giving the entire top of the plant a "feathery" appearance. In an attack when the plant is small, the internodes are shortened and the entire plant takes on a very stunted appearance. Such a plant may remain in an inactive state of growth for weeks. When the attack becomes severe after the vegetative growth is well advanced, the internodes may be lengthened and greatly reduced in diameter and the leaves narrowed greatly.

Figure 2.—The stem on the left is from a normal tomato plant. The one in the center is from a plant showing a well developed case of psyllid yellows, while the one on the right shows the symptoms of a case farther advanced. Note the small leaves, reduced diameter of the stems, and stunted growth.

The effect of psyllid injury upon the setting and the quality of the fruit is dependent upon the time and severity of the attack. An early attack may so stunt the plant that it will entirely fail to fruit, or set only a few tomatoes which remain small. An initial attack late in the season after the plant has become well developed vegetatively may stimulate blooming and fruit setting. Many fruits that remain small may be set near the end of the branch growths.

Figure 3.—Two branches from fruiting plants showing advanced symptoms of psyllid yellows. Note the small leaves, stunted growth, and tendency to blossom and set many small fruits at the end of the branches.

The effect upon the size and quality of the fruit varies with the degree of infestation. Lowered quality is often evident in fruit from plants too lightly infested to show the leaf or growth symptoms, but it becomes very evident in fruit from plants which show growth symptoms. The central mass and partition walls of the tomato fail to color normally upon ripening, being rough and even rubbery in extreme cases. The juicy pulp about the seeds is much reduced, often to the extent of leaving cavities. The outer walls do not color normally. The natural red and purple fruit-colors of the standard varieties take on a yellowish cast that is very undesirable. The housewife soon learns that this is an indication of an insipid taste and general lack of quality.

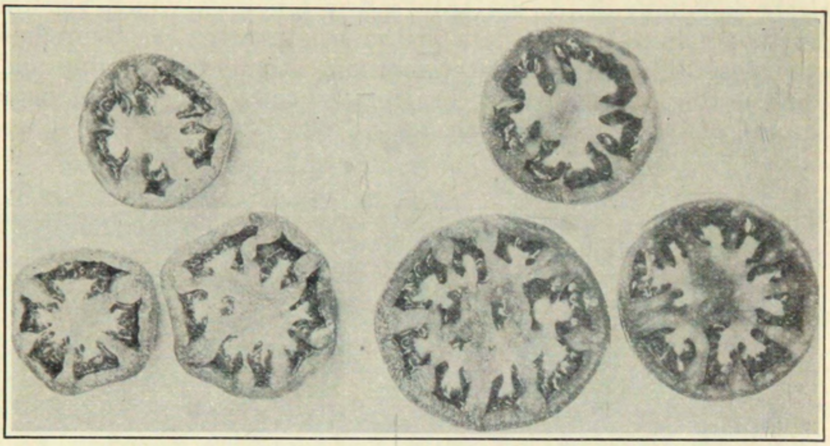

Figure 4.—The three fruits on the left were from untreated plants heavily infested with psyllid nymphs. Those on the right were from plants in the same field that had received three applications of sulfur dust for psyllid control. The largest fruit was 3½ inches in diameter. Note the angular shape of the psyllid-injured fruits and their thinner cell walls. The central masses are tough and pithy. The juicy pulp about the placentae is reduced and some cavities exist. All fruits are of the John Baer variety.

Description of the Psyllid

The psyllid may be recognized in any of its three stages of development.

Adults

The adult psyllids are about one-tenth of an inch in length and at first glance somewhat resemble winged plant lice. However, their bodies are more robust and they are more active. Their hind legs are developed for jumping, making it possible for them to move very quickly. This appearance and habit has given them the common name of jumping plant lice. Their four wings are transparent, being held roof-like over the body when at rest. They are rather strong fliers.

When they first emerge, the adults are of a light green color, but after a few hours the general color becomes grayish to brown. A number of whitish-to-yellow lines may be seen on the head and thorax. A similarly colored prominent band appears at the base of the abdomen.

The tip of the abdomen has on the top a white marking more or less resembling an inverted Y.

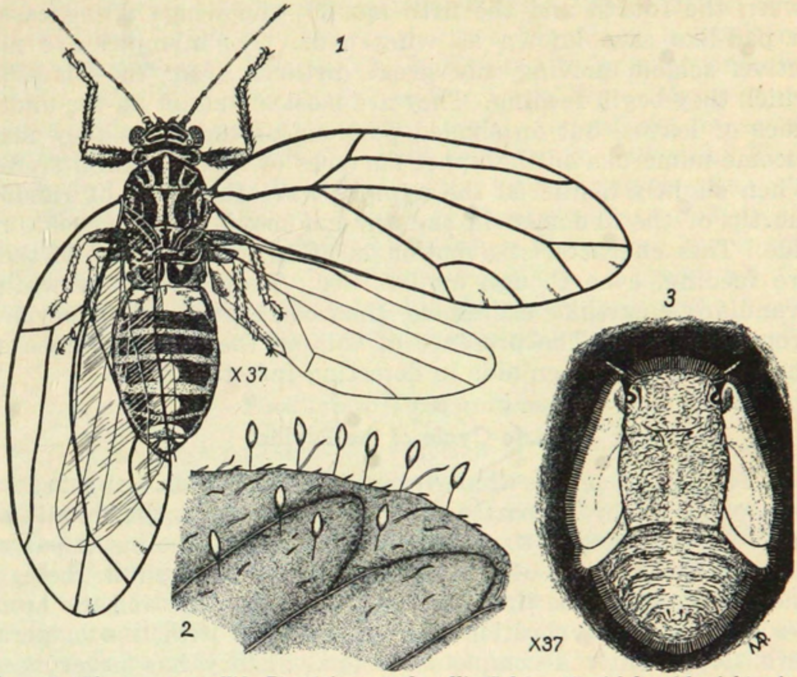

Figure 5.—The tomato psyllid, *Paratrioza cockerelli* (Sulc): (1) Adult with right wings spread. (2) Eggs. (3) The nymph or immature form. Note the flat scale-like form, the wing pads and the fringe of horizontal spines around the entire border of the insect. M. A. Palmer, delineator.

Eggs

The eggs are elongate, about one-thirty-second of an inch in length, and bright yellow to orange in color; they are placed on slender white pedicels or stypes of about the same length as the egg. They are usually placed on the edge of the leaves or on the veins on the under side, but at times are found on all parts of the plant.

Nymphs

The nymphs or immature forms are elliptical, very flat, and scale-like in appearance. Their flat appearance is emphasized by a band of short horizontal spines around the entire margin of the insect. When first hatched they are very small and almost orange in color. Later, the color becomes yellowish green, which subsequently, as the nymph approaches maturity, changes to a light green not greatly unlike the color of the tomato leaf. The two reddish, compound eyes are fairly prominent. During their development the nymphs moult five times, the last moult bringing forth the adult winged insect. During the fifth instar (between the fourth and the fifth moult), the wings are encased in pad-like sacs known as wing pads. The nymphs are not active, seldom moving any great distance from the place at which they begin feeding. They are most abundant on the under sides of leaves, but on shaded portions of the plant they may become numerous on the upper surfaces of leaves and on stems. When slightly disturbed the nymphs have the habit of raising the tip of the abdomen in the air and moving it from side to side. This characteristic motion is often exhibited while they are feeding, even though undisturbed. They give off a white, granular, sugar-like excrement that corresponds to honeydew from plant lice. The presence of this on the upper surface of the lower leaves often aids in detecting infestations.

Life Cycle of the Psyllid

The insect passes the winter as an adult and appears on the spring hosts in tomato-growing areas about the middle of May. As indicated in the previous descriptions, the insect passes through three stages of development, namely, the adult, the egg, and the nymph. The time necessary for this cycle and the number of cycles or generations per season vary with the temperature. Apparently a complete seasonal history has never been carefully worked out. Essig (3) says the number of generations is from 3 to many, while Daniels (2) believes there are from 8 to 10. Under winter greenhouse temperatures, which proved to be very suitable for multiplication of psyllids, it has been found that the time from the emergence of adults until they were sexually mature varied from 3 to 6 days, with an average of about 5 days; time of incubation varied from 5 to 8 days, with an average of about 6 days; and the time of development of the nymphs varied from 13 to 24 days. The average developmental period for 73 nymphs was 17.47 days. This would indicate a complete cycle in about 27.5 days, on the average. Undoubtedly under some conditions the insects will go through the complete cycle in a shorter period. Field observations indicate that the number of generations in a season is usually about five. This is not of major importance, however, from the control standpoint, because the adults continue to lay eggs over a period of from 2 to 3 weeks, which results in an overlapping of generations to the extent that all stages are present in the field during most of the season.

The number of eggs deposited per female is probably from about 300 to 400. Knowlton and Janes (5) give the average number of eggs deposited under cage conditions as 318, with a maximum for one female of 1,300 eggs.

The psyllid has been reported by Essig (3) as hibernating in the adult stage on "evergreen food plants or in sheltered places elsewhere." Daniels (2) has found them overwintering on red cedar at Gering, Nebr., and at Lusk, Wyo. Many hours, and even days, have been spent by Daniels and others‡ in searching trees, under rubbish and dead host plants, and other likely places in Colorado without finding the hibernating insects.

If hibernation on evergreens in especially favorable localities is the insects' only method of passing the winter, the spring infestation in some of the Plains areas can be accounted for only by migrations of considerable distances from these hibernating areas or from early spring breeding grounds.

Reaction to Temperatures

A series of studies of the reaction of the psyllid to certain temperatures, together with a correlation of the results of field observations on the behavior of the insect, has been reported recently (10). Although these studies have been discontinued, certain very important points were indicated. Studies made in glass-topped incubators at controlled temperatures indicate that the insect thrives best at relatively low temperatures, 80°† appearing to be near the optimum. A record of the eggs deposited under certain temperature conditions is given in table 1.

TABLE 1.—*Effect of temperature upon egg deposition of tomato psyllids.*

Temperature	Number of adults	Number of eggs	Number of eggs per adult
60° constant	25	108	3.2
70° constant	50	792	15.8*
80° constant	40	1257	31.4*
90° constant	155	162	1.0
90° for 9 hrs., 80° for 15 hrs.	50	1566	31.3
100° constant	140	73	0.5
100° for 9 hrs., 80° for 15 hrs.	50	102	2.0
100° for 5 hrs., 80° for 19 hrs.	70	275	3.9
100° for 2 hrs., 80° for 22 hrs.	100	665	6.6

It will be noted that eggs are deposited most freely at about 80°, very few eggs being deposited when the adults are exposed to a temperature of 100° for as short a period as 2 hours each day. It is interesting to note that at 100° temperature the adults became very restless, often leaving the plant and crawling nervously over the cages.

‡Unpublished notes.

†All temperatures are in Fahrenheit.

*These eggs deposited in 8 days; many adults alive at that time. Complete record not taken.

The higher temperatures greatly reduce the length of life of the adults. At a temperature of 80° many are active and laying eggs after 20 or 30 days. Death occurs very early at temperatures of 100°. Fifty-five newly emerged adults in cages held at this temperature for only 5 hours each day were all dead on the seventh day.

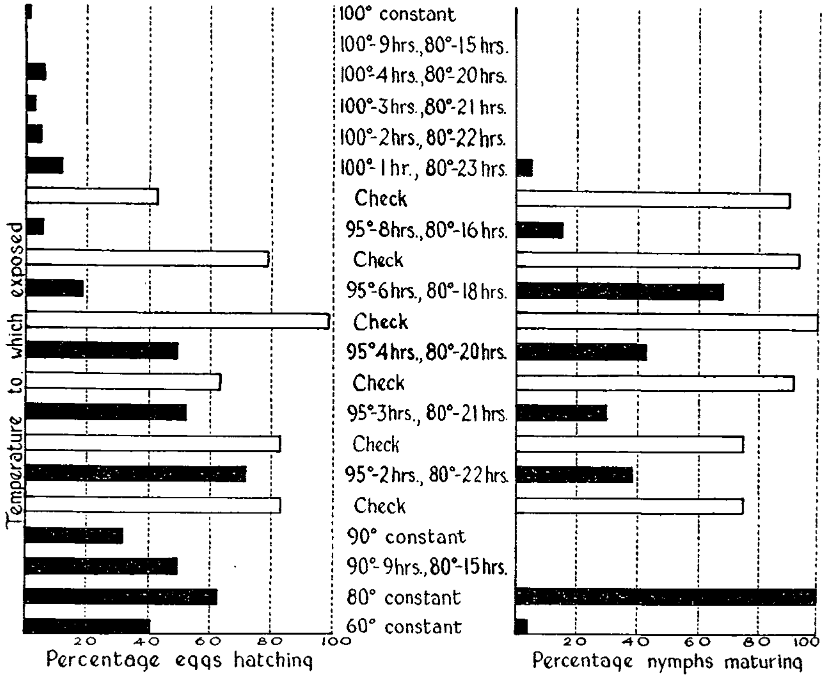

Figure 6.—The percentage of tomato psyllid eggs hatching and nymphs maturing under certain temperature conditions.

The effect of certain temperatures upon egg hatching and nymphal development is shown graphically in figure 6. It will be seen that 95° temperature for all or even a part of the day reduces the percentage of eggs which hatch and the percentage of nymphs which mature. Under conditions of 100° temperature, very few eggs hatch, and the effect upon nymphal development is even more marked. From 17,439 eggs only 21 nymphs developed to maturity when the eggs and nymphs were exposed to 100° temperature for only 1 hour each day.

Correlation of Laboratory Temperature Studies With Field Observations

The effects of high temperatures upon the increase in numbers and the activity of the potato and tomato psyllid afford some explanation for certain field conditions which are not fully understood. For many years the insect has been noted almost to disappear from certain regions of Colorado during midsummer while in other parts of the State the numbers continue to increase during the entire season. In the Grand Valley of Colorado heavy populations on early potatoes are almost annual in occurrence, making the early crop a very hazardous one to grow unless control methods are carefully followed. On the other hand, the insect is usually difficult to find on tomatoes and late potatoes during late summer and fall. A similar condition exists in the Arkansas Valley in that an early spring infestation occurs annually but largely disappears before midseason. Potatoes are not grown there but tomatoes usually show an early infestation. The seriousness of the damage is not realized by the growers because the plants largely recover after the feeding stops, the loss being represented by a delayed crop and a shorter season. However, in the upper part of the Valley, in the Canon City region, breeding often continues until later, with the result that heavy crop losses follow. Just outside this area in nearby mountain valleys, serious injury of potatoes occurs almost annually.

Near Fort Collins, at an altitude of about 5,000 feet, where the insect has been observed as a tomato pest for more than 20 years, the infestation usually causes early damage to tomatoes and potatoes. It then appears to be held in check during midsummer but propagates rapidly enough in late summer to do serious damage to tomatoes and late potatoes.

Table 2 gives a summary of the temperature records from three representative areas of the state over a period of years. It will be noted that the high temperatures at Grand Junction may well be responsible for the almost complete disappearance of the insect during midsummer. The temperatures at Fort Collins appear to be such that the insects usually live through the summer in sufficient numbers to increase rapidly in the late summer and fall when temperatures are more favorable. Hartman (4) has called attention to a similar retarding effect of high temperatures upon the psyllid in parts of Wyoming. In the extreme southern part of its range, the insect is considered a winter-breeding species, disappearing almost completely with the coming of high temperatures. In the Garnett region, which is typical of the high mountain areas of Colorado, no unfavorable high temperatures occur. When a spring infestation occurs under such conditions, a steady increase in numbers throughout the growing season may be expected. This seems to be responsible for the almost annual heavy infestations that develop in many of the high-altitude areas.*

TABLE 2.—*The average number of days per month and per season having maximum temperatures of 90 degrees and above, 95 degrees and above, and 100 degrees and above for an 11-year period in 3 regions of the State.*

Month	Average number of days at designated temperatures								
	Grand Junction, elevation 4,587			Fort Collins, elevation 4,985			Garnett, elevation 7,576		
	90° (days)	95° (days)	100° (days)	90° (days)	95° (days)	100° (days)	90° (days)	95° (days)	100° (days)
May	1.09	....	....	....	....	....	....	....	....
June	13.27	5.00	.50	2.81	.27	.10	.27	....	....
July	23.72	13.00	3.36	8.27	2.00	....	.09	....	....
August	17.90	6.00	.27	4.54	.27	....	....	....	....
September	3.00	....	....	.10	....	....	....	....	....
Season	59.98	24.00	4.13	15.73	2.54	.10	.36	....	....

The almost complete disappearance of the insect from the Grand Valley during the summer brings up the question of the source of the early spring infestation. Sufficient numbers are not present when winter comes to account for it. It is suspected that the spring infestation comes at least in part through movements from some distant breeding ground. In a study of this phase of the problem a number of insect traps were operated in the Grand Junction area during the springs of 1933, 1934, and 1935.† During each spring psyllids were taken in sufficient numbers to account for the infestations that followed. In the opinion of those who examined the traps, at least a majority of the insects taken represented spring forms that could not

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*The seasons of 1938 and 1939 have been observed since this paper was prepared. In 1938 the tomato crop in the Fort Collins area and south, including the Denver and Littleton areas, was almost a complete failure on account of an unprecedented psyllid infestation. Serious losses also occurred in the Brighton-Fort Lupton and the Arkansas Valley regions. Temperatures were favorable for psyllid development. In the Fort Collins area, for example, the temperature reached 90° only six times before August 1, by which time the tomatoes were injured by psyllids beyond recovery. Even in the Arkansas Valley a sufficient number of psyllids came through the summer for the fall increase in psyllids to affect so seriously the quality of fruit that canneries closed before the end of the season.

The spring infestation in 1939, while probably not as heavy as that of 1938, was such that early injury was apparent and the indications were that heavy losses would again occur where controls were not used. Temperatures of 90° occurred at Fort Collins as early as June 4, and there were 15 days during July when the temperature went to 90° or above. During 9 of these days the maximum temperature was 95° or above and 2 days, 100° or above. The mean daily maximum for the period July 8 to 20 inclusive was 96.4° while the mean daily maximum for the entire month was 90.6°.

Those temperatures apparently so checked psyllid development that little injury occurred.

†In cooperation with the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine.

have developed in the immediate vicinity. In addition, psyllids were often taken along with beet leaf hoppers, *Eutettix tenellus* (Baker), that were known to be coming in flights from southern Arizona. It is conceivable that with the coming of hot weather in the southern breeding areas, where federal workers reported psyllids to be numerous on wild hosts, the psyllids took flight and were carried into the Grand Valley by the same air currents that brought in the beet leaf hopper. This evidence is supplemented by the fact that at that time the psyllid largely disappeared from the southern breeding area. It is possible that other regions of Colorado may receive at least a part of their spring infestations from similar sources.*

Control Measures

In 1918, after having made two seasons' tests of materials for the control of psyllids on tomatoes, it was shown (6) that lime sulfur, 1 gallon of the standard commercial liquid to 33, 40, 45, or 50 gallons of water, gave marked control of the psyllid. The higher concentrations caused a definite retardation of the growth of tomato plants. Later, when growers made actual use of the 1 to 50 concentration, they found it caused rather severe burning and retardation of the growth of plants. This fact, together with the difficulty of getting through tomato fields with sprayers, discouraged general use of lime sulfur as a control method.

List and Daniels (7) reported the effectiveness of lime sulfur in controlling the psyllid on potatoes in 1934. Since that time it has become the standard control on potatoes with the

*Since this paper was presented for publication the following has appeared in print—Breeding Areas of the Tomato Psyllid, *Paratrioza cockerelli* (Sulc). V. E. Romney, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, Journal of Economic Entomogoly: Vol. 32, No. 1, p. 150—

"*Paratrioza cockerelli* normally breeds abundantly on *Lycium andersonii* A. Gray and to some extent on *Lycium macrodon* A. Gray, which occur along washes in the semi-desert areas of southern Arizona at altitudes below 3,000 feet. The distribution of *L. macrodon* is rather limited but *L. andersonii* occurs commonly along washes throughout most of southern Arizona. Breeding normally occurs on these plants from January to May. The peak in numbers usually occurs late in April or early in May, after several generations have been produced. The adults move completely from the breeding source by the middle of June, and thereafter it is not possible to find the psyllid in its winter and spring breeding areas until an influx occurs late in October or early in November from an unknown source. . . .

"East of the Continental Divide, *Paratrioza cockerelli* and a closely related species, *P. mexicana* F. D. K., occur together in varying proportions, but the latter species apparently does not occur west of the Divide. This would indicate that the source of the psyllid west of the Divide is different from that east of the Divide. Limited observations indicate that the tomato psyllid and its closely related species *P. mexicana* breed on *Lycium* along the Rio Grande drainage above Laredo, Tex., for several hundred miles. There is a possibility that this is the main source of spring infestations that occur east of the Divide as far north as Colorado. **11-15-38.**"

result that thousands of acres are sprayed each season in the Western States. Studies on the control of the psyllid on tomatoes were again taken up in 1934 with special emphasis being given to the use of sulfurs and lime sulfur. Because much of the data has been published (9, 10, 11), only the more important findings are briefly discussed here.

Repelling Effect of Lime Sulfur and Sulfur Upon Adult Psyllids

Early in the studies it was suspected that sulfur and its compounds had a repelling effect upon the adult psyllids. After two of four equal-sized stems of a potato plant were sprayed with lime sulfur diluted to a concentration of 1 gallon to 40 gallons of water, a number of adults were caged with the entire plant. Four days later, 400 eggs were counted on the unsprayed portion and 20 on the sprayed portion. This was repeated several times with both potato and tomato plants with similar results. Adults confined with sprayed plants did not oviposit as freely as those confined with unsprayed plants.

A very simple but convincing test on tomatoes was made in a heavily and uniformly infested greenhouse. As many as from 10 to 30 adults were found on a single leaf of fruiting plants before three rows of plants were sprayed with liquid lime sulfur, 1 part to 45 parts of water. Two days after spraying, only an occasional adult could be seen on these plants. Four additional rows were sprayed with similar results, a large percentage of the adults moving to unsprayed plants. The increase in eggs deposited upon the unsprayed plants was very noticeable within 4 days, after which all plants were destroyed by the grower.

The repelling effect of the following materials was tested in a tomato field about midseason: (a) 1 part commercial liquid lime sulfur to 50 parts of water; (b) 1 pound dry lime sulfur to 10 gallons of water; (c) 75 percent dusting sulfur to 15 percent dry lime sulfur to 10 percent bentonite; and (d) 200-mesh dusting sulfur, undiluted. Counts were made 1 week after the application by placing a muslin cage over the individual plants and then shaking the plants to cause the adults to move to the side of the cage. They were then collected and counted. Ten plants in each plot were examined, the counts of which appear in table 3.

TABLE 3.—*The repelling effect of certain materials upon adult tomato psyllids.*

Material	Average reduction per plant over check	Standard error	Average number adults per plant on check
Liquid lime sulfur, 1-50	8.1	±2.66	8.9
Dry lime sulfur, 1-10	13.3	±2.60	15.1
Sulfur and lime sulfur dust	10.2	±0.77	11.7
Sulfur dust	11.7	±2.08	13.1

The data indicate that all the materials tested had a definite repelling effect with no significant difference in the repelling effects of the various treatments.

Some preliminary observations were made upon the tendency of the psyllid to avoid treated plants in a cage designed to equalize the light factor. The cage was 2 feet long by 2 feet wide by 16 inches deep, with muslin sides and glass top, and so balanced on a central axis that it could be revolved horizontally. Four plants, two treated and two untreated, were placed in the cage, one toward each corner and an equal distance from the center. The cage was turned one-quarter of the way around each hour of the days of the test. One hundred adults of varying ages which had been collected in the greenhouse were introduced into the cage. At the end of 5 days the eggs and adults on each plant were counted.

Table 4 gives the results, the counts made on the two checks in each test being averaged. This practice also was followed with the treated plants when both had received the same treatment.

TABLE 4.—*Repelling effect of certain materials upon the tomato psyllid as shown by the number of adults and eggs present on treated and untreated plants.*

Test No.	Liquid lime sulfur, 1-45		Dry lime sulfur 1 lb. 10 gallons		Wettable sulfur 1 lb. 10 gallons		Dusting sulfur		Check	
	Adults	Eggs	Adults	Eggs	Adults	Eggs	Adults	Eggs	Adults	Eggs
1	....	......	10	145	....	......	14	94	16.0	412
2	4	26	7	10	....	......	....	......	12.5	337
3	....	......	26	40	16	160	....	......	27.0	375
4	....	......	....	......	....	......	7	124	14.5	437
5	10	94	....	......	....	......	....	......	22.0	1182
6	....	......	....	......	20	425	13	117	28.0	745
7	13	78	....	......	....	......	14	115	16.0	450
8	31	275	....	......	12	115	....	......	23.5	638
Total	58	473	43	195	48	700	48	450	159.5	4576
Average	14.5	118.2	14.3	65	16	233.3	12	112.5	19.9	572

The reduced numbers of eggs on the treated plants indicate a marked repelling effect of all materials.

It is recognized that the repelling effect of the materials alone can not be depended upon for complete protection, but it can aid materially in crop protection.

Lethal Effect of Certain Materials Upon Psyllid Nymphs

Lime sulfur has been shown (6) to have a very definite lethal effect upon psyllid nymphs, but the search has been largely for an equally effective material that would not injure tomato plants. Consequently, attention has been directed toward comparing other materials with lime sulfur.

Table 5 shows the effectiveness of certain materials in reducing the number of nymphs. The sulfur and dry lime sulfur dust mixture was made up of 75 percent dusting sulfur, 15 percent dry lime sulfur, and 10 percent bentonite. The sulfur dusts were undiluted. Liquid lime sulfur testing 33° Baumé was used at the rate of 1 part to 50 parts water. Records were taken by counting all nymphs upon a 2-ounce sample of leaves taken from each of eight plants in each plot. The samples from the plots treated with pyrethrum and derris powders and their check were taken 5 days after treatment, the other, 15 days after treatment.

TABLE 5.—*The effect of certain sprays and dusts on psyllid nymph populations on 2-ounce samples of tomato leaves.*

Material	Average number of nymphs
Sulfur and dry lime sulfur dust	0.6
Sulfur dust, 300-mesh	0.3
Sulfur dust, 200-mesh	1.0
Liquid lime sulfur, 1-50	1.0
Check	193.0
Pyrethrum powder, .17 percent pyrethrins	280.3
Derris powder, .5 percent rotenone	229.0
Check	367.5

All the sulfurs showed very marked effectiveness. The pyrethrum and derris powders were not effective at the strengths used. A later test with a pyrethrum product known as dry pyrocide, which was used as a dust at the rate of one part to nine parts of gypsum by weight, showed definite effectiveness. The undiluted pyrocide contained 2 percent of stabilized pyrethrins from pyrethrum flowers.

The results of a second test of sulfur and lime sulfur are given in table 6. Each treatment was replicated five times. Counts were made of the live psyllid nymphs on 2-ounce samples of leaves taken at random from each plot 10 days after treatment.

The liquid lime sulfur which tested 33° Baumé was diluted 1 part to 50 parts of water; the wettable sulfur was used at the rate of 1 pound to 10 gallons of water, while the sulfur dusts used were undiluted.

TABLE 6.—*The lethal effect of sulfurs and lime sulfur upon nymphs of the tomato psyllid.*

Treatment	Mean number of nymphs per plot sample
Liquid lime sulfur	2.4
Wettable sulfur	9.8
Gashouse dusting sulfur	14.6
300-mesh dusting sulfur	5.6
Check, untreated	210.8
Level of significance (5% point)	39.63

An analysis of variance indicates that all treated plots show highly significant reduction of the number of nymphs over the untreated plots, the results failing to show any significant difference in the effectiveness of treatments. The data indicate that the materials were very effective.

Residual Effect of Certain Materials Upon Psyllid Nymphs

Most contact insecticides are effective only at the time of application and against only the insects that are struck by the spray. It would be very desirable to have a material that would remain on the sprayed surface and kill those insects that move to or hatch on the treated surface. This is especially true when protection throughout the season is necessary and when even a few individuals can do serious damage. The sulfur that is set free on the foliage following the breaking down of lime sulfur, and the sulfur remaining after the spraying with wettable sulfur or the application of a dusting sulfur, appear to be effective against the nymphs as long as the chemical is present. When several hundred nymphs were transferred to treated leaves from 1 hour to 16 days after the leaves had been treated, practically 100 percent were killed. On several occasions, when very heavy deposits of eggs occurred, it was noted that even though the eggs hatched freely after being treated, very few nymphs were able to survive on a treated surface. This has a very important bearing upon the timing and the number of applications for seasonal protection. It makes it possible to use treatment as a "preventive," a very important measure when the prolonged feeding of a very limited number of nymphs seriously affects a plant.

Effect of Sulfur Compounds Upon the Tomato Plant

In the original work with lime sulfur for the control of the psyllid on tomatoes (6), attention was called to certain injurious effects of the material on the plants. The injury was so general when the desired strengths were used that it seemed advisable to reinvestigate the subject of psyllid control on tomatoes. The extent of injury varies with conditions, injury being most severe when temperatures are high and on plants that are growing very rapidly. To a great extent, also, the type of application determines the degree of injury. A drenching spray that causes drops to collect on the axils of the leaves or the tips of the growing branches makes injury more severe, as does also a coarse, driving spray. A mist spray that is discontinued before the dripping point is reached causes the least injury. The injury may show in the form of a definite burning of the bases and tips of the small leaflets or occasionally along the midribs. In many cases where blackened areas do not appear, the tissue, especially the under side of the leaf veins, may be so injured that the leaves curl downward when growth is resumed. Probably what is most serious is a general checking of the growth for a few days, caused by what is commonly spoken of as "sulfur shock," which delays the maturing of the plant and the setting of fruit. However, it should be said that these injuries are not as serious as the usual injury from psyllids.

In testing various materials it was found that dry lime sulfur, when used on the basis of sulfide-sulfur content, is as injurious as the liquid lime sulfur, but wettable and dusting sulfurs have failed to produce visible injuries. The comparative effect of these materials on plant growth is shown by plant measurements made on the plots of the seasonal control experiment in 1936. The measurements given in table 8 are the mean lengths of plant growth obtained by measuring the length of the three longest branches on each of eight plants in five replicates 11 days after the first application. The psyllid infestation was so light that the growth of the check can be used for comparison. It will be noted that the liquid and dry lime sulfurs retarded the plant growth significantly, while no significant retardation was caused in the plots treated with dusting and wettable sulfur.

Plant measurements could not well be made following the second and third applications to determine if these also affected the growth. However, no visible burning resulted. Experience has shown that the slow late-summer growth is more resistant to lime sulfur injury than the rapid early growth, and it may be possible that the plants become somewhat more resistant after the first application. It will also be noted that the number and weight of fruits produced in the plots treated with lime sulfur were significantly lower than in those treated with sulfur. This will be discussed more in detail along with the discussion of seasonal control.

In 1936 it was suggested that the addition of hydrated lime to the liquid and dry lime sulfur sprays might bring about a reaction with the higher polysulfide compounds and reduce the tendency for plant injury. Tests were made by adding 1 pound of hydrated lime to each gallon of the concentrated liquid lime sulfur and to each 5 pounds of dry lime sulfur. Each combination was then used in three dilutions with the result that injury was slightly more severe than with the same dilutions without the hydrated lime. In the same series of tests, wettable sulfur and flotation sulfur were each used in three standard dilutions without showing injury. Three-hundred-mesh dusting sulfur and gashouse dusting sulfur produced no visible injury.

A combination of wettable sulfur with a lime sulfur, diluted beyond the point of plant injury, i.e., one-half ordinary strength, shows promise for conditions where a spray is especially desired. Some preliminary tests with 1 gallon of 33° Baumé liquid lime sulfur, plus 4 pounds of the wettable sulfur to 80 gallons of water, showed a strong killing effect upon the nymphs without noticeable burning or retardation of plant growth. There is some evidence to support the theory that the somewhat larger particles that make up wettable sulfur give a residual effect of longer duration than do the extremely small colloidal particles of sulfur formed in the decomposition of lime sulfur. Unfortunately this combination has not been tested for seasonal protection.

Field Control Tests

Field tests for seasonal control were carried out in 1934, 1935, and 1936 in the Fort Collins area. Each season presented a different problem as to psyllid infestation.

Tests During 1934

In 1934 the infestation was rather severe in the earliest planted fields. Because no definite experimental plots were available, the work was limited to a few tests in cooperation with commercial gardeners. Under these conditions the tests could not be properly varied and replicated to bring out the best information. There was little or no opportunity for checking. On only one field was it possible to make complete yield records. In this case, only liquid lime sulfur, 1 part to 50 parts of water, was used in one, two, and three applications, with no replication and with only one untreated plot for checking. Records were taken by picking, counting, and weighing all fruit from eight plants in each plot. The results are given in table 7.

TABLE 7.—*Yield of tomatoes in pounds from plots sprayed with liquid lime sulfur, 1 part to 50 parts of water.*

Treatment	Average weight per plant in pounds	Average weight of fruits	Yield per acre in pounds	Increase in pounds per acre over check
Check	2.18	0.066	5,934	....
One spray	11.06	0.095	30,105	24,171
Two sprays	12.27	0.108	33,399	27,485
Three sprays	15.97	0.148	43,470	37,536

This field was heavily infested, and without treatment it would have produced little marketable fruit. This is shown by the check which produced at the rate of only 5,934 pounds per acre of very small, poorly-colored fruit. Each application of chemical resulted in a good increase in yield, which was partly due to increased size of the fruit. The first application of lime sulfur noticeably retarded plant growth for a few days and undoubtedly interfered some with the season's growth, but by controlling the psyllids which were far more injurious, the net results from its use were good.

Undiluted sulfur dust and wettable sulfur, 1 pound to 10 gallons of water, were used in plantings where yield tests could not be obtained. It was certain that they gave good control, although they could not be compared one with the other or with lime sulfur.

Tests During 1935

In 1935 a field of tomatoes was planted for experimental purposes. The plan was to compare results of the use of (1) liquid lime sulfur, 1 gallon to 50 gallons of water; (2) dry lime sulfur, 1 pound to 10 gallons of water; (3) wettable sulfur, 1 pound to 10 gallons of water; and (4) 300-mesh dusting sulfur, undiluted. Each treatment was to be applied in one, two, and three applications. There were to be untreated plants for checking in each case. Because of an extremely light psyllid infestation only one application of each material was made. The harvested crop failed to show any significant differences among treatments or between treated and untreated plants.

Tests During 1936

The 1935 plans were repeated in 1936, the John Baer variety of tomato being planted. The plots were arranged in blocks at random to permit an analysis of variance. Each plot consisted of 12 plants, 8 of which were selected as the record plants, the other 4 being discarded. A detailed record was kept throughout the season of the number and weight of fruits from each plot, together with date of picking. The effect upon plant growth was ascertained by length measurements from the ground level to the terminal bud for the three longest branches of each plant. These measurement data have been considered under the discussion of the effects of materials on plant growth. Seasonal population of psyllids was ascertained by counts of nymphs upon 2-ounce samples of leaves taken at random from each plot.

The psyllid infestation during 1936 was only light to moderate. The plants from which the records were taken became naturally infested while in the cold frame. They were set in the field on May 20. At this time, an occasional plant carried enough nymphs to produce symptoms of mild psyllid injury. Originally it had been planned to treat them early in June, but a hail storm on June 4 destroyed most of the older leaves that bore the nymphs. Weather unfavorable for the psyllids followed, with the result that the infestation remained light until late summer. After the middle of August the population increased to the point where psyllid symptoms were apparent on the untreated plants.

The first application of insecticides was made on June 26. The plants were growing rapidly following the hail injury. The second application was made on July 7, when the plants were breaking over and blooming freely. The third application was made on August 11 at a time when a few fruits were ripening.

A summary of the more essential data is given in table 8. When the aggregate data from each phase of the study were analyzed it was found in all cases that the differences between treated and untreated plots were highly significant. Therefore, in order to permit a closer comparison of the results of the use of the different materials, the data afforded by the check plot were excluded except in the study of the effect upon plant growth.

A comparison of the number of nymphs per plot sample on treated and untreated plants (table 8) shows the effect of treatments upon late psyllid infestation to be very pronounced. However, the analysis shows no significant difference among the treatments. Therefore, they must be considered equally effective in holding down the size of the psyllid population.

The influence of one or more applications of insecticide was measured. The average number of nymphs on the uniform samples of leaves was as follows: 1 application, 93; 2 applications,

TABLE 8.—*Summarized data taken in a study of sulfurs and lime sulfurs for the control of the psyllid on tomatoes during 1936.*

Items	Treatments					
	Check untreated	Dry lime sulfur	Wettable sulfur	300-mesh dusting sulfur	Liquid lime sulfur	Level of significance (5% point)
Mean number nymphs per plot sample	157.73	60.13	61.20	79.20	58.86	....
Mean length of plant growth (in inches)	17.22	14.04	17.26	17.11	14.82	1.07
August mean total yield (in pounds)	53.37	39.98	58.84	60.47	41.68	5.56
August mean number fruits	214.46	155.13	221.33	220.46	154.66	22.56
August mean weight individual fruits (in pounds)	0.25	0.26	0.27	0.27	0.27	0.02
Season's mean total yield (in pounds)	161.49	155.56	164.15	174.74	152.10	10.83
Season's mean weight individual fruits (in pounds)	0.22	0.25	0.24	0.24	0.25	0.01
Total mean number fruits (ripe and green)	1289.40	1059.53	1121.26	1172.60	1070.73	47.50

72.5; and 3 applications, 29.3. The variance analysis indicates the difference resulting from three applications as compared to two and one is highly significant and the difference between one and two applications approaches significance.

It appears clear, therefore, that one application of dry lime sulfur, liquid lime sulfur, wettable sulfur, or 300-mesh dusting sulfur made on June 26, had a very marked effect upon the September infestation of psyllids, with no important differences appearing in the effectiveness of these materials. Two applications increased the effectiveness to a point approaching significance, while three applications increased the effectiveness very significantly.

The effect of materials upon plant growth, as shown in table 8, has previously been discussed but it should be noted here that the first application of both dry and liquid lime sulfurs caused rather serious burning and retardation of plant growth, all of which is reflected in the yield records.

It will be noted in table 8 that the yield records for the period before September 1 are considered separately from the records for the entire season. This is done because the effects of the treatments upon the early fruit harvest were so definite. September 1 is near the end of the picking season in some years on account of killing frosts.

It is clear from the data in table 8 that there is a significant difference in the early fruit yield due to the treatments. When this is put on the basis of yield per acre, as in table 9, the extreme difference amounts to almost 2 tons per acre. Use of dusting sulfur and wettable sulfur is demonstrated to be superior to absence of treatment while use of dry and liquid lime sulfurs is inferior. With such large differences it seems safe to conclude that the sulfur dust and the wettable sulfur, by controlling the rather light psyllid infestation without causing spray injury, resulted in a marked increase in August yield over the untreated plots. Even though they demonstrated an equal control of the psyllids, the dry and liquid lime sulfur caused so much plant injury that the yields were distinctly lower.

The differences in the total yield for the season are not as great as shown in the early fruit. This would again indicate that the injurious effects of dry and liquid lime sulfurs were produced largely by the early application and were being overcome as the season advanced. A comparison, however, shows the dusting sulfurs superior to dry and liquid lime sulfur. The difference between dusting and wettable sulfur plots approaches significance, with the dusting sulfur giving the higher yield.

When the data on the size of the fruit is analyzed, it is found that there is no difference in size in treated plots but the fruits from the untreated plots are significantly smaller. This would indicate (1) that the control of even a light infestation of psyllids resulted in larger fruit; (2) that the injurious effect of dry and liquid lime sulfurs upon the yield was a retardation of setting and ripening and not a retardation of fruit growth.

One of the symptoms of a moderate infestation of psyllids on the bearing tomato is a stimulation of blooming and fruiting. The increase in the number of fruits set on the untreated plants over the treated plants is highly significant. An analysis of the data without the check also shows a significant difference in results of the various treatments. The low numbers of fruits from the plots treated with lime sulfur may be attributed to plant injury since no difference was shown in psyllid control by the various treatments.

Table 9 gives the yield computed on an acre basis. The August yield is given separately since the greatest differences in the results of treatments occurred early in the harvest.

TABLE 9.—*The yield in pounds per acre of tomatoes produced by plants treated with sulfurs and lime sulfurs for tomato psyllid control.*

Treatment	August yield per acre in pounds	Season yield per acre in pounds
Check	11,624.5	35,172.1
Dry lime sulfur	8,707.6	33,880.9
Wettable sulfur	12,816.7	35,752.4
300-mesh dusting sulfur	13,171.6	38,058.3
Liquid lime sulfur	9,079.2	33,127.3

No difference in psyllid control was apparent among the various methods of treatment but plants treated with liquid or dry lime sulfur gave lower yields than the untreated check. This was not true in 1934 when under conditions of heavy infestation the check yield was reduced to a greater extent by psyllid injury. Under such conditions the net gain from lime sulfurs was high in comparison with the untreated check. No distinct difference in the acre yield between the wettable and dusting sulfur plots is shown, but an increase over the check is clear. The large margin of difference in pound yield from plants treated with the sulfurs and those treated with the lime sulfurs appears to be due to plant injury by the lime sulfurs.*

Discussion of Psyllid Control

Control of the psyllid and the condition known as psyllid yellows should be looked upon largely as a problem of prevention rather than one of cure. The tomato plants show a remarkable power of recovery after an infestation is destroyed but there is a question whether this recovery is ever complete. Even when recovery is complete, time is lost and the crop fails to do its best on account of a short season. It has been shown that sulfur on the plant resulting from the application of dusting or wettable sulfur or from the breaking down of lime sulfur sprays, acts to some extent in repelling adult psyllids and kills almost all nymphs attempting to settle on the plant. Thus, injury can be prevented by thoroughly protecting the plants before the nymphs begin to feed. Adults usually appear on the plants in the cold frame early in May, or about 2 weeks before the plants go to the field. From two to four nymphs on a small plant at this time will seriously retard growth. After the plants have been taken to the field, adult psyllids that had not found the cold frames are usually attracted, the first plantings attracting more than the later ones. Nymphs from these begin their damage before the plants have fully recovered from transplanting.

This emphasizes the necessity of treating at least once in the cold frame and again in the field as soon as the plants are somewhat established and before field-deposited eggs begin to hatch. Two more applications, one when the plants are branching freely and the other as they are starting to break over, will give seasonal protection in all parts of the state where the sum-

*The following observations were made during 1938 after the psyllid project was closed and this report prepared.

In the Fort Collins area, adult psyllids were found in considerable numbers on May 17 on tomatoes in the cold frames, on early potatoes, and on some wild host plants. Temperature conditions were very favorable for the insect during the remainder of May and the months of June and July, with the result that the insect developed in almost unprecedented numbers. By the latter part of July the garden plantings in northeastern Colorado were beyond recovery and many commercial plantings were abandoned. Reports indicated a severe early infestation in the Arkansas Valley that seriously retarded plant growth before control was undertaken. In the Brighton-Fort Lupton area the general complaint was that the tomatoes were especially late. This is a result of early psyllid injury that is usually attributed to other causes. The conditions gave a severe test of control. In the writer's garden and in another where the work was supervised, dusting sulfur gave almost complete protection. It was used by growers in several commercial plantings with varying results, depending upon the degree of injury before control was started and the thoroughness of application. The experience emphasized again the importance of early protection rather than attempting to cure after serious damage has resulted.

mer temperatures prevent a serious mid-season infestation. This applies to all canning areas, thus making it possible to secure protection without having a residue of sulfur on the fruit. In the area near the foothills from Fort Collins south to Littleton and in a few other regions where conditions are more favorable for the insect, a later application or two may be advisable. Fruit from plants receiving such later applications should be carefully washed, peeled, and trimmed before being canned or made into juice. Otherwise it might carry enough sulfur to affect the color and possibly the keeping quality of the product.

There will be years when fairly satisfactory crops will be grown without treatment, but unless a definite control program is followed each season, many reductions in yield and quality, and even crop failures, can be expected.

Thoroughness of application is essential because a few unprotected leaves may support enough nymphs to cause injury. The nymphs feed mostly on the under side of the leaves, so sprays and dust shoulds be applied with this in mind. With the small hand sprayers used in home gardens, the nozzle should be on an angle so the under side as well as the upper side of the leaves can be sprayed. Row crop sprayers should be so equipped that three nozzles can be directed on each row—one from above and one from each side. The latter should direct the spray somewhat upward and into the plant. A fine mist spray that is not continued to the dripping point causes the least injury when lime sulfur is used.

Sulfur dust should be applied only when the air is still. Coverage can be increased, when the size of the plant will permit, by blowing the dust into a covering over the plant, allowing the cover to remain in position for a few seconds. In home gardens and even market gardens, a grocery store paper carton will be found satisfactory and light to handle. Cut a hole in the top or side just large enough for the nozzle. By selecting a box only slightly larger than the spread of the plant, considerable dust can be saved. The writer has used a box efficiently by attaching it to the nozzle of the duster and carrying it from plant to plant by holding to the dust exhaust pipe.

With care, a satisfactory coverage can be secured in the average home garden planting with the small plunger type of hand duster, especially if a box covering is used. In the market gardens and factory plantings of a few thousand plants, the bellows type of hand duster will be found satisfactory. The powered field dusters are the most practical for large acreage. Whatever type of duster is used, thoroughness of coverage should be emphasized. Do not expect results by throwing sulfur onto the center of the plant out of the hand or shaking it from a sack or can in which holes have been punched. A fog of dust should cover the entire plant and so float through the foliage that both the under and upper surfaces are covered.

Small hand sprayers are not as satisfactory as small hand dusters. The best coverage of spray is secured with the powered row-crop sprayers such as are used in potato spraying.

The proper selection of material is important. The liquid lime sulfur should be a standard product testing 30° to 33° Baumé. If it varies much from this, dilute according to dilution tables made for psyllid spraying (8). Dry lime sulfur should be a fresh product that has been kept in an airtight container. The dusting sulfur should be a product prepared especially for dusting purposes. Such preparations have a small amount of other materials added to prevent lumping and insure a more regular flow through the duster. Just any sulfur on the market will not do. At least 95 percent of the material should be guaranteed to pass through a screen of 300 or 325 mesh to the inch.

Wettable sulfurs are sulfurs that have had small amounts of other materials added to cause them to mix readily with water and go into suspension. They also should be 300- or 325-mesh materials.

If a spray is preferred to a dust, the writer is inclined to favor the combination of lime sulfur and wettable sulfur, even though this has not been given a season's test under severe conditions. Liquid lime sulfur, 1 part to 80 parts of water, plus 1 pound of wettable sulfur to each 20 gallons of spray appears to have most of the advantages of the lime sulfur without the danger of burning and sulfur shock that so often follow the use of lime sulfur, 1 part to 50 parts of water. Five pounds of dry lime sulfur can be substituted for each gallon of liquid lime sulfur, if preferred.

Infestations of the winter crop of greenhouse-grown tomatoes result from the insect being carried over in the house after frosts have destroyed the host plants outside. Spring crop infestations appear to originate largely from the entrance of adult psyllids through unscreened doors and ventilators during their early spring flight. With care in bringing plants into the house in the fall and the proper screening of the houses with wire netting of 14 mesh to the inch, much of this can be avoided. However, both spraying and dusting has proven very effective in controlling these greenhouse infestations. It might be said here that clear symptoms of psyllid yellows do not develop as rapidly under glass as in the field, but another danger may be introduced: in two large houses under observation the psyllids appeared to spread mosaic diseases of the tomato.

Summary

The tomato psyllid, *Paratrioza cockerelli* (Sulc), is a native of the Rocky Mountain region and is western in distribution. It has been reported as a tomato pest in Colorado since 1898. The principal food plants in Colorado belong to the potato or nightshade family.

The insect feeds by piercing and sucking. The feeding of the nymphs upon the tomato plant causes a condition known as psyllid yellows. This seriously affects plant growth and fruit production.

The adult psyllid is somewhat similar in appearance to the winged plant lice but is more robust and active. The egg is very small, yellow, and is placed in a short stype or stem, usually on the edge of the leaves. The nymph is flat and scalelike in appearance, yellow to orange in color at first, but a light green when near maturity.

Psyllids are reported to winter elsewhere on pines and cedars. There are believed to be five generations per year on tomatoes in the Fort Collins section, but this no doubt varies with temperature conditions. Laboratory studies indicate that the insect thrives under comparatively low temperatures. Eighty degrees appears to be near the optimum. Temperatures above this retard the insect's development and multiplication more than temperatures below this point. Ninety-degree temperature is definitely detrimental to the insects, 95° temperature for any great length of time reduces numbers materially, while 100° temperature for even a few hours per day soon almost eliminates the infestation. This temperature effect appears to account for the disappearance, before total crop losses result, of early infestations that occur in certain tomato growing areas almost each year. It also seems to explain the continued building up of the psyllid population throughout the growing season in certain cool, high-altitude regions. High temperatures cause the adults to become restless. This may be partly responsible for many of the insects getting into air currents and being carried into the Grand Valley as indicated by trapping records in 3 different years.

The residue after spraying with lime sulfur and the deposit of sulfur after dusting with sulfur or spraying with wettable sulfur definitely repel adult psyllids.

Two seasons' tests with dry and liquid lime sulfurs, wettable sulfur, 300-mesh dusting sulfur, and gashouse dusting sulfur, failed to show any differences in the effectiveness of these materials in killing psyllid nymphs. All killed a high percentage of the nymphs.

Sulfur deposits from lime sulfur sprays, and sulfur sprays and dusts, kill nymphs that attempt to settle upon sprayed or dusted surfaces as many as 16 days after treatment.

Liquid lime sulfur, 1 part to 50 parts of water, and dry lime sulfur, 1 pound to 10 gallons of water, seriously retarded plant growth as shown by plant measurements. This was reflected in yield of fruit.

In field control experiments in 1934 under conditions of heavy infestation, plants treated with lime sulfur spray gave a large increase in yield over the untreated plants, even though some spray injury occurred. In 1936 under conditions of a light to a medium infestation, liquid and dry lime sulfur sprays caused a reduction in yield as compared with the yield from untreated plants, while dusting sulfur and wettable sulfur treatments resulted in increased yields. Since population counts showed no differences in the effect of these materials in the control of the psyllids, this difference can be attributed only to the plant injury caused by the lime sulfurs.

Temperature conditions in 1938 were favorable for psyllid development. An almost complete tomato crop failure resulted on untreated plantings. Sulfur dust thoroughly applied gave good protection.

Recommendations

Make plant protection a program of prevention rather than "cure."

Treat all plants thoroughly before injury occurs, with one of the following:

(a) Three-hundred-mesh dusting sulfur, undiluted.

(b) Three-hundred-mesh wettable sulfur, 1 pound to 10 gallons of water. (One heaping tablespoonful to 1 gallon of water.)

(c) One gallon of 32° Baumé liquid lime sulfur and 4 pounds of 300-mesh wettable sulfur to 80 gallons of water. (Three tablespoonsful of liquid lime sulfur and 1 tablespoonful of wettable sulfur to 1 gallon of water.)

Make applications as follows:

(a) Ten days before the plants leave the cold frame or greenhouse. (If plants should be untreated at setting time dip the entire tops into water that carries wettable sulfur at a concentration of 1 ounce to the gallon.)
(b) Ten days after the plants have been planted in the field.
(c) When the plants are branching freely and beginning to blossom.
(d) Just before the plants break over and begin to spread.

In the area along the foothills from Fort Collins south to Littleton, and in similar regions, watch the plants during midseason and late summer and treat them again if many nymphs are detected. Before canning or extracting juices from fruit that has been treated with sulfurs near harvest, carefully wash and peel it.

Preliminary tests indicate that reasonably effective control can be secured and excessive amounts of sulfur on the fruit avoided by using pyrethrum dusts when treatment during the harvest season becomes advisable. Use one part of dry pyrocide, contained 2 percent of stabilized pyrethrins, to nine parts of talc, colloidal clay, or other suitable dusting material.

Screen with netting of 14 mesh to the inch the doors and ventilators of greenhouses being used for growing of tomatoes. Treat plants at first appearance of psyllid infestation.

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NOTES

NOTES

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