U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 99, Part I.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON INSECTS INJURIOUS TO CITRUS AND OTHER SUBTROPICAL FRUITS.

THE ORANGE THRIPS:

A REPORT OF PROGRESS FOR THE YEARS 1909 AND 1910.

BY

P. R. JONES AND J. R. HORTON,
Agents and Experts, Deciduous Fruit Insect Investigations.

ISSUED MARCH 6, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

U. S. D. A., B. E. Bul. 99, Part I. D. F. I. I., March 6, 1911.

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THE ORANGE THRIPS: A REPORT OF PROGRESS FOR THE YEARS 1909 AND 1910.

By P. R. JONES and J. R. HORTON,[a]

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INTRODUCTION.

The orange thrips (*Euthrips citri* Moulton), a small, yellow, active insect belonging to the order Thysanoptera (popularly known as thrips), scars the fruit and curls and distorts the leaves of the orange. At the present time its control constitutes the chief insect problem confronting the citrus growers of the San Joaquin Valley orange belt of California, which winds along the Sierra Nevada foothills, from east of Fresno to south of Delano. This insect, the work of which was first noticed 15 or 16 years ago, has increased in numbers with the growth of the citrus industry and recently has assumed serious economic importance.

At the urgent request of a number of orange growers of Tulare County, an investigation of the insect was begun the latter part of April, 1909. The present paper is a preliminary report of the results obtained during the seasons 1909 and 1910.

The writers wish to acknowledge the financial assistance of the Tulare County board of supervisors, the Lindsay Citrus Growers' Protective League, and the Tulare County Fruit Exchange; they desire to acknowledge the kindness of Messrs. P. M. Baier, Harry Postlethwaite, and R. H. Shoemaker in allowing the Bureau of Ento-

[a] The investigation of the orange thrips by members of the force engaged in studies of deciduous-fruit insects appeared desirable, because these men were familiar with a closely related species—the pear thrips—which is very destructive to prunes, pears, cherries, etc., in the San Francisco Bay region. However, in order to keep together the articles dealing with insects damaging citrus and other subtropical fruits, the present paper is published in a series of articles dealing with insects of that class.—A. L. QUAINTANCE, *in Charge of Deciduous Fruit Insect Investigations.*

mology the use of their orchards for experimental and demonstration purposes; and they would express their indebtedness to the large number of orange growers in Tulare County who have put into effect in their own orchards the recommendations of the Bureau, thereby demonstrating the value of the spraying treatments advised.

ORIGINAL HOME AND DISTRIBUTION.

The orange thrips is probably native to North America. Its natural habitat is probably the Sierra Nevada foothills or the adjoining plains of the southern San Joaquin Valley, and it was no doubt attracted from its natural food plants by the more succulent and luxuriant orange trees. This insect is distributed throughout the entire orange belt of the San Joaquin Valley and has been collected in several places in Southern California and at Phoenix, Ariz., by the senior author. The infestation in Arizona embraces orange groves in the Salt River Valley surrounding Phoenix, and was reported upon by Prof. J. Eliot Coit in a bulletin of the Arizona Agricultural Experiment Station.[a] This gentleman, in sending specimens to Dr. W. E. Hinds for identification, probably did not obtain the true orange thrips (*Euthrips citri* Moulton), but some specimens of *Euthrips occidentalis* Pergande, which is found occasionally upon citrus trees, but which rarely causes any serious injury. The true orange thrips was described as a new species by Mr. Dudley Moulton in a bulletin of the United States Department of Agriculture, issued February 11, 1909.[b]

The orange thrips has also been reported from Hermosillo, Sonora Province, Mexico, but the writers have not been able to obtain specimens from that locality.

The occasional scarring of oranges in the north-central portion of California is caused by the grain thrips (*Euthrips tritici* Fitch), and not by the orange thrips.

FOOD PLANTS.

Although the orange thrips, when described, was thought to infest only citrus trees, the writers have taken it from a number of other host plants. The following list shows the wide range of food plants upon which this insect can exist:

Of citrus fruits the following are affected: *Citrus aurantium* var. *sinensis* (Washington Navel, Australian Navel (?), Thompson Improved, Valencia Late, Mediterranean Sweet, Parson Brown, Ruby

[a] Arizona Agricultural Experiment Station, Bulletin No. 58, Citrus Culture in the Arid Southwest, p. 319, 1908.

[b] U. S. Department of Agriculture, Bureau of Entomology, Technical Series No. 12, Part VII.

Blood, St. Michael, Homosassa, and seedlings); *Citrus nobilis* (Satsuma and tangerines); *Citrus decumana* (grapefruit); *Citrus medica* var. *limon* (lemon); *Citrus medica* var. *acida* (lime, varieties of); and *Citrus japonica* (kumquat).

The following miscellaneous plants are infested: *Punica gramatum* (pomegranate); *Vitis vinifera* (European grape, varieties of); *Schinus molle* (California pepper tree); "umbrella tree;" *Pyrus communis* (pear); *Prunus armeniaca* (apricot); *Prunus persica* (peach); *Prunus domestica* (European plum, varieties of); *Salix* sp. (willow); *Rumex* sp. (dock); *Portulaca oleracea* (purslane); *Olea europea* (olive); *Rubus idæus* (red raspberry); *Rosa* sp. (rose); *Solanum* sp.

CHARACTER AND EXTENT OF INJURY.

Injury to citrus trees and fruit is caused directly by the feeding of both adults and larvæ upon the surface of the parts attacked. This feeding may be on the young fruit (Plate I, figs. 1, 2), the nearly mature fruit (Plate II), or the new, tender foliage (Plate III), and generally takes place on all of these. The injury to foliage is generally on young leaves, but may also occur on the axillary buds.

The manner of feeding of both the adult and larva of the thrips is identical, and consists in piercing the plant tissues with the sharp mouthparts with which both stages are equipped and then rasping the wound by a "rooting" motion of the head. The vegetable juices thus liberated from the plant cells are sucked into the alimentary canal of the insect. The characteristic marking or scabbing of the fruit, so noticeable at picking time, is started when the fruit is very small—just after the petals have fallen from the blossoms. This scabbed area is small at first, but as the fruit grows and the thrips continue to feed the markings deepen and at the same time the area of injury is enlarged. The continued feeding of a large number of thrips results in the scabbing of nearly the entire surface of the fruit. Often the marking is so large and deep over a portion of the orange that it causes the fruit to be misshapen and aborted. Frequently the entire surface is scarred while the fruit is still small, with the result that it ceases to grow and falls from the tree.

Orange trees in the Tulare County citrus belt make about four distinct growths a year, and it is on this tender foliage that the orange thrips multiply in greatest numbers. The feeding of large numbers of these little insects causes the young leaves to curl and become distorted and the whole growth to present a sickly appearance. Young trees are often held back a year or more in growth by the prompt destruction of the terminal buds soon after these make their appearance.

DESCRIPTION AND LIFE HISTORY.

THE ADULT.

The adult female of the orange thrips is a small, four-winged, orange-yellow insect, which moves very rapidly by running, leaping, and flying. The mouthparts, which are suctorial in nature, form a sharp cone projecting from the underside of the head. The adult male is smaller than the female and much more rapid in its movements.

The original description of the adult female by Moulton[a] is as follows:

Euthrips citri n. sp.

Measurements: Head, length 0.75 mm., width 0.15 mm.; prothorax, length 0.09 mm., width 0.18 mm.; mesothorax, width 0.24 mm.; abdomen, width 0.25 mm.; total body length 0.86 mm. Antennæ: I, 12μ; II, 36μ; III, 39μ; IV, 39μ; V, 30μ; VI, 34μ; VII, 6μ; VIII, 12μ; total, 0.205 mm. *Color*, yellow to orange-brown, with thorax and segment 2 of antennæ more noticeably orange-brown.

Head twice as wide as long, retracted considerably into the prothorax, broadly rounded in front, with only slight depressions to receive the basal joints of the antennæ; two spines on anterior margin, other spines not conspicuous; cheeks almost straight and parallel. *Eyes* large, occupying almost one-half the length of the head, prominent; pigment deep red to purple; facets of eyes large, eyes pilose. Ocelli subapproximate, margined inwardly with yellow-brown crescents. *Mouth-cone* short, reaching almost to posterior margin of prothorax, broadly rounded and with black spot at tip; maxillary palpi 3-segmented. *Antennæ* 8-segmented, with segment 2 orange-yellow, other segments uniformly light brown; segments 2, 4, 5, and 6 almost equal in length; style about one-half the length of segment 6. All spines inconspicuous; sense cones transparent.

Prothorax about twice as wide as long, posterior angles broadly rounded; with long brown and outer small spine at each posterior angle, other spines not conspicuous. *Mesothorax* largest and with anterior angles broadly rounded. *Legs* light yellow-brown, with tarsi lighter but dark brown at the tip; spines on legs brown. *Wings* present and fully developed, forewings broadest near base and pointed at tips; with the ring vein and a single longitudinal vein which divides at about one-third the length of the wing from the base, the anterior part running parallel and approximate to the anterior part of the ring vein, and ending abruptly near the tip, the posterior paralleling and approaching the posterior part of the ring vein and ending about one-half the wing's length from the end, each branch with a dark-brown marking immediately at its tip. The costa bears a row of about 29 regularly placed spines. Other spines placed as follows: A group of 5 near base of median longitudinal vein; 2 on either side of where second vein branches from the first, and 3 scattered spines about equidistant on each branch vein and in each case one of these spines immediately at the end of the vein; several rather long spines on scale. Veins of the forewing unusually strong and conspicuous, somewhat orange colored near base but fading to yellow near tip. Membrane of wings transparent.

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[a] Loc. cit.

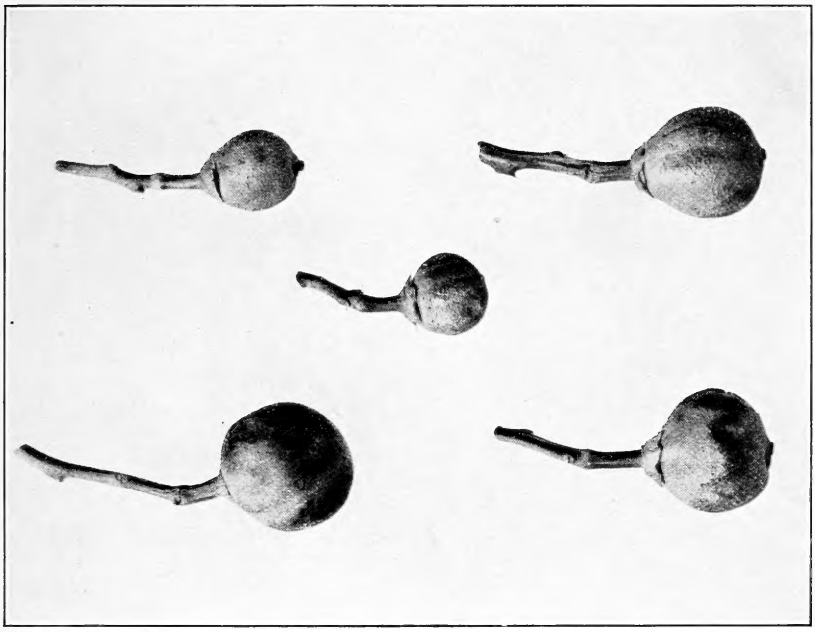


FIG. 1.—YOUNG ORANGES, SHOWING INJURY BY THE ORANGE THRIPS (EUTHRIPS CITRI). SOMEWHAT ENLARGED. (ORIGINAL.)

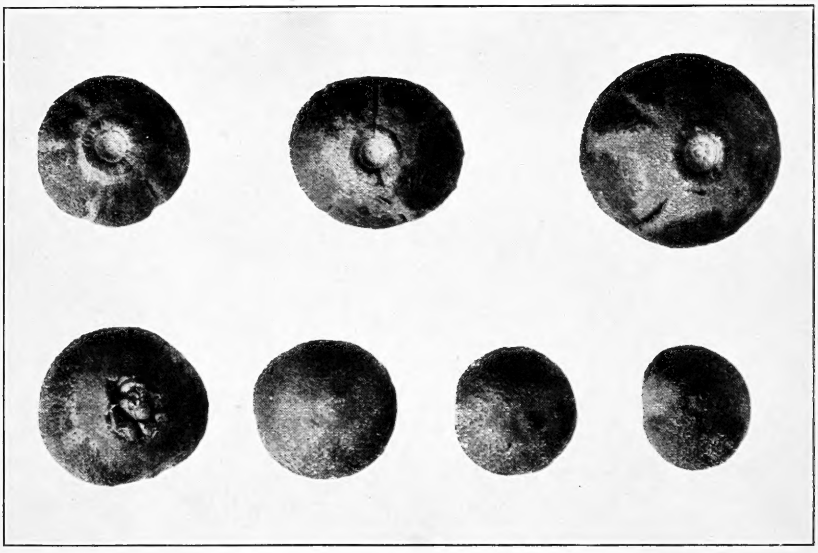
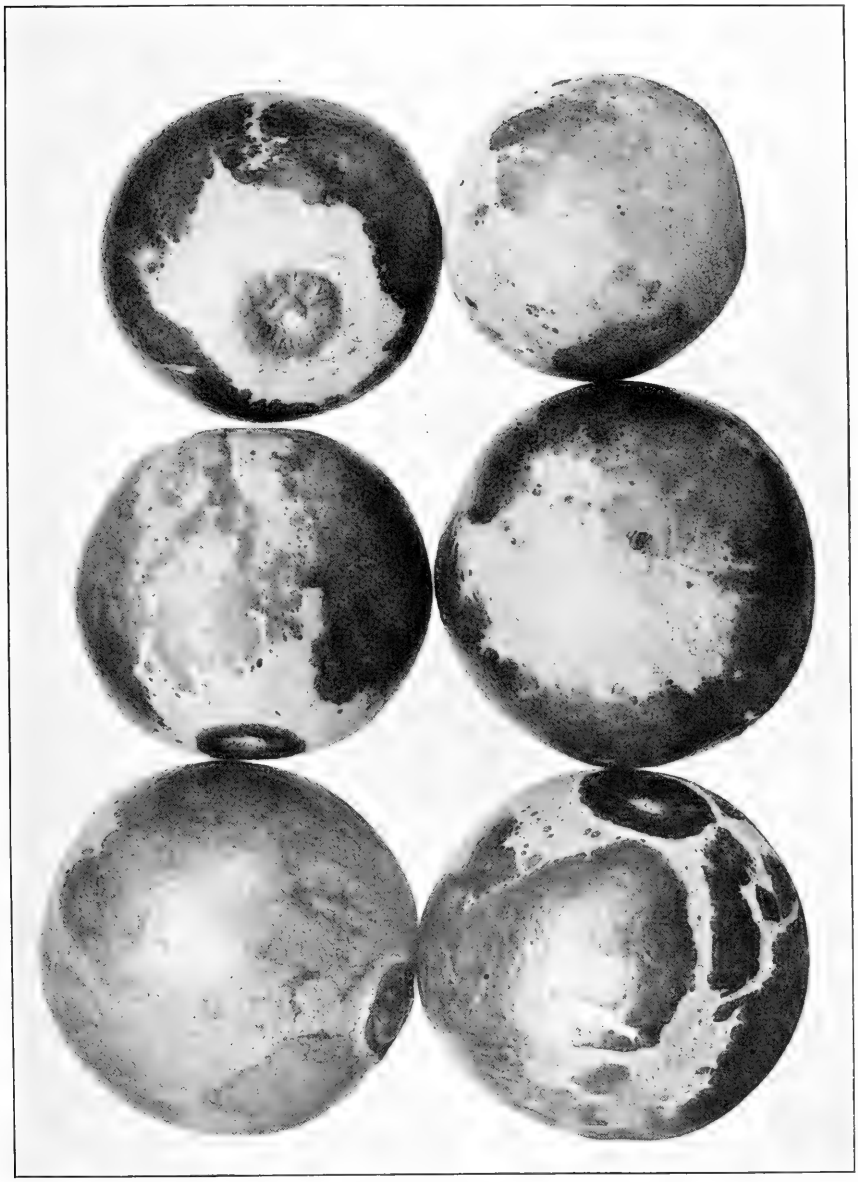


FIG. 2.—YOUNG ORANGES, SHOWING INJURY TO STEM AND BLOSSOM ENDS BY THE ORANGE THRIPS (EUTHRIPS CITRI). SOMEWHAT ENLARGED. (ORIGINAL.)



MATURE ORANGES, SHOWING INJURY DUE TO THE ORANGE THRIPS. (ORIGINAL.)

ORANGE FOLIAGE, SHOWING CURLED AND DISTORTED CONDITION OF LEAVES DUE TO WORK OF THE ORANGE THRIPS. (ORIGINAL.)

Abdomen ovoid, tip conical, all spines, excepting a very few at tip, inconspicuous.

Described from many female specimens collected from orange foliage and fruit at Exeter, Tulare County, Cal.

The males are similar to the females, but smaller and more active, with the orange-colored testes prominent.

THE EGG.

The egg is a bluish white, bean-shaped object measuring from 0.2 mm. in length to about 0.075 mm. in width, with a very thin shell.

THE LARVA.

First-stage larva.—Length 0.041 mm.; width of mesothorax 0.011 mm.; general shape fusiform. The antennæ, head, and legs are large and unwieldy in proportion to the rest of the body. Color translucent white. *Antennæ*, length 0.015 mm.; distinctly 4-segmented; I short, cylindrical; II more than twice as long as I, slightly urn-shaped, longer than wide; III about as long as II, obtusely fusiform; IV about as long as the other joints combined, fusiform, very finely drawn out at the distal end. Segments II, III, IV (II very obscurely) ringed, the distal rings on segment IV appearing as segmental divisions. A few fine hairs present on all segments, most numerous on IV but not very conspicuous on any of the segments. *Head* subquadrate; eyes reddish-brown. *Abdomen* gradually tapering, 10-segmented, first 8 segments subequal; IX and X large and more abruptly tapering, hairs inconspicuous. *Legs* stout, femora and tibiæ nearly equal in length, tarsi one-jointed, ending in a single claw.

Second-stage larva.—Length 0.9 mm.; head length 0.1 mm.; width 0.083 mm.; length of antennæ 0.175 mm.; width of mesothorax 0.266 mm.; width of abdomen 0.3 mm.; *Antennæ*, I, 2μ; II, 3μ; III, 9μ; IV, 45μ; V, 9μ; VI, 15μ; color orange-yellow. In shape similar to first-stage larva except that the abdomen is oval to ovate and generally more robust. *Head* quadrate, small in proportion to body, eyes reddish. Antennæ apparently 4-segmented under 2/3 objective, but under 1/6 objective distinctly 6-segmented, the chitin not extending into the fifth and sixth segments; I short, conical, about as broad as long; II cylindrical, broader than long and slightly longer than I; III obtusely spindle-shaped, about twice as long as broad and about as long as I and II combined; IV obtusely spindle-shaped but blunt on the distal end, about as long as III; V very short and thick, slightly broader than long, about one-fifth as long as IV; VI cylindrical, longer than broad, about one-third as long as IV. *Abdomen* oval to ovate, 10-segmented, the last segment tubular. *Legs* short and stout, hind femora and tibiæ about equal, hairs everywhere inconspicuous except a few under 1/6 objective, which are the most prominent on last segments of antennæ.

THE PUPA.

First-stage pupa.—Length 0.56 mm.; width of head 0.15 mm.; width of mesothorax 0.18 mm.; width of abdomen 0.25 mm.; antennæ, length 0.2 mm. Color pale translucent yellow; antennæ, legs, and wing-pads lighter. Shape similar to advanced first-stage larva; abdomen elongate ovoid. Antennæ projecting cephalad, 4-segmented; I short, thick, slightly wider than long; II obtuse, urn-shaped, about as wide as long; III obtusely spool-shaped, about as

long as I and II combined and about twice as long as wide; IV about as long as III, tapering to obtuse apex. Wing-pads extending to distal margin of the second abdominal segment, those of hind wings slightly longer. Legs stout, hind femora and tibiæ about equal. Hairs present on live specimens but not prominent, short, slightly longer on tip of abdomen.

Second-stage pupa.—Length 0.666 mm.; width of head 0.133 mm.; width of prothorax 0.133 mm.; width of mesothorax 0.166 mm.; width of abdomen 0.133 mm. Shape similar to that of the adult. Color translucent white to pale yellowish; eyes reddish, more prominent than in first-stage pupa. Antennæ 4-segmented, projecting backward over the head and thorax and reaching to the middle of the prothorax, second segment forming a kind of elbow from which 3 or 4 long setæ project cephalad. Prothorax nearly twice as broad as long; wing-pads in pupæ just entering the second pupal stage extending to the distal margin of the sixth abdominal segment; in pupæ in which the adults are nearly ready to emerge the wing-pads extend to the distal margin of the ninth abdominal segment. Abdomen similar in shape to that of the adult. Legs stout, hind femora and tibiæ about equal in length, setæ more prominent than in first-stage pupa, longer at the tip of the abdomen; conspicuous in fresh specimens but not in mounted ones. Tip of abdomen often with a cremaster-like formation resembling in shape a fork with 4 tines. Male pupæ smaller, resembling the adults, their wing-pads usually reaching past the tip of the abdomen. Setæ usually not so prominent.

SEASONAL HISTORY.

The orange thrips passes the winter in the adult state, and it is generally the adult form which first becomes conspicuous upon the orange trees in the spring. Although no large number of adults has been collected in hibernation, these undoubtedly pass the winter in sheltered places, such as the dead leaves and twigs forming the trash under most orange trees; they are occasionally found on living plants and on citrus nursery stock in midwinter.

Adult thrips appear in limited numbers during March. They deposit very few eggs in the early part of April, prior to the blossoming of the Navel orange trees, but soon after most of the petals have fallen larvæ become quite numerous. Oviposition has not been observed, but it is probable that it takes place mostly at night. Examinations for eggs revealed the fact that most of them are placed in the new, tender growth, being inserted into both upper and lower leaf surfaces, and also in the shoots. They are also placed in the receptacles of the blossoms after the petals have fallen and in young fruit and fruit stems.

The larvæ are wingless and when full grown are orange colored. When ready to pupate they fall from the trees, get into a curled dead leaf, amid cobwebs, dust, and leaf particles, and hide until the transformation is completed. Pupæ are not found in numbers proportionate to the larvæ and adults, since it is in this stage that the mortality rate of the insect is greatest. The pupæ are very soft-bodied and less active than larvæ and adults. They move readily, however, when disturbed.

Eggs, larvæ, and adults are found on the trees, and pupæ in the dead leaves under them, from early May until early November, all four forms being present during the entire period. The broods thus overlap so closely that it is very difficult to separate them.

INTERRELATION OF ABUNDANCE OF THRIPS AND FOOD PLANTS.

The orange thrips feed only on very tender plant tissues, namely, the young leaves, shoots, and tender fruit. This makes it necessary for them to pass from foliage to fruit and from plant to plant as the suitability of the tissues as food changes. They first make their appearance in April and May on the new growth of the Navel orange, reaching the first maximum of abundance about the time four-fifths of the petals are off. When most of the petals have fallen a few thrips pass to the more advanced fruit and the number feeding on the latter rapidly increases as the first growth of foliage becomes hardened and distasteful. The thrips continue feeding on the fruit until the latter, in turn, becomes somewhat tough, and reach a second

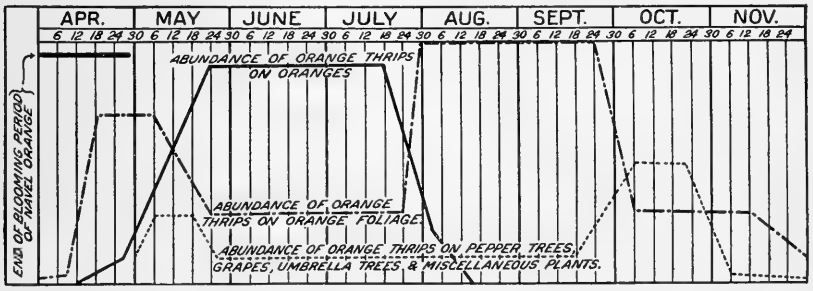


FIG. 1.—Diagram illustrating the relative abundance of orange thrips on oranges, on orange foliage, and on other plants during the season. (Original.)

and greater maximum in May, June, and July. They then pass once more to the succulent growth which has come on in the meantime, and reach the third and final maximum of concentration in August and September.

As the first citrus growths are becoming tough and before the fruit is quite tender, the thrips begin to work on the leaves of the grape, pepper tree, umbrella tree, and some uncultivated plants, reaching a minor maximum of abundance on these at the time of greatest abundance of tender leaves and stems. A second maximum of concentration is reached on some of these secondary food plants in the fall, when most all of the summer growths on citrus trees have become tough.

The relative abundance of the orange thrips on its various food plants, at different times during the season, is shown diagrammatically in the accompanying chart (fig. 1); the diagram represents the results of observations made at regular intervals in different parts of the Tulare County citrus belt.

LIFE CYCLE.

In ascertaining the length of the life cycle the average lengths of egg, larval, and pupal stages were added together, and to this an additional 3 days, which was the usual time from the appearance of the adult female until ovipositing began. The life cycle thus includes the period from egg to egg, or from the time the egg has left the abdomen of the female of one brood until the eggs of the next brood appear.

Egg stage.—The length of the egg stage was determined by confining adult thrips on potted orange plants overnight, then removing all insects and examining the plants twice daily, and counting the larvæ hatched until they cease to appear. The length of the egg stage of 19 eggs during the month of August, 1909, was found to be 2½ days for a minimum and 8 days for a maximum, with an average of 6.2 days. Eggs deposited the latter part of September required from 20 to 24 days for incubation. During May, June, July, and August, 1910, observations on 45 eggs gave a minimum of 5 days, a maximum of 13 days, and an average of 8.1 days for 3 months. It is probable that the majority of eggs deposited during May, June, July, and August would require from 6 to 8 days for incubation, while in March, April, September, and October the length of the egg stage would be considerably more.

Larval stage.—The number of days required for the development of the larva varied from a minimum of 3 days to a maximum of 13 days, with an average of 6.06 days for 55 individuals; and a minimum of 3 days, a maximum of 13 days, and an average of 7.2 days for 73 individuals during April, May, June, July, and August. The length of the larval stage would probably be extended, similar to the egg stage, during September and October. Two distinct larval stages were observed. The first stage is usually about two-thirds as long as the second, and the larvæ more active.

Pupal stage.—The pupal stage was best observed by keeping larvæ in confinement until they pupated. The total length of the pupal instar for 30 individuals, under observation during June and July, 1909, varied from 2 to 5 days, with an average of 3.6 days; while 287 observations during April to August, 1910, gave a variation of 2 to 7 days, with an average of 4.8 days. Two pupal stages were observed, there being a distinct molt from the first to the second stage, which begins with a splitting of the skin from the head back dorsally to about 7 to 9 abdominal segments. The pupæ are more active in the first than in the second stage.

Total life cycle.—The life cycle, obtained by adding the average lengths of egg, larval, and pupal stages, and allowing 3 days

before eggs were deposited by the newly formed adults, made a total of 18.68 days for May to August, inclusive, 1909. For the months April to August, inclusive, 1910, this period was 23 days. The length of the life cycle of 8 individuals actually recorded from the egg, upon potted plants, allowing 3 days, as before, for the adults to oviposit, varied from 20 to 36 days. The data upon the 8 individuals was obtained during September and October, and the life cycle was undoubtedly longer at this time than in midsummer. The length of life of the adults observed on confined individuals was from 4 to 36 days.

Number of broods.—Although the number of generations in a season has not been definitely observed, there are probably four and a partial fifth during the period of May to July, inclusive, and one generation in each of the months March, April, August, September, and October, making in all a possibility of eight to ten generations for the season.

HABITS.

The orange thrips is very active, especially in the adult form. Its ability to run, leap, and fly is much greater than that of any other thrips so far observed by the writers. This activity and their small size allow them easily to pass unobserved. The writers have frequently seen adults fly from one tree to another 20 feet or more distant. They undoubtedly move about to a certain extent, and will go from one orchard to another in search of suitable food. Frequently they will desert the orange groves, between periodical growths, for grapes and certain deciduous fruits.

The orange thrips appear to thrive best in sunny and even very hot weather. On cool cloudy days they are less active and generally group themselves on the underside of the leaves.

Their reproductive habits are only partially understood. Males are present part of the year, but usually in more limited numbers than the females.

EXPERIMENTS WITH METHODS OF CONTROL.

CULTIVATION.

Attempts have been made to control the orange thrips, in part, by means of cultivation, but none of these endeavors has been in the least successful. One orchard was hand-raked under the trees and the soil stirred up in the fall, with the hope that pupæ would be destroyed, but results were negative. Another orchard which was plowed deeply in the fall yielded similar results.

FUMIGATION.

Some experiments have been conducted in the hope that fumigation with hydrocyanic-acid gas would prove effective in controlling the orange thrips, but all results have been unsatisfactory, because of the activity of the insects, the large number of generations, and the expense of the operation.

SPRAYING.

The only method of control which has given good results is spraying at high pressure with a contact insecticide. No sprays aside from those which kill by contact have been tried because such sprays have been unsuccessful in controlling other species of injurious thrips.

Experiments to Determine Killing Effect of Different Sprays.

The following sprays were tested in the field for killing effect on the thrips: Homemade distillate-oil emulsion, in combination with black-leaf tobacco extract, which is a dark, almost viscid liquid containing $2\frac{3}{4}$ per cent nicotine; and commercial lime-sulphur (33° Baumé) in combination with the tobacco extract. All sprays were applied with a hand pump, maintaining a pressure of 140 pounds. A large number of young fruit was examined for live and dead thrips. While this method did not give absolutely accurate results, because of the number of thrips knocked off by the force of the spray, it offered some means of comparison. Table I shows the relative killing effect of the various washes:

Table I.—*Killing effect of various sprays on orange thrips.*

Number of fruits examined.	Formula.	Total number of thrips counted.	Number of thrips dead.	Percentage of thrips dead.
150	Blackleaf 1–50 and distillate-oil emulsion 1 per cent	129	126	97.6
200	Blackleaf 1–60 and distillate-oil emulsion 1 per cent	182	170	93.4
100	Blackleaf 1–80 and distillate-oil emulsion 1 per cent	67	64	92.5
Several hundred	Blackleaf 1–85 and distillate-oil emulsion 1 per cent			75
Do	Commercial lime sulphur 1–75 and blackleaf 1–50			90
Do	Commercial lime-sulphur 1–50 and blackleaf 1–100			95

Experiments to Prevent Marking of the Fruit.

Experiment No. I.—A block of 150 Washington Navel orange trees was sprayed three times with distillate-oil emulsion and blackleaf tobacco extract; the former at the strength of 2 per cent and the latter in the proportions of 1 to 80 and 1 to 100 parts of spray. The spraying was tried as a means of preventing the thrips from curling the tender foliage and marking the young fruit. The first application was made May 4, 1909, after most of the petals had fallen

and when both larvæ and adults were present. The second application was made eight days later, and the third three weeks after the second, at which time the thrips began again to be numerous. All the spraying was done with a hand outfit, maintaining a pressure of 140 pounds.

In recording the results of the spray applications to ascertain their efficiency it was necessary to class the fruit, as regards injury, in four grades, as follows:

Sound: No thrips marking.

Slightly marked: A slight marking at one end or a few streaks on the surface.

Moderately marked: Both ends of fruit marked and some scabbing on the rest of the surface.

Badly marked: Nearly one-half to three-fourths of the surface marked, often with misshapen fruit.

At picking time 20 loose, or "lug," boxes of oranges from the sprayed trees and 20 from an adjoining block of unsprayed trees were counted. The results obtained are given in Table II.

TABLE II.—*Injury to sprayed and unsprayed fruit by orange thrips.*

SPRAYED.

Number of loose boxes.	Total number of oranges examined.	Number sound.	Number slightly marked.	Number moderately marked.	Number badly marked.	Per cent of sound fruit.	Per cent of slightly marked fruit.	Per cent of moderately marked fruit.	Per cent of badly marked fruit.
20	2,070	1,533	506	31	.....	74.5	24.5	1	0

UNSPRAYED.

20	2,365	337	1,047	710	271	14.5	44.5	30	11

A commercial grading of the sprayed fruit would have placed nearly 75 per cent as "Fancy" and the remainder as "Choice," while the unsprayed fruit would have run not more than 15 per cent "Fancy" and 50 per cent "Choice," the remainder going out as "Standards" and "Culls." Of the fruit counted from the unsprayed trees, 85.5 per cent was marked, while 25.5 per cent only of that from the sprayed trees showed injury, indicating that 60 per cent of the sound fruit was due to the spraying. The thrips-marked fruit was smaller than the sound fruit, as will be seen by comparing the total number of oranges from the 20 boxes of sprayed fruit with that from the 20 boxes of unsprayed fruit. The writers have frequently noticed in the packing houses that the smaller fruit is worse marked than the larger, making it appear that the thrips injury holds back the growth of the oranges.

The sprayed block contained 121 bearing trees. These yielded 165 loose boxes of oranges. The unsprayed block contained 152 bearing trees, which yielded 162 loose boxes of oranges. The sprayed block, therefore, produced three more boxes of fruit, though containing 31 less trees, than the unsprayed block.

Experiment No. II.—A block of Washington Navel oranges embracing about 5 acres was selected in the spring of 1910 and treated three times with a spray of commercial lime-sulphur (33° Baumé), 1 part to 75 of water, combined with blackleaf tobacco extract, 1 to 150. A gasoline power sprayer was used and a pressure of 200 pounds maintained. The first application was made May 4, the second May 17, and the third June 14. The first application was timed at a date when most of the petals had fallen. The second and third applications were made when the thrips became sufficiently numerous. An effort was made to keep the young fruit free from thrips until it was the size of an English walnut, as it appeared that this would insure a high percentage of clean fruit.

Examinations and counts made of 92 loose boxes of sprayed fruit and 20 loose boxes of unsprayed fruit from an adjoining unsprayed "check" block gave the results shown in Table III.

TABLE III.—*Injury to sprayed and unsprayed fruit by orange thrips.*

SPRAYED.

Number of loose boxes.	Total number of oranges examined.	Number sound.	Number slightly marked.	Number moderately marked.	Number badly marked.	Per cent of sound fruit.	Per cent of slightly marked fruit.	Per cent of moderately marked fruit.	Per cent of badly marked fruit.
92	8,458	4,995	3,383	68	12	59	39.9	1	0

UNSPRAYED.

20	1,697	498	1,108	65	26	29.3	65.2	3.8	1.5

The sprayed fruit shows a total of 40.9 per cent marked, while 71 per cent of the unsprayed fruit was marked, and more severely. The amount of benefit due to the spraying was 30.1 per cent, which was considerably less than in 1909, due to the fact that the thrips were more numerous and infestation worse in 1909. The total output of oranges from Tulare County in 1910 was 50 per cent freer from thrips markings than in 1909.

EXPERIMENTS WITH NURSERY TREES.

Several blocks of young nursery trees were sprayed in the fall of 1909 with commercial lime-sulphur, 1 to 75, combined with blackleaf tobacco extract, 1 to 150. By two thorough applications it was

possible to save the tender foliage and axillary buds and to promote a growth of 1 to 2 feet more on the sprayed trees than on those unsprayed.

Spray Injury.

While no actual spray injury, immediate or cumulative, developed from the use of distillate-oil emulsion and blackleaf tobacco extract at the strengths indicated above, the uncertainty of this combination as compared with the lime-sulphur and blackleaf tobacco extract led to the adoption of the latter as a spray for demonstration work during the season of 1910.

RECOMMENDATIONS.

In view of the success attained in reducing injury to fruit and foliage by the orange thrips, it is believed that it will be possible to control this species in normal seasons with four applications of lime-sulphur combined with blackleaf tobacco extract.

Time of Application.

Three of the treatments should be made in the spring to free the fruit and spring growths of foliage from injury, since the more severe marking of fruit is done while the fruit is small. The fourth treatment should be made in August or September, according to season, for the protection of the later growths of foliage, and should be timed to catch the thrips when numerous, but before the leaves show much curling. The three spring applications should be made about as follows:

First. Just after most of the petals have fallen from the blossoms.
Second. Ten to fourteen days after the first.
Third. From three to four weeks from the time of the second treatment.

The dates for spraying in any given season must be timed by the abundance of thrips.

Spray Dilutions.

Lime-sulphur solutions should be diluted according to density. In the homemade product this may be determined by the use of a Baumé or a specific gravity spindle. The density of the commercial product will be stated by the manufacturer or may be obtained by the use of the spindle.

Lime-sulphur solution of a density of 33° Baumé should be diluted at the rate of 1 volume to 75 volumes of water; that of a density of 36° Baumé should be diluted at the rate of 1 volume to 86 volumes of water. Therefore the formula for orange-thrips spraying would be:

(1) Lime-sulphur (33° Baumé) 1 to 75 and blackleaf tobacco extract (2¾ per cent nicotine) 1 to 100; or, using blackleaf "40" (40 per cent nicotine) tobacco extract 1 to 1,800.

(2) If lime-sulphur of 36° Baumé is used the formula would be, lime-sulphur 1 to 86 and blackleaf tobacco extract 1 to 100; or blackleaf tobacco extract "40" (40 per cent nicotine) 1 to 1,800.

To load a sprayer having a 200-gallon tank, proceed as follows: First turn water into the tank until nearly full, add 2⅔ gallons lime-sulphur (33° Baumé) and 2 gallons blackleaf tobacco extract (2¾ per cent nicotine); or 14 fluid ounces blackleaf "40" tobacco extract (40 per cent nicotine). If the lime-sulphur is 36° Baumé, use 2.1

FIG. 2.—Power spraying outfit in use in spraying for the orange thrips. (Original.)

gallons, and 2 gallons of blackleaf tobacco extract; or 14 fluid ounces of blackleaf "40" tobacco extract.

HOW TO SPRAY.

In spraying for the orange thrips only those insects actually hit with the spray will be killed. As this insect obtains its food by sucking the plant juices, stomach poisons are of no avail. In order to spray with greatest efficiency it is necessary to use a gasoline power sprayer, maintaining a pressure of 180 to 200 pounds. (See fig. 2, showing a power outfit in operation.) Angles or elbows should be used on all spray rods so that "overshot" and "undershot" spraying can be done; that is, spraying from above downward, and from below up-

ward to reach the lower surface of the leaves. The trees should be drenched until they drip freely.

Especial care should be taken with the outside fruit as the thrips scar this badly, but cause little or no injury to inside fruit.

Either chamber nozzles of the Cyclone type or Bordeaux nozzles may be used. If the former are used, disks with holes of about $\frac{3}{32}$ inch diameter will be best. Double nozzles can be used to advantage on large trees, and will save time. It is preferable to use two lines of hose as this will insure more thorough work than where four leads are used. A majority of orange growers fail to apply a sufficient number of gallons of spray per tree. The following table will show approximately the correct amount to apply, and will enable those intending to spray to estimate the quantity of spray material needed for the season:

TABLE IV.—*Quantities of liquid required in spraying for orange thrips.*

Age of trees.	One application.		Total gallons of diluted spray per acre of 100 trees, 4 applications.
	Gallons diluted spray per tree.	Gallons per acre of 100 trees.	
Years.			
2–3.....	2	200	800
5–7.....	4	400	1,600
8–10....	5	500	2,000
12–14...	8	800	3,200

SUMMARY.

The orange thrips, a minute, orange-yellow insect of the order Thysanoptera, curls the leaves and scars the fruit of citrus trees in the San Joaquin Valley of California, the southern California orange belt, and the Salt River Valley of Arizona.

Although this insect has been known by its work for some fifteen or sixteen years it has but recently been described, and it has now become of serious economic importance in the orange belt of the San Joaquin Valley of California.

The orange thrips has numerous generations yearly, its life cycle requiring approximately 20 days, and it is to be found upon the orange trees from March to November.

It can be controlled by four sprayings of lime-sulphur solution combined with a commercial tobacco extract, which should be applied when the thrips become sufficiently numerous. Three applications should be made in the spring months to save the fruit and spring

growths from injury, and one in the fall to lessen the feeding injury to the fall growth of the orange trees.

From two to eight gallons of this combination spray should be applied per tree, at a high pressure, and in a very thorough manner, as only thrips that are hit will be killed.

Experiments in spraying have shown that three thorough applications at the proper times have resulted in from 20 per cent to 60 per cent more "fancy" fruit in the sprayed as compared with the unsprayed blocks.