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THRIPS OF ECONOMIC IMPORTANCE IN CALIFORNIA

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The insects known as thrips constitute an important group of crop pests deserving much more attention than has been given them in the past. The increasing demand for higher-quality fruits and vegetables, free from blemish, has directed attention to the silvering and small scars usually produced by the rasping-sucking feeding process of thrips. Also, during the dry seasons recently experienced in this state (1929–1934),

The adult male bean thrips.

thrips injured many crops through defoliation and through bud and flower injury. During this period the gladiolus thrips, an entirely new species, became the most serious pest of gladiolus in North America. In southern California the greenhouse thrips has so increased out-of-doors on avocados and citrus that control measures have become necessary. Another major outbreak of the pear thrips has forcefully recalled to mind an old pest in this group. Likewise the bean thrips for some time known as injurious to beans, cotton, and alfalfa, has become of concern

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to pear growers in northern California, because it is responsible for premature defoliation of pears in nonirrigated sections. The widely distributed onion thrips and the western flower thrips have been proved to carry plant-virus diseases.

As a result of the conditions outlined above, considerable experimental work has been done, and valuable observations have been made on the thrips of economic importance. Growers, packing-houses, and other agricultural organizations repeatedly have requested this information. Also, since the life histories and habits, as well as the control, of the various species of thrips vary, often quite markedly, some confusion has inevitably followed in the application of general recommendations. This publication has been prepared, therefore, to answer questions and to present certain new facts concerning these tiny but important pests. With but few exceptions, all the thrips of economic importance in North America occur in California.

GENERAL DESCRIPTION OF THRIPS

Being so small, thrips are usually overlooked on plants. Their size ranges from $\frac{1}{50}$ to $\frac{1}{25}$ inch in length. Some larger species measure $\frac{1}{16}$ inch. The thrips here discussed have two pairs of fringed wings, carried lengthwise over the back when not in use. A pair of antennae project forward from the head. The posterior end of the body is bluntly pointed. The male is usually smaller than the female. Besides flying and running rapidly, many adults have the ability to hop.

The eggs are extremely small, bean-shaped, and very delicate (fig. 1, *A*). They are most commonly inserted in plant tissue, indicating their presence only by a tiny bump, and are rarely seen.

The larval[2] stage is soft-bodied, without wings, and with other appendages much less developed. The newly hatched larvae (fig. 1, *B*) are very minute but when full-grown (fig. 1, *C*) are about the size of the adult. The larvae are usually much more sluggish than the adults and feed in colonies. One molt occurs when the larva is about half-grown, and a second when it is fully developed.

The pupal or resting stage, though likewise soft-bodied, has wing stubs present. A third molt comes at the end of the prepupal stage (fig. 1, *D*). The last molt occurs when the adult emerges. The pupa (fig. 1, *E*) does not feed and, unless disturbed, does not move.

[2] The terms *larval* and *pupal*, implying that these insects have a stage of development as larva and pupa, is in accord with the usual entomological nomenclature used with reference to the order Thysanoptera. These terms became fixed in the literature on account of the resemblance of these corresponding stages to the true larval and pupal stages of insects that have a complete metamorphosis wherein the adult is entirely unlike the immature form.

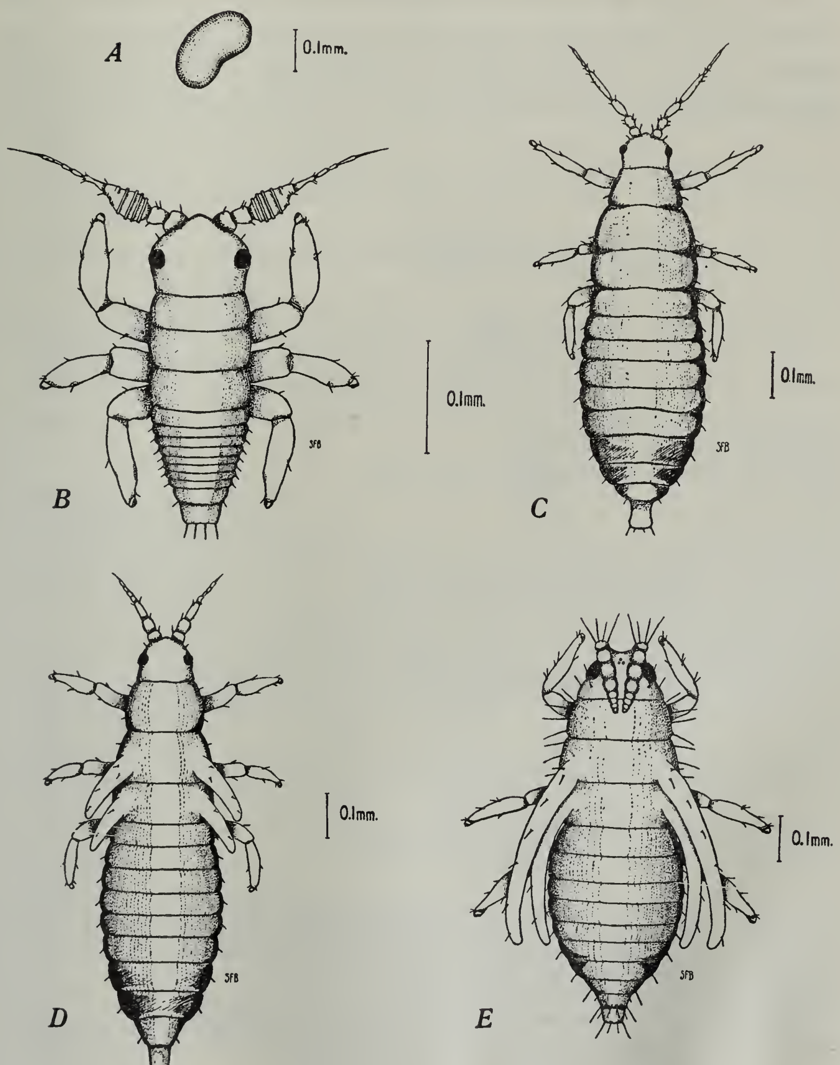

Fig.1.—Life stages of the bean thrips: *A*, egg; *B*, newly emerged larva; *C*, mature larva; *D*, prepupa; *E*, pupa. (From Hilgardia Vol. 7, No. 12.)

THE IDENTIFICATION OF SPECIES OF THRIPS

There are about 125 species of thrips in California; but thus far, fortunately, only 8 are major crop pests. The majority of species are very similar; to one unfamiliar with their habits, hosts, and seasonal history they are difficult to distinguish. Most of the specific characters can be

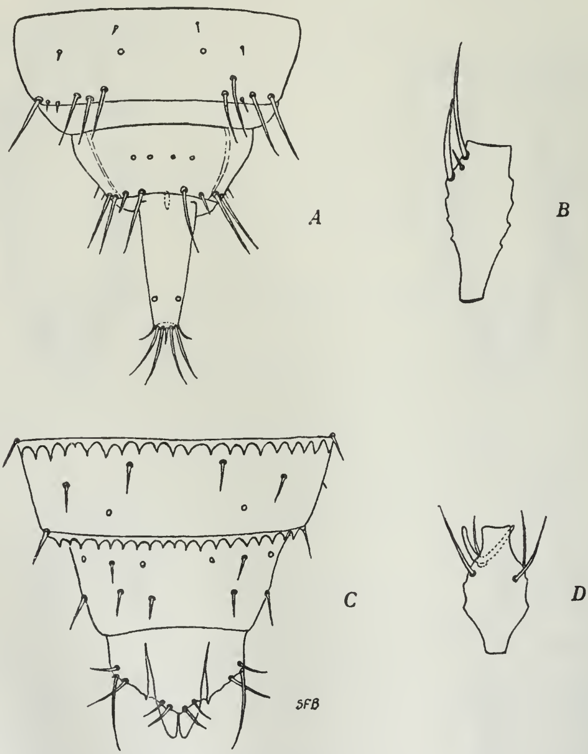

Fig. 2.—*A*, Posterior segments of the abdomen of a female toyon thrips. Note the tubular shape of the last segment and the absence of an ovipositor. *B*, Fourth antennal segment of a greenhouse thrips, showing the simple sense cones. *C*, Posterior segments of the abdomen of a male composite thrips. Note the comblike serrations on the posterior margin of the segments. *D*, Fourth antennal segment of the bean thrips, showing the forked sense cone.

seen only with a compound microscope after the insect has been mounted on a slide. All attempts to prepare a practical key for the accurate field identification of thrips have had to be discarded because of the great range of hosts, the variation in color, and the impossibility of seeing the body structures necessary to positive identification. The discussion of each species in later sections of this circular includes the general habits and characteristics from which fairly accurate determinations can be made. Those who desire to make definite identifications, however, and have the facilities for doing so, may use the following key.

A KEY TO THE SPECIES OF THRIPS OF ECONOMIC IMPORTANCE IN CALIFORNIA

1. Antennae 6-segmented (fig. 33) . . Vine or grape thrips, *Drepanothrips reuteri* Uzel
   Antennae more than 6-segmented 2
2. Posterior end of abdomen tubular (fig. 2, *A*); females without an ovipositor . . 3
   Posterior end of abdomen bluntly pointed; females with an ovipositor (figs. 4 and 22) 5
3. Forewings narrowed in middle; mouth cone rounded . . . .
   Haplothrips leucanthemi (Schrank)
   Forewings not narrowed in middle 4
4. Head little or no longer than prothorax, which is large and heavy; prothorax with median dorsal thickening; mouth cone long and slender . . . .
   Toyon or Christmasberry thrips, *Rhynchothrips ilex* (Moulton)
   Head clearly longer than prothorax; wings fully developed . . . .
   Lily thrips, *Liothrips vaneeckei* Pr.,
   and hollyhock thrips, *Liothrips varicornis* Hood
5. Antennae 7-segmented 6
   Antennae 8-segmented 7
6. Posterior margin of abdominal segments on dorsum with a comb of broad teeth (fig. 2, *C*) . . . .
   Composite thrips, *Microcephalothrips abdominalis* (D. L. Crawford)
   Posterior margin of 8th abdominal segment only with comb of fine hairs . . . .
   Onion thrips, *Thrips tabaci* Lind., and *T. nigropilosus* Uzel
7. Surface of body, particularly notum of head and prothorax with network of lines (fig. 30) 8
   Surface of notum not reticulated 10
8. Antennal style 1-segmented; forewings broad, with a fine network of lines, and constricted in basal third . . . .
   Dracaena thrips, *Parthenothrips dracaenae* (Heeger)
   Antennal style 2-segmented; forewings narrow, without network, and not constricted in basal third 9
9. Hind coxae closely approximate, separated by a fraction only of their transverse width; antennal segments 3 and 4 with forked sense cones (fig. 2, *D*)
   Bean thrips, *Hercothrips fasciatus* (Perg.),
   and sugar-beet thrips, *H. femoralis* (Reuter)
   Hind coxae not approximate; antennal segments 3 and 4 with simple sense cones (fig. 2, *B*) . . . . Greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché
10. Forewings with only one longitudinal vein reaching to tip of wing . . . .
    Citrus thrips, *Scirtothrips citri* (Moulton) (fig. 22)
    Forewings with two longitudinal veins reaching to tip of wing 11
11. Anterior angles of prothorax on each side with a long, strong bristle . . . .
    Flower thrips species, *Frankliniella moultoni* Hood (fig. 10),
    F. occidentalis (Perg.), and *F. minuta* Moulton
    Anterior angles of prothorax without a strong bristle (fig. 3) . . . .
    Pear thrips, *Taeniothrips inconsequens* (Uzel) (figs. 3 and 4),
    and gladiolus thrips, *T. simplex* Morison (fig. 28)

GENERAL BIOLOGY AND HABITS

Most thrips attacking plants have a simple life history that varies but little fundamentally in the different species. The minute, bean-shaped eggs are inserted in the tender plant tissue by a tiny, sawlike ovipositor. After a few days the delicate, soft-bodied larvae hatch and immediately begin feeding gregariously. The length of all the stages varies, of course, with the temperature. Under favorable conditions the larvae attain full growth in 7 to 10 days, when feeding ceases and the larvae either drop to the ground or rest quietly on the host. Some mature larvae such as the pear thrips make an earthen cell in the soil, in which they transform. During this period the wings and other organs develop, and in 4 to 14 days the adult stage is reached. Reproduction commonly occurs without mating; some species have no males.

There are one to many generations of thrips a year, and though less prolific than some insects, each female lays 25 to as many as 200 eggs, though more commonly 40 to 50. During the growing season and the warmer parts of the year the generations more or less overlap. The greatest seasonal abundance depends on the requirements of the particular species. Ordinarily, however, thrips are most numerous during the warmer and drier seasons; being small and rather delicate, they are destroyed by severe weather.

Hibernation most commonly occurs in the adult stage. The citrus thrips, however, passes the coldest months in the egg stage. Also, larvae of the onion thrips and the western flower thrips are found all winter in California. The only species here discussed that winters in the ground is the pear thrips. Other thrips hibernate under bark, in curled leaves, on evergreen plants, and other suitable hiding places.

Migration is not pronounced. If sufficient food is available, the adults move about very little. Many species with well-developed wings use them infrequently and are weak fliers. Local migrations, such as occur in the pear thrips and the western flower thrips, are usually occasioned by a shortage of food or by the discovering of a more desirable supply. In such event the migration is for only a few hundred yards, generally in the direction of the prevailing wind.

Thrips are found on the most tender, succulent portions of the host plants—usually in buds, in blossoms, under bracts, in leaf sheaths, or on bulbs. In some cases, however, they feed unprotected on the leaf surface, as, for example, the bean thrips on cotton or the greenhouse thrips on avocados.

Usually the host range of thrips is very wide, though some species, such as the gladiolus thrips, exhibit a narrower choice than others. This cosmopolitan host range and the habit of living somewhat concealed make control difficult and eradication almost impossible. Among the factors effecting natural control, heavy rains and cold weather are the most important. Thrips have a few insect enemies but all are, unfortunately, of minor importance.

Table 1 presents in condensed form the life history of the various species discussed in the text.

DISTRIBUTION AND INJURY

Except for a few species, such as the eastern flower thrips, all thrips of major economic importance in the United States occur in California. In the eastern, southern, and central states *Frankliniella occidentalis* and *F. moultoni,* our common flower-inhabiting species, are replaced by *F. tritici, bispinosa,* and *fusca.*

One cannot well generalize regarding the distribution of the various species because of their apparent specific requirements or limitations in respect to minimum winter temperature, soil conditions, rainfall, and host-plant range. For example the onion thrips and the two common species of *Frankliniella,* are found from the seashore to as high as 8,800 feet; the toyon thrips is limited by the distribution of its host plant; and the citrus thrips is confined to hot, arid, citrus-growing districts. More details concerning the distribution, host range, and other factors appear in the discussion of each species.

Larvae and adults feed in the same manner. The mouth parts are constructed primarily for sucking, and only liquid food is taken. Some scraping or rasping is done, however, to puncture the epidermal cells of the plant and start the flow of the plant juices. The effect is a silvering or bleaching of the surface of leaves, fruits, and stems. Also, once injured, growing tissue rapidly becomes deformed or dried up and later often cracks. Though the total injury from one thrips is not great, the habit of feeding in colonies soon produces a marked effect. Tiny, black dots of excrement deposited by some species render fruit or flowers unsightly. The injury occasioned, then, by thrips is distortion of growing points such as terminal leaf and flower buds and ovaries of fruit, silvering and scarring (often ringing) of fruits, and premature defoliation.

Recently the onion thrips and *Frankliniella* species have been proved to be carriers of plant viruses, among which the spotted wilt of tomatoes, peppers, celery, and lettuce is the most serious.

As this brief description shows, the actual monetary loss to a crop by thrips is hard to estimate. The scarring of fruits and malformation of nursery stock increase the percentage of culls. On gladiolus, pears, and prunes the bud injury is often so severe that the flowers fail to open

TABLE 1

LIFE-HISTORY SUMMARY OF THRIPS OF ECONOMIC IMPORTANCE IN CALIFORNIA*

Species	Length of egg stage (days)	Length of larval stage (days)	Length of prepupal and pupal (nonfeeding) stages (days)	Longevity of adult female (weeks)	Number of eggs per female	Approximate length of total life cycle (days)	Stage and place of overwintering	Number of annual generations	Peak of seasonal abundance	Major crop hosts
Pear thrips	7–10	14–21 on trees, then 150–210 in soil	14	4 on trees, then 4–16 in soil	100–200	365	Adult in soil	1	In San Francisco Bay counties: adults' emergence peak March 5-15; peak of larvae on trees April 1–10	Pears, prunes
Flower thrips	5	7–12	4–5	3	20	15–20	Larvae and adults on weeds and ornamentals	5–7	May	Nectarines, plums, peaches, alfalfa, peas, cut flowers
Bean thrips	7	10	5	3	30–50	20–25	Adult on weeds and ornamentals	6–11	August	Beans, pears, cotton
Citrus thrips	6–24; longer in winter	8	7	3–4	26–70	15–30	Egg in new growth	6	April 15 to May 15 and August 15 to September 15	Citrus
Onion thrips	5	5	4	2–3	20–100	15–20	Larvae and adults on alfalfa, onions, weeds, and ornamentals	6–10	June to midsummer	Onions, carnations, roses
Gladiolus thrips	4–5	5	4–5	4	100–200	15–20	Larvae and adults on gladiolus. Adults on iris, carnations, and *Tritoma*. All stages on corms in storage.	6–7	May to midsummer	Gladiolus

Greenhouse thrips	17–20	13	5	7	25	33–38	All stages out-of-doors on host in frost-free areas	5–7 (out-of-doors)	Midsummer	Citrus, avocados, many greenhouse and ornamental plants
Grape thrips	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Adults under bark on vines (in Europe)	2 or more	Midsummer	Grapes
Toyon thrips	21–28	21–28	14	24–36	10	90	Adults in curled leaves of host	1–2	May to June	Toyon
Lily thrips	17	35	15	10	Unknown	48	Larva and adults on bulbs	1–2	Summer (?)	Lily bulbs
Sugar-beet thrips	13	13	6	3–4 (estimated)	Unknown	30–38	Adults on hosts in greenhouse	Unknown	Summer	Sugar beets, sugar cane, various ornamentals in greenhouses

* The data in this table have been compiled from various sources and represent as nearly as possible the average conditions in California. All stages and activities of course vary with the temperature and other factors.

normally; the result is practically a total loss. Premature defoliation of cotton or beans greatly reduces the crop, and plants suffering also from lack of water may be killed outright.

CONTROL

Control of injurious thrips has for years concerned both entomologists and growers. When this group of insects was first recognized as crop pests, the life history and habits were practically unknown. The information since collected has aided greatly in control, particularly in the timing of insecticides and the removal of native host plants.

Natural control by parasites and predators is of little consequence. The best-known internal parasite is a minute chalcid, *Thripoctenus risselli* Crawford; but it has never become sufficiently abundant to be really beneficial. Among the recognized predators of thrips are other thrips, lacewings, ladybird beetles, pirate bugs, and spiders. None of these are sufficiently effective to reduce thrips infestations noticeably. As was mentioned above, heavy drenching rains deter thrips by beating them off the plants.

Among the early insecticides used against thrips were "sulfur washes," dusting sulfur, "tobacco decoctions," and the older types of oil emulsions, such as kerosene and soap. For many years nicotine sulfate in various forms has been recommended. Newer materials such as pyrethrum, fluosilicates, and rotenone-bearing compounds have all been employed with variable results. Investigations on the control of the gladiolus thrips showed that the arsenicals, used as sweetened-poison sprays, were useful against such sucking-rasping insects. Judging from recent experimental work, a given material or dosage is not equally effective against different species. Therefore no general recommendations can be made for controlling thrips as a group; each species, or often the same species on different crops, constitutes a distinct problem.

There are usually two primary reasons why satisfactory chemical control is difficult or unsatisfactory. First, growers do not notice the thrips (chiefly because of their small size) until considerable damage has been done and the infestation is well established. In such cases the eggs in the plant tissue and the pupae in the soil (greenhouse thrips excepted), both representing a major part of the population, are not affected by the insecticide. Second, great difficulty is experienced in obtaining penetration of a spray into leaf buds and blossoms or thorough coverage (of a dust) on the undersides of leaves of annual plants.

Cultural control by dry plowing, irrigation, and weed eradication has its uses and is described under the various species below.

Naturally a clear understanding of the thrips life history, proper timing, and thorough application of the best-known control measures for the problem at hand are prime requisites.

PEAR THRIPS

Description.—The pear thrips, *Taeniothrips inconsequens* (Uzel), is of a uniform dark-brown color, slender and bluntly pointed at both the head and posterior ends (figs. 3 and 4). The total length of the body is about $\frac{1}{25}$ inch. The grayish wings when not in use project backwards over the body and are lighter near the base, giving the appearance of a light band in the center of the body. In some deciduous-fruit-growing areas of the state this thrips occurs in large numbers in the fruit buds and blossoms during the spring for a period of about a month or 6 weeks; this period is from about the first of March to the middle of April.

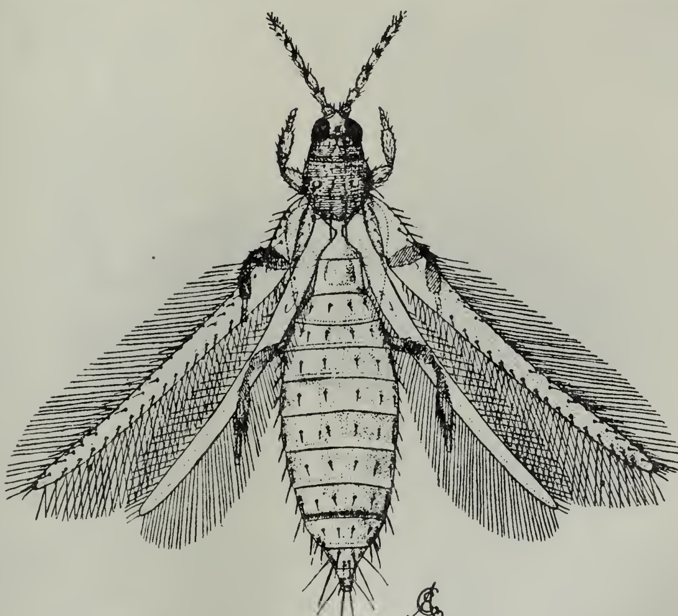

Fig. 3.—The adult female pear thrips. (Courtesy of Canada Department of Agriculture.)

After full bloom numerous white larvae are seen on the young fruits and leaves. They move less rapidly than the western flower-thrips larvae that are sometimes also present. The latter are orange-yellow. The pear thrips larvae, however, frequently take on a yellowish cast when mature and have dark-red eyes. A hand lens reveals a ring of strong black or dark-brown spines near the posterior end of the pear thrips larvae (fig. 5, *A*)—a characteristic separating them from other species present.

The pupal form (fig. 5, *B*) is very delicate, white, and almost transparent, with dark eyes. This form, being present for only 2 or 3 weeks in the fall in the soil of infested orchards under the trees, is very difficult to find.

Distribution.—In North America the pear thrips has a unique distribution. Except for one collection in Ontario, Canada, it occurs only on the Atlantic and Pacific coasts. On the east coast it has been found in New York, Pennsylvania, and Maryland. Only in New York state does it occasion any loss, and this is sporadic. To the west, the pear thrips is known in British Columbia, Washington, Oregon, and California. In all the Pacific Coast areas the injury is severe.

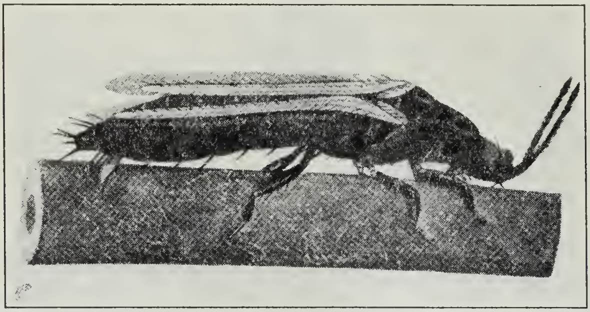

Fig. 4.—The adult female pear thrips, showing normal position when ovipositing. (Courtesy of Canada Department of Agriculture.)

The world distribution is much wider than is generally realized. The pear thrips is listed from England, France, Italy, Denmark, Norway, Germany, Crimea, Turkestan, Central Asia, and Argentina.

In California this thrips occurs only in central coastal counties within a radius of about 100 miles of San Francisco Bay. The principal counties involved are Sonoma, Napa, Solano, and Santa Clara. During epidemics local areas in Mendocino, Lake, Yolo, Placer, Sacramento, El Dorado, San Joaquin, Contra Costa, Marin, Alameda, San Mateo, Santa Cruz, and San Benito counties suffer varying amounts of injury. During the spring of 1938 injury was observed for the first time in Yuba County.

Hosts.—Though many plants are listed as hosts of the pear thrips, not all are important. Aside from deciduous fruit trees, the most common are willows, madroña, California laurel, and various weeds and grasses in and near infested orchard districts. The principal trees attacked are prune, pear, plum, cherry, and occasionally apple. A complete list of all the host plants recorded throughout the distribution of this thrips would add little to this discussion.

Injury.—The pear thrips occasions two definite types of injury. Before full bloom of the trees attacked, the adults upon emergence from the soil make their way into the opening buds where their intense activity causes a bleeding or gumming of pear buds and a blackening of prune buds (fig. 6). Often the damage is so severe as to prevent blooming altogether (figs. 6, 7, and 9) or to cause distorted, short-stemmed fruit (fig. 8). This injury continues over a period of several weeks and is par-

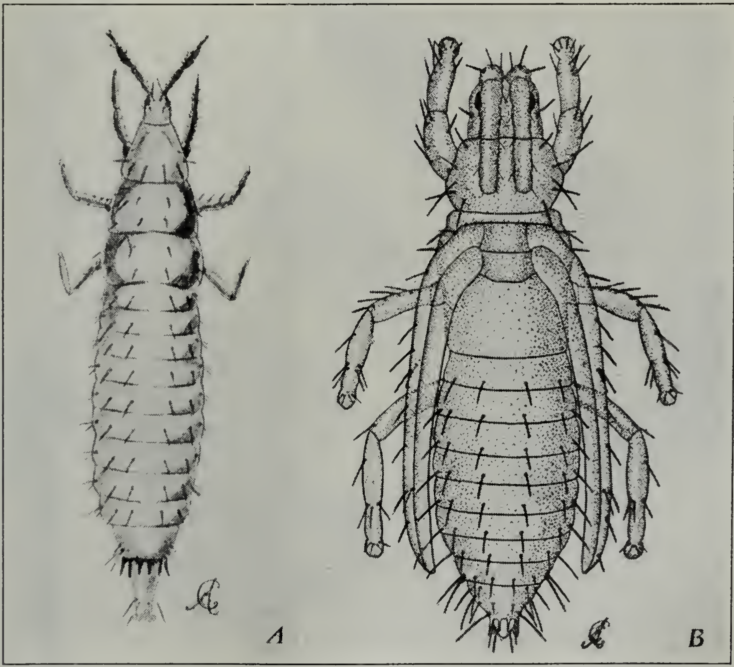

Fig. 5.—*A*, Pear thrips larva. Note the circle of spines near the posterior end of the abdomen; this character distinquishes it from other species. *B*, Pear thrips pupa. This stage occurs only in the soil in the fall and is rarely seen. (Courtesy of Canada Department of Agriculture.)

ticularly severe in a delayed spring when the buds open slowly. As the fruit clusters develop, the adults (all females) often insert so many eggs in the stems that the latter become weakened, and the blossoms wither and drop.

After full bloom innumerable larvae hatch and feed under the husks or jackets (calyx), on the surface of the small fruits, or in the unfolding leaves. The result is a scabbing, scarring, or distortion of the fruit. The leaves are so curled or injured that they appear scorched, with ragged margins and many small holes (figs. 6 and 7).

Pears and Imperial prunes usually suffer more from the thrips' attack than any other deciduous fruits. When these fruits are grown near French prunes all the adult thrips emerging in the vicinity congregate in those buds which open first, namely, those of pears and the Imperial prune. Some varieties injured more than others in one season may, however, escape the next year, since the time of blooming in relation to the

Fig. 6.—Pear-thrips injury to prunes. The holes in the leaves result from the larval injury done as the leaves are unfolding. Typical blossom-bud injury by the adult thrips is shown at the right.

peak of emergence of the adult thrips varies from year to year. In a season of great and prolonged emergence—often as long as 5 weeks—all varieties are damaged. If the soil warms up rapidly and if most of the thrips emerge in a few days, even though there is a small carryover in the soil, considerable concentrated damage may result. If the trees develop rapidly at the same time, the bud injury is greatly lessened.

Almonds and apricots bloom early enough to escape the peak of the emergence and subsequent damage. In exceptional cases nectarines and peaches may be injured.

Biology.—This thrips differs in its life history from all others of economic importance. The outstanding fact concerning its biology is that there is only one generation. Ten months of the year are spent in the soil under the host plants.

As was mentioned above, no males of this species are known in North America. All the adults, therefore, reproduce, so that under favorable conditions the species may increase very rapidly. The adults normally emerge from the soil the last of February as the soil begins to warm up—

Fig. 7.—Pear-thrips injury to pears. *A,* The two leaves at the lower left are normal; the others are curled and ragged as a result of thrips injury made when at the stage shown in *B*. *B,* Blossom bud injury to pear buds showing the normal flower buds and those blackened and stunted by the thrips. *C,* In severe cases the entire bud is killed.

when its temperature, at a 6-inch level, reaches 50° to 55° Fahrenheit. The emergence may continue for 3 to 6 weeks, according to the temperature. In the Bay counties the seasonal peak of emergence is reached during the first two weeks in March; at higher altitudes and northward, somewhat later. The adults quickly reach the tree buds by crawling and flying; then they begin to feed and oviposit.

The eggs are inserted under the bud scales, petals, and sepals; in stems; and in other succulent flower and leaf parts. If suitable buds are available, egg laying continues throughout the active life of the adult, which is 3 to 4 weeks. Each adult female lays 100 to 200 eggs. The length of the egg stage varies with the temperature and the stage of development of the embryo at the time egg was laid; normally it is 7 to 10 days.

Immediately after hatching, the larvae begin feeding gregariously in the buds, blossoms, fruits, or leaves. The first larvae are usually found on almonds, apricots, myrobalan plums, California laurel flowers, and willow catkins at the margins of orchards—about March 1 in early districts. By April 1 they are present in large numbers on pears and prunes.

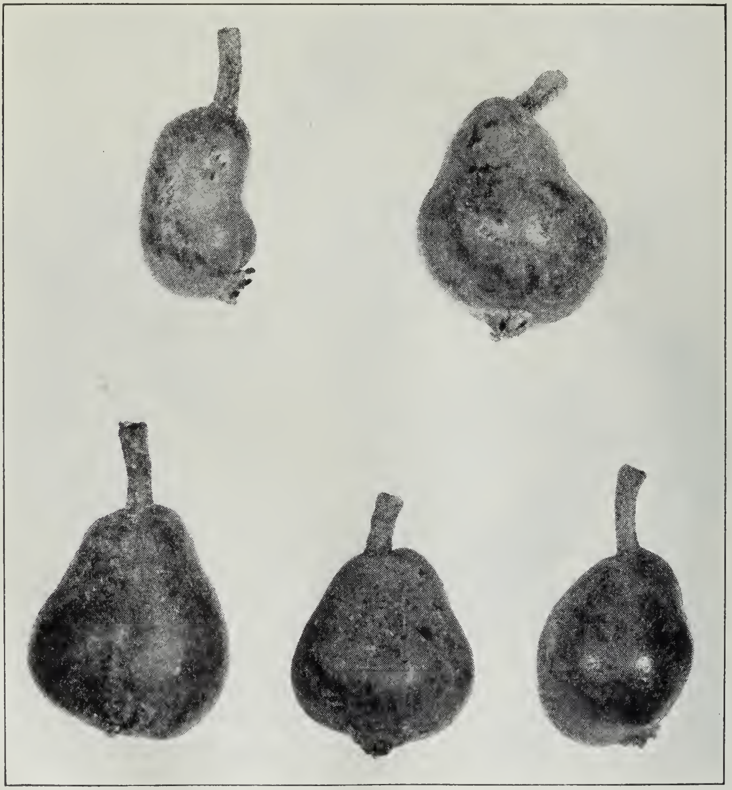

Fig. 8.—Pear-thrips injury to Bartlett pears. The short, scarred stems and the roughened, malformed appearance of the fruits are produced by the thrips larvae within about two weeks after full bloom.

After about a week's feeding, one molt takes place; another period of feeding completes the larval stage. The larvae eat almost continuously and mature in 2 to 3 weeks. Since the emergence and egg laying cover several weeks, it is about May 1 before all larvae have matured and entered the soil. The maximum abundance of the adults is reached about the middle of March, before full bloom. The peak of the larval infestation takes place after full bloom and during the so-called "calyx stage." In seasons when the fruits develop rapidly the larvae desert them and feed on the undersides of the leaves. They prefer, however, to feed within the calyx. Thus the pear thrips are to be found on the trees from the last of February until the first of May.

When fully grown the larvae drop from the trees to the soil directly underneath. At this time the covercrops are usually plowed under, and the soil surface is broken and rough. Immature larvae usually die when knocked to the ground, if no weeds are present upon which to feed. Ma-

Fig. 9.—Pear-thrips injury to French prunes in the Healdsburg district. What appears to be a shadow cast by a cloud on the 42-acre orchard in the background is the bloom entirely blackened by the thrips. The nearest orchard trees are in full bloom and are only slightly injured, since the thrips emergence was very light in this area. (Photograph by J. F. Lamiman.)

ture ones immediately crawl downwards through cracks, porosities and worm holes, until they find a suitable niche. Each forms a rather crude, oval cell by turning around and around and by smoothing the soil particles with the posterior end of the body. The depth to which they penetrate depends on the type or physical structure of the soil resulting from cultural practices. As a rule they do not penetrate hard, gravelly, or sandy soils as they do sedimentary or loamy types. If a plowsole or hardpan is near the surface, they will usually go down to it but not into it. Practically none are found within 6 inches of the top of the ground in cultivated orchards. The extreme depth at which they have been found is 20 inches. In orchards of Santa Clara, Sonoma, Napa, and Solano counties the majority are found between 8 and 14 inches, or in the moderately compact moist soil beneath the surface mulch, and always concentrated directly under the drip of the trees.

From May to October or November the larvae remain quietly resting in the cells. As the soil dries out and crumbles, as in very sandy areas, some mortality occurs among those nearer the surface. In the fall, as the soil temperature drops and the moisture increases, the larvae begin transforming to the adult stage. The time of pupation often varies as much as a month in different districts. In the warmer, drier areas, pupation takes place last. The first fall rains, if sufficient to wet down 6 or 8 inches, usually stimulate the change. Individual thrips generally remain in the true pupal stage about 2 weeks, but pupae may be found in different types of soil in an orchard over a period of a month. In most of the orchards infested, pupation occurs from about October 15 to November 15. In a very warm, dry fall, transformation may be a month later. The mature larva molts to a short prepupal stage in which the wings begin to develop. This stage molts to the true pupal stage, which in turn molts and gives rise to the fully developed winged adult female. The adults remain in the cells all winter until they emerge in the spring.

The distribution definitely indicates the narrow limits under which this insect can survive. High summer soil temperatures and heavy rains in April, May, and the early fall are the most important limiting factors. Any condition making for a high soil moisture during the pupal stage is very detrimental, and produces a high mortality. No natural enemies are known, with the exception, perhaps, of a fungus that appears to attack the resting forms in wet soil.

Since its first discovery in California about thirty-five years ago the pear thrips has apparently reached its maximum spread as limited by soil and weather conditions. The dissemination or local movement is not great. Infestations in adjoining orchards gradually, in favorable seasons, spread several rows a year, usually in the direction of the prevailing wind. Local migrations of the adults in large numbers occur only when the infestation is so great as to destroy the immediate food supply and the buds suitable for oviposition.

Control.—This thrips is among the most difficult to control, chiefly because of its concentrated activity in the spring and the cyclic tendency of its outbreaks. For many years a spray of nicotine sulfate and oil has been recommended for the adult stage in the buds before full bloom. There are several reasons why satisfactory control by this means has not been widespread or consistent. The emergence of the adults extends over so long a period that many applications are often necessary. Such a contact spray is effective only for a short time, because the spray penetrates the buds with difficulty. Some bud damage nearly always results as well as a later larval infestation. With the increased use of orchard dusters, nicotine dust for the larval stage has resulted favorably. In general, dusts are less effective in an orchard before full bloom than afterwards, when the leaves come out and hold the dust in the trees.

During the last important epidemic of the pear thrips (1930–34) a demand for more effective and cheaper control was made. Of the newer materials the rotenone-bearing sprays and dusts employing derris and cubé have been the most satisfactory, used at the rate of 4 to 6 pounds to 100 gallons of water. Slightly better results have sometimes been indicated with the addition of 1 per cent of light-medium oil. Also, stabilized pyrethrum extracts, ¾ to 1 pint to 100 gallons of water, with a suitable spreader, show considerable promise but as yet have not been widely used. Certain organic chemicals now employed against other insect pests need careful testing for the pear thrips. The rotenone-bearing sprays have been successfully combined with the arsenate of lead calyx spray on pears. Rotenone-bearing dusts (0.75 per cent rotenone), particularly for the larvae, when used at the rate of not less than 30 pounds per acre on prunes, have given excellent control.

Though this experimental work is still incomplete as to the best mixtures and amounts, such materials may be expected to replace the older contact insecticides; they have definitely continued to kill the larvae up to 5 days after application. Before full bloom (for the adult thrips) sprays or dusts are often ineffective. If, however, the emergence has taken place over a very short period and the buds have opened rapidly, kills may be very satisfactory.

Control by cultural methods when the thrips are in the ground has a limited use. Although heavy covercrops have sometimes been thought to delay the emergence, the degree to which they lower the soil temperature is slight. At 50° to 55° F the thrips emerge, regardless of the covercrop. Though they may crawl about on the weeds for a short time, they soon fly to the trees.

Spring plowing of infested orchards before blooming is not recommended, since disturbing the soil at this time facilitates emergence and accentuates bud injury. Dry fall plowing, on the other hand, has been employed with limited success. Since most of the larvae in the average orchard are found from 6 to 12 inches beneath the surface mulch, they may be turned up by a moldboard or single-disk plow. Plowing one way and from the trees is most effective and, if done in the early fall, will dry out the soil sufficiently to kill many thrips. The disadvantages, however, doubtless overcome the advantages of such control and greatly limit its use. If early fall rains occur, the clods do not dry out sufficiently to produce a high mortality; some of the disturbed larvae work down deeper; the natural covercrop is disturbed; surface roots may be injured by the plow.

Irrigation is very satisfactory if done at the right time. At two critical periods in the life cycle of the insect in the soil, the addition of water is detrimental. These periods occur toward the last of April or the first of May, after the larvae have left the trees and before the cells are formed, and again late in October or early in November when they are in the delicate pupal stage. The check or contour system must be used, and the checks must be filled; the more thoroughly the soil is wetted and the longer it can be kept moist, the better the control. The spring irrigation is probably less practical than the fall treatment. For best results one must know the actual time of pupation. This method is strongly recommended wherever possible, since it reduces the carryover and lessens the potential bud damage the following spring.

FLOWER THRIPS

The term "flower thrips" has been used rather indiscriminately in California to designate three common species of the genus *Frankliniella*—namely *occidentalis* (Perg.), *moultoni* Hood (=*californica* Moulton), and *minuta* Moulton. Other common names such as "wheat thrips" and "grass thrips" are often used to designate the western species of this group. These terms are confusing and should be avoided since the name grass thrips has long been used for *Anaphothrips striatus* (Osb.) in the eastern states. Also, in the East, South, and Middle West *Frankliniella tritici* (Fitch) is known as the wheat thrips, or perhaps better as the eastern flower thrips. The writer and others have called *F. moultoni* Hood the western flower thrips, differentiating it from all others except *F. occidentalis* (Perg.) which in this economic discussion is considered biologically identical with *moultoni.* The third species, *minuta,* has no common name in general use.

The smallest of the three *Frankliniella,* namely the species *minuta,* is uniform dark brown, with dusky-gray wings. It is only a minor crop pest, and, though widespread throughout the state, rarely becomes abundant. In spring and summer it is moderately abundant on wild vetch, lupine, ceanothus, and various composites such as dandelions, asters, and daisies. Its life history is not known, and control is not necessary. Along with the other two species, *minuta* is frequently seen in blossoms of deciduous fruit and occasionally, later in the season, in blossoms of beans, tomatoes, peas, and the like.

Aside from a wide distribution in California from the seacoast to about 7,000 feet elevation this thrips is known from Oregon, Washington, Utah, Idaho, Nevada, Arizona, Texas, Mexico, and Panama.

The species *Frankliniella occidentalis* and *moultoni* (figs. 10 and 11) are very difficult to distinguish, being of about the same size, frequenting the same type of environment, and both exhibiting a wide range of color variation. Typical specimens of *F. moultoni* Hood (=*californica* Moulton), are slightly larger than the occidental species and are uniform dark brown, with the central portion of the body (thorax) orange-brown. This characteristic cannot be seen without magnification. *F. occidentalis*

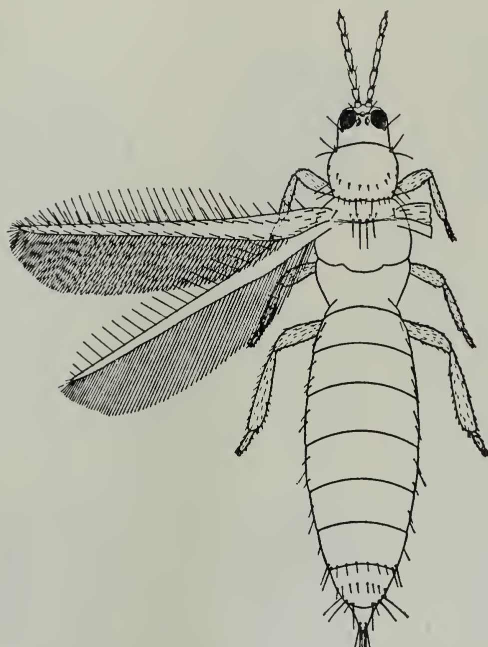

Fig. 10.—The adult female flower thrips, *Frankliniella moultoni* Hood. (Courtesy of California State Department of Agriculture.)

varies from clear lemon yellow to dusky yellowish brown, with darker pigmented areas on the abdominal segments especially. Though both species are found together all year, the darker species is much more abundant in the winter and early spring. They are found on practically all types of plants. Being flower lovers, these thrips are not numerous on deciduous fruit trees before blooming. The adults are attracted to the tree blossoms from the covercrops, weeds, alfalfa, and other crops in the vicinity. Thus there is no serious damage to the fruit buds as with the pear thrips. Although, some feeding is done in the blossoms, little actual damage results. After full bloom the larvae hatch and feed in numbers on the tiny fruits, causing the typical scarring. These scars spread and "check" as the fruit grows (fig. 12). Pits, rings, irregular streaks, or silvering are formed, since the injured tissue cannot develop. In severe cases "cat-faced," malformed, or distorted mature fruits evidence the early injury (fig. 16). Usually by the time the jacket or calyx has dropped from the fruit, the larvae have matured and left. Some injury to the unfolding leaves is frequently observed, later causing a ragged and perforated appearance in the fully expanded leaves.

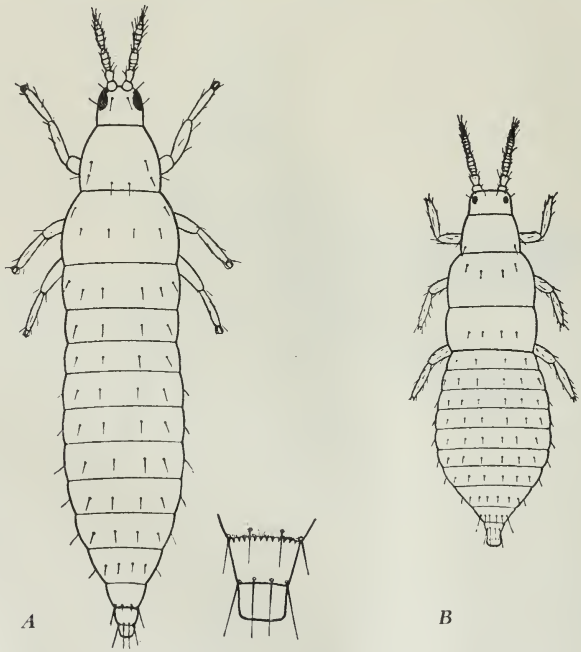

Fig. 11.—*A*, Full-grown flower thrips larva with enlargement of the tip of the abdomen to show spines. *B*, Full-grown citrus thrips larva. Note the absence of spines and the smaller size in comparison with the flower thrips. (Courtesy of California State Department of Agriculture.)

In central and northern California, almonds and apricots bloom before the flower-thrips population becomes sufficiently abundant to cause any damage. In southern California, however, where the mean temperature is somewhat higher, the thrips develop on their native hosts near apricot orchards before blooming. The adults are attracted to the blossoms and considerable scarring of the apricots later shows up (fig. 13).

The same condition exists with peaches, and particularly nectarines, in most fruit-growing areas of the great valleys, as well as in Solano, El Dorado, and Placer counties. The lower mean temperature of these districts results in a slower increase of the thrips, which move into the trees blooming later than the apricot—namely, the plum, peach, and nectarine. As a rule the smooth-skinned peach varieties are more severely injured (fig. 14) than the fuzzy. Though many flower-thrips larvae are often found feeding on the hairy surface of the tiny fruits, unless the

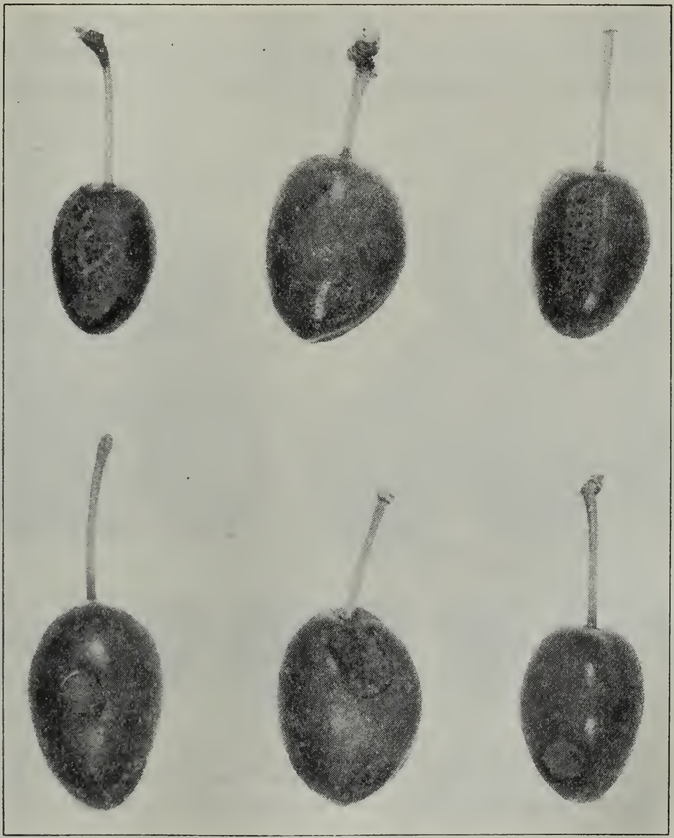

Fig. 12.—Flower-thrips injury to sugar prunes. The round, depressed scars in the lower row result from the concentrated feeding of a colony of larvae. The injury takes place within two weeks after full bloom. These fruits were photographed when about one-third grown.

injury is very deep most of the injured tissue appears to slough off as the fruits develop. Without a doubt, nectarines are the most severely injured of all fruits (figs. 15 and 16), since they have a smooth skin and since the calyx or husk sticks tightly and is constricted over the fruit at the blossom end (fig. 15). The larvae, ideally protected under this type of calyx, are impossible to reach with insecticides. Plums are attacked similarly, so that the shipping fruit is often badly scarred. The time of blooming varies from year to year, as does the degree of thrips scarring to different plum varieties, according to the weather and the abundance of the thrips. In early, warm seasons such early-blooming varieties as the Santa Rosa are injured; and in a late spring the President, one of the last to bloom, may bear the brunt of the local infestation.

Pears seem less attractive to the flower thrips than the fruits mentioned above, although the adults are nearly always present in the blossoms. The reason may be the absence of a jacket offering the desired protection. Some injury, however, does occur, particularly in the Little Rock area (Los Angeles County). Injury to apples, though known, is of minor importance, at least in California.

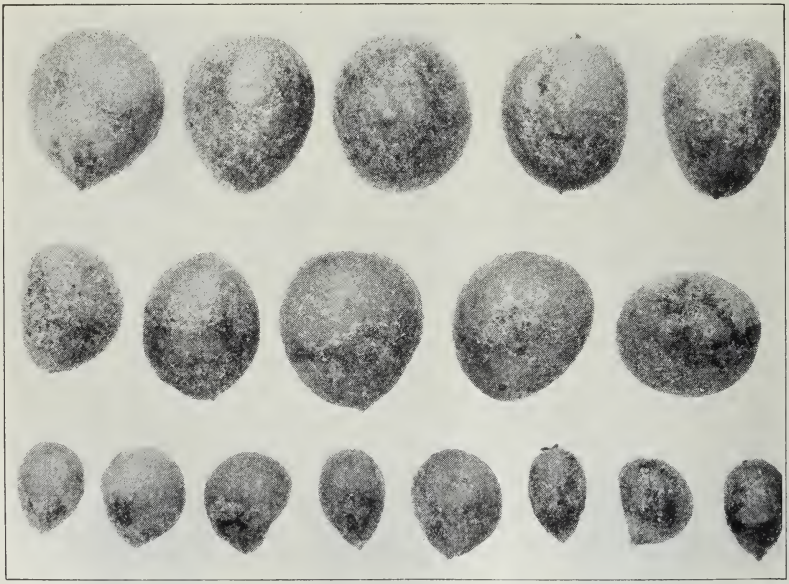

Fig. 13.—Flower-thrips injury to apricots. This type of damage occurs while the calyx or husk is still attached to the tiny fruit. Such injury to apricots rarely occurs in northern California. (Photograph by A. M. Boyce.)

The flower thrips often abound in orange blossoms, but apparently do little or no damage. The larvae, though found feeding on the leaves and fruits along with the citrus thrips, are not considered a problem in comparison with the latter. Some injury to grapefruit occurs, however, in the Imperial Valley.

Likewise in the spring and early summer, the flower thrips injure a number of crops other than fruits. In favorable seasons they abound in grape blossoms and (in company with the grape or vine thrips) produce some scarring on the berries and some stringy bunches. They do not, however, injure the leaves and canes as do the grape thrips.

As the cotton and bean plants come through the ground, numerous flower thrips collect on the undersides of the first pairs of leaves. Their feeding and that of the larvae shortly produced make the first leaves ragged, crinkled, and often cupped (fig. 17). In severe cases this condition may cause temporary stunting. As the hot weather comes on and as the plants grow more rapidly, this injury disappears; and the thrips become scarce, although they may be found in the blossoms all summer. Severe injury to the foliage of kidney beans during the entire summer is known in the Sacramento Valley. Cucumbers, cantaloupes, and squash

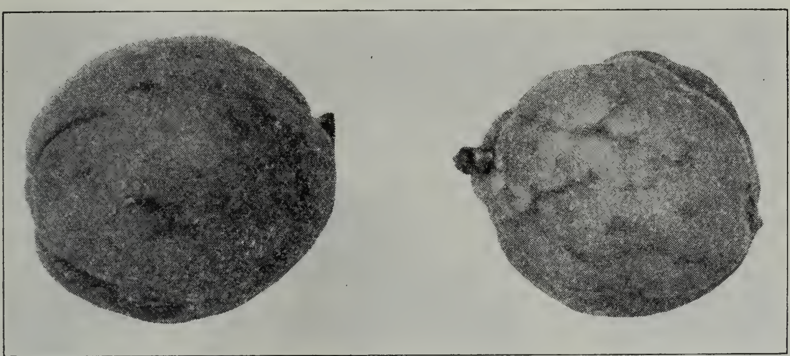

Fig. 14.—Flower-thrips injury to peaches. These irregular lines, pits, and scars on the surface of the fruit are formed by the thrips larvae during the calyx period of fruit development in the spring.

vines suffering from lack of water are also often badly damaged. The adults become extremely numerous in blossoms of peas, tomatoes, melons, and the like, and are thought to cause considerable "blossom drop."

The injury to berry crops is considered minor, though some distortion of the fruit results when the thrips are numerous. Strawberries are particularly susceptible, the blossoms being sometimes killed outright by the flower thrips (fig. 18). In many cases, however, the malformed berries result from a genetic or inherent characteristic. One cannot always distinguish the two types of injury unless the thrips are actually known to be present.

Alfalfa (particularly the seed crop) is subject to considerable loss by the flower thrips. Unbelievable numbers breed in alfalfa and cause browning and withering of stems, leaves, and flowers if the crop is not cut regularly and irrigated, as in the case of seed production. Other seed crops such as onions (fig. 19), carrots, and beets are often reduced as much as 50 per cent by the flower thrips and the onion thrips.

Cut flowers, both in the greenhouse and outdoors, frequently appear blotched, scorched, or streaked after the feeding of the flower thrips. Roses, carnations, sweet peas, and gladiolus are particularly susceptible. On the darker colors, such as red and purple, the injury is more pronounced. Both the larvae and the adults feed in the flower buds as soon they open sufficiently to be penetrated.

Fig. 15.—Flower-thrips injury to nectarines. The top row shows the tiny fruits already scarred (when the calyx is prematurely removed by hand). The center row shows how tightly the tip of the calyx adheres to the tip of the fruit. The lower row demonstrates the normal position of the calyx from a side view.

Nursery stock, particularly June-budded peaches, are very susceptible to "stopping-back" or malformation by flower thrips (fig. 20). The adults and larvae concentrate in the terminal buds and either kill or weaken them, diverting the growing strength into the lateral buds below. The young trees then become one-sided or crooked and therefore unsalable. This type of injury commonly amounts to 20 to 25 per cent. The same condition exists in rose nursery stock.

According to recent experiments, the flower thrips is a carrier of the plant virus causing spotted wilt, an important disease of tomatoes, as well as of lettuce, peppers, broad beans, chicory, spinach, celery, and numerous ornamentals.[3] The virus, picked up by the larval thrips from numerous ornamentals and native-weed reservoirs, is transmitted to the tomato-plant beds or fields by the adults after maturing and migrating. A thrips carrying the virus has to feed only once on a plant to transmit the virus. The ability to continue to transmit the virus is retained by the adult. The flower thrips also carry fermenting organisms into figs.

As this review has shown, the injury caused by the flower thrips is

Fig. 16.—Flower-thrips injury to Quetta nectarines. This type of scarring is done by the thrips larvae between the time the petals fall and the calyx is shed. Of all deciduous fruits, nectarines are the most severly injured by this insect.

not confined to a few plants nor is it always specific in type. While some thrips may cause greater loss to certain crops, this species surpasses all others in the amount of damage done in the aggregate.

Biology.—The life history and habits of the flower thrips are not yet thoroughly understood. The fundamental facts regarding the various stages and seasonal habits can, however, be given here.

Like most thrips, the females insert the eggs in tender portions of the host plants, particularly stems, buds, and flower parts. The egg stage lasts 15 or more days in the early spring, 5 days in the summer. In the

[3] For further information on spotted wilt see:

Porter, D. R., and John H. MacGillivray. The production of tomatoes in California. California Agr. Ext. Cir. 104:52–56. 1937.

Tavernetti, A. A., and John B. Schneider. Head-lettuce production in California. California Agr. Ext. Cir. 105:41–44. 1938.

laboratory the number of eggs laid by each female averages less than 20. After hatching, the larvae feed on the most succulent portions of plants. Under favorable field conditions this stage consumes 7 to 12 days. Those larvae found during December, January, and February doubtless require several weeks to mature. When fully grown the larvae drop to the ground to pupate. They seek out curled leaves, sod, cracks in the top soil, or some similar place in which to transform. They do not make a cell or cocoon. The larva molts once on the host and again after finding a suit-

Fig. 17.—Flower-thrips injury to cotton seedlings. In addition to the curling of the leaves, the terminal bud is often destroyed, causing a stunting of the plant. (Photograph by G. L. Smith.)

able place for pupation. One molt occurs during the resting (pupal) stage, which lasts 4 to 13 days, the length of time depending on the temperature. The number of generations a year varies with the locality, since reproduction continues the year around in districts free from freezing. Under severe winter conditions the adults hibernate in protected places and resemble the onion thrips in their life history. In spring the numbers increase rapidly; almost any flower cluster shaken into the hand will yield several adults and larvae. The peak of the seasonal infestation is reached in the late spring—that is, May or June, the time depending on the locality. As the native hosts dry up and the mean temperature increases, the population drops sharply, often concentrating on the later-maturing plants or the crops in the vicinity. There is a production of overlapping generations, probably five or six throughout the summer. Frequently in the fall, with the cooler weather and new plant growth developing from the first rains, a gradual dispersal and increase in abundance can be noted.

As the hills, grasslands, and desert flora dry up, and when covercrops are plowed under or alfalfa cut, definite migrations occur. With the wind, the adult flower thrips will travel a considerable distance. The migrations are usually local, however, from the margins of the fields, orchards, or greenhouses and are particularly noticeable when alfalfa is cut. In the middle of the day the adults are normally not seen upon the exposed parts of the host; but in the early morning and late afternoon they are often seen running and flying about among the buds and flowers.

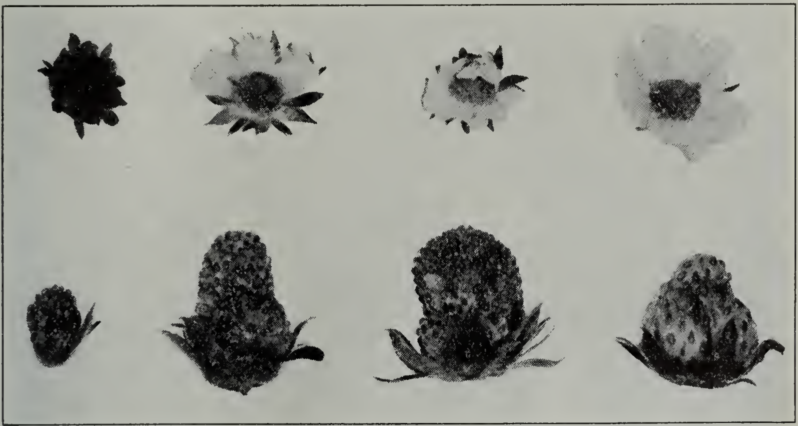

Fig. 18.—Flower-thrips injury to strawberries. The flower at the upper left has been completely blackened by thrips feeding. At the upper right is a normal, uninjured flower. The lower row shows various types of misshapen berries resulting from thrips injury in the early stages of development.

Along the cooler, coastal areas and at higher altitudes the flower thrips are much more abundant during the summer than in the hotter interior valleys. As the numbers vary considerably from year to year, the subsequent injury fluctuates. In general, during warm springs without rain when the native weeds dry up early, the migration to fruit trees is early and concentrated, particularly if the covercrops were well established during the winter and the weather was mild, allowing reproduction during December, January and February. But even though winter conditions favor an increase, if the spring is cold and wet activity is slowed down so that little injury is evident.

Control.—The primary consideration in control is the source of the infestation. Under the conditions discussed in the foregoing pages, the flower thrips almost always originate in the immediate vicinity of the crop attacked. With deciduous fruits such as plums, peaches, and nectarines, the source—usually the covercrop and weeds at the margins of the orchards—should be eliminated two weeks or more before the trees bloom. When the covercrop is plowed under, the adult thrips are forced to leave, and the larvae will die from lack of food. The pupae in the soil will transform; and the newly emerged adults, finding no suitable hosts, will also migrate. Clean cultivation during the winter will, of course, have the same result.

This method is particularly effective in large acreages that have adequate protection from the uncultivated area surrounding the orchard.

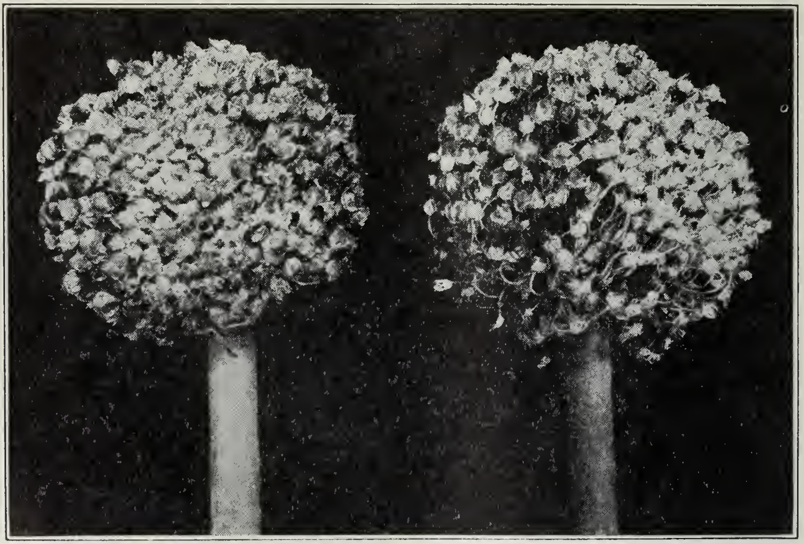

Fig. 19.—Flower-thrips injury to onion seed. The small, white florets are those that have been killed by the thrips. As high as 50 per cent loss in the seed crop often occurs in this way.

Small blocks of trees are not protected because of migration to the blossoms from nearby properties that cannot be cleaned up, such as grain or alfalfa fields. On heavy soil, also, the covercrop often cannot be disked early enough; or in the hillside orchards early cultivation is undesirable because of the erosion hazard.

The critical period, when the fruit becomes scarred, is between the time the petals fall and the calyx is shed from the fruit. The length of this period varies from year to year. Nevertheless, if the flower thrips larvae are present, an insecticide should first be applied when about three-fourths of the petals have fallen. For a heavy, prolonged infestation a second treatment may be needed 6 or 7 days later.

Though experimental work on the flower thrips is still in progress, the more promising materials employed in chemical control can be mentioned now. As in the control work on the pear thrips, the rotenone-bearing insecticides and the pyrethrum mixtures have been used both as sprays and dusts. On deciduous trees the sprays have succeeded some-

Fig. 20.—Flower-thrips injury to June-budded nursery stock. The poor shape results from injury to the terminal buds. Every time the terminal bud is injured, a lateral bud is stimulated. Such nursery stock is unsalable.

what better than the dusts, probably because the dust does not readily penetrate the fruit clusters, and the leaves are not sufficiently developed to hold the dust in the trees.

The rotenone-bearing mixtures (0.75 per cent rotenone) have given fair results on peaches and plums, but have been less effective on this species than against the pear thrips. Such materials as derris and cubé were used at the rate of 4 and 5 pounds to 100 gallons of water; the addition of 1 per cent of light-medium oil apparently increases the penetration somewhat under the calyx and into fruit clusters.

Also the improved pyrethrum extracts (0.2 per cent pyrethrins), using ¾ to 1 pint to 100 gallons of water with a suitable spreader, offer considerable promise for the control of this pest.

If the covercrop or other source of infestation remains, adult thrips will continually reinfest the sprayed trees, seriously offsetting any control. Later study may show it practical to spray the covercrop along with the trees.

This insect on nectarines is most difficult to combat. The structure of the constricted calyx over the end of the fruit makes it almost impossible for any insecticide to contact the larvae beneath. Elimination of the source before blooming seems to be the only hope. In small orchards, as mentioned above, this precaution is nearly impossible in bad thrips seasons, particularly if the trees are adjacent to alfalfa, grain, or pasture.

On annual crops such as beans, cotton, and cantaloupes, the dusts mentioned above—about 30 pounds per acre—are recommended. Apparently, however, some rotenone dusts do not control thrips so well under summer conditions as in the spring. The pyrethrum dusts have given good results with a pyrethrin content as low as 0.1 per cent. Other materials—certain organic mixtures not yet commercially obtainable—look extremely promising.

The field control of flower thrips on gladiolus is the same as for the gladiolus thrips. In greenhouses on the San Francisco peninsula one of the most effective materials yet used is a 2 per cent thiocyanate spray. Screening the ventilators with fine cloth prevents the thrips from entering the greenhouse when flying about.

The same difficulty encountered on nectarines is presented on budded nursery stock—that is, the thrips cannot be reached with a spray or dust. They penetrate and reproduce in the terminal buds and continually migrate into the new buds as they form. The insecticides used appear to give protection for a day or two only. The best results have been obtained with a sweetened poison spray composed of 75 pounds of molasses, 4 pounds of basic lead arsenate, and ½ pound of casein spreader to 100 gallons of water. This material did not burn the foliage as did paris green. The control was far from satisfactory, however, especially with a constant reinfestation taking place from weeds and from other unsprayed blocks of trees. Apparently the best procedure in such instances is to plant the budded nursery stock in a location affording the minimum of infestation from other trees, pasture land, or grain fields. The prevailing wind should also be considered. If the young trees are stimulated by proper cultural methods and if rapid growth of the grafted bud is insured, the injury can be much reduced. Screening or bagging is not practical.

In the coastal areas where spotted wilt is a serious problem on tomatoes, peppers, and lettuce, direct chemical control measures alone are not effective. So few thrips as to be entirely unnoticed will, if carrying virus, cause serious losses as the season progresses. In respect to this problem there is much to be learned concerning the seasonal migrations and local host succession of the thrips; the following suggestions will only aid in reducing the hazard of infection. Plant beds should be isolated as far as possible from home gardens, ornamentals, alfalfa, and weed patches that serve as winter quarters for the thrips. Clean cultivation should be strictly practiced in and about the plant bed at all times. Infected plants should be carefully removed from the field and destroyed to prevent any thrips present from spreading the disease. Plants from infected beds should not be used. During the growing season weeds should be kept down at the margins of the fields, particularly in relation to the prevailing wind.

BEAN THRIPS

Description.—The adult bean thrips, *Hercothrips fasciatus* (Perg.) (see frontispiece) is dark grayish black, with the forewings banded with two light and two dark areas. Its total length is about $\frac{1}{25}$ inch. With wings folded lengthwise over the body the thrips appears to the naked eye to be grayish black with two white bars across the center. The legs and antennae are also banded with alternate light and dark areas. The adults hop readily for a few inches at a time and are weak fliers.

In sharp contrast to the adult the larva (fig. 1, *B* and *C*) is reddish yellow or pink. When first hatched it is nearly translucent white; when mature it is often deep crimson. The larvae are usually seen feeding together with the adults in groups, chiefly on the undersides of leaves. The pupal stage (fig. 1, *D* and *E*), which is passed in the soil, is mobile if disturbed and resembles the larva. The crimson blotches are retained but gradually disappear as the adult matures and darkens.

Distribution.—In the United States the bean thrips is present in California, Oregon, Nevada, Idaho, Utah, Wyoming, Arizona, Colorado, Florida, and South Carolina. Foreign records are at hand from China, the west coast of Mexico, and Argentina.

This thrips is widely distributed in California, occurring throughout the state with the exception of the mountainous counties of Inyo, Mono, Alpine, Sierra, Plumas, Lassen, and Modoc. In this state it is most abundant in the Sacramento and San Joaquin valleys. It is also often injurious in certain nonirrigated valleys of the Coast Range, in the Sierra foothills, in the Imperial Valley, and in local areas in southern California. In hot, dry years the injury to beans, cotton, and pears is severe.

Of the factors apparently restricting the spread and relative abundance of the bean thrips, temperature and rainfall are most important. Though either may be a limiting factor, their combined influence and the degree to which they vary from "normal" determine the local and seasonal abundance. Usually where the normal mean temperature for the summer months is about 70° F or above, the bean thrips are numerous enough to be injurious if other conditions are favorable. With normal mean summer temperatures from about 64° to 70°, crop injury may occur in very hot, dry seasons. Districts enjoying mean summer temperatures below approximately 64° are rarely concerned with this pest.

California's summer rainfall, usually less than 1 inch, is of little aid as a limiting factor, since only heavy showers of driving force are effective. The minimum summer precipitation that appears to prevent the bean thrips from becoming abundant is about 4 inches. A high rainfall during the growing season will prevent the increase even though the temperature is favorable.

Hosts.—Most of the numerous host plants of the bean thrips are chance or transitional. During the growing season they may include nearly all plants of the locality. In addition, certain plants and parts of plants are used for hibernation only. A true host is one on which the egg, larval, and adult stages are found. These crop plants are recorded as hosts: alfalfa, almond, apple, asparagus, avocado, bean, beet, cabbage, cantaloupe, carrot, cauliflower, clover, corn, cotton, fig, garlic, grape, hops, kale, leek, lettuce, melon, olive, onion, orange, peach, pear, pea, pepper, persimmon, plum, potato, prune, radish, Swiss chard, tangerine, tomato, turnip, and walnut.

The crops subject to the greatest loss are alfalfa, beans, cantaloupes, cotton, lettuce, pears, peas, and tomatoes.

Among the many native or uncultivated plants known to support the bean thrips the most common are buckeye, morning-glory, poppy, prickly lettuce, bur clover, white melilot, common sow thistle, and wild vetch. The two generally preferred weed hosts, prickly lettuce and sow thistle, are native to Europe. They occur very commonly in fields and waste places, particularly in valleys throughout California, and have spread rapidly in irrigated districts.

Injury.—The bean thrips might be defined as primarily a foliage feeder, although it does sometimes attack fruit. The chief result is premature defoliation of beans, cotton, and pears, produced by the gregarious feeding of the larvae and adults. The effect of feeding on the surface of leaf or fruit is a silvering or bleaching. Injured tissue often becomes papery and wilts rapidly, particularly if suffering from lack of water. Annual plants are frequently killed by continued feeding. Infested pear trees are often prematurely defoliated, especially in the lower half, so that the fruit and new wood will sunburn. Naturally the trees are somewhat weakened for the following season. Besides the silvering, the tiny black dots of excrement (fig. 21) render the fruit unmarketable. Pears, string beans, peas, and certain ornamental flowers are particularly subject to such injury. Because of this thrips' habit of con-

Fig. 21.—Bean-thrips injury to pear fruit. Note speckling on the lower half of the fruit, caused by surface feeding and deposition of excrement. (From Bul. 609).

gregating in large numbers on leaves and fruit of citrus (particularly the navel end) in the autumn, the Board of Commissioners of Agriculture and Forestry in Hawaii require all citrus fruits entering the territory between September 1 and March 31 to be fumigated.

Biology.—A discussion of the biology might well begin with the adult as it emerges from hibernation in the spring. The females insert eggs in the petioles of leaves and flowers, or in both surfaces of leaves, and even in the surface of young fruits and pods. Egg laying begins early in April and continues until late in September. The number of eggs deposited by an individual female varies, the maximum being about 134. During the summer the average longevity of an adult is about 3 weeks, and most females lay 30 to 50 eggs each.

The average length of the egg stage in warm weather is 7 days. In most cases the larvae feed in clusters on the underside of the leaf and, as the underside becomes fed over, move to the upper side. Thus the lower leaves on the host plants are injured first; and the infestation progresses upward to the newer and more tender leaves. Adults and larvae feed together, the proportion being about 5 larvae to 1 adult.

There are two larval stages: when about half-grown one molt occurs on the host; a second skin is shed when the mature larva molts to the prepupal stage in the soil. After dropping off the host, the larva crawls down to the top soil and goes from 3 to 6 inches into a suitable crack or niche. The length of the larval feeding period under summer field conditions is about 10 days.

After the prepupal stage, lasting only 1 or 2 days, another molt occurs. The pupal stage under optimum conditions consumes about 3 days.

The depth at which pupation takes place depends chiefly on the type and condition of the soil and upon the soil temperature. In cultivated pear orchards the pupae are usually found 3 to 6 inches below the surface. No cell is made; the pupae, when abundant, frequently cluster in small groups. Those within 3 inches of the surface do not survive in the summer in unshaded soil. Where the ground cracks deeply or other conditions offer easy access, pupation has been observed as deep as 15 inches. If, on the other hand, the top soil is very fine, dry, or sandy, the larvae cannot force their way downward and do not survive. Crops on very sandy soil are infrequently attacked. The adult bean thrips have very little ability to force their way up through compact soil. If the structure and position of the soil particles are altered (as by irrigation or cultivation) after the mature larvae have pupated, the adults cannot reach the surface and usually die.

There are in normal seasons about 6 generations, though in the Imperial Valley, with its high temperatures, as many as 11 are thought to occur.

A summary of the seasonal cycle might well begin with the fall, when the adults seek out protected places in which to hibernate. About the last of October they migrate and concentrate on suitable winter hosts. Egg laying ceases in early October, and larvae disappear by the middle of the month. None of the immature stages survive November.

A principal winter host in the San Joaquin Valley is the sow thistle. Adults are also frequently found in numbers on ornamentals and alfalfa near bean and cotton fields. In more wooded regions and at higher altitudes many hibernate on evergreen trees and shrubs adjacent to orchards and gardens. In citrus-growing areas hibernation commonly takes place in the navel end of oranges. The most suitable quarters are apparently under old scale insects; in curled leaves or the undersides of hairy leaves of live oak; on toyon, pine cones, some winter annuals, and ornamentals near residences.

By the last of March the surviving adults gradually concentrate on the hosts preferred for reproduction. For several weeks they feed, copulate, and lay eggs. The first larvae appear about the last of April in small numbers on sow thistle and prickly lettuce growing on ditch lands or roadsides. Other annual plants such as poppy, filaree, and bur clover are also hosts, but to a minor extent. By the first of May the overwintering adults have nearly all died, and by the middle of the month the adults of the first spring generation mature. The larvae of the second generation may be found about June 1; they also feed and mature on the wild hosts.

By the time the adults of this second generation emerge from the soil, the hosts are beginning to mature and to become unfavorable. Thus about the last of June a migration takes place from the native plants to cultivated crops nearby. During July, August, and September, when the generations overlap considerably, there are no distinct periods when any stage is entirely absent. The third, fourth, fifth, and doubtless a sixth generation are passed on crop plants such as beans, pears, cotton, sugar beets, tomatoes, alfalfa, and cantaloupes. In the hotter areas such as the lower San Joaquin Valley and Imperial Valley even more generations appear during the growing season, the seasonal peak being reached about the first two weeks in August.

In the fall, after the bean vines, cotton plants, or pear leaves mature, a large migration takes place to whatever crops or plants are still green. At this time fall-cultivated lettuce, carrots, sugar beets, asparagus ferns, and alfalfa often support a great population of adults. In a warm, dry fall one generation may be completed on these crops; but with the cooler weather reproduction ceases, and the larvae rarely become abundant enough to be injurious.

In California nearly every case of crop injury by the bean thrips is traceable to a local infestation on nearby weeds.

Control.—The most important factor in controlling this thrips is to eliminate the source of the infestation—that is, weeds, particularly prickly lettuce in or near the fields and orchards. As soon as the annual crops come up, the adult bean thrips start moving into the fields from the marginal areas. In very dry years this migration is early and often severe enough to set back the young plants. Thus an early-spring campaign of weed control is important.

In large areas planted to one crop, such as beans, the control depends fundamentally upon removing all prickly lettuce and sow thistle at the margins of the fields, roadsides, ditch banks, and railroad tracks at least

2 weeks before the bean plants come through the ground. All eggs and larvae on the weeds are killed, and the adults are forced either to leave or to starve. This work may be done by hand, by disking, oiling, burning, or sterilization. In addition, all the principal host plants of the immediate locality must be destroyed and kept down during the growing season. With proper cultivation and irrigation of the crop to keep the plants growing vigorously, large acreages may thus be protected at a low cost as compared with the expenditure necessary in applying insecticides later in the season.

Weed control in deciduous fruit orchards, where the bean thrips is a pest, is fundamentally the same as with annual crops and is equally important, especially under dry farming.

In some districts the native-host elimination may become a supplementary aid because weed control is difficult in brushy or hilly country or on land surrounded by sloughs, rice fields, and the like.

The effect of irrigation on an infested field is twofold. The plants are stimulated, send out new leaves and runners, and keep somewhat ahead of the infestation. Also, water brought up to and around the base of the plants destroys many pupae. In an orchard the check or contour system should be used. Overhead irrigation with the so-called "rain machines" has often checked the bean thrips. Fields which are only subirrigated are usually more severely injured because the top soil remains dry and warm. Under such conditions the thrips multiply rapidly.

In spraying pear orchards during the past few years the following formula has proved satisfactory: Summer oil 1½ to 2 per cent and nicotine sulfate ½ to 1 pint for each 100 gallons of water. In hot weather, spraying should not be done during the middle of the day. The first application is usually needed about the middle of July. If the trees exhibit severe premature defoliation, a second application may be necessary after picking. Though no extensive experimental data are at hand on pyrethrum for this pest, the writer believes, on the basis of other work, that pyrethrum extract (about 0.2 per cent pyrethrins) may be substituted for the nicotine sulfate. Very recently excellent control has been obtained on pears with a spray of 1 per cent summer oil and 5 pounds of derris (0.75 per cent rotenone) per 100 gallons of water. Only one application was necessary. Dusts have not given consistent results during hot weather, and the use of sulfur on pears should be avoided at high temperatures.

Chemical control on annual crops is difficult because of physical obstacles such as the necessity of irrigation and the lack of coverage of dust on the undersides of the leaves. Thrips on the upper side are usually killed by most of the contact dusts. Colonies of larvae on the underside are, however, hard to contact and to reduce materially on large leafy plants. Also, the amount of money that can be spent per acre for control, on beans particularly, is so small that effective results must be obtained with one application. Under such conditions a light application (20 pounds per acre) of a moderately effective contact dust does not give a satisfactory kill. Since eggs and pupae are not killed by the insecticides, the hatching of the larvae and the emergence of adults continue for about a week after the application. Thus a material continuing to kill over a period of several days to a week after application is preferable to a straight contact dust.

Experiments during the past two seasons show that several materials have produced a continued kill, up to 5 days at least. One of the best is a pyrethrum dust (0.1 to 0.2 per cent pyrethrins). Several carriers such as talc and walnut shell are satisfactory, although some mixtures with sulfur have proved too wet to pass through the duster properly. The rotenone-bearing dusts (0.75 per cent rotenone), though also effective, have been less consistent at high temperatures. Certain new organic materials (not yet obtainable commercially) are extremely promising.

Such dusts should be used at the rate of about 30 pounds per acre and applied thoroughly with properly functioning modern equipment as soon as injury to the lower leaves is evident.

CITRUS THRIPS

Description.—The citrus thrips, *Scirtothrips citri* (Moulton) (fig. 22), is one of the smallest thrips of economic importance, being about ¾ mm or about 1/50 inch in length. The male is slightly smaller. The insect is a uniform orange yellow, with black eyes. It may be told from the western flower thrips, frequently seen on citrus, by its small size and great activity. The adults run about very fast and fly readily. When numerous they usually congregate on the new buds and shoots. The larva (fig. 11, *B*) is pale yellow to orange yellow, with dark-red eyes. When full-grown it is about the same size as the adult. The pupa is somewhat lighter colored than the larva, is typical in appearance of all thrips pupae, and is rarely seen.

Distribution.—This thrips prefers a hot, dry climate and is very limited in its distribution. Outside of California it occurs only in Arizona. There are unconfirmed records from Utah, Texas, and Sonora (Mexico). In California it is found in the following counties: Glenn, Colusa, Yolo, Sacramento, Fresno, Tulare, Kern, Ventura, Los Angeles, Orange, San Bernardino, and Riverside.

The citrus thrips is most abundant in the citrus-growing areas of the San Joaquin Valley, in Fresno and Tulare counties, and in southern

California, particularly in groves on sandy soils near San Bernardino, Redlands, and Riverside. Recently considerable injury has become evident in the San Fernando Valley. Toward the coast the abundance and injury become greatly reduced. In northern California it is not common, doubtless because of the lower winter temperatures and the cooler spring weather.

Apparently it is a native insect that has found citrus trees most suitable for extensive local reproduction.

Hosts.—The principal host plants of the citrus thrips are citrus (particularly navel oranges), including oranges, grapefruit, limes, lemons, and the kumquat. Aside from citrus the only other crop injured is grapes, and this seldom.

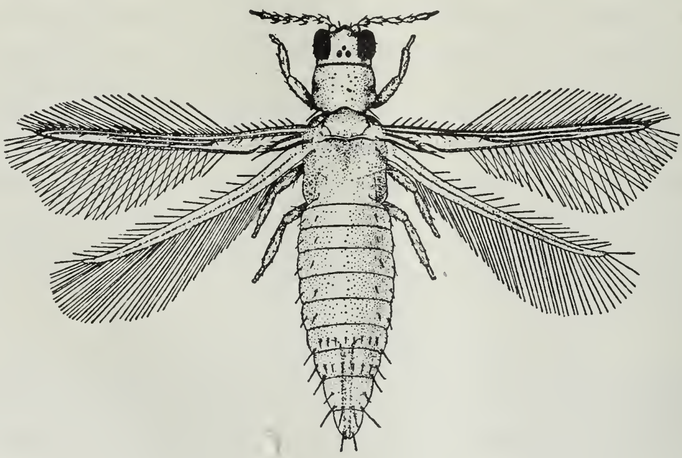

Fig. 22.—The adult female citrus thrips. (Courtesy of Bureau of Entomology, U. S. Department of Agriculture.)

Injury.—The citrus thrips causes two types of injury: scarring or ringing of the fruit (fig. 23) and leaf and bud injury to the trees. The most common and probably the best-known evidences of injury are the characteristic streaks and rings of grayish or colorless scar tissue on the surface of oranges. Generally these injured areas occur on the stem end, where the thrips find protection under the sepals of the small fruit and concentrate their feeding. As the fruit grows the injured cells form scar tissue, which often cracks or "checks" with the expanding fruit. Surface feeding on the fruit after it attains the size of a walnut is rare. The fruit injury is rarely severe enough to cause dropping or malformation, although some splitting is attributed to excessive thrips attacks. Though the eating quality remains unaffected by the surface scarring, the market grade is definitely lowered and the selling price reduced.

Citrus nursery stock and young groves are often stunted and malformed by thrips attacks (fig. 24). The feeding of numerous larvae and adults on the small leaves produces yellowish or grayish streaks, often parallel to the midrib. A curling or cupping of the leaves also is evi-

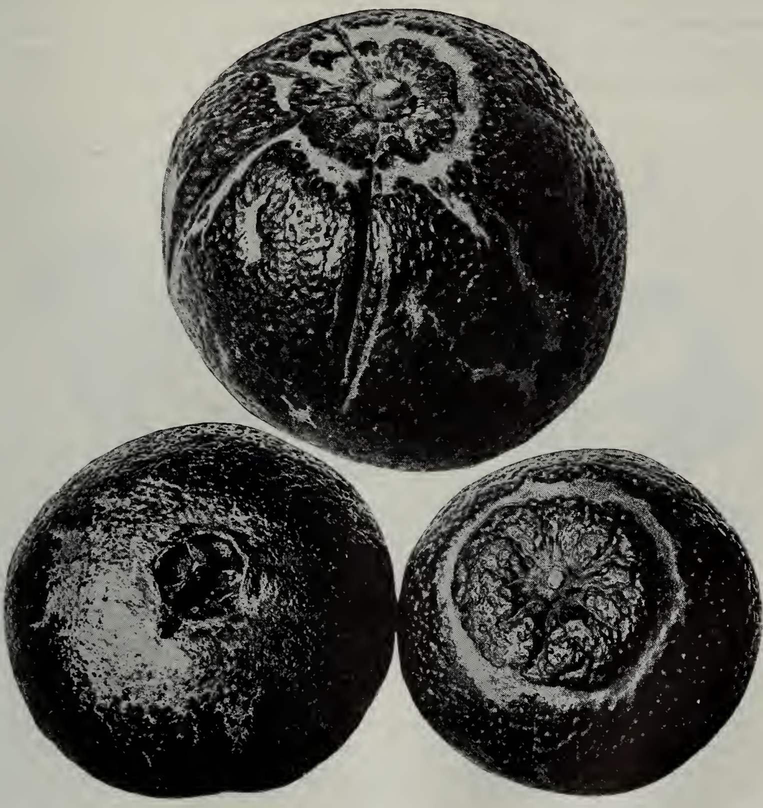

Fig. 23.—Typical scar rings and blotching of citrus thrips on oranges. (From Bul. 214.)

denced. In severe cases the buds and new shoots are blackened and killed outright, producing a rosette appearance or stimulating lateral shoots which result in an ill-shaped tree.

The citrus thrips are not abundant in the blossoms as are the western flower thrips. Injury to citrus blooms by thrips has never been serious.

Biology.—This thrips differs biologically from all others of economic importance in that it passes the colder winter months of January and February in the egg stage. The adult female inserts the eggs in the new leaves, tender twigs, small fruits, and fruit stems. Occasionally eggs are laid in the larger fruits, but only in small numbers after the fruit is more than one-third grown. Each female averages 26 to 70 eggs during her normal adult life. The length of the egg stage varies with the season—from 6 to 24 days, or even longer in winter.

Upon hatching from the egg the larva begins feeding immediately. The larval stage lasts on the average 8 days, during which feeding is almost continuous. One molt occurs at the end of about the fourth day, and another at full growth. In the cooler weather of spring and fall the larval stage lasts about 2 weeks.

Fig. 24.—Citrus-thrips injury to citrus nursery stock. The blotching and curling of the leaves are seen at the left; the twig at the lower center exhibits the bud rosettes caused by continual "stopping back" of new growth; at the right are shown the one-sided type of growth and fresh injury to a young terminal shoot.

After the second molt the larva ceases feeding and seeks a protected place in which to transform to the adult stage. This stage is passed in curled leaves on the ground under the trees, under cobwebs, in cracks of the bark near the base of the trees, or in similar places. The pupae are widely scattered but are only rarely found on the upper portion of the trees. Here, again, temperature largely regulates the rate of development. The average length of the resting stage is about 7.5 days, with a complete range of from 2 to 28 days. At the end of about the second day a third molt occurs and a fourth and last molt takes place before the adult emerges.

The adults are extremely active and prefer sunny exposures. They feed only upon the newer growth, where they congregate in large numbers. As new growth becomes available they will often migrate quickly about in a local area. Normal adult life is 25 to 30 days, and adults are usually present from April to November. During May the complete life cycle extends over about 30 days, whereas in the hot weather it is reduced to about 15. In a normal year there are six generations. The greatest concentrations of thrips are evident from the middle of April to the last of June and again in August and September particularly.

Apparently the dispersion of the citrus thrips takes place chiefly in the egg stage on nursery stock during the dormant season. Local migrations are largely by flight. Since this thrips is a pest of citrus and prefers a hot, arid, frost-free climate, its future distribution is greatly limited.

The natural mortality is not high. Insect enemies are of little importance. Rain also has little effect, since the heavy rains do not arrive in the fall until most of the active stages have disappeared. The effects of severe freezing weather on the overwintering egg stage has not been investigated.

Control.—As was pointed out above, natural or biological control is ineffective and cultural methods have no application in this case, at least up to the present writing.

Among the earliest sprays employed for this citrus pest was a combination of lime-sulfur and tobacco extract. Lime-sulfur, 2 per cent, with 10 pounds of wettable sulfur to 300 gallons of water, has given good results. This material (about 6 to 10 gallons per tree) is best applied when the petals have fallen from the south side of the tree. A second application is recommended 2 or 3 weeks later. In Tulare County the use of a 4 or 5 per cent lime-sulfur spray during January, February, or early March was formerly common.

E. A. McGregor of the Federal Bureau of Entomology, who for years has conducted an extensive series of control experiments, sums up as follows the degree of control obtained by the various materials in central California:

Treatment	*Per cent thrips damage to fruit*
Three sulfur dustings	3.8
Lime-sulfur (at petal time)	9.6
Two sulfur dustings	9.9
Lime-sulfur (January–March)	26.1
Lime-sulfur (mist spray)	21.5
No treatment	46.6

Three applications of a good grade of dusting sulfur is one program widely used at present. The first dusting of about 1 pound per tree (average size) should be applied about March 15–20. The second dusting should be made when the petals are about all dropped—that is, about April 15 to early May. The suggested amount is ¾ pound per tree. Two or three weeks later, May 15 or thereabouts, a third application of about ½ pound per tree is advisable. The dates naturally vary from season to season and from district to district. The first application should be thoroughly done to reduce the first larval infestation as much as possible. The second dusting is to prevent scarring of the fruit, which takes place shortly after the petals fall. Later dustings give added protection against fruit injury, which occurs up to the time the oranges attain walnut size. Some authorities stress the importance of dusting both sides of the trees, particularly on the first two applications. Large trees should receive proportionately greater amounts of dust.

According to McGregor, dusts employing pyrethrum (0.19 per cent pyrethrins and 44 per cent sulfur) or rotenone (0.5 per cent rotenone and 50 per cent sulfur) have reduced the citrus thrips 95 and 96 per cent respectively. These materials, being somewhat higher priced than the dusting sulfur, are not in general use at present against this pest.

ONION THRIPS

Description.—The adult onion thrips, *Thrips tabaci* Lind., is almost too similar in size, shape, and color to the flower thrips to be distinguished with the unaided eye. It is variable in color, ranging from a very pale yellow to a uniform dark brown. The more commonly encountered individuals are light brown and about $\frac{1}{25}$ inch long. The wings are a uniform dusky gray without bands. The male, which is rarely seen, is somewhat smaller than the female. The creamy-white larvae have no readily recognizable characters to separate them from many other thrips larvae. In general, however, they are white or very pale yellow in contrast to the deeper-yellow flower-thrips larvae and are found in large numbers, usually on onions only. Since pupation takes place in the ground, this stage is seldom seen.

Distribution.—The onion thrips is probably the most widely distributed thrips in the world, being found, apparently, wherever onions grow. In this country, though not actually recorded from all states, it undoubtedly occurs everywhere, since some specimens can nearly always be found on onions in storage, feeding on the leaf sprouts or moist surface of the bulb. In this way the thrips is readily transported about, and its spread is unrestricted. Having been collected from the equator to Siberia, from New Zealand to Sweden, and from sea level to 9,000 feet elevation, the onion thrips is evidently able to survive under widely varying conditions. It was first described in 1888 from Bessarabia but had been known in the eastern United States since about 1872. The first record in California is in 1889.

Hosts.—The several hundred hosts of the onion thrips are too numerous to be listed here. They include many types of plants from alfalfa to zinnia and from garlic to roses.

The great majority of the hosts are, however, incidental and on which little or no reproduction takes place. Aside from onions, the chief crop hosts are garlic, cotton, carrots, cucumbers, melons, peas, tobacco, roses, and carnations (chiefly in greenhouses); also, to a lesser extent, beans, gladiolus, and hops.

Injury.—The injury to onions generally known as "blasting" or "silvering" is the most common and serious damage caused by this species. The rasping-sucking mouth parts puncture the surface cells of the leaves and suck out the contents. The result is a collapse and withering at this point. Since the thrips feed together in small colonies, light-colored patches appear on the leaves. In severe cases the entire plant is stunted or killed, particularly during very hot weather (fig. 25). In the field the tops only are injured, but the bulb production is thereby considerably reduced. In storage the thrips feed on the moist surfaces of the bulbs (fig. 26) and on the sprouts, particularly in varieties which have loose scales under which they can crawl readily. They are also commonly seen on "splits" or divided bulbs, which are easily entered. The actual injury is of little importance, but the bulbs furnish winter quarters for the thrips and provide an easy method of dispersal in shipment. The injury to garlic and leek in the field is of the same type.

Seed crops, especially onions and carrots, are reduced by the activities of the onion thrips (and also flower thrips) in the flower heads (fig. 19). Both the adults and the larvae feed on the flower parts, preventing normal development by reducing the "set" or killing the florets. In years of severe infestation onion seed crops are reduced as much as 50 per cent by thrips.

In the spring or early summer, peas, cotton, cucumbers, and melons are sometimes injured. In such cases the injury takes the form of crinkled, rolled, or dwarfed leaves on the small plants. Such injury to cotton and tobacco is of considerable moment in the southern states. In California, peas are sometimes subject to silvering of the leaves and small pods. In greenhouses, roses and carnations in particular are damaged by the onion thrips together with the flower thrips. The adults enter any buds sufficiently open to allow penetration. The feeding of the adults and the larvae on the unfolding buds results in spotting (really an extraction of the pigment from the cells) and streaking of the petals.

Like the flower thrips, this species transmits plant diseases, especially pineapple yellow spot in Hawaii and spotted wilt in California and elsewhere. The onion thrips carries decaying and fermenting organisms into the fig.

Biology.—The life history of the onion thrips might be called "usual" or general in type. The female inserts the eggs in the more tender surface

Fig. 25.—Onion-thrips injury. The three rows in the foreground to the left are the variety White Persian, which is very resistant to thrips attack; the others are Australian Brown, a variety very susceptible to thrips injury. (From Hilgardia Vol. 8, No. 7.)

tissues of the host plants. Under summer conditions the average length of the egg stage is about 5 days. The tiny, white larvae feed in the growing points on small local areas of the epidermis, extracting the cell contents. One molt occurs on the plant when the larvae are about half-grown. In approximately 5 days the larvae attain full size, leave the plants, and drop to the soil. Under favorable conditions the pupal stage lasts 4 days. Thus a complete generation extends over about 2 weeks. Since average longevity of an adult female is between 2 and 3 weeks, generations overlap considerably. Individual females lay from 20 to over 100 eggs each, with often as many as 14 in a single day.

In California, reproduction continues the entire year, especially in mild winters. Though adults and larvae can be found all winter on onion and other plants in the field, reproduction is greatly reduced. By August, usually, the onions are all harvested, and most of the adults migrate to other plants, both native and cultivated. Near onion fields during the fall and winter they have been found on such plants as nightshade, water

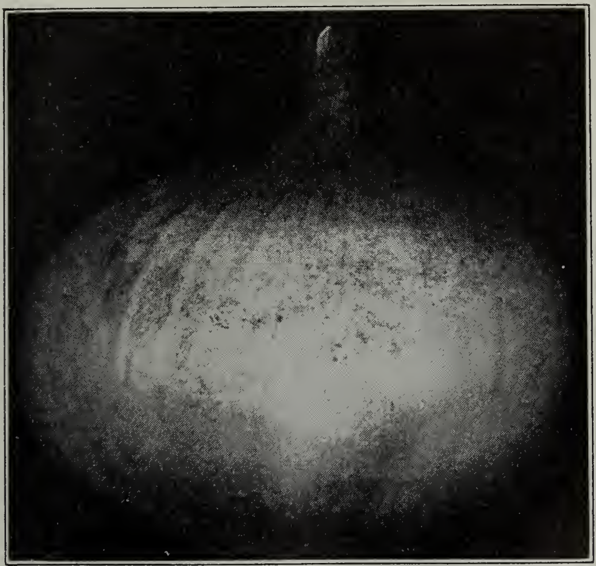

Fig. 26.—Onion-thrips injury to the surface of an onion bulb. This injury is done in storage but does not harm the bulb seriously.

grass, bur clover, wild mustard, Bermuda grass, and even cattail. Of the cultivated plants, alfalfa, celery, and, in particular, asparagus ferns serve as alternate hosts. In the Sacramento delta most of the asparagus tops are cut and burned by January 1, and most of the celery is harvested by February. From late November to January green-onion seedlings are put out, and the adult thrips in the locality gradually migrate to them and later to the onion plants coming up from seed.

As was mentioned above, all stages of these thrips are found on onion bulbs in storage; the bulbs have usually become infested in the field while curing. Thus in localities where dry sets are used, the overwintering individuals are probably given an ideal start in the spring by being literally "planted."

In exceptionally warm, dry years, the onion thrips are very abundant. Since the winter rains are a prime factor in reducing the field population, in dry years many thrips survive. During hot weather, too, the injured plants show up much sooner because of bleaching and withering. The peak of the seasonal infestation is frequently reached by June; as the plants mature, the thrips population rapidly diminishes. If, however, succulent plants were available, the high level of reproduction and injury would continue through July and August and well into September.

Control.—For about three-quarters of a century a satisfactory method of control has been sought. As has been pointed out above, thrips are readily killed by contact insecticides—but only if they can be reached, and often only after several rather costly applications. On young plants control with such materials as nicotine sulfate (and pyrethrum extract), 1 to 800, with a good spreader is fairly satisfactory; but as the plants become larger many thrips are protected between the inner leaves even though a good spreader is used. If high pressure is employed the plants are bent over or beaten to the ground, and protection is still afforded the thrips on the undersides of the overlapping and closely appressed leaves. In large acreages the difficulty of manipulating the spray equipment is a problem in itself. We have, however, come a long way from the recommendations of 30 years ago: "Apply kerosene emulsion (1 part to 10 parts of water) with knapsack sprayer twice a week."

Among the latest contributions to the control of this pest, two are of interest. A mixture of 40 pounds of crude chipped naphthalene and 60 pounds of hydrated lime applied by hand to the row (40 pounds to the acre) has given very satisfactory control in New York state. Five applications of this dust (200 pounds to the acre) increased the yield by 100–150 bushels to the acre; the cost (1934) was, however, $12.80. Naphthalene flakes used in this form in California have dissipated so rapidly under high temperatures and low humidity that they were of only temporary value in reducing the thrips population. Still more recently in New Jersey, a solution made from 2 pounds of crude chipped naphthalene dissolved in 3 pints of carbon disulfide, which was emulsified with sulfonated castor oil, was used against the onion thrips. This stock solution was diluted to make 100 gallons of spray, and potassium oleate was added to give an actual soap concentration of 0.25 per cent. Three applications made about a week apart gave three times as good control as did nicotine sulfate, at about one-third the cost.

Another method of attack offering a more lasting solution has been studied recently. Growers who have compared different varieties of onions planted side by side have for some time observed the Spanish types to be generally more resistant to thrips injury than such varieties as Australian Brown and Southport Yellow Globe. Under conditions of extremely severe infestation, however, the Spanish types are also killed prematurely. This difference in susceptibility of varieties suggested the possibility of developing resistant ones. This work has now been in progress for seven years at the California Agricultural Experiment Station. Of the forty-four varieties and strains of onions, including those com-

Fig. 27.—Difference in type of growth of two varieties of onion plants. At the left is the Australian Brown; on the right, White Persian. In the latter variety the thrips do not find suitable hiding places. (From Hilgardia Vol. 8, No. 7).

mercially important, one variety (a foreign introduction now called White Persian) was outstanding both as to the small number of thrips present and as to its ability to withstand injury. Its resistance is apparently determined by two groups of factors; of these, one probably controls those characters that hold the thrips population to a minimum; the others helps the plant to withstand injury. Several characters apparently aid in restricting the thrips population—namely, the shape of the leaves, the angle of divergence of the innermost leaves, and the distance apart of the leaf blades on the sheath column (fig. 27). Also, the difference in the shape of the leaves is probably important. In most varieties the leaf blades have a flat side; these sides are face to face and, in the newly forming leaves, are closely appressed, protecting the thrips larvae. In White Persian the leaves are circular in cross section, which reduces the protective area to a minimum. If commercial varieties had these leaf characters, one might secure more efficient control by spraying or dusting, since practically all the foliage could be covered.

The chief objections to White Persian as a commercial onion are its tendency to split badly and its poor keeping quality. Its strong tendency to bolt is another undesirable characteristic, but in this respect it is no worse than some other varieties. The plants mature very late, and the bulbs are white and oblate. The flavor is exceptionally mild.

GLADIOLUS THRIPS

Description.—The adult gladiolus thrips, *Taeniothrips simplex* Morison, (fig. 28) is very dark brown and measures about $1/20$ inch in length. As in the pear thrips, the wings have a light-colored area at their base or near the center of the body, appearing like a gray band. There is little danger, however, of confusing the two species because the habits and the hosts vary so widely.

The larva is pale yellow; the pupa, orange. The eyes are red. Both immature stages are found inside the buds and leaf sheaths; they seldom crawl about with the adults on the outside.

Distribution.—One of the first authentic records of this pest is from Cleveland, Ohio, during the summer of 1929. In 1931 Moulton and Steinweden described the gladiolus thrips and named it, appropriately, *Taeniothrips gladioli.* G. D. Morison, however, had already described the same insect as *Taeniothrips* (*Physothrips*) *simplex* from specimens found on carnations at Urrbae, South Australia, in September, 1928.

Since its first discovery it has spread extremely rapidly. It is now known from practically all states and from many widely separated foreign countries, including Africa, Australia, the Bahamas, the Hawaiian Islands, New Zealand, and Canada. In California it is recorded from 21 counties.

Hosts.—In comparison with many other thrips the gladiolus thrips has a very limited range of true host plants. The principal and preferred host is the gladiolus, on which extensive reproduction takes place. Minor infestations have been noted on various types of iris, calla lily, poker plant (*Tritoma* or *Kniphofia*), carnations, montbretia (*Tritonia*), and tigerflower (*Tigridia*). In the greenhouse this thrips has been known to reproduce on amaryllis, narcissus, and freesia. The adults (chiefly incidental) have taken on about thirty other plant species.

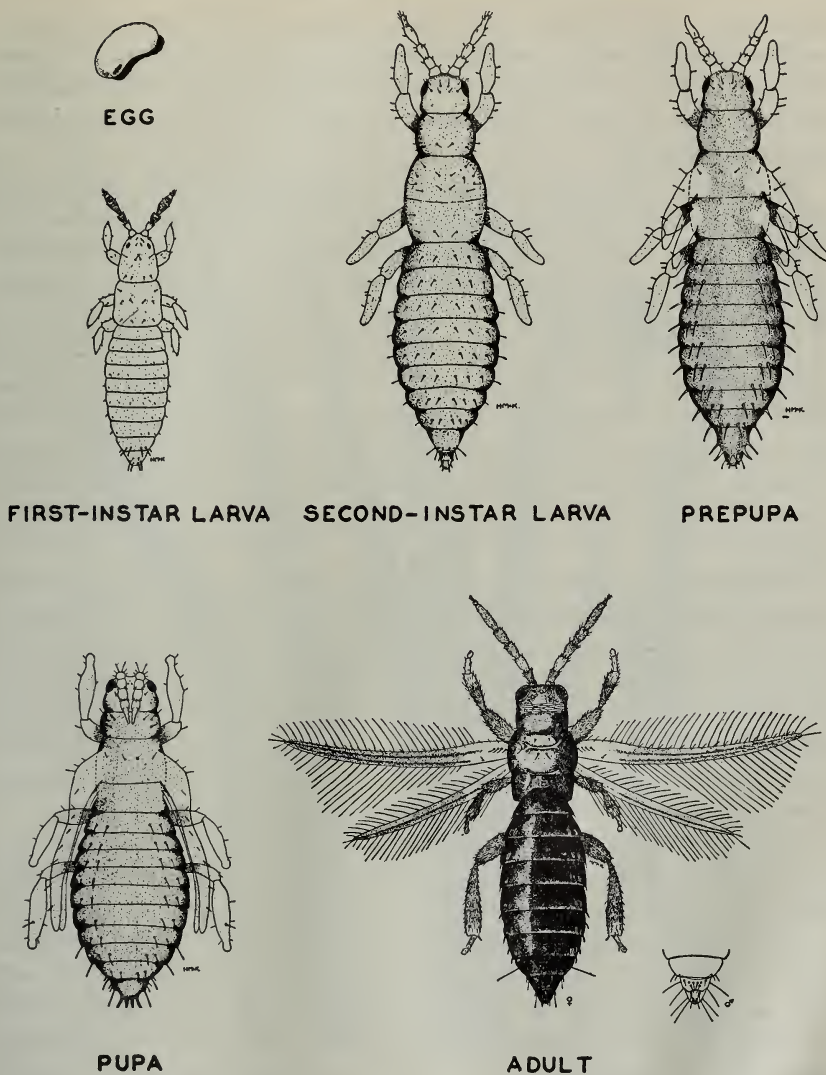

Fig. 28.—Stages of development of the gladiolus thrips.
(From Cir. 337.)

Injury.—This thrips is the most severe pest of gladiolus. If no control measures are practiced in infested fields, the entire crop may be ruined. One writer[4] states: "On the basis of 75,000 corms per acre, with each corm producing one salable spike and the flowers selling at 50 cents per dozen, the loss per acre on cut flowers alone may amount to over $3,000

[4] Herr, E. A. The gladiolus thrips *Taeniothrips gladioli* M & S. Ohio Agr. Exp Sta. Bul. 537:4–5. 1934.

for each acre lost." In addition, excessive injury to the leaves and flowers results in stunted corm growth, which lowers the quality and volume of corms produced. To the grower attempting to build up a stock of valuable varieties or to maintain a large stock of corms for a mail-order business, this loss is serious.

The injury to leaves and flower spikes (fig. 29) results from the rasping-sucking feeding activity of the adults and larvae. Injured areas present a withered, bleached, and spotted appearance. When the flower buds are badly damaged the spikes fail to open, and the plants are generally stunted. The flower injury is sometimes confused with sunburn, but a careful inspection of the plants together with the presence of the thrips will readily disclose the cause of the trouble. When the infestation begins early, the developing leaves in the sheath are so severely injured that they turn yellow or brown when expanded. Even though the flowers open normally, the extraction of the coloring matter in irregular areas produces silvery blotches, which are particularly noticeable on red or purple petals.

In storage the activity of the thrips continues, and corm injury is very common when a field infestation has previously occurred. The thrips reproduce on the surface of the corms. The surface becomes sticky and then hardens, forming dark irregular or "scabby" areas. In addition, feeding around the base of the corm injures the root buds. If any soft tissue is exposed on the sprouts, direct feeding injury is soon evident. The effect is a retarding and stunting of growth after planting. The tiny corms or cormels are protected from injury by the capsulelike covering.

Biology.—When ready to reproduce, the adult females seek out succulent plant tissue in which to deposit their eggs. Out-of-doors, egg laying begins as soon as the weather warms up in the spring. The length of the egg stage varies from as long as 3 weeks in very cool weather to as little as 2 days, the average time being about 5 days in the early summer. The newly hatched larvae prefer to feed within the leaf or bud sheaths or within the flowers, away from the direct light. They are commonly seen feeding in groups or colonies and move about very little if undisturbed. One molt takes place when the larva is about half grown. The average length of the larval stage is about 5 days. When fully developed the larvae either remain within the leaf sheaths or flowers or drop to the ground to transform. Those that leave the plants make their way down into the top soil for 1 to 3 inches. Fully as many larvae pupate on the plants as in the soil. The resting stage also averages about 5 days. Under favorable field conditions, therefore, a complete life cycle lasts about 15 days. Some females perhaps lay as many as 200 eggs; but the average is much less, probably nearer 100. The adults normally live about

1 month but, especially in cool weather, they may live twice that long. Reproduction also continues during the winter on the corms in storage, the length of the stages varying with temperature.

Fig. 29.—Gladiolus-thrips injury to the leaves and flower spikes of gladiolus. The thrips usually feed concealed in the leaf sheaths and in the flower buds and bracts. Such infested plants should be removed from the field and destroyed to prevent severe infestation of later-blooming varieties.

In California, at least as far north as Sacramento, the gladiolus thrips can survive the winter out-of-doors on carnations, Spanish iris, and volunteer gladiolus. At planting time the thrips are often actually set out into the field and given a good start on the infested corms. If additional thrips have survived near the gladiolus planting, they will gradually migrate to the new plants; and by the time the early varieties bloom, some injury becomes evident. In addition to their normal increase, the cutting of early varieties concentrates the infestation and results in severe injury.

The number of generations of the gladiolus thrips in the field depends on the temperature and on the availability of hosts during the year. Approximately six or seven generations develop during the gladiolus season. During the colder months of November to March all reproduction ceases; but the larvae, pupae, and adults can often be found up to January in the coastal areas with higher mean temperatures. Only adults have been found out-of-doors during February. The period of cutting flower spikes in California extends over a long period. In San Diego County the first flowers may be on the market as early as February, and the cutting period finished by the time the San Francisco growers are just beginning. Though this varies from year to year, the early blooming varieties largely escape thrips damage. The peak of the seasonal infestation is reached in the late spring or summer (according to the district), when the late-blooming varieties are severely injured.

Migration from plot to plot in commercial plantings, though rather slow, is greatly facilitated by a strong prevailing wind. When the early bulbs are dug and allowed to dry in the field, very little migration to them will take place if there are still green gladiolus plants in the vicinity. If, however, all the remaining varieties are topped and no other suitable hosts are present, many adults will infest the drying corms in the field.

Control.—The control measures employed against this thrips are of two types—cultural and chemical. The former include certain indirect methods of planting, watering, harvesting, and storing the corms. Only entirely clean, sound corms, free of thrips (and disease), should be planted. The field should be carefully laid out with respect to early and late-blooming varieties, particularly in relation to the prevailing wind. Along the coast, for example, the prevailing wind (blowing almost daily) is from the west. Planting should, therefore, start from the east side with the early-blooming varieties and progress toward the wind with the later-blooming ones; the migration from any early-infested plants to the remainder of the field is thereby greatly retarded. Fields planted with the intention of cutting spikes for the market should not be located near nurseries, cemeteries, or private properties devoted to gladiolus growing, since infestation before the end of the season is almost certain. In the last two or three years growers have moved their plantings to localities isolated from outside infestation and have taken only treated corms to the new fields. By strictly regulating the visitors and allowing no cut flowers to be brought in, these plantings have been kept largely free of the gladiolus thrips.

Since heavy rains greatly reduce the thrips population, growers irrigating with the overhead sprinkling method, use a light sprinkling every day or a heavy watering every other day to keep the thrips at a minimum and to insure clean spikes. In small plantings or in private flower gardens a thorough hosing every day or two will answer the same purpose. Good drainage is necessary when heavy watering is practiced.

Any infested plants observed should be cut and burned to prevent further spread. In harvesting or topping the plants before digging the corms, one should burn, bury, or entirely remove all stalks, spikes, and other plant refuse; otherwise the newly emerging adults from the larvae and pupae in the infested refuse piles will migrate to late-blooming varieties or to the dug corms left exposed in the field for curing. The freshly dug corms may be taken from the field immediately and cured elsewhere to avoid infestation from the tops.

After being sufficiently cured, the corms should be stored by any approved method—for example, in trays, in paper bags, or on wire screen. There are several ways of treating the stored corms to prevent thrips injury or to kill thrips present. If the temperature of the storage chamber can be maintained at 50° F or lower, the thrips cannot reproduce, and little or no injury results. Naphthalene flakes, calcium cyanide, corrosive sublimate (mercuric chloride), other commercial mercuric compounds, and hot water are all effective.

Naphthalene flakes are widely used, particularly for small lots of corms; they are inexpensive, safe to handle, and easily obtained. They may be employed at any time during storage except on sprouting corms, which may be injured at the growing points. The crude, chipped naphthalene is particularly apt to burn any tender tissue exposed. The flakes should be used at the rate of 1 ounce (a heaping handful) to about 100 medium-sized corms, or 1 pound for about 2,000 corms. The corms should be placed in closed paper bags or covered trays to confine the fumes. At temperatures of 60° F or above, the treatment should continue for not less than 3 weeks; at lower temperatures, longer, for the eggs are not killed as are the active stages of the thrips. Usually the flakes must be replenished about every 2 weeks.

Calcium cyanide is an effective fumigant. It has, however, certain disadvantages—namely, its poisonous quality, the necessity of providing an air-tight container, and repeating the treatment, for the eggs are not always killed. For the best results a high humidity should be maintained in the chamber or room being fumigated. The dosage varies from 2 to 5 ounces of cyanide per 1,000 cubic feet of space, the amount of chemical required depending on the tightness of the storage room; the treatment lasts for about 24 hours. The dose must be repeated 10 to 14 days later. Dosages as strong as 30 ounces for each 100 cubic feet for 4 hours have killed all stages, including the eggs, without injuring the corms. *Being very poisonous, this material should be handled with great care; the fumes also are deadly.* After fumigation, use the flakes as a repellent.

Extreme care should be taken to prevent reinfestation of treated lots of corms by those brought in from the field untreated.

Dipping the corms is not recommended until spring, since this treatment usually tends to break the rest period and stimulate growth, which is undesirable until planting time. The peeled corms may be placed in cloth bags and dipped in mercuric chloride (1 ounce to 100 gallons of water) for 4 hours. This treatment will kill all stages as well as any fungus or bacteria present. Submersion in Semesan, 1 ounce to 3 quarts of water, for 7 hours has also given satisfactory results. Hot water, maintained at 112° to 114° F for 20–30 minutes, will destroy all stages of the thrips on corms thus submerged.

Field control is the most difficult phase of the gladiolus-thrips problem. Since the thrips live inside the leaf sheaths and flower buds, where it is impossible to reach them with a spray, it is necessary to maintain a toxic residue on the foliage. Although thrips are fundamentally sucking insects, a sweet poisoned spray (as first used against the greenhouse thrips) is effective. Of all the materials for field control, the following mixture has been most widely used:

	Small quantities	*Large quantities*
Paris green	1 teaspoonful	½ pound
Molasses	¾ pint	3 gallons
Water	3 gallons	97 gallons

Brown sugar was formerly used; but experiments have shown that the paris green was more toxic with molasses, in which the arsenic is much more soluble. Other arsenicals such as calcium arsenate and lead arsenate show some toxicity to the thrips but are perhaps slower in acting. Manganese arsenate, formerly rather widely used, is no longer obtainable. All the arsenicals, however, have caused varying degrees of foliage injury. More recent experimental work of the United States Bureau of Entomology has shown that a spray employing tartar emetic (antimony and potassium tartrate) eliminates this hazard and also gives an excellent control of the thrips. The minimum effective dilution is as follows:

Tartar emetic	4 pounds
Brown sugar	16 pounds
Water	100 gallons

This spray as yet has not been widely used but offers excellent promise.

The chief disadvantage of the paris green spray is that it is apt to burn if high humidity prevails, particularly in the coastal districts. Also, unless one maintains the very best agitation in the tank, paris green settles out and gives an uneven coverage.

Other materials such as the rotenone-bearing materials (derris, cubé, and the like), thiocyanate, and pyrethrum extracts are used by some growers with good results. As yet there are insufficient data on the newer organic insecticides to permit any recommendations for their use on gladiolus thrips.

Multiple applications every 7 to 10 days are necessary to obtain field control with any of the better materials used to date. If the plants are sprinkled they should be resprayed after each watering. Spraying should begin as soon as any sign of injury is observed and continued until the first flowers begin to open.

Some varieties are definitely resistant to thrips—a fact which has possibilities. Since, however, there are hundreds of varieties of gladiolus already listed, the breeding problem is somewhat removed from the normal field of the entomologist. The exact nature of the resistance is not known, and much is yet to be learned concerning genetic constitution of the gladiolus before a fundamental breeding program can be started.

The writer's preliminary experiments have shown the most resistant varieties—at least of those used—to be Alma Needhan, Gay Hussar, Salbach's Pink, Butterboy, Pearl of California, and Magna Blanca. All varieties used were artificially infested at the same stage of development. This grouping is only relative and is based on the degree of injury to the leaves as well as on salability of the flower spike. In this study no attempt has been made to correlate the resistance with such characters as early blooming, vigor, tightness of leaf sheath, toughness of leaves, color of leaves or flowers, or chemical composition of sap. Undoubtedly several of these factors play an important part in resistance. The general observation was made, however, that the "whites" and the early-blooming varieties largely escape damage. Also, the purple and dark reds as well as the slow-growing varieties suffer the worst damage. There are exceptions; and, as only a few of the many hundred varieties were studied, there is little basis for any definite conclusions at present.

GREENHOUSE THRIPS

Description.—The adult greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché) (fig. 30), is one of the easiest distinguished of all the thrips known as plant pests. The head and central portion of the body are covered with a deep network of lines much more distinct than in the bean thrips. The body is blackish brown with the posterior end much lighter. The length of the mature insect is about $\frac{1}{24}$ inch. The legs are a uniform light yellow, the wings slightly clouded but without bands, and the antennae slender and pronouncedly needlelike at the tip. No male of this species is known. The young larvae are white with red eyes. When older they become yellow, as do the pupae, which also have red eyes. All stages occur on the host plants and are very sluggish.

Distribution.—Judging from the literature, this thrips has practically a world-wide distribution. In the United States it occurs out-of-doors in California, Florida, District of Columbia, Georgia, and possibly other

Fig. 30.—Adult greenhouse thrips. (After Russell, United States Department of Agriculture.)

southern states. In greenhouses it is known from Connecticut, District of Columbia, Indiana, Iowa, Kansas, Louisiana, Massachusetts, Michigan, Mississippi, New Jersey, New York, Ohio, Oregon, Pennsylvania, South Carolina, and Washington. The localities in California in which it has been injurious are Alhambra, Anaheim, Berkeley, Butte County, Ben Lomond, Davis, Fresno County, La Honda, Los Angeles County (several localities), La Jolla, Menlo Park, Napa, Oakland, Orange County, Pacific Grove, Pasadena, Redwood City, Sacramento, San Diego County (several localities), Santa Barbara, San Mateo, Santa Paula, Santa Rosa, San Francisco, San Luis Obispo, and Ventura.

Hosts.—The host-plant range of the greenhouse thrips is very extensive, including chiefly greenhouse and ornamental plants but also a few crop and tropical plants. No attempt can be made here to compile an exhaustive list of hosts; the author's files record about 100 host plants. Some of the more important plants which are known to be severely injured are as follows: avocado, azalea, cacao, citron, guava, lime, mango, orange, persimmon, coffee, croton, laurustinus, pinks, rhododendron, toyon, and viburnum.

Injury.—The greenhouse thrips feeds almost entirely on the foliage and fruit of the plants it attacks. The youngest or oldest leaves, however, support very few. This thrips feeds in concentrated colonies, all stages being present on the leaves but with only the larvae and adults feeding. The familiar silvery or bleached appearance quickly becomes evident after feeding has occurred on a leaf or fruit surface. Severely injured leaves become papery and wilted, and soon die. If the infestation is serious, defoliation results. The inner leaves and fruits are usually preferred, and this thrips rarely feeds on the outer surface of the trees and shrubs unless they are entirely shaded. When fruit (such as avocado and citron) is attacked, the surface becomes brownish or russet and, if injured while growing, often exhibits cracks. The black or brownish dots of excrement typical of thrips-feeding activity are also a ready means of identifying the injury (fig. 31).

In southern California citrus and avocados are badly damaged. Oranges are usually attacked at points of contact within a cluster of fruit or where a leaf overlaps the fruit. The injured area often becomes silvery and waxy. Very little feeding is done on orange fruits less than 1½ inches in diameter; full-sized or coloring fruits are apparently the most attractive. The dark, reddish-brown dots of excrement deposited on the fruits and leaves readily distinguish the injury from that of the citrus thrips. Also, judging from the apparent climatic preferences of the two species, the greenhouse thrips will probably not become serious in areas subject to citrus-thrips injury. Various ornamentals grown in the open, such as azalea, viburnum, laurustinus, myrtle, and toyon, suffer foliage injury. Many greenhouse plants—ornamentals and others—are damaged at times.

Biology.—As was mentioned above, all stages of the greenhouse thrips are found on the host plants. The females (no males are known) insert the eggs in the epidermis in the normal manner. About 25 eggs are laid by each adult living the maximum period. The eggs are incubated 17 to 20 days, under optimum conditions. The larvae feed over a period of 13 days, stopping to molt once when about half-grown. Pupation, which takes place alongside the larvae and adults, lasts 5 days. A complete life cycle can be passed in 33 to 38 days. Under mild weather conditions in California, there are probably 5 to 7 generations a year out-of-doors. In the winter practically all active stages disappear, and the egg stage may last as long as two months. Naturally all stages vary in length of time with the temperature. The writer believes that this thrips can survive much lower temperatures than is generally supposed. During the winter of 1936–37, one of the coldest in the history of California, the greenhouse thrips survived (in the egg stage) out-of-doors as far north as Napa. Very likely, strains have been developed to withstand local conditions, as is known to be the case with other insects.

Fig. 31.—Greenhouse-thrips injury to avocado leaves. The light areas are portions where the cell contents have been sucked out by the thrips. The black dots are excrement.

Migration is slow, as are all movements of the greenhouse thrips. The colonies gather chiefly on the undersides of the leaves and do not work over on the tops of the leaves and fruits until the tissue becomes unsuitable for feeding and oviposition. In many cases the fruits are apparently preferred to the leaves. Although winged, the adults rarely fly. Normally they move about slowly and prefer a cool, shady, fairly moist environment. Hot, dry weather, as well as heavy rains, is very detrimental to field populations.

Control.—Of all the thrips of economic importance, the greenhouse thrips is among the easiest to control; all stages (except the egg stage) can be killed by direct chemical control. A second application after the eggs have hatched—that is, 10 to 20 days later—will usually prevent any build-up of importance during the remainder of the season. Also the majority of the thrips feed on the flat surface of the fully expanded leaves, not in the buds, flowers, or curled leaves. Thus they are readily sprayed. In greenhouses, calcium cyanide (¼–½ ounce per 1,000 cubic feet) and nicotine dust, as well as thiocyanate and pyrethrum sprays, have given very satisfactory results. In Canada a spray made of 2 tablespoonfuls of paris green, 2 pounds of brown sugar, and 3 gallons of water was recommended as early as 1922 for thrips in greenhouses. This mixture has also recently come into prominent use against the gladiolus thrips.

On avocados highly refined light-medium oil (70° viscosity) has been successfully used at 1½ per cent with 1 pint of nicotine sulfate, to which is added 1 pound of spreader (casein) for each 100 gallons of water. If spraying is done carefully, more than a second application should be unnecessary. According to recent experimental work of the Citrus Experiment Station at Riverside, this pest may be effectively controlled on oranges with nicotine sulfate as well as with pyrethrum extract (1 part to 1,200 parts of water). The effectiveness of both these materials is increased by the addition of 0.5 per cent of light-medium, highly refined petroleum oil.

Indications are that some kill of the eggs is also obtained. The nicotine sulfate or pyrethrum extract may be incorporated in the regular late summer-oil spray for scale insects and the citrus red mite. If, however, one must spray for the greenhouse thrips earlier and if the treatment coincides with that for citrus aphids, the nicotine sulfate is to be preferred, since it apparently gives a better kill of the aphids than does the pyrethrum. Also, one may well remove all "off-bloom" fruits and "break-clusters" of fruits at each picking, as measures supplementary to spraying.

GRAPE OR VINE THRIPS

This European thrips, *Drepanothrips reuteri* Uzel, was first found in Sacramento County, California, in 1926. For two years after its earliest discovery in this country, grape growers in the San Joaquin Valley reported injury of the vines and berries. Then little was heard of this pest until the summer of 1936, when it again appeared in injurious numbers in this area. Also in 1937 it was serious in certain localized areas, particularly on the Malaga variety. At present the known distribution in California is as follows: at Mountain View, Davis, Florin, Lodi, Modesto, Turlock, Sanger, Dinuba, Orosi, Cutler, and Delano. As yet it has not been reported from Sonoma or Napa County or from southern California. Its world distribution includes England, Bohemia, Austria, Hun-

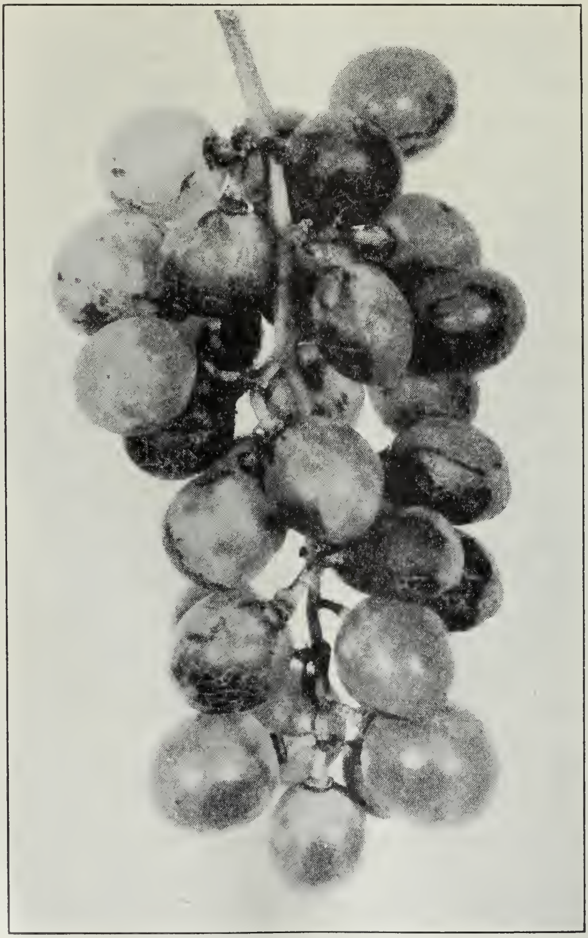

Fig. 32.—Typical injury to grapes by the grape or vine thrips. The berries become russeted from the surface feeding and later crack as they grow.

gary, Italy, Russia, and Caucasia. In addition to grape varieties the grape thrips has been collected in Europe from oak, beech, willow, maple, hazelnut, and *Orchis* sp.

Information on its life history and habits is scanty. In Europe it is reported that the adults overwinter under the bark on the grapevines. Apparently they pass through a spring and summer generation. According to observations by the writer during the past two seasons, activity begins in the spring as soon as the canes develop, and the first group of larvae is present shortly after blossoming. The feeding injury (fig. 32) when severe causes stringy bunches of fruit and a brown, cracked appearance of the berries, which does not show up until early summer. The flower thrips is also present at the time of this early injury, to which both species contribute. The flower thrips largely disappear from the

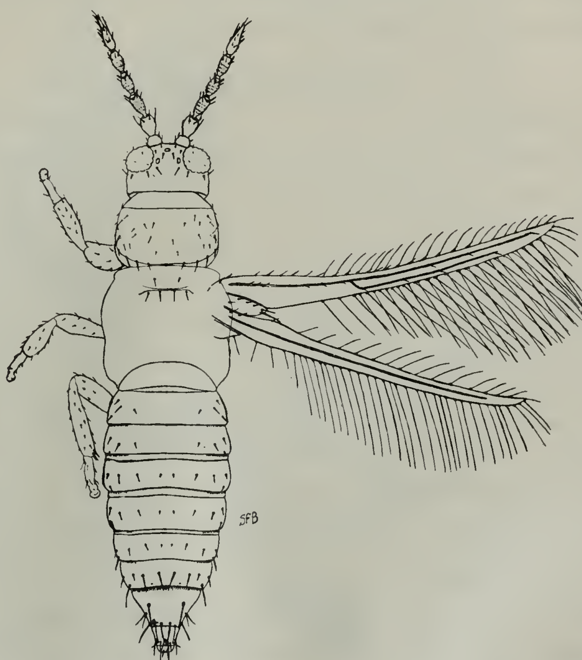

Fig. 33.—The adult female grape thrips.

vines, however, after the hot weather begins and the berries are about one-third grown, whereas the grape thrips continue to reproduce on the vines and by midsummer have caused severe "burning" and curling of the young leaves and canes. All stages except the pupal stage have been found on the vines. Pupation probably occurs in the soil under the vines.

In general appearance this thrips (fig. 33) much resembles the citrus thrips. It is slightly darker, being often a more brownish yellow, but is very small and active. The mature larvae are golden or amber yellow; the younger larvae are pale yellow. As both the flower and citrus thrips also occur on grapes, it is nearly impossible to tell these three species apart in the field.

Early control suggestions included various combinations of nicotine sulfate and highly refined oil emulsions. Under the present conditions, with new materials and equipment, the following are suggested: nicotine sulfate dust (with or without dusting sulfur) at 5 to 10 per cent; the pyrethrum-sulfur dusts now available (using standardized pyrethrum extracts); or the "vine-hopper" sprays applied according to the "vapo-dusting" principle. The application should come as soon as the thrips are in evidence on the vines, usually about the time the berries are setting. In severe cases a second application may be necessary in early July or as soon as any leaf injury is observed.

CALIFORNIA TOYON THRIPS

The Christmasberry or toyon is widely used in California as an ornamental shrub, and the thrips attacking it is apparently specific on its native host. The glossy black adult of this species, *Rhynchothrips ilex* (Moulton), is about $\frac{1}{16}$ inch long, with silvery-white wings folded lengthwise over the abdomen. From the last of February to the first of April, the adults come out of hibernation in the curled leaves, mate, and begin feeding on the new unfolding leaves. The light brownish-yellow eggs have a waxy surface and are deposited loosely on the leaf. The egg stage lasts 3 to 4 weeks. The larvae, after hatching, feed together with the adults on the new growth, causing the leaves to become distorted, curled, or even killed (fig. 34). The larvae are pale yellow when first hatched; but, as they develop, the tip of the abdomen becomes reddish black, and two areas of the same color appear on the prothorax. The antennae, head, and legs are brownish black, and the remainder of the body is reddish orange. This stage consumes 18 days to 4 weeks. When mature the larvae drop to the ground and often spend as long as 18 days seeking out a suitable place in which to pupate. Most of the mature larvae and pupae are found in the loose, dry, top soil, beneath rocks, curled leaves, and the like, under the shrubs. This resting stage, which lasts about 2 weeks, usually occurs about the time the toyon is in bloom. After the blooming period a second flush of new growth generally appears, which is also injured by the newly emerged adults and by the larvae of the partial second generation. In the late summer and fall, little reproduction occurs; and many adults apparently do not feed after emerging, but seek out a place in which to hibernate.

As far as is known, this thrips is found normally and reproduces on only the one host, although there are records of its having been taken on *Rubus* sp., tree malva, and hollyhock. It is most abundant in the coastal areas. In the interior of California it is found rarely in the floor of the valleys but more often in the foothills, particularly near lakes, streams, and shady hillsides.

The natural spread is very slow, and artificial dissemination takes place largely on nursery stock moved during the dormant period when the adults are hibernating on the host. Where infestations are severe enough to render the host unfit to serve as an ornamental, the following control measures are suggested: Pick off and destroy all curled leaves in

Fig. 34.—Toyon, showing the curled and misshapen leaves caused by the toyon thrips. The adult thrips pass the winter in these curled leaves.

the fall, winter, or early spring. As soon as the active feeding stages appear on the new growth, spray with a contact insecticide such as nicotine sulfate or pyrethrum extract, about 1 part to 800 parts of water, adding a suitable spreader. A dust does not penetrate the curled leaves so well as a spray. Hosing off the plants with water and thoroughly wetting the ground beneath the shrubs during the summer markedly reduce the thrips present.

HOLLYHOCK THRIPS

This thrips, *Liothrips varicornis* Hood, though not common, has been collected from hollyhock in various localities in California from Riverside to Ukiah. The injury results from the feeding of the adults and larvae in the axils of the hollyhock leaves, the stalks near the ground and the roots. Colonies of the thrips often feed in depressions on the leaves, stems, stalks, and roots; but the injury seldom affects the plants noticeably.

In appearance the adults cannot be told from the toyon or the lily thrips, being all large and black. They pass the winter on the roots; adults only are found during January, February, and March. In the spring the survivors move up to the new growth, which sprouts from the old stalks, or crawl to new, young plants nearby. The buff-colored eggs are laid unprotected in the angles of the leaves, stems, and stalks, under the bracts, or in depressions and cracks of the old roots or stalks. They hatch in about 4 weeks. The larvae are brilliant red with the terminal segments of the abdomen, the head, prothorax, legs, and antennae black. Full growth of this stage is attained in 18 to 25 days. Pupation may occur in the top soil, inside the hollow stalks, or in the midst of a colony of larvae if protected. All stages are sometimes found clustered together. Ten days usually suffice to develop the pupa to the adult winged stage.

The first generation is greatly prolonged, and from the time the adults of the second generation appear there is some overlapping of the first and second generations. This second brood is even more irregular than the first and continues through the fall on the meager portions of the host plants that are still succulent, or on the roots. Dispersion is very slow, even in local areas. Heavy watering of the soil about the base of the infested plants and destruction of all old stalks and volunteer plants during the fall and winter appear to be the most practical means of discouraging this thrips.

LILY THRIPS

On three occasions, the lily thrips, *Liothrips veneeckei* Pr., has been reported from California—once from Ukiah, once from Los Angeles County, and very recently (September, 1938) from Berkeley—but it has never proved injurious in this state. It spends its entire life cycle on lily bulbs, feeding upon the epidermis of the outer scales near the base. This resulting injury is usually not serious; the injured area tends to turn a rusty brown and presents a sunken or flabby appearance.

Like its close relative, the hollyhock thrips, the adult is shiny black and about $\frac{1}{16}$ inch long (fig. 35). The eggs are light brown. The larvae and pupae are salmon pink, with certain parts of the body black; namely, the head, portions of the antennae, legs, thoracic plates, and the tip of the abdomen. The average duration of the various stages in days is as follows: egg, 17.2; larva, 35.9; pupa, 15.9; adult life, 70.3; from egg to adult, 66.2. Winter is passed in the adult and larval stages. As a result, two overlapping groups develop simultaneously during the growing season. Each group appears to pass through one and one-half generations annually.

In North America this thrips is known from Canada, Mexico, New York, North Carolina, California, Oregon, and Washington. Its world

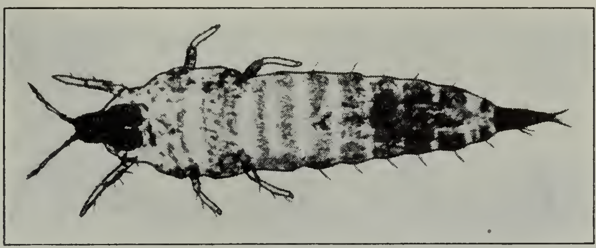

Fig. 35.—Mature lily-thrips larva. The hollyhock and the toyon thrips larvae are very similar in appearance. (After W. E. H. Hodson.)

distribution includes Austria, Belgium, England, Ceylon, China, France, Holland, India, Italy, Japan, and Russia. Its host range is limited to lily bulbs and orchids.

Fumigation of the bulbs with crystalline paradichlorobenzene (P D B) at the rate of 3 ounces per cubic foot of space for 96 hours (58° F) is recommended in England. It has not yet become necessary to treat for this pest in California.

SUGAR-BEET THRIPS

Although known to be injurious out-of-doors, the sugar-beet thrips, *Hercothrips femoralis* (Reuter), is primarily a greenhouse pest in this country. First described from Finland in 1891, it had been known in Massachusetts since 1884. At present it occurs in California, Connecticut, District of Columbia, Florida, Illinois, Indiana, Kansas, Maryland, Massachusetts, Minnesota, Nebraska, New Jersey, New York, North Carolina, Ohio, South Carolina, Virginia, Washington, Wisconsin, and in Ontario, Canada. Abroad it is recorded from thirteen countries. In California it is known to occur at Hamilton City, Davis, San Jose, and Riverside.

Like its close relative, the greenhouse thrips, it has been collected from many different plants. Some of its more common hosts are amaryllis, aster, banana, bean, begonia, cactus, celery, chrysanthemum, cotton, cucumber, date palm, gardenia, gladiolus, grape, lily, orchids, potato, spinach, sugar cane, sugar beet, sweet potato, and tomato. Most of these plants have been attacked in greenhouses; but a few such as sugar cane, cactus, and sugar beets (fig. 36) have served as hosts out-of-doors. The injury, as evidenced by the silvering, blotching, and drops of excrement, resembles that of the bean thrips, greenhouse thrips, and others. In addition, this thrips transmits bacterial disease of beans.

Fig. 36.—Young sugar-beet plant grown in the greenhouse, showing injury by sugar-beet thrips. The bleached appearance of the leaves and the black dots of excrement are always good indicators of the presence of thrips.

It (fig. 37) may be readily told from the greenhouse thrips by the bands on the forewings and by the dark-brown basal segments of the legs. The latter characteristic, together with the more slender, needlelike antennae, will distinguish this species from the bean thrips. The immature stages (that is, the larva and pupa) are translucent or very pale yellow with red eyes.

The female sugar-beet thrips inserts the eggs in the more tender portions of the host plants; but the number of eggs laid by each female is not known. The average length of the egg stage is 13 days, and about an equal period is required for the larvae to develop. The pupal stage lasts about 6 days. Judging from the limited data available on this species, the total life cycle averages 30 to 38 days. Reproduction occurs all season in the greenhouse but is considerably slower during the winter. No infestations out-of-doors in California in the winter have been recorded. The adults and larvae feed together in colonies on the leaves and move rather sluggishly, even when disturbed. Pupation normally occurs on the host (fig. 38)—for example, under spider webs, in curled portions of the leaves, and on the undersides of the leaves next to the larger veins—but also on the surface of the soil under the host in protected places.

Fig. 37.—The adult female sugar-beet thrips. (Courtesy of Bureau of Entomology, U. S. Department of Agriculture.)

The usual nicotine sprays and dusts have proved effective against this thrips. More recent work has shown, however, that a pyrethrum spray (0.01 to 0.02 per cent pyrethrins, 1 part to 5,000–10,000 parts of water) with 0.25 per cent potassium oleate soap gives good control in the greenhouse. The writer believes that for such slow-moving types of thrips the rotenone-bearing materials (0.75 to 1.0 per cent strength) will also give satisfactory results under greenhouse conditions.

COMPOSITE THRIPS

Among the thrips of minor importance is a species known as the composite thrips, *Microcephalothrips abdominalis* (Crawford), frequently found on zinnias, marigolds, calendulas, and other flowers. Flower seeds of these hosts, particularly those with a thin coat, are injured (fig. 39) by the composite thrips in the summer and early fall.

The entire life cycle is passed in the flower heads. The eggs are inserted in the more tender portions of the flowers, stems, and buds. They hatch in about 5 days, and the larvae feed 10–14 days before pupating. The pupae, found in the flowers, remain quiescent for 3–5 days. The adults are very small and dark brown. Both sexes are winged; but some males have short, nonfunctional wings. In gardens where not all the flowers are winter-killed, adults and larvae are found all winter. Generations

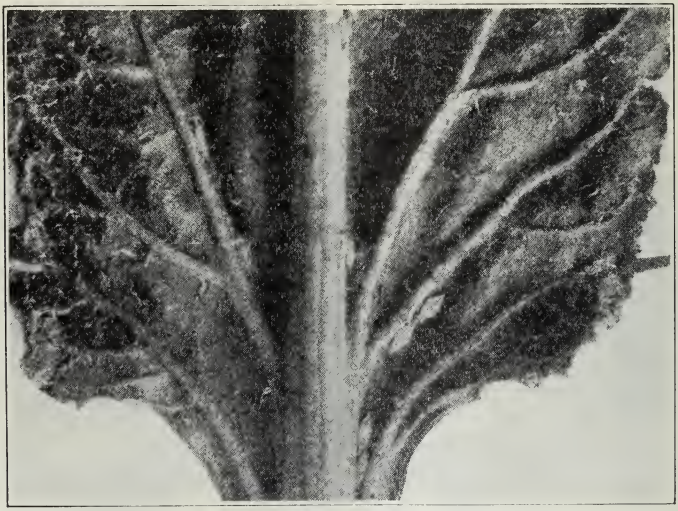

Fig. 38.—Pupae of sugar-beet thrips on the underside of a sugar-beet leaf. This thrips and the greenhouse thrips are among the very few species that do not pupate in the ground. (Courtesy of Bureau of Entomology, U. S. Department of Agriculture.)

overlap considerably from about April to October; the greatest seasonal abundance is reached in the fall. Clean culture and the destruction of all volunteer plants of the composite type during the winter and early spring in the vicinity of seedbeds are desirable practices when this thrips is observed injuring commercial seed plantings.

OTHER SPECIES OF THRIPS

Certain other species of thrips for which there are no common names, at least in general use, are of minor importance, occurring mostly on ornamentals and in greenhouses. These are: *Parthenothrips dracaenae* (Heeger), sometimes called the dracaena thrips; *Thrips nigropilosus* Uzel; *Scirtothrips longipennis* (Crawfd.); *Anaphothrips obscurus* (Müller); and *Haplothrips leucanthemi* (Schrank). Concerning the details of their life histories and habits, very little is known. The harm done by these species on such plants as asters, dahlias, azaleas, *Ficus,* and on croton foliage is typical of the injury described for the other species. Greenhouse fumigation or spraying with the suggested materials will suffice to keep these forms under control.

In January, 1934, a species sometimes called the Arizona cotton thrips, *Frankliniella gossypii* (Morgan), was found in numbers on oranges, grapefruit, and lemons at Hemet, California. The fruit injury was most

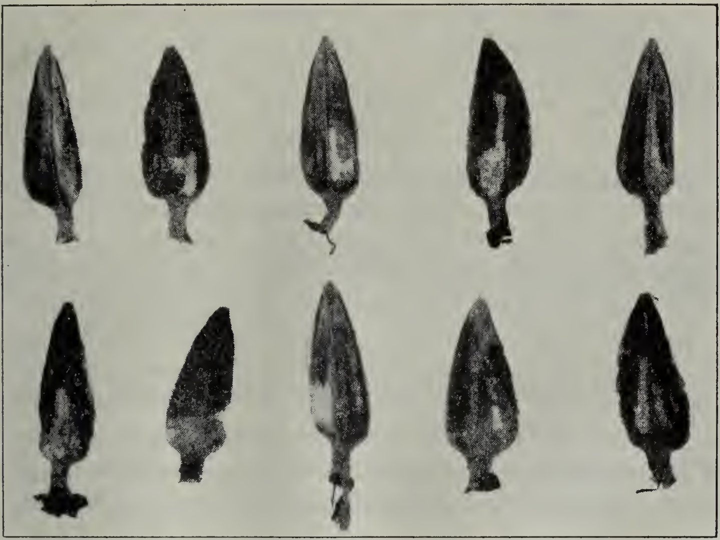

Fig. 39.—Composite thrips injury to zinnia flower seeds. Both the adults and the larvae feed on the surface of the seed coat as long as it remains succulent.

pronounced on oranges. Again during the winter of 1937–38 this species was reported injurious in the same district. About its life history or hosts, very little is known. Possibly other plants act as hosts during the summer and it moves into the citrus in the fall and has one generation on the trees during the winter months. At present it is known only from Yuma, Arizona, and from Hemet, California.

Beneficial Thrips.—Among this group of insects known as thrips, a few beneficial forms feed on other insects, mites, and spiders. In California the most common predacious thrips are the black hunter, *Leptothrips mali* (Fitch), which feeds on mites, red spiders, thrips larvae, and sometimes aphids; the six-spotted thrips, *Scolothrips sexmaculatus* (Perg.), which also attacks thrips larvae, mites, red spiders, and possibly young scale insects; and two other predacious species, *Aeolothrips kuwanaii*

Moulton, and *Aeolothrips fasciatus* (L.), which appear to feed chiefly on mites and thrips. Though technically beneficial, having as their sole diet injurious insects and mites, these thrips are never numerous enough to be of any real value in suppressing serious infestations.

OTHER THRIPS OF ECONOMIC IMPORTANCE IN NORTH AMERICA THAT DO NOT OCCUR IN CALIFORNIA

As was mentioned at the beginning of this discussion, practically all the thrips of major importance to agriculture in the United States are already to be found in California. The species which do not occur in this state are briefly discussed below.

Frankliniella tritici (Fitch) is the common flower thrips of the East and Middle West; *F. bispinosus* (Morgan) is injurious in Florida; and *F. fusca* (Hinds), the tobacco thrips, often injures tobacco and cotton in the southern states. *F. insularis* (Franklin), an important vector of spotted wilt in Australia, occurs in Arizona, Texas, and Florida. The camphor thrips. *Liothrips floridensis* Watson, was formerly a pest of camphor in the southern states; but now that camphor is of minor importance as a crop, this insect is of little concern. The cacao thrips, *Selenothrips rubrocinctus* (Giard.), a serious pest in the West Indies, occurs in Florida. The iris thrips, *Bregmatothrips iridis* Watson, is known on the Atlantic coast and in Washington on the west coast. It may eventually find its way into this state, the genus being already known from California. At present, at least, it is of very minor importance. Four other species have been recorded in the literature as injurious. They are *Anaphothrips striatus* (Osb.) (known as the grass thrips in the East), injuring grass; *Dendrothrips ornatus* Jabl., damaging privet; the currant thrips, *Liothrips montanus* Hood, attacking currants; and *Prosopothrips cognatus* Hood, called the wheat thrips in the Middle West. These last-mentioned species have been of no importance in recent years, and no control measures have ever been necessary.

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There is no general treatise or text dealing exclusively with thrips of economic importance, although three monographs of a taxonomic nature have been published. Aside from the systematic works, most of the literature discussing thrips as crop pests appears in agricultural experiment station publications, in publications of the United States Department of Agriculture, and in scientific journals or other periodicals. These references are scattered and often difficult to locate; therefore, the references for further reading are given below in the same order that the various species are discussed in the text.

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