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CONTROL OF THE CITROPHILUS MEALYBUG.[1]

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INTRODUCTION.

In the fall of 1913 a mealybug infestation was noted on citrus at Upland, Calif., over an area of approximately 3 acres. At first it was assumed to be the common mealybug (*Pseudococcus citri* Risso), a species highly damaging in some citrus localities but never before reported in the Upland district. Growers were considerably alarmed over the discovery, knowing the severity of this pest and the ineffectiveness of control in other localities. Considerable damage was done to the infested groves in a hasty attempt at eradication by fumigation. At a convention held at Ontario, Calif., on January 30, 1914, the seriousness of the problem was discussed, although no real solution was evolved. A specific determination was made at this time by Essig[4] as Baker's mealybug (*Pseudococcus maritimus* Ehrh.), a species then considered as of minor importance to citrus. In September, 1915, Clausen,[5] after a brief investigation of the insect,

[1] *Pseudococcus gahani* Green; order Hemiptera, suborder Homoptera, family Coccidæ.
[2] Resigned September 11, 1920.
[3] Resigned December 5, 1921.
[4] Essig, E. O. The mealy bugs of California. *In* Calif. Mo. Bul., v. 3, no. 3, p. 110–111. 1914.
[5] Clausen, Curtis P. Mealy bugs of citrus trees. Univ. of Calif., Bul. 258, p. 30–35. 1915.

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considered it a new species and gave it the name *P. citrophilus*. During the first four years various measures of control were tried by the growers and county and State officials without any marked success; in fact, the infested area continued to increase rapidly and the infestations became more severe.

The importance of this pest to the citrus industry and inability to control it led, in the summer of 1917, to a request for the United States Department of Agriculture to take up the problem, and the investigation was immediately started. Effective control methods were worked out in 1917 and 1918 and were generally employed throughout the infested area during 1919.

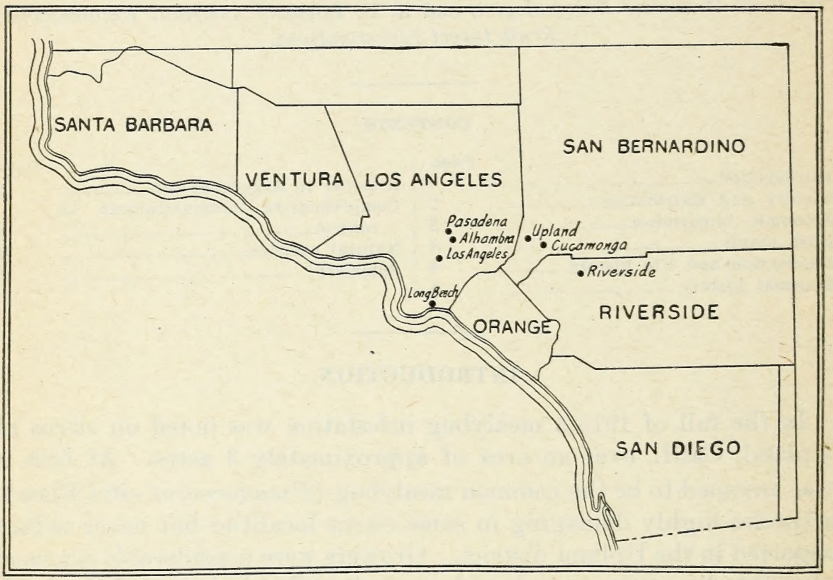

FIG. 1.—Present known distribution of the citrophilus mealybug (*Pseudococcus gahani*) in Southern California.

HISTORY AND DISTRIBUTION.

Definite records of the introduction of this mealybug into Southern California are lacking, but a study of its earliest occurrence and spread would indicate that it was brought in on some ornamental plants imported into Upland during 1910. The infestation of about 3 acres at the time of the first records (1913) had spread by the fall of 1915 to twice that area. By 1917 approximately 600 acres were infested, but since that time its spread has been greatly retarded by control means, though a few small infestations outside of the control area have been noted (fig. 1).

Shortly after the discovery of the Upland infestation the pest was found in Pasadena and has now become distributed over a consider-

able area in the northern part of the city. In 1916 over 100 acres of citrus were found to be infested at Riverside, and at the present time this infestation covers approximately 250 acres. Smaller infestations are recorded at Cucamonga and Alhambra on citrus. It is reported at Long Beach and Los Angeles on ornamentals and occurs in the northern part of the State in the San Francisco Bay region.

There is little probability of distribution by natural travel as the insect remains close to its host. The more important means of distribution are the picking boxes, picking sacks, clothing of the pickers and pruners, teams, wagons, and ladders; of slightly less importance is distribution by wind, birds, and insects. Several new infestations have been definitely traced to distribution through picking boxes previously used to transport infested fruit.

ECONOMIC IMPORTANCE.

In a severe infestation the mealybug not only masses on the twigs and foliage but also on the fruit. These masses may even cover from one-half to two-thirds of the surface and hang down in cottony festoons from the bud end. Such masses are common on severely infested lemons and on navel oranges, in the case of the latter particularly at the navel end. Where two fruits touch, a similar favored area of infestation is formed, especially on grapefruit and lemons. On young green fruit the immature forms crowd under the sepals, weakening the supporting tissues and influencing premature drop. The insects are also found in numbers on the young succulent new growth and sucker growth.

They secrete a honeydew which falls to the foliage or fruit below and in this medium grows a black fungus commonly known as "smut." The fruit and foliage become so black with this deposit as greatly to retard their development and to necessitate a special washing before the fruit can be packed.

The combination of the attack of the insects under the sepals and the deposit of "smut" frequently causes a heavy dropping of young, green fruit and also of the mature fruit, if held long on the trees. The deposit on the foliage results in a heavy leaf drop, often an almost complete defoliation of the tree. The feeding of the insects on the fruit destroys its natural gloss and often causes deep brown pittings in the rind which seriously affect the grading of the fruit. One packing-house manager reported a lowering of the grades from one severely infested orchard of from 30 to 40 per cent of the highest classed fruit. The lower grades are also seriously affected and frequently fall to culls, or unmarketable fruit. Severe infestations on lemons have been known to result in an almost complete loss of the crop, the fruit grading as culls.

HOST PLANTS.

The citrophilus mealybug is of importance commercially principally because of its infestation of citrus plants. The insect does occur, however, on a large number of other plants, principally ornamentals, upward of 30 different species being listed as hosts. On the citrus fruits it possibly shows its most rapid development on lemons, followered by grapefruit, navel oranges, and Valencia oranges, in the order given. It has been observed to develop very rapidly on the rhubarb, potato, grevillea, walnut, grape, and on species of Coleus and Pittosporum.

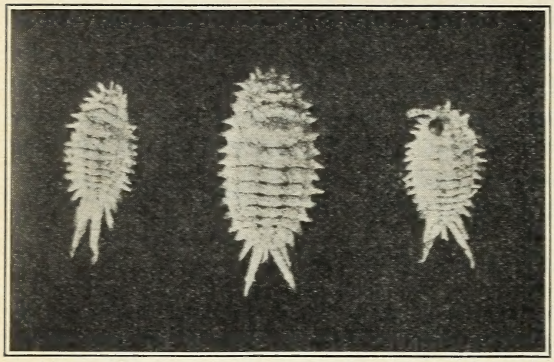

FIG. 2.—The citrophilus mealybug: Immature stages of the female.

DESCRIPTION AND LIFE HISTORY.

The synonymy of the citrophilus mealybug was first correctly determinated by G. F. Ferris in August of 1919.[6] As stated, this insect was first confused with the common mealybug and later, by Essig, with Baker's mealybug. Clausen, in September, 1915, noted certain differences in him to describe it as characters which led a new species (*P. citrophilus*) but Ferris found that the same insect had been described by Mr. E. E. Green during May, 1915, as *P. gahani* from specimens taken from *Ribes sanguinea* in London, England. Un-

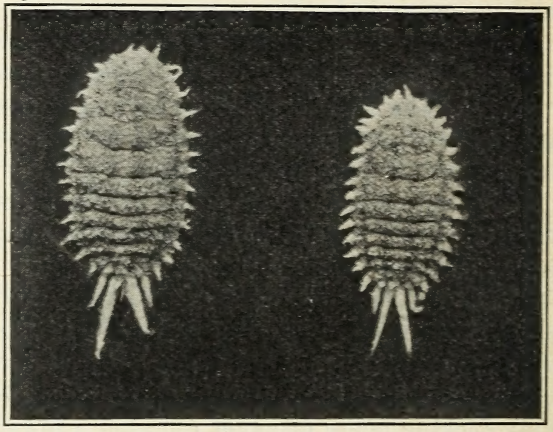

FIG. 3.—The citrophilus mealybug: Mature stages of the female.

[6] FERRIS, G. F. OBSERVATIONS ON SOME MEALY-BUGS (HEMIPTERA; COCCIDAE). *In* Jour. Econ. Ent., v. 12, no. 4, p. 292–293. 1919.

fortunately the scientific name *citrophilus* had been adopted as the common name long before the correct determination was given.

The eggs are deposited in a flocculent mass behind the adult female and may number up to 1,000, though from 500 to 600 is the average. The period of incubation during the warm season is from 7 to 10 days.

Except in size, the larvæ are similar to the adult in appearance after the first molt and pass through three molts before reaching maturity. The characteristic arrangement of the wax is not strikingly noticeable until after the third molt. The immature stages of the female are illustrated in figure 2, the mature stages in figure 3.

The following description of the adult of *Pseudococcus gahani* is by Mr. E. E. Green:[7]

Adult female thickly coated with greyish-white mealy secretion, which is thinner in the folds of the segments and in the depressed areas. These depressions are in four more or less confluent longitudinal series which are more marked on the posterior half of the body. The darker color of the insect showing through the mealy covering at these spots, produces a distinct symmetrical pattern. There is a complete marginal series of 33 short conical waxy processes, an anterior and posterior pair being usually larger than the others. On each side of the anal orifice is a much longer, broadly laminate process which is transversely curved and spirally twisted, and between these is a pair of shorter processes, which together form a tube. Antenna, 8-jointed, the 8th longest; first joint strongly developed, approximately as long as it is broad; antennal formula (excluding 1st), 8 (3,2), (5,4,6,7), the last four being only approximately equal and varying slightly in their relative positions in the series. Limbs well developed; tarsus approximately half the length of the tibiae. Eyes prominent. Mentum distinctly biarticulate; longer than broad; terminal joint longest, acutely pointed. Dorsal glandular pits present but rather inconspicuous. Anal ring large and conspicuous, with six long stout setae. Anal lobes broadly rounded; only slightly prominent; more strongly chitinized than the surrounding parts, the margins of the chitinous area sharply defined; each with two stout conical spines, several fine hairs, some conspicuous circular pores, and a terminal seta which is approximately equal in length to those of the anal ring. Margins of segments, each with a small protuberance, bearing similar spines, pores and hairs, all of which become smaller and less conspicuous as they approach the anterior extremity. Derm with scattered, small, and inconspicuous pores. Many longish hairs on under-surface of head. Length, 2.50 to 3 mm. Breadth, 1.25 to 1.50 mm.

Adult male similar in appearance to that of *Ps. citri*. Length, 1.50 mm.

Though the structural characters agree somewhat closely with those of *citri*, the general appearance of the living insect is strikingly different, and it is of a much more active habit. * * *

Mr. Gahan observes that the insect, when irritated, exudes "a claret coloured liquid in round drops, two close to the head end and two at the tail end." The exudation evidently emanates from the glandular pits that are present in the positions indicated. He further remarks that the "dark-coloured secretion soon dries, looking like a small balloon. The liquid hardens into a solid substance which resembles lac or something of a similar nature."

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[7] GREEN, E. E. OBSERVATIONS ON BRITISH COCCIDAE IN 1914, WITH DESCRIPTIONS OF NEW SPECIES. *In* Ent. Mo. Mag., v. 51, p. 179–180. 1915.

SEASONAL HISTORY.

A most important feature in the biology of this insect was determined by observing the habits of the insect during the spring migration. The females, which during the winter have developed almost to maturity on the twigs, foliage, and fruit, migrate, in the spring, down the limbs to the trunk to oviposit. This migration usually begins during the early part of April and continues throughout the month of May. It is estimated that over 90 per cent of the insects take part in this movement, although not all have reached full development at this time. They settle on the rough places in the bark of the main limbs and trunk and soon begin ovipositing. On severely infested trees these accumulations of females with their cottony egg masses appear as large bunches of cotton hanging from the limbs and massed about the trunk and may be collected by handfuls. (Fig. 4.) These egg masses begin to hatch the latter part of May or early part of June, and the young larvæ start a migration back up the main limbs to the foliage and green fruit. The young settle along the midribs of young foliage, on the tenderest twigs, and under the sepals of the green fruit. Here they start feeding and their development is comparatively slow. By late fall many have become half grown and have settled in the more secure positions on the bud end or navel end of the fruit or between the fruit in clusters, and their development from then on is very irregular. During the winter many may have reached the oviposition stage, but the majority of the insects are still immature. There is a great reduction of numbers throughout the late fall and winter; in fact, on many trees it is often difficult to find them, but with the opening of spring the matured forms again enter into the migration. There is only one main generation a year, although the retarded development of some insects and the hastened development of others cause an overlapping of generations and consequently the presence of some insects in various stages of development at different times of the year. There is a possibility of an offhatch or overlapping of generations in the appearance of egg masses during the winter. This occurrence, however, is of minor importance in that the numbers of the mealybug are at their lowest at this time and most of the damage to the host has already occurred.

The young larvæ hatching from the egg masses in June are often killed by hot weather. In the summer of 1917 a very large percentage of the larvæ and eggs were destroyed by a short period of hot weather when the temperature exceeded 110° F. Again in the summer of 1918 the hatching occurred just before a warm spell and many larvæ were killed. That weather conditions and natural enemies are powerful factors in the control of this mealybug is very evident,

for only a small percentage of the larvæ hatching from the egg masses ever reach maturity. Many are washed off and destroyed by

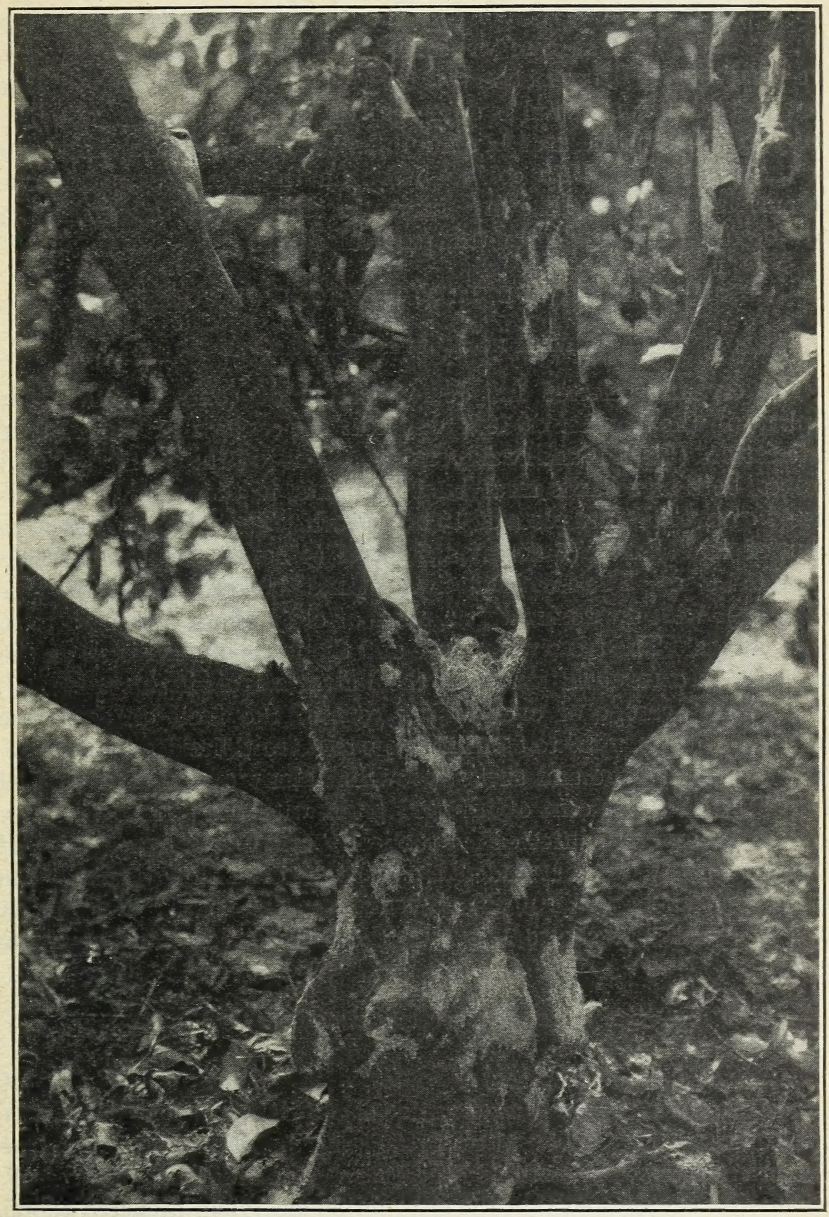

FIG. 4.—Trunk of lemon tree showing masses of ovipositing females of the citrophilus mealybug following the spring migration.

rain during the winter months and the development of others is greatly retarded during this cooler period.

RELATION TO ARGENTINE ANT.

In not a single instance has this mealybug become serious excepting where it has been attended by the Argentine ant (*Iridomyrmex humilis* Mayr). One case was noted in 1918 at Cucamonga where the mealybug had been observed for several years previous to that time, but never considered as doing any commercial damage. During the year 1918–19 the area became infested with Argentine ants and in the summer of 1919 control work on the mealybugs and ants became imperative. In every known locality where this mealybug now occurs it is attended by this particular ant.

COMPREHENSIVE DEMONSTRATIONS OF CONTROL.

EXPERIMENT NO. 1. DEMONSTRATION PLOT.

The orchard selected for demonstration of control methods at Upland in the summer of 1917 was near the center of the mealybug infestation (fig. 5) and was considered one of the worst infested groves, both as regards mealybugs and ants, in the colony. It consisted of two distinct plots of 10 acres each. The first 10 acres were planted to Valencia (6 acres) and navel (4 acres) oranges and had in all 674 trees. The second plot was planted largely to navel oranges (8 acres), with approximately 2 acres of old lemons, making a total of 676 trees. The trees were large and the lower limbs rested on the ground. A careful inspection of the Valencia fruit in August, 1917, showed an average of over 50 per cent of the fruit on each tree infested, with from 20 to 35 mealybugs to a fruit, besides the infestations on the foliage and sucker growth. Many of the trees carried from 90 to 100 per cent of infested fruit, with the foliage and new growth as severely infested. Practically every tree had a trail of ants and many were attended by two and even three trails. The infestation on navel oranges and lemons in the second 10-acre plot was as severe but showed only on the small green fruit and new growth.

Argentine Ant Eradication.

Investigations, by the senior writer, of the common mealybug of citrus trees resulted in the discovery that this insect was effectively controlled by natural enemies, principally predators, in Argentine ant-infested territory provided the ants were eliminated. Therefore, when a survey showed that the citrophilus mealybug occurred exclusively in districts frequented by these ants, the first efforts were confined to a campaign against the ant in the hope that only such activity would be necessary, as had proved the case for the common mealybug.

The first operation undertaken was the trimming up of the branches from the ground so as to force the ants to ascend the trunks where the poison was placed. Two men trimming averaged 78 trees per day of 8 hours at a cost of approximately 8 cents per tree. The orchard was in a state of clean cultivation and entirely free of weeds beneath the trees.

Ant control was begun on about 1 acre of the first 10 in September, and the remainder completed by October 5, 1917. The second 10 was covered by ant control in November, 1917. An arsenical-sweetened sirup, known as the Barber formula, was used for the first distribution in this orchard, a small amount being placed in each container, one of which was attached to each tree. (Fig. 6.) Complete eradication was effected the following spring at a cost of 2.6 cents per tree on the first 10 acres and at a cost of 4.9 cents per tree on the second 10 acres. The control is summarized in Table 1.

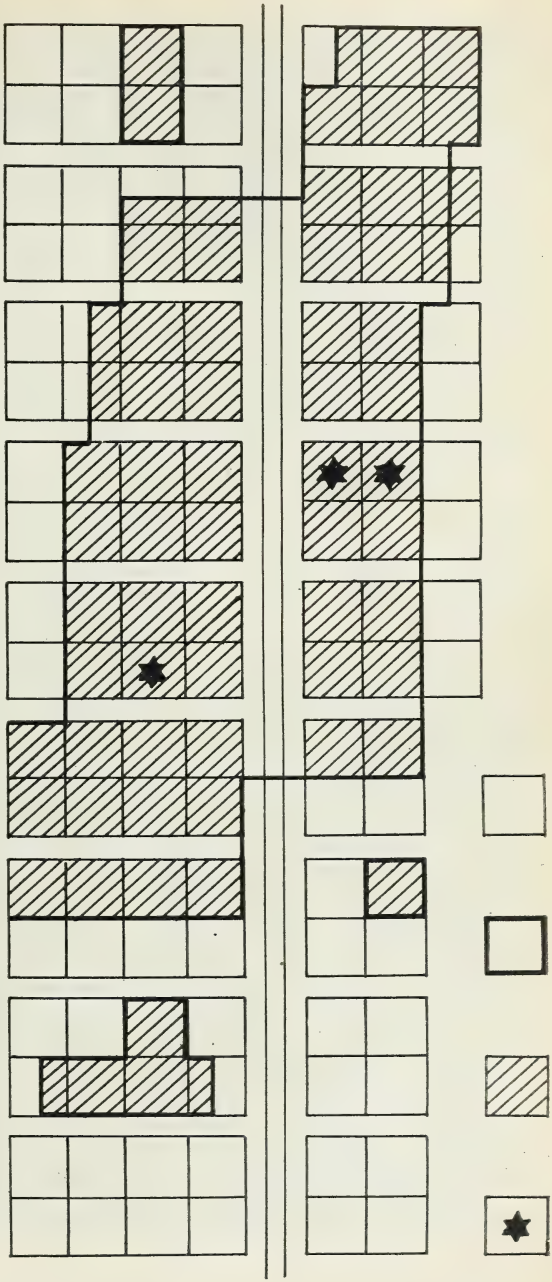

FIG. 5.—Citrophilus mealybug control areas, Upland district, 1917–1919.

FIG. 6.—Tree trunk showing burlap band and ant poisoned-sirup can in position.

TABLE 1.—*Control of the Argentine ant in a citrus orchard at Upland, Calif., 1917.*

DEMONSTRATION PLOT, FIRST 10 ACRES, 674 TREES.

Date of inspection.	Poison distributed.	Trees with ants.					Check area.				
		Clean.	Very light trail.	Light trail.	Medium trail.	Heavy trail.	Clean.	Very light.	Light.	Medium.	Heavy.
Sept. 23		5	99	312	133	125					
	Oct. 5	Over entire area.									
Mar. 24		671		3							
	Apr. 9	Only on trees with ants.									
Apr. 9		648	20	6							
	June 17	Only on trees with ants.									
June 17		642	17	15							
June 29		672	2								

DEMONSTRATION PLOT, SECOND 10 ACRES, 676 TREES.

Sept. 23		2	157	266	107	68		9	23	20	24
	Nov. 5	On 600 trees.					Trap nest under 76 trees.				
Mar. 20		391	119	61	15	14	8		19	23	26
	Apr. 1	On 600 trees.									
	Apr. 5						On 76 trees.				
Apr. 30		546	39	10	4	1	57	13	5	1	0
June 11		577	18	5	0	0	75	1	0	0	0
June 29		593	7	0	0	0	76	0	0	0	0

BURLAP BANDING.

Although by winter the ants were controlled and early the following spring were almost completely eradicated, the mealybugs continued in severe infestations and during the latter part of March were noted to begin descending the tree trunks. The descent continued to increase in April and no large number of natural enemies appeared as was anticipated. It soon appeared that elimination of the ant was not alone sufficient to bring about control of the citrophilus mealybug, as had proved the case for the common mealybug. The citrophilus mealybug species was not attacked by either numerous or effective natural enemies. The necessity of artificial means of control to supplement ant eradication was thus at once apparent.

A study of the habits of this mealybug showed a spring migration to the trunk and rough places on the main branches where egg masses for the succeeding generation are deposited. The accumulation of insects and egg masses in cases of severe infestations, as previously pointed out, became so great as frequently to present the appearance of large tufts of cotton. This massing on the trunk and lower branches presented a favorable point of attack and the spraying of these masses with an effective insecticide promised a great reduction of the total insects present. It was noted, in the case of some trees which had been banded with cotton bands by an orchardist at Upland in 1915, that these acted to attract the ovipositing females beneath them in great masses. Since cotton bands were scattered by the winds and birds, it was decided to substitute burlap and ac-

FIG. 7.—Trunk of lemon tree with burlap band removed showing masses of ovipositing females of the citrophilus mealybug collected under band.

cordingly in the spring of 1918 the trees in the demonstration orchard were thus banded. (Fig. 6.) A band of burlap about 6 inches wide was wound around the trunk just below the main branches and caught at each end with a finishing nail. The migrating females

readily collected under the bands preparatory to oviposition. (Fig. 7.)

The success of burlap bands as used on the demonstration plot led the growers throughout the infested area to adopt the practice. This necessitated a large supply of burlap bands and the problem was solved by buying the burlap of 30-inch width in bolts of about 100 yards. The bolts were cut at a printing office under a large paper knife into six rolls, 5 inches in width, which could readily be carried into the orchard and cut in appropriate lengths for individual trees. The ends of each band were fastened over a 4d finishing nail driven into the trunk of the tree. The average orchard of 900 trees was banded with one full bolt of burlap. The average cost in 1919 was as follows:

1 roll burlap (100 yards)	$12.60
Cutting	1.00
Nails	.15
Labor (1 man, 1 day)	3.00
	16.75

Cost per tree, approximately $0.02.

During April and May insects continued to descend in great numbers, the burlap bands proving a center of attraction. In cases of light infestation the majority of the descending insects would settle beneath the band, and this was particularly true on smooth-barked orange trees. (Fig. 8.) Lemon trees with the more irregular trunks and depressions where the main branches join the trunks offered favored places for the mealybugs to settle, although even these seemed less favored by them than the bands. By the latter part of May hatching started, following which the larvæ migrated back to the foliage and fruit on the tree. Before this happened the bands were removed and dipped in an effective insecticide, usually pure petroleum distillate, and the trunks were then sprayed.

Spraying.

Spraying operations on the first 10 acres were conducted on May 23 and 24, and on June 6 and 7 on the second 10 acres. Only the main limbs and trunks were sprayed and for this a petroleum distillate-soap emulsion applied with a power sprayer at 150 pounds pressure proved most satisfactory. Two leads of hose with angled Bordeaux nozzles were used. The burlap bands were removed and thoroughly sprayed as the trunks were being sprayed. The formula used was as follows:

Distillate 28° to 30° B	gallons	10
Soap powder	pounds	20
Water to make	gallons	200

If a lighter oil, as stove distillate, is used, the amount should be increased to 15 gallons. A good agitator is necessary in mixing the spray. After a few

inches of water are in the bottom of the tank, the soap powder is sifted in as the tank is being filled and the agitator is running. The oil is added last before the tank is full.

FIG. 8.—Three burlap bands from the trunks of orange trees following spring migration of the citrophilus mealybug.

It was felt that the spraying of the bands was not entirely satisfactory unless the greatest care was used, so in subsequent work it was decided to dip them just before spraying. The application, to

be effective, must be thorough and to accomplish this it is necessary to go beneath the tree. The most satisfactory work was done when the nozzle was connected directly to the hose, allowing free manipulation in any direction. A long rod should never be used as it does not allow the ready manipulation necessary on heavily branched trees to spray from any direction.

The trees on the demonstration plot were of an open type with smooth trunks and high headed, so they could be entered with ease and quickly and thoroughly covered with spray. It required only 3½ tanks of spray to cover each of the 10 acres. The cost (1918) is summarized herewith:

35 gallons distillate, at $0.05 per gallon	$1.75
70 pounds soap powder, at $0.05 per pound	3.50
Team and teamster for 1½ days	9.00
Two men spraying for 1½ days	9.00
Gasoline and oil	1.25
Total	24.50

Cost per tree, $0.036.

The time, 1½ days, included considerable engine trouble. Fifty-two trees were sprayed in 30 minutes. A tank of spray (200 gallons) covered approximately 200 trees.

Several days after the spraying the burlap bands, now dry, were replaced on the tree trunks and left for a year. At no time were insects noted under the bands except an occasional one, which the natural enemies destroyed before oviposition was completed.

Throughout the following fall and winter (1918–19) it was very difficult to find even individual mealybugs, and the packing house handling the fruit reported it to be cleaner than any that had been turned in during the five preceding years, with an increase of grade amounting to from 30 to 40 per cent.

During the spring of 1919 an inspection was made of the demonstration plot and very few mealybugs and no ants were found. Under the old bands not more than 10 to 12 insects were found on any one tree. The grove was sprayed again by the owner in June of 1919, as outlined above. An inspection in May, 1920, showed a practically clean grove, not more than 5 insects being found under the bands of any tree, and most of the trees were entirely free of mealybugs.

EXPERIMENT NO. 2. FARLOW GROVE, 888 TREES.

In the summer of 1919 a second demonstration plot was employed which consisted of 10 acres of heavily infested oranges. Ant control and banding had been carried on the previous spring, and the ants were greatly reduced at the time of spraying. In this grove, as in the former, a power sprayer with two leads of hose and Bordeaux

nozzles were used. Distillate-soap powder emulsion, soap powder, and water were used, as shown in Table 2, and data were gathered on the efficiency of the different solutions.

Before the spraying started a man was sent through to remove the heavily infested bands, dip them in pure distillate, wring them out, and place them to one side to dry.

TABLE 2.—*Summary of spray operations against the citrophilus mealybug.*

Spray.	Total number of trees sprayed.	Average number of trees per tank.	Average spray time per tank.	Average number of gallons per tree.	Effectiveness of spray.
			Min.		
5 per cent distillate-soap powder emulsion	777	59	58	3.4	Excellent.
Water	69	34	85	5.7	Poor.
40 pounds soap to 200 gallons water	42	42	45	4.8	Do.

Both the water and soap-powder treatments were discontinued, as it was found to be impractical in application to get a thorough clean-up of the egg masses. The distillate-soap emulsion was quicker in application and more effective.

The bands were replaced shortly after the completion of the spray work, and field observations made from time to time throughout the following year. Though some mealybugs appeared under the bands following the spraying, they were completely controlled by natural enemies and required no further treatment. Throughout the fall and winter no mealybugs were apparent, and in the spring of 1920 so few mealybugs appeared under the bands that hand treatment was all that was required. The grove is now commercially clean, and there has been a marked increase in the grade of the fruit.

The data obtained in this experiment not only demonstrated the practicability and efficiency of the distillate-soap emulsion but also demonstrated the advisability of proper pruning before spraying. The trees on this grove were low on the ground and it was difficult to treat the trunks owing to low branching and inside growth. In consequence of this condition it took much more material and a longer time to make the application. The cost of spraying was as follows:

Removing and dipping bands, 1 man, 1 day	$3.00
16½ tanks spray:	
330 pounds soap powder, at $0.07 per pound	23.10
165 gallons distillate, at $0.07 per gallon	11.55
Two men, at $4 per day, 2 days	16.00
Team, at $4 per day, 2 days	8.00
Gasoline and oil, 2 days	2.50
Total	64.15

Cost of $0.072 per tree.

HAND-TREATMENT METHOD.

In a 5-acre citrus orchard, comparatively lightly infested with mealybugs and banded early in the spring of 1919, the hand-treatment method was effectively employed. This consisted of removing the bands and dipping them in a bucket of 25 per cent distillate-soap emulsion, wringing the bands out dry, scrubbing the trunks with a suitable brush, and replacing the bands.

Different strengths of the emulsion were tried with results as shown in Table 3.

TABLE 3.—*Results of hand-treatment method against the citrophilus mealybug.*

Strength of solution.	Effectiveness—	
	On adults.	On egg masses.
5 per cent	Poor killing	No effect.
10 per cent	50 per cent killing	Poor.
25 per cent	100 per cent killing	Excellent.

The 25 per cent solution is prepared as follows:

Place 6 quarts of water in a bucket and thoroughly dissolve ½ pound of soap powder. To this slowly add 2 quarts (30° Baumé) distillate while constantly stirring. Attach the bucket pump and pump the solution back into the bucket through a mist nozzle until a perfect emulsion, free of oil globules, is obtained. The emulsion should be used soon after preparation.

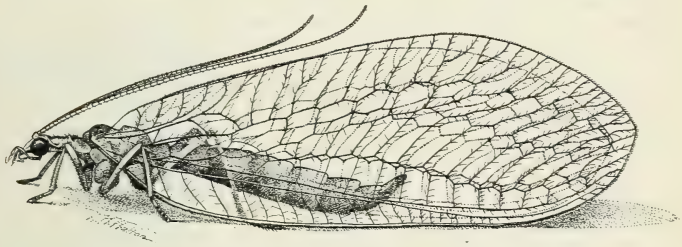

FIG. 9.—Adult of *Chrysopa californica*. Much enlarged.

Several growers have used this method successfully on light infestations, where followed up at intervals of about every two weeks from the middle of May to the latter part of June, at a cost of 2 cents per tree for each treatment. It is as important to effect ant eradication when this method is employed as it is with the regular trunk-spray method.

CONTROL WORK—UPLAND DISTRICT, 1919.

The great success of the demonstration work of 1917 and 1918 led to the general adoption of the control methods by the growers throughout the infested area. (Fig. 5.) Up to and including 1919 ant control was practiced on 630 acres. The entire mealybug-infested

acreage was banded with burlap in the spring of 1919. Of the area infested with the mealybug in that section all but 10 acres were sprayed according to the methods outlined, with excellent results throughout. The 10-acre orchard was left as a check for control by natural enemies.

The ant control was handled partly by the growers themselves, partly by the citrus associations of which the orchardists were members, and partly by contract operators. The sirup was for the most part prepared by the citrus associations, or purchased from druggists at a cost of $1.50 to $2 a gallon. The spice tin was the preferred container. The average cost to the grower for ant control, including refilling where necessary, was 4 to 6 cents per tree. The cost of burlap banding averaged 2 cents per tree. The cost of trunk spraying varied. On dense, unpruned lemon trees, headed low, spraying proved somewhat difficult and slow. The amount of material used on such trees was also greatest. High-headed orange trees with smooth trunks were most easily and effectively sprayed.

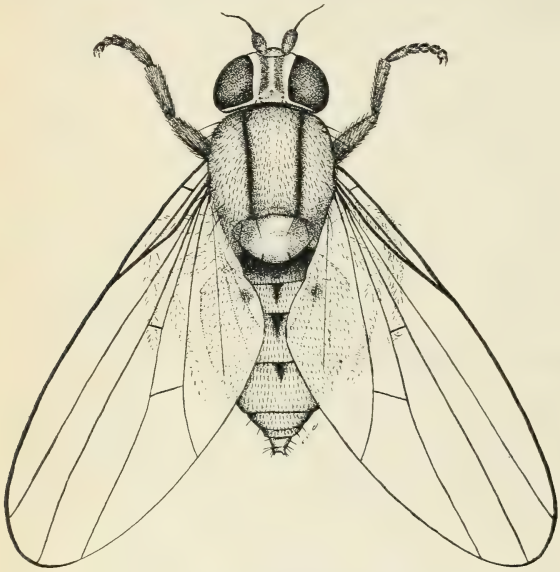

FIG. 10.—Adult of *Leucopis bella*. Greatly enlarged.

These spray operations were conducted by the growers and commercial outfits and an average of 10 acres a day was covered at a cost approximating the figures given for the two demonstration plots, the cost being more or less proportional to whether the trees were well pruned and open or unpruned and difficult to spray. Work carried out by the owners themselves was for the most part thoroughly done. A few orchards were trunk-treated by hand.

The general results of the control campaign of 1919 at Upland were very gratifying. Orchards which had shown severe infestations in the spring of 1919 were commercially clean in the spring of 1920. The reduction in grade or total loss of fruit from mealybugs had been reduced to a negligible factor. Packing-house managers and growers were convinced that the citrophilus mealybug was no longer a menace to their orchards and that the control of

this insect was on such an effective commercial basis that timely future attention would effectively hold it in check.

NATURAL ENEMIES.

Though the ant control, banding, and trunk spraying have given excellent control of the citrophilus mealybug, the importance of its natural enemies in conjunction with this artificial means of control needs emphasis. The natural enemies are very effective against light infestations, if the ants are not present, and even in heavier infestations are important in assisting to destroy the insects on the foliage and trunks following spray treatment. The most effective natural enemies present in the groves are all predators and appear to rank in order of importance as follows: *Chrysopa* spp. (fig. 9), *Leucopis bella* Loew (fig. 10), and *Scymnus sordidus* Horn (fig. 11). They breed freely in the cottony mass of ovipositing females on the trunks, although by no means noticeably reducing the mealybug on heavily infested trees. It is, however, following the migration of the mealybug larvæ to the tender fruit and foliage that the effectiveness of these natural predators is most felt. Here they search out and destroy the young mealybugs, and in the case of light infestations frequently prevent the development increasing to severe proportions. Chrysopa and Leucopis are usually most numerous during the late spring and summer, while Scymnus is most effective during the early fall.

FIG. 11.—Adult of *Scymnus sordidus*. Greatly enlarged.

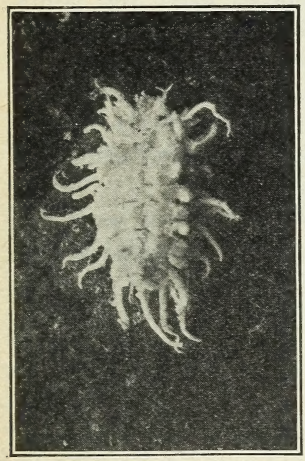

FIG. 12.—Larva of *Cryptolaemus montrouzieri*. Much enlarged.

The natural predators of primary importance in controlling the common mealybug, namely, *Sympherobius* spp. and *Hyperaspis lateralis* Muls., are of very secondary value against the citrophilus mealybug. *Cryptolaemus montrouzieri* Muls. (figs. 12, 13), however, is very effective against either species. This predator was first tried against the citrophilus species by the writers at Alhambra during

1916 and proved so effective that several hundred were distributed beneath a tented citrus tree at Upland during the autumn of 1917. Some specimens successfully passed the winter and started breeding freely the following spring. The Insectary Branch of the California State Commission of Horticulture followed the writers' lead and has since distributed many thousands over the Upland district, with such successful returns that the work should be supported and continued.

SUMMARY.

(1) Ant control. This is most effectively accomplished by the use of a special arsenical poisoned sirup in small containers, one to each tree. Best results follow distribution during the autumn or spring.

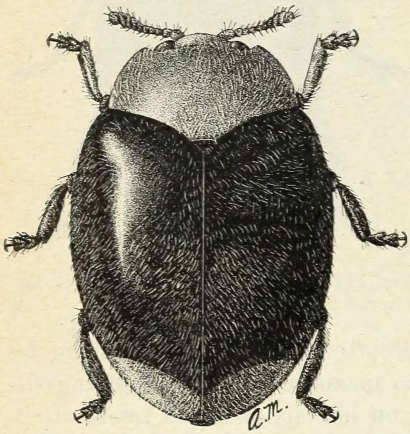

FIG. 13.—Adult of *Cryptolaemus montrouzieri*. Much enlarged.

(2) Trunk banding. Strips of burlap about 5 inches wide should be placed around each tree trunk, from February to April, to attract ovipositing female mealybugs.

(3) Removal and dipping of burlap bands in distillate. This should precede the trunk spraying. The bands should be dry when replaced after the trunk treatment.

(4) Trunk treatment. Spray thoroughly with distillate-soap powder emulsion after the mealybugs have massed on the trunks and just before the eggs begin to hatch. This is usually during the latter part of May.

(5) The propagation and distribution of *Cryptolaemus montrouzieri*, *Leucopis bella*, *Chrysopa* spp., and *Scymnus sordidus* are to be recommended.

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