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THE LIFE HISTORY OF LECANIUM KUNOENSIS KUWANA (HOMOPTERA: COCCIDAE)

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In Walnut Creek, California, the Kuno scale, *Lecanium kunoensis* Kuwana, passes the winter in the second nymphal stage on twigs. Late in the winter the males become differentiated and secrete the white waxy test under which they complete their development. The adult males (described for the first time) are delicate, and each has two large wings with halters. They emerge during March but their life span does not usually exceed 3 days. The female second-instar nymphs begin shedding their exuviae as early as February 15 and increase rapidly in size, secreting a large amount of honeydew. Copulation takes place at this developmental stage. Maturity is reached during March and the early part of April. At this time the females become globular and reddish-brown. At the same time they become hollow underneath, forming the brood chamber. Eggs are produced in great numbers beneath the scale, averaging about 1,200 per female. After an incubation period of 1 to 3 weeks, the eggs hatch and the first-instar nymphs crawl to the leaves where they settle, on the underside. During the summer the first-instar nymphs molt and the second-instar nymphs migrate back to the twigs where they spend the winter in a quiescent stage.

A complete description of all instars, the present taxonomic status, the distribution, and a host list are also included.

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THE LIFE HISTORY OF *LECANIUM KUNOENSIS* KUWANA (HOMOPTERA: COCCIDAE)[1]

MOHAMED MAMDOUH HUSSEINY[2] and HAROLD F. MADSEN[3]

INTRODUCTION

THE KUNO SCALE, *Lecanium kunoensis* Kuwana, was first reported from Temescal, Alameda County, in 1894, on cherry, and again in 1944 on various deciduous fruits in several areas in Contra Costa County. In 1948, California State Survey entomologists conducted a more intensive survey in California. The results showed that the scale is apparently restricted to Contra Costa and Alameda counties and definitely centered in the Walnut Creek area and the Moraga Valley. In these localities it has become injurious on restricted individual properties.

Since little is known about this Asiatic insect and since it has been removed from the category of infestations being given eradicative attention by the State Bureau of Entomology and Plant Quarantine, more thorough knowledge of the life history and habits of this insect seems desirable.

This paper is a preliminary study of the different developmental stages of the Kuno scale with notes on its general habits. The winged male is reported and described for the first time.

TAXONOMY

The Kuno scale, *Lecanium kunoensis* Kuwana, was originally described in Japan (Kuwana, 1907) from specimens collected on Japanese apricot, Chinese flowering apple, and Buckthorn. Craw (1894) reported it on cherry from North Temescal, Alameda County, California. In his discussion of the pine scale *Lecanium insignicola,* Craw states, "Commissioner Pyrol, of North Temescal, found a cherry tree infested with this scale. It was growing near an infested pine, and the scale presented the same spherical form and gregarious habits as those upon the pine." What Craw described on pine as *Lecanium insignicola* is *Physokermes insignicola* (Craw), and the actual specimens collected by Craw on cherry were determined by McKenzie (1951) to be *Lecanium kunoensis.* Superficially, the two scales resemble each other to a marked degree. Tyrrell (1896), in her discussion of *Lecanium insignicola*

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(Craw) on pine, presents a photograph of the scale on cherry from North Temescal which, if properly interpreted, is *L. kunoensis*. Cockerell (1909), reviewing Kuwana's description of the Kuno scale, refers to its resemblance to *L. cerasorum* (Cockerell), stating that it "may possibly be the same."

In the United States, Essig (1941) was first to report this scale from specimens collected by A. D. Borden on plum at Walnut Creek, California, April 21, 1941. The scale was rediscovered by Osborn (1944) during the Federal Maritime Port Survey.

Kuwana (1907) originally described this species from adult females as follows:

> Diameter, about 5 mm. (the largest); globose, with many small pits, shiny chestnut in color. Antennae are composed of seven segments, third segment the longest, almost equal to found fifth, sixth and seventh segment together. Legs subequal; femur and tibia subequal in length; tarsus less than one-half of the length of the tibia; claw short, stout. Anal plate small. Type in the entomological collection of the Imperial Agricultural Experiment Station, Japan.

Description of the winged male will be found on pages 197–198.

GEOGRAPHICAL DISTRIBUTION

The Kuno scale was described originally in Japan, and later Sasscer (1923) reported it on pear stock imported from China. In a discussion of an internal parasite of the Kuno scale, Clausen (1932) states that this scale is the most common of the lecanine Coccidae attacking cherry in Ch'osan (Korea). In the United States[4] the Kuno scale is confined in its distribution to the southwestern portion of Contra Costa County and to a restricted area in the northeastern section of Alameda County (Berkeley-Oakland Hills) in California.

In Alameda County it has been collected several times at Temescal (a restricted area in northwestern Alameda County). Specimens studied were collected principally from Walnut Creek and Lafayette, California.

In a particular orchard the scale may attack isolated trees, while adjacent trees may not be infested.

HOST PLANTS

The scale was originally described from specimens collected on Japanese apricot (*Prunus mume*), Chinese flowering apple (*Pyrus sinensis*) and Buckthorn (*Rhamnus japonica*). Clausen (1931) reported it on imported stocks of gooseberry and currant. In California it was collected first on cherry by Craw (1894), then on plum on April 21, 1941, by A. D. Borden. Osborn reported it May 30, 1944, on apple, plum and walnut, and on September 1, 1944, on pear. Later Armitage (1947) reported it on almond, peach, prune, and quince. It was also found once on walnut and once on California buckeye although there is a definite preference for prune and plum. Host plants with their scientific names and localities are presented in table 1.

The scale occurs in rather large numbers on the shaded side of 1- and 2-year-old wood; however, it may be found on any part of the branches.

[4] Distribution here given is based partially on federal surveys performed during 1941 and state surveys conducted up to March 1, 1946.

TABLE 1
HOST PLANTS OF THE KUNO SCALE

Common name	Scientific name	Family	Locality
English walnut	*Juglans regia*	Juglandaceae	California
Buckeye	*Aesculus* sp.	Hippocastanaceae	California
Buckthorn	*Rhamnus japonicus*	Rhamnaceae	Japan
Japanese apricot	*Prunus mume*	Rosaceae	Japan, China
Cherry	*Prunus* (*Cerasus*) sp.	Rosaceae	California, Korea
Almond	*Prunus* (*Amygdalus*) sp.	Rosaceae	California
Peach	*Prunus* (*Amygdalus*) sp.	Rosaceae	California, China
Plum	*Prunus* (*Prunophora*) sp.	Rosaceae	California
Prune	*Prunus* (*Prunophora*) sp.	Rosaceae	California
Chinese (flowering apple)	*Pyrus sinensis*	Rosaceae	Japan, China
Pear	*Pyrus* sp.	Rosaceae	California, China
Siberian crab	*Pyrus baccata*	Rosaceae	China
Hawthorn	*Crataegus* sp.	Rosaceae	California
Quince	*Cydonia oblonga*	Rosaceae	California
Apple	*Malus sylvestris*	Rosaceae	California
Gooseberry	*Grossularia* sp.	Saxifragaceae	Japan
Currant	*Ribes* sp.	Saxifragaceae	Japan
Pyracantha	*Pyracantha* sp.	Rosaceae	California

ECONOMIC IMPORTANCE

Pierce (1917) reported this scale in a list of dangerous insects likely to be introduced in the United States, referring to its importance on apricot, peach, and pear in China. Just three years later, Sasscer (1920) reported this species from San Francisco on imported nursery stock of plum from Japan and later (1923) on *Pyrus baccata* from China. The main damage to fruit trees is done by the enormous amount of honeydew which covers all the foliage of the trees. In the second week of May, infested trees in Lafayette were dripping honeydew in drops as large as or even larger than the mature insect itself.

This scale is important not only because it can attack many important deciduous fruits but because of its tremendous reproductive potential and its ability to attack ornamentals and native plants. Although it is now restricted to a limited area, it could spread from there to other localities in California and later to other states. While simple control methods may be effective now, it may present a problem if it becomes widely distributed on its cultivated and wild host plants.

NATURE OF INJURY

This insect causes injury first by sucking the sap from the trees and second by covering the leaves and branches with honeydew excreted during the adult female stage. The injury to the trees from loss of sap is considerable in heavy infestations, but it is small compared to the damage resulting from the deposit of honeydew. This deposit would not cause much injury were it not for a black fungus (sooty mold) which grows abundantly in the honeydew and may cut down photosynthesis by shading the leaves. On trees which are badly infested, the fruit becomes covered with a black sticky coat which appreciably reduces its market value.

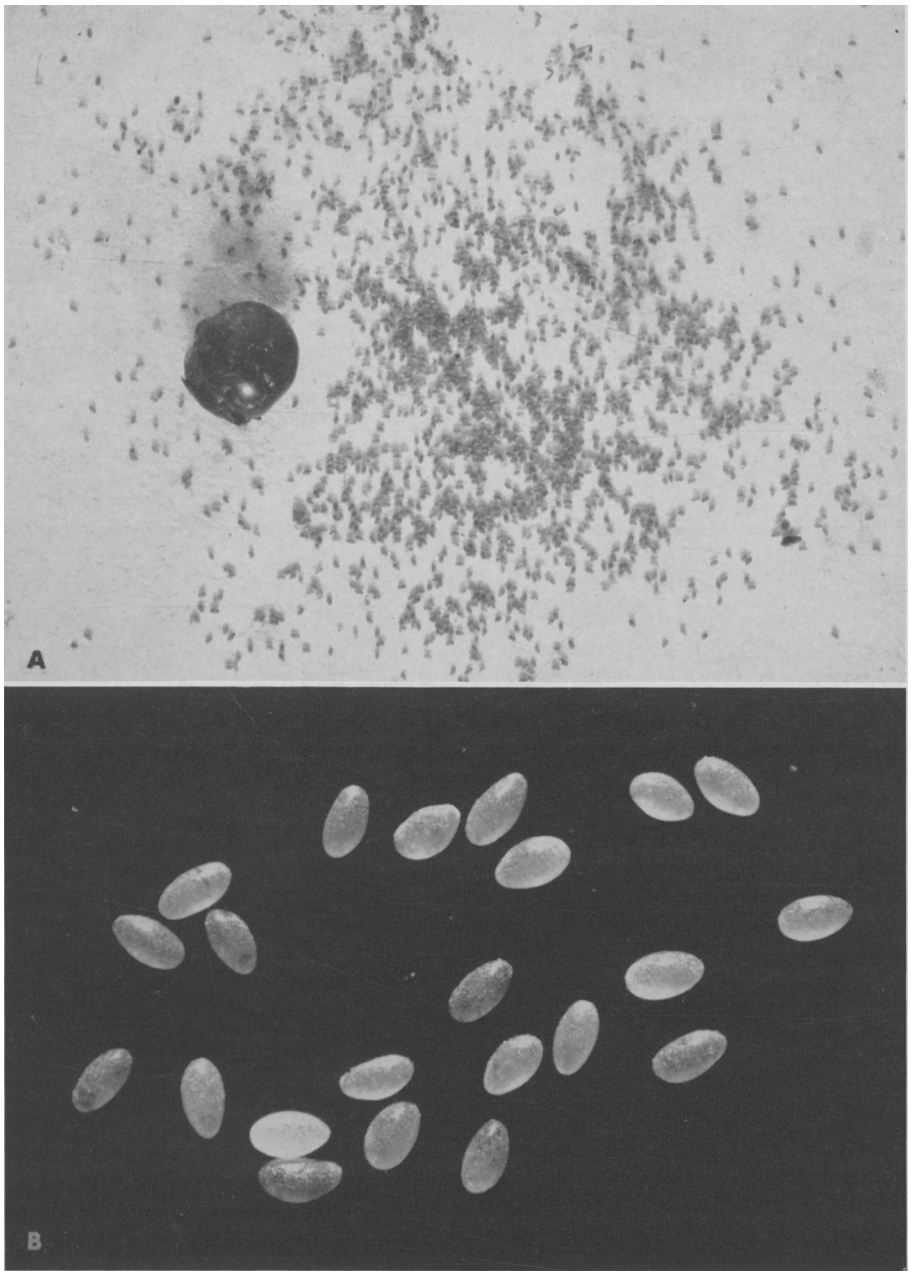


Plate I. **A.** Eggs from one female Kuno scale, *Lecanium kunoensis* Kuwana. Notice the approximate number and size of eggs as compared with the adult female. × 3.4. **B.** Eggs of the Kuno scale. × 29.6.

LABORATORY TECHNIQUE

Microscopic slides of the insects were made using Canada balsam as the mounting medium for most of the stages. Hoyer's solution was preferred when a fast mount was desired, because the insect could be transferred directly from the alcohol to this medium. It was then covered and placed on the hot plate for about 2 minutes for clearing. The following instructions for mounting the insect in balsam were followed in the laboratory:

1. Kill specimens in 95 per cent alcohol. 2. Puncture body with a fine pin and transfer to 10 per cent KOH—cold solution, leave for few days to a week; hot solution, leave for only a few minutes. 3. Transfer to basic fuchsin for 5 to 10 minutes. 4. Transfer to glacial acetic acid to destain. 5. Transfer to 95 per cent alcohol for 1 hour. 6. Transfer to xylol for 1 hour. 7. Transfer to clove oil—leave 1 hour to indefinite period. 8. Mount in balsam on slide.

Slides were made of females in the early stages but it was difficult to get a good mount after the derm had hardened. The following instructions for mounting the delicate winged male were followed in the laboratory:

1. Kill specimens in 95 per cent alcohol. 2. Transfer to a clearing solution composed of a) 1 part acetic acid, b) 2 parts lactic acid. 3. Leave in oven at 70° C for about 1 hour until cleared. 4. Wash several times in water. 5. Transfer to 75 per cent alcohol. 6. Transfer to xylol. 7. Mount in balsam on slide.

This clearing medium prevented corrosion of the delicate structure of the male. Specimens prepared by this method could have been stained, but the pigmentation of the male insects usually made staining unnecessary.

LIFE HISTORY

The Egg (Pl. I)

The egg is oval, nearly ellipsoidal, about .371 mm in length and .186 mm at its greatest width. Under high magnification it is seen to be covered with minute dustlike, waxy secretions from the ventral abdominal pores of the mother scale. In Walnut Creek the first eggs were laid during the last week of April. At this time they were pale yellow but became gradually more reddish or carmine before hatching. Incubation period in the laboratory at 30° C was about 9 days. Under field conditions, it varied from 1 to 3 weeks.

The First Nymphal Stage (Pl. II)

Description: Pale, translucent yellow; body oblong and flat with dorsal and ventral surfaces meeting acutely at the margin, where a limited number of slender spines emerge. Two stout spines at each of the spiracular emarginations. Two dark eyespots close to the margin at the two opposite anterior corners of the body.[5] Two pairs of spiracles, the first pair just behind and outward from the bases of the anterior legs, the second pair behind and outward from the bases of the middle legs. Three pairs of legs similar and equal; tibia and tarsus merged; three slender spines at regular intervals on the inner side of the tibia; the claw slightly curved with two digitules on the outer

[5] The writers were not able to distinguish these eyespots in mounted specimens, even though they are conspicuous in living insects.

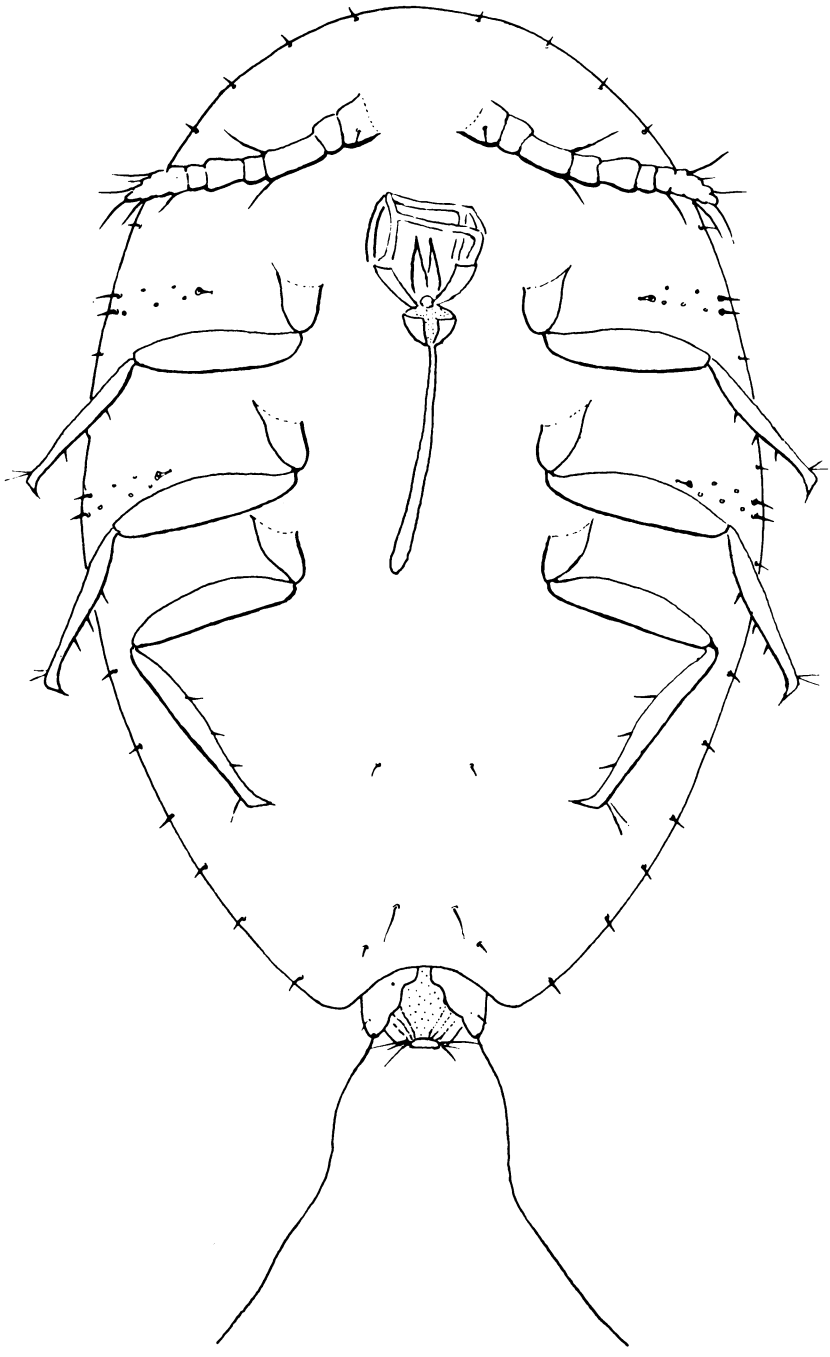


Plate II. Ventral view of first nymphal instar of the Kuno scale, with the anal ring protruded between the anal plates. × 223.5.

side. Antennae with seven joints, the last notched and with five or six delicate spines. Feeding tube folded midway upon itself. Anal plates triangular, each having a major apical seta. Anal ring with six slender spines.

Measurements (in mm—made before feeding). Average length, excluding the apical setae, .543; width, .286; length of the major apical setae, .192; total length of antennae, .137.

Habits. As soon as the first-instar nymphs hatch from the egg, they start crawling about actively and in 3 to 5 days work themselves out from under the mother scale. In some cases, however, the scales may be attached strongly to the twigs, preventing the nymphs from emerging. Scales were found with the brood chamber full of these dead nymphs. Crawlers which succeed in escaping from under the mother scales proceed to the leaves where they settle down along the veins, mostly on the underside. As soon as they settle down they insert their feeding tubes in the leaf tissues and start feeding and increase gradually in size. This leafward migration is a strong element in the spread of the scale over the branches of infested trees, but it is not directly effective in spreading it from one tree to another unless the trees are in actual contact. During this migrating period, birds, animals, insects and orchard workers may aid in the dispersal of the scale. When these first nymphal instars reach maturity about the middle of the summer, they cast their exuviae, losing the two major apical setae. The absence of these setae is positive evidence that the first molt has passed.

Sexual dimorphism. There are no noticeable indications of sexual dimorphism during this instar.

Length of the first instar. The average length of this instar is about 80 days. This stage was present in the field from about the middle of May to the middle of September.

The Second Nymphal Stage (Pl. III. Also see Pl. VI.)

Description: Yellowish brown, becoming darker during the winter; elongated oval form, considerably flattened, with the dorsal and ventral surfaces meeting acutely at the margin, which is entire except for slight emarginations opposite each of the four spiracles, and a very deep anal fissure formed by the lobes of the posterior end of the body. Numerous marginal spines, totaling over 130, nearly equidistant from one another. Two larger and stouter spines at each of the spiracular emarginations. Antennae more definite with the intersegmental lines clearer, and the terminal segments proportionately narrower and smaller than the basal segment. Spiracles more elongated and prominent. Legs little changed in size; trochanter easily distinguishable as a triangular segment of the femur. Tarsi now clearly separated from tibia. Exceedingly small, circular pores scattered between the spiracles and the spiracular emarginations. Anal plates very small, with three or four small apical and subapical setae.

Measurements (in mm). Length, .985; width, .50; length of the marginal spine, .016; average distance between two successive marginal spines, .011; length of spiracular spine, .019; total length of antenna, .186; length of anal plates, .042.

Habits. In this instar the insects can still reattach themselves and be transferred to new plants, as was done in the laboratory. In the field, the

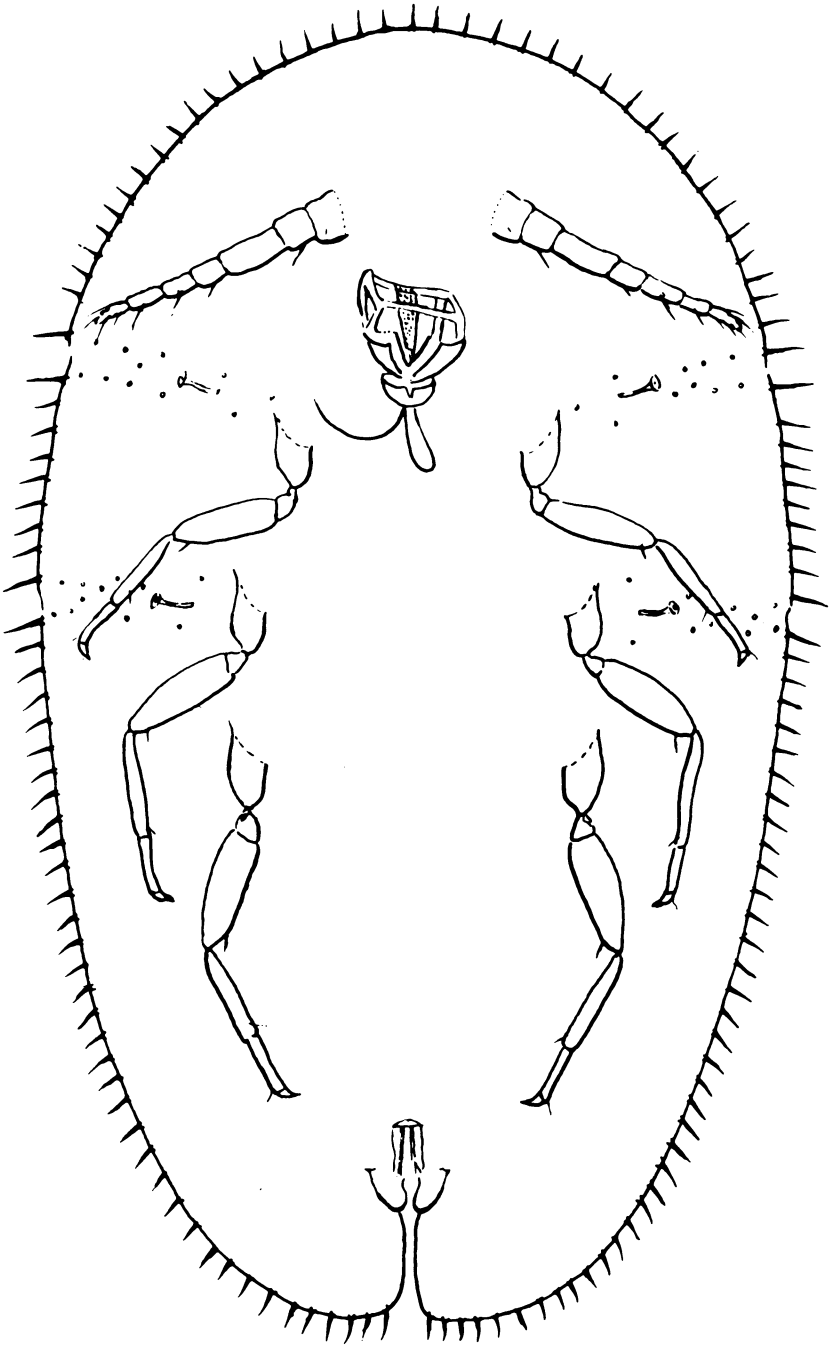


Plate III. Ventral view of the second nymphal instar of the Kuno scale, × 173.

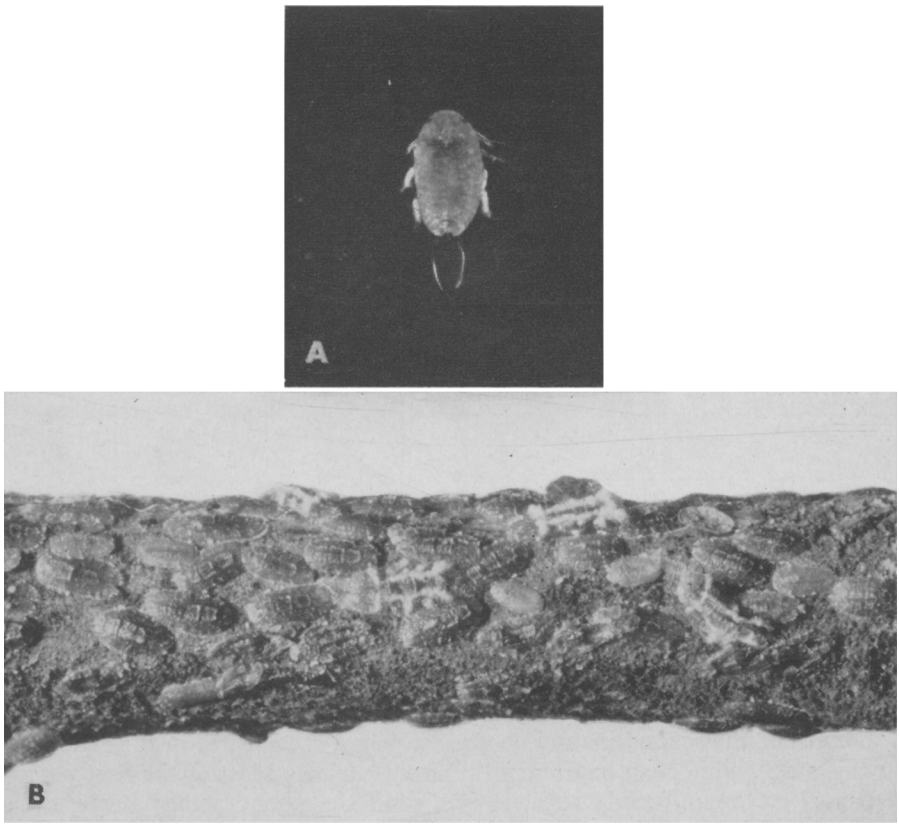


Plate IV. **A.** Dorsal view of the first nymphal instar of the Kuno scale. × 38. **B.** Dorsal views of the second nymphal instar of the Kuno scale on a twig of plum in the spring. × 8.25.

nymphs, induced apparently by the lack of food in the leaves during the fall, migrate back to the twigs, insert their feeding tubes and enter a quiescent stage in which they pass the winter. A large number of these nymphs, however, especially those which feed on a main vein of the leaf, fail to migrate, drop to the ground with the leaves, and perish. This failure to migrate back to the twigs is of great importance in the reduction of the surviving individuals.

Sexual dimorphism. Sexual differentiation begins in this instar. The female nymphs in late winter begin to widen and become circular in outline, while the males lengthen and increase in size. The males secrete the characteristic test which is formed over the dorsal surface. The only structural differences in the sexes are several wax ducts found in the males and arranged in a row a short distance from the body margin. The differences in body shape and external features become more apparent during the later part of this life stage.

Sex ratio. Sex counts were made as soon as the second-instar nymphs

became differentiated. Infested twigs were collected at random in the orchard and brought to the laboratory for study. The proportions of sexes varied greatly from one branch to another, but from the 1,392 specimens which were counted, 44.8 per cent were males, 53.1 per cent were females, and 2.1 per cent undetermined (table 2). It seems, therefore, that the sex ratio is about 1 to 1.

TABLE 2

THE SEX RATIO OF THE KUNO SCALE*

Twig number	*Males*	*Females*	*Undetermined*	*Total*
1	56	94	5	155
2	35	86	1	122
3	12	83	0	95
4	140	106	6	252
5	62	40	7	109
6	42	38	0	80
7	85	77	3	165
8	43	46	0	89
9	31	62	0	93
10	56	61	4	121
11	35	39	2	76
12	27	7	1	35
Total	624	739	29	1,392
Percentages	44.8	53.1	2.1	

* Counts made February 18 to February 28, 1953.

Length of the second instar. The insect passes the greater part of the year in this stage, which can be divided into two periods. Most of the first period is passed on the underside of the leaves, while the second period starts in the fall when the insects migrate to the twigs where they remain through the winter in a quiescent state. During the later part of the second period, the second-instar nymphs seldom move and take no food. The end of hibernation is largely dependent upon the weather conditions. In Walnut Creek the first signs of activity were noticed as early as January 25, and the molts of second-instar exuviae began as early as February 15. The total length of the second nymphal stage varies from 6 to 8 months. Specimens of this stage can be picked up in the field any time from August to March.

Development of the Female

Just after hibernation is ended, the insect begins to feed, increasing in size and height. Excretion of honeydew begins and this material accumulates as a pure translucent drop on the dorsum. After about 3 weeks, the insect becomes ready for the second molt, at which time the nymph simply casts its second-instar exuvia without any change in position.

The third nymphal stage. Just after molting, the female third instar is very flat and pale greenish-brown, a little lighter than in the preceding stage. In these studies, specimens started shedding their second exuviae, which stayed attached to the posterior end, about the third week of February. Right after the second molt, the young females begin a period of rapid growth.

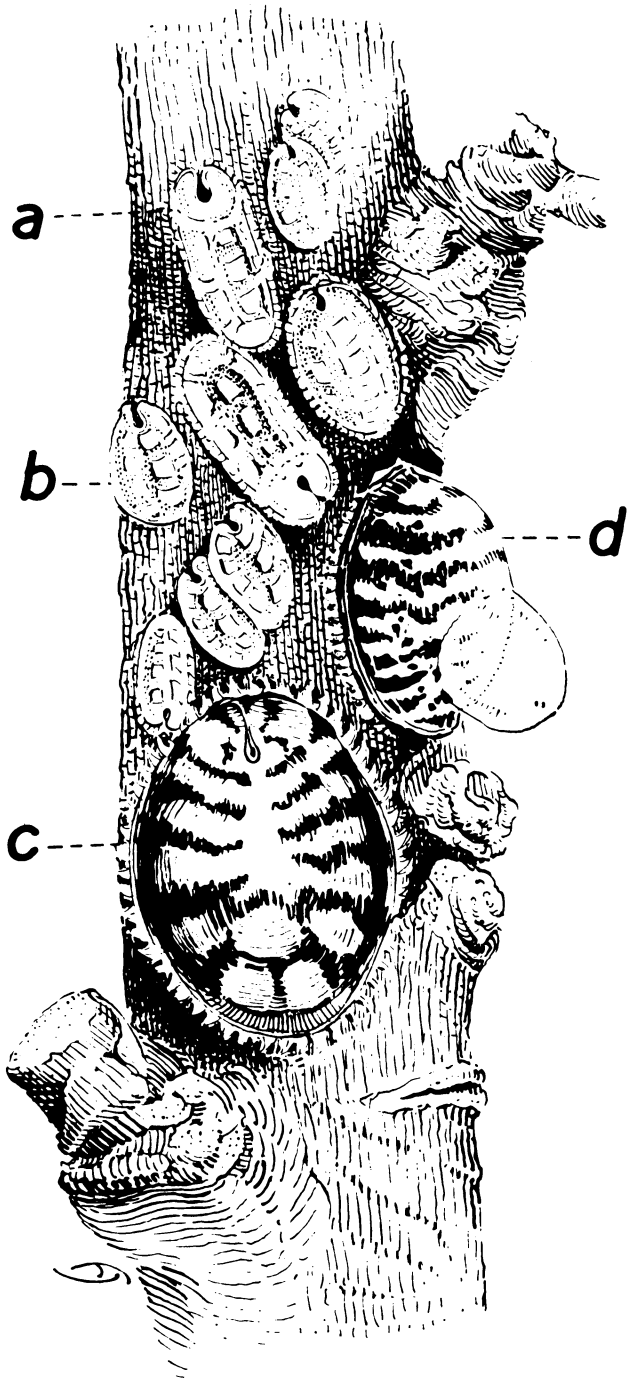


Plate V. Dorsal views of different stages of the Kuno scale on plum in the spring. ×12. **a.** Second nymphal stage of the male. **b.** Second nymphal stage of the female. **c.** Developing third-instar female. **d.** Developing third-instar female, secreting honeydew.

Meanwhile, the dorsum changes from a flat to a convex surface. A small red blotch appears over the oral region, and another similar blotch appears over the anal region; at this time the black markings start to appear, while the pale brown body color of the nymph begins to turn to reddish amber. By the middle of April, most females in the field have assumed both the characteristic shape and color of the adult. After that, there is no change in the color pattern. The pigmentation, however, deepens, and the derm continues to harden but at a decreasing rate. During this period, females become hollow underneath, thus forming a small brood chamber in which the eggs will be laid. This chamber is covered inside by white cottony wax secretions. During the egg-laying period, the brood chamber keeps increasing in size until it occupies most of the body of the insect.

Description of the developing female (Pl. VI). Almost spherical in shape, 2.8 mm in diameter; reddish brown with seven to eight transverse bands formed of blackish, confluent spots; the first anterior band occupying the cephalic area and the second on the thoracic area; those on the abdominal area more interrupted, becoming less distinct toward the anal extremity. At maturity, the blackish markings partially disappear, and the color changes to shiny reddish-brown or dark chestnut.

Description of the Adult Female

It was pointed out by McKenzie (1951) that the wide ventral "lip," which is so evident when the scale is removed from the host plant, immediately distinguishes this *Lecanium* from other species in this state. This character, however, cannot be seen in the slide specimens, which are almost circular.

Exceedingly small circular pores scattered over dorsum. A few very small, slender dorsal setae in no definite arrangement. Slender, pointed marginal setae. Two spiracular setae stouter and a little longer than marginal setae. Many tubular ducts scattered over ventrum. Interrupted bands of pores on abdominal area and extending toward the spiracular emargination. Legs similar to those of the second instar (Pl. V, d). Spiracles in the same position as those of the second instar, but much larger in size. Antenna normally seven-segmented with the third segment the longest, and the last two segments together (Pl. V, c). The terminal segment somewhat notched and furnished with a few fine setae. Anal plates heavily chitinized, triangular in outline, each with five or six long, slender dorsal setae, and eight to eleven ventral setae (Pl. V, b).

Measurements (in mm). Diameter about 2.8. Total length of antenna, .16. Length of marginal spine, .035. Length of anal plates, .16.

Honeydew

Shortly after the end of hibernation in the late winter, the young females start excreting honeydew at an increasing rate until the insects reach maturity. The rate of excretion then decreases until the end of the egg-laying period, when it stops completely. The anal apparatus is especially adapted to the excretion of this sugary, colorless, viscous excretion. The anal plates, near the posterior end of the derm, are so hinged at their anterior ends that they can be both elevated and separated, thus letting the honeydew ooze out. It

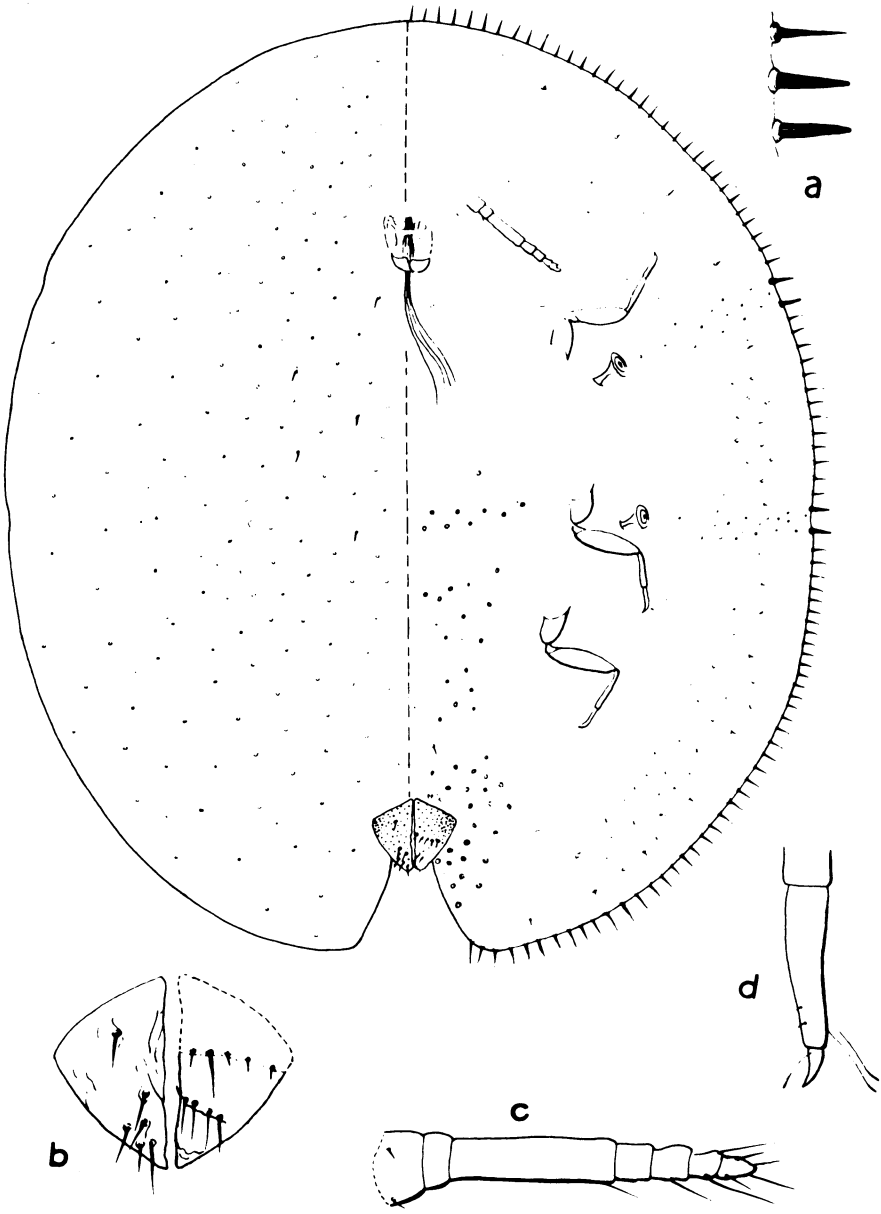


Plate VI. Adult female of the Kuno scale, left—dorsal, right—ventral. × 50.5. **a.** A marginal spine and two spiracular spines. **b.** Anal plates, left—dorsal, right—ventral. **c.** Antennae. **d.** Tarsus.

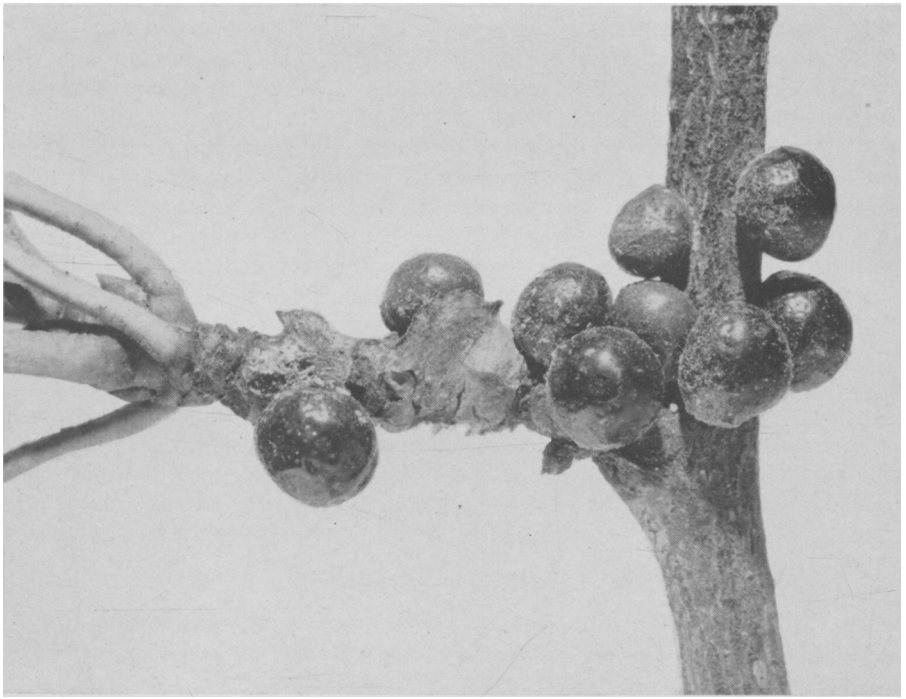


Plate VII. Dorsal view of mature females of the Kuno scale on a twig of plum from Walnut Creek, California. × 3.5.

forms a bubble which increases slowly in size until it reaches the size of the insect, then drops down on the foliage, fruit and ground. Ants were often observed crawling in masses over these females and collecting the honeydew.

Reproduction

Fertilization of the female takes place in the early adult stage while the adult males are emerging. As soon as the female attains maturity, it begins to form a tremendous number of eggs, which accumulate in the brood chamber. This process continues until the body of the mother is depleted and nothing is left but the hard shell. In fact, the function of the adult female seems to be solely that of developing eggs and almost all other internal organs are sacrificed to this purpose. Mature eggs begin to appear toward the last of April. The total number of eggs laid by each female varies according to the size of the female. Counts of the eggs laid by eighteen females show an average of about 1,200 per female, with a maximum near 1,700 and a minimum of about 300 eggs.

Development of the Male

In the second nymphal stage, after hibernation comes to an end, the males become differentiated. The length becomes about twice the width so that the

sides are nearly parallel, and the dorsal surface is elevated. At the same time, the white waxy test becomes conspicuous (Pl. VIII).

Formation of test. The waxy, whitish test becomes apparent as early as the last week of January. It is secreted by the wax pores which are scattered on the surface of the insect dorsum. The test is traversed by two longitudinal and three crossing bands made of curled, very thin threads of white wax, which divide the test into seven plates. The test is also furnished with marginal strands of the same number and shape as the marginal spines of the second-instar nymph.

Second molt. By the time the test has been secreted, the nymph has laid up a considerable quantity of food and ceases to increase further in size. The pupa begins to form within the larval skin; new antennae and legs begin

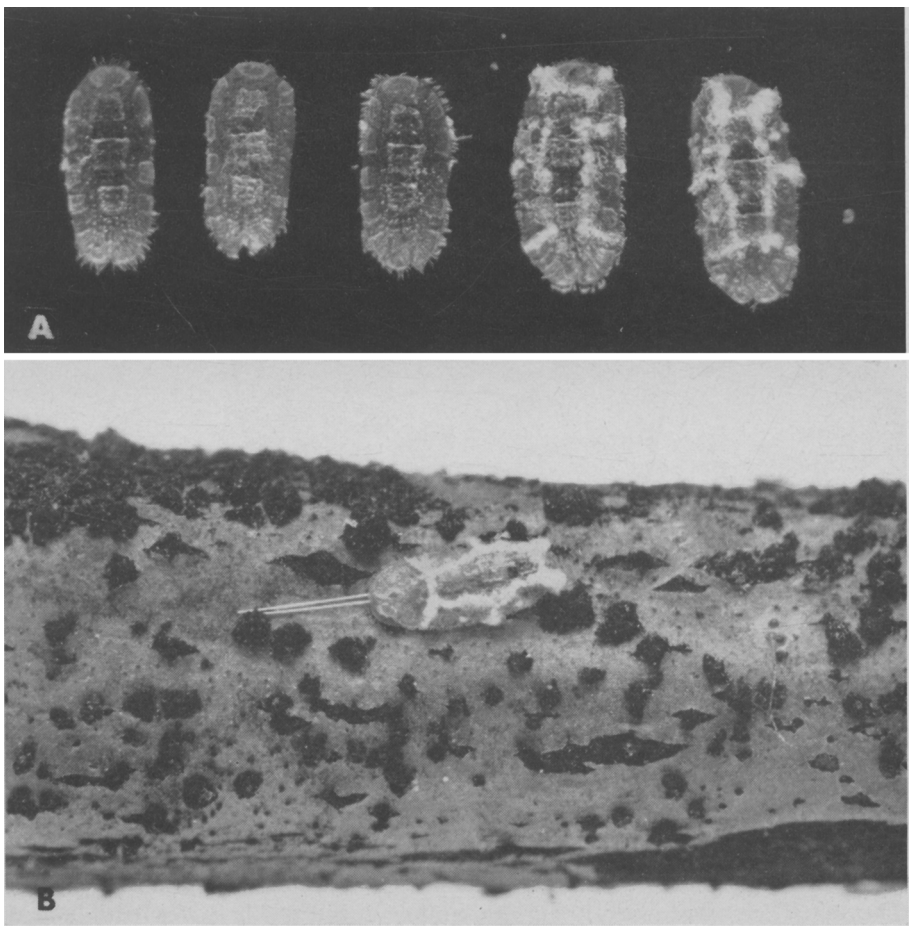


Plate VIII. **A.** Dorsal views of the second nymphal instar of the male Kuno scale secreting the white waxy test. × 15.1. **B.** Dorsal view of male Kuno scale before emergence from the second nymphal instar, showing the waxy caudal filaments. × 11.6.

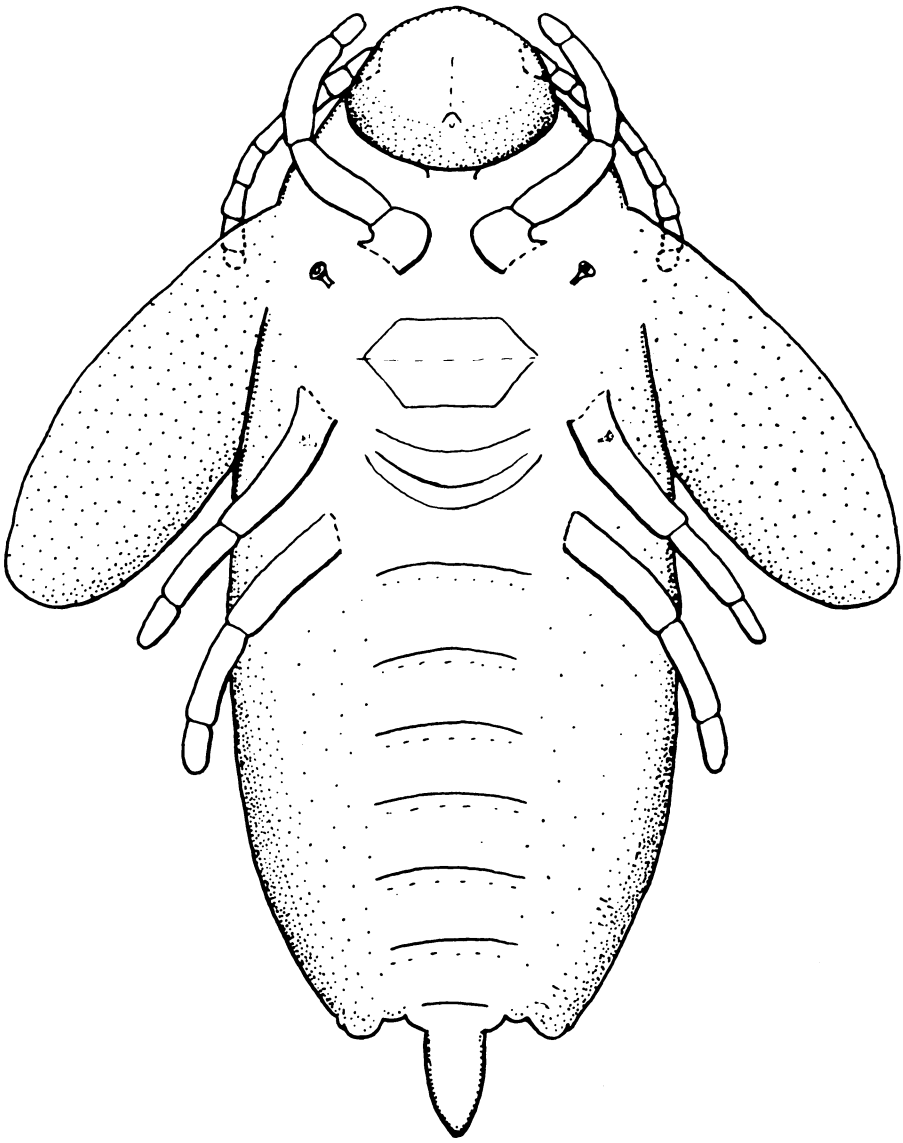


Plate IX. Ventral view of pupa of the male Kuno scale, an intermediate stage between second nymphal stage and the adult male. × 81.

to bud out and develop gradually, and the first indication of wings appears. Abdominal segmentation and a stylelike penis become apparent (Pl. IX). The pupa decreases slightly in size, and at this time it sheds its skin and usually pushes it back under the test. This exuvia is much larger than that of the second-instar female, and is sometimes found under the test after the adult male has emerged. The appendages grow gradually in size and definite-

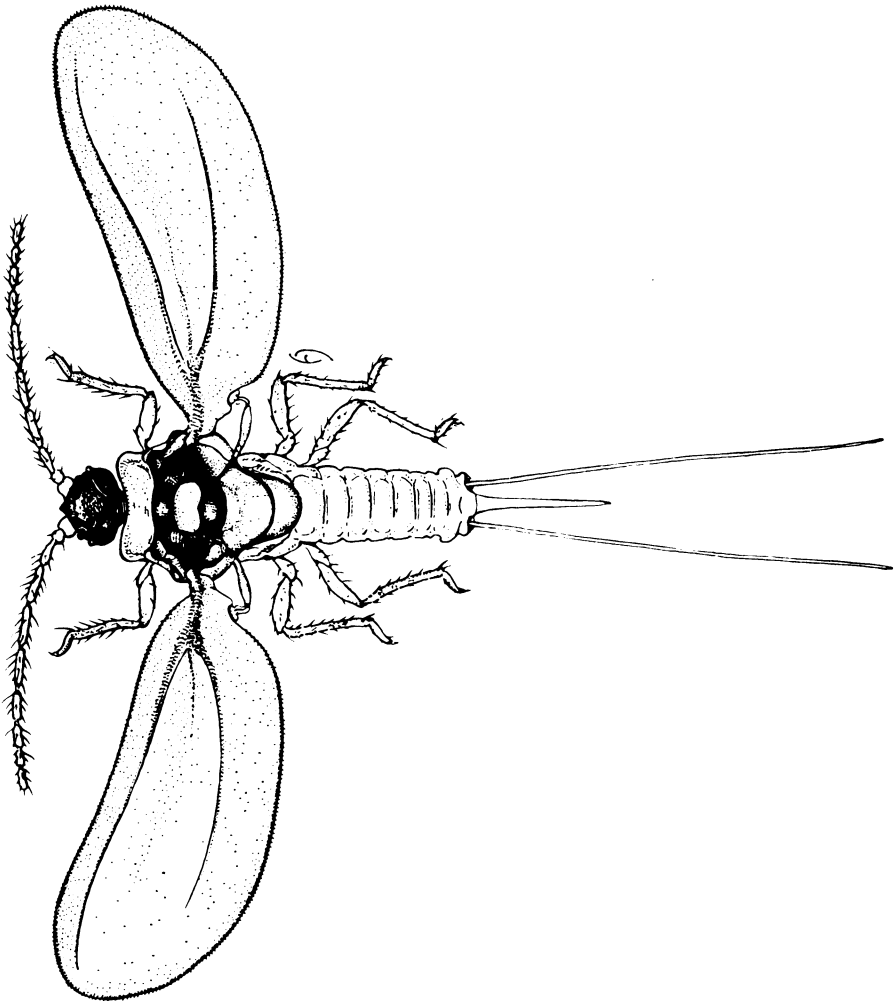
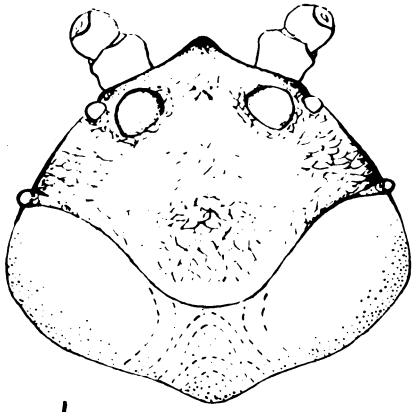


Plate X. Dorsal view of the adult male of the Kuno scale. × 33.75.

ness of form until their full development is reached. Then the wings and all parts of the male become fully developed but are still very soft and pale; the long caudal filaments begin to be projected on both sides of the penis (Pl. VIII, 2). These filaments are composed of a brilliant white waxy secretion and continue to grow until they reach more than the insect's entire length. The test now becomes loosened at the posterior end while the head end remains fast. The caudal filaments are conspicuous and always a sure sign that the fully developed male is to be found beneath the test. In escaping from the test, the male backs out, keeping the wings close to the body and helping to raise the test by moving the tip of the abdomen up and down. After emergence, the test remains fast to the twig at the anterior margin for a considerable time.



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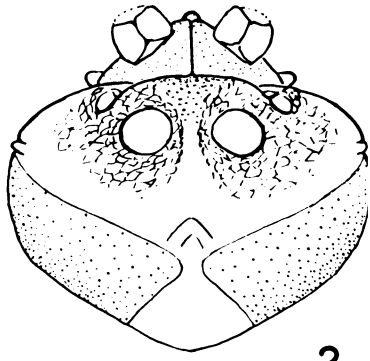

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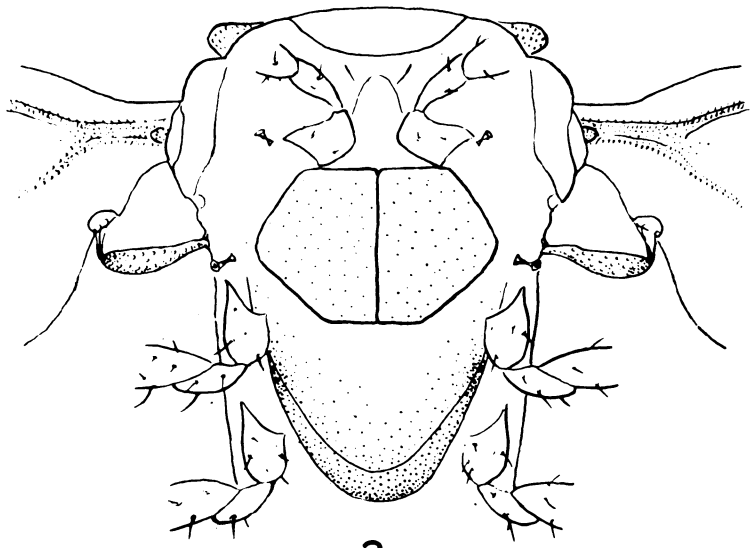

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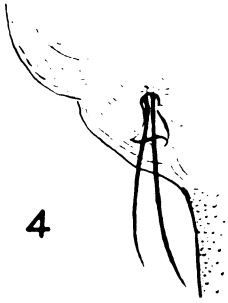

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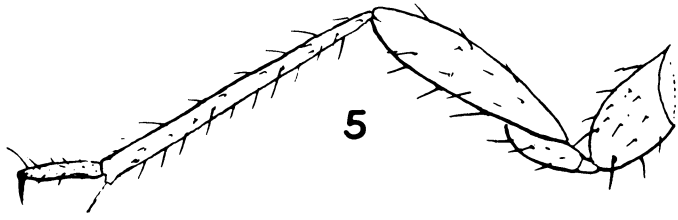

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Plate XI. Adult male of the Kuno scale. **1.** Head, dorsal view. × 167.3. **2.** Head, ventral view. × 167.3. **3.** Thorax, ventral view. × 92.9. **4.** Part of the last abdominal segment, showing pit at root of caudal filament **5.** Leg. × 167.3.

Adult emergence. When the male first backs out from under the test, he is pale and soft but soon becomes darker and stronger and starts walking about quite rapidly. Since it has no mouth parts and no alimentary tract, the male lives but a few days. Hence, it is important that both males and females reach maturity at about the same time, and that the males emerge gradually rather than at one time. In these studies, the adult males appeared on February 18 and continued to emerge until April 16. Males in flight travel only a few feet at a time, since their wings, although relatively large, are frail and not easily manipulated. Emerging adults in the laboratory had their wings spread and were ready for flight within 2 minutes.

Description of the Adult Male (Pl. X)

Male is chestnut brown with brilliant rose-colored wings. Head (Pl. XI) nearly globular, pointed below, separated from the thorax by a slender neck; entirely rigid; prolonged in front into obtusely conical point on each side of which is a large convex eye. A small black ocellus a short distance outward from each eye. Sides or cheeks very large and globular, forming the larger part of head. Two large convex vertical eyes at ventral apex of head. A small ventral ocellus a short distance anterior to and outward from each eye. The two ventral and two large dorsal eyes are similar in size and appearance, both pairs convex, smooth and simple. Small sutures, probably remnants of external mouth parts, between ventral eyes and a little posteriorly on top of conical projection. Ten-jointed antennae which originate just below frontal apex; first joint, short and thick; second, more globular; fourth, fifth and sixth, subequal and the longest; seventh to ninth, progressively decreasing in length; tenth, a little longer than the preceding. All the joints thickly furnished with slender hairs.

Large thorax closely connected with abdomen. Dorsal surface divided into a number of distinct pieces. Prothorax pale brown, large and prominent, projecting over neck. Followed by what appears to be mesothorax, composed of three successive subrectangular sclerites; middle one very pale, the other two much darker and heavily sclerotized. Scutellum immediately following mesothorax; large, convex, somewhat triangular-shaped, projecting over the first and second abdominal segments. Sides of the mesothorax made of three sclerotized pieces; the first anterior two more heavily sclerotized than the third. Ventral side of thorax comparatively flat. Prosternum narrow and triangular, allowing coxae of the anterior legs to approach close to one another. Mesosternum a large, flat subhexagonal plate, divided longitudinally into two equal parts. Metasternum short and broad, membranous, pale brown.

Two pairs of small spiracles similar to those found in the second instar, a short distance anterior to attachment of the two anterior pairs of coxae. Legs long and slender compared with those of the female; densely covered with long, slender hairs. Coxae quite large and stout. Trochanter long and slender, immovably united to femur. Femur about twice as long as the trochanter, and stouter. Tibia more slender, longer, furnished on inside at extremity with a prominent spine. Tarsus about one fourth the length of tibia, tapering toward extremity; terminated by short claw and by four digitules; two

longer digitules attached to outside of tarsus near the tip; two shorter digitules attached to enlarged portion of claw.

Wings thin, membranous and composed of two layers when fully developed. Each wing furnished with a rather stout vein a short distance from anterior margin, and a more slender vein directed somewhat parallel to posterior margin, both veins disappearing before reaching margin. Surface of wings covered with numerous, very fine hairs. Pocket in which rest the three hooks of the halter on the posterior inner side of each wing. Two halters inserted a short distance anterior to base of second pair of coxae. Halters slender, smooth and rounded at apex, terminating with two or three hooks, which rest in previously mentioned pockets.

Abdomen pale brown; longer and more slender than thorax. Divisions of abdominal segments often difficult to see in mounted specimens, but in living insect nine segments can be distinguished. Ninth segment very small, lying on both sides of the base of the penis, furnished with two glands, one on each side, from each of which arise two spines (Pl. XI, 4). Two white, waxy caudal filaments secreted by these two glands. Penis a long, slender style, tapering to a rounded point at the end.

Apparently no opening for a mouth, nor any indication of stomach or intestine.

Measurements (in mm). Length, including penis, about 1.85; width, wings expanded, about 3.5. Head, greatest width, .3; total length of antenna, .87. Thorax, greatest width, .62; length of halter, .15. Length of penis, .29.

Mating Habits

The writers observed the process of copulation on three occasions only. The male mounted the back of the female with his head in the same direction and the penis was then inserted between the anal plates to the extent of its entire length. The process took place about 10 to 20 minutes after emergence of the male, and the actual union took not more than 10 seconds. The male then went off to another female. On one occasion, the male copulated with three females all in the young adult stage. In another instance, a male mounted a female with a large amount of honeydew on its back. He tried to effect copulation, but failed to get the penis through the bubble of honeydew. The process was observed March 26, but mating continued during the entire period of male emergence, which in this locality was from the third week of February until the third week in April.

Life span of the adult male. The life of the male is brief. Ten males were kept in individual cages under favorable conditions, but only one of them survived for 4 days, and the others were dead by the third day. There seemed to be no difference in the life span between males which mated and those which did not.

SEASONAL LIFE CYCLE

The seasonal history of the Kuno scale is not narrowly defined, and the successive instars are not clearly demarked. The rate of development as a whole is subject to considerable fluctuation, depending upon the climatic

factors. This study was done under the conditions prevailing in Walnut Creek, California, during the season 1952–53 (Pl. XII).

The winter is passed in the second nymphal stage on the one- and two-year-old twigs; the underside of the branch is generally preferred. These nymphs appear as small, brown, flattened oval bodies closely pressed to the surface, with the appendages withdrawn beneath the scale. This period of hibernation

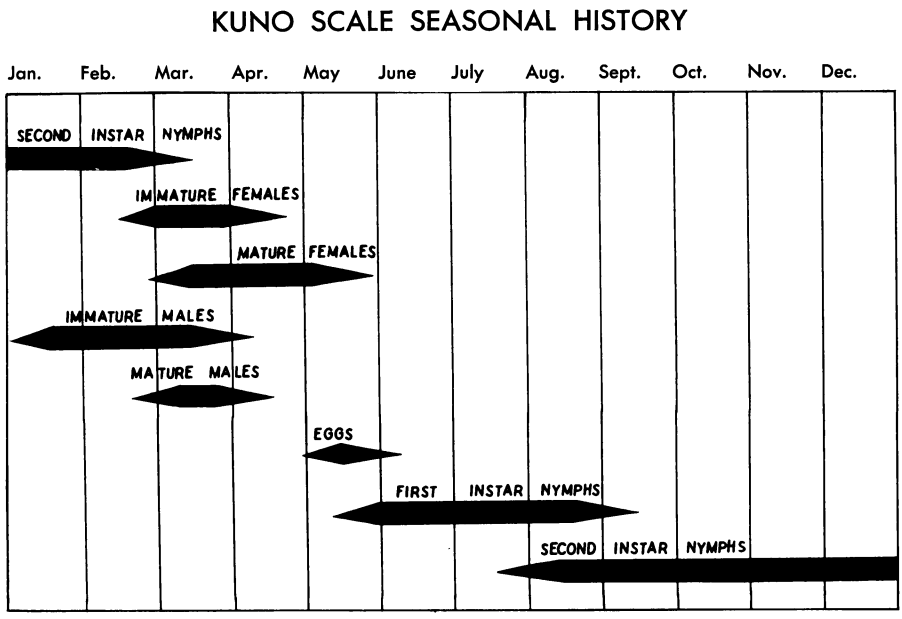

Plate XII

(November through February) is not one of complete inactivity or a true diapause for, under laboratory conditions, individuals fed and continued their development. On March 17, two females of those remaining on a seedling in the laboratory reproduced ovoviparously and parthenogenically, but the writers were unable to make a careful study of this interesting phenomenon.

In the field, the driving rain kills many of the overwintering nymphs, unless they are well protected, by beating them off the host, thus decreasing appreciably the number of overwintering individuals. The nymphs in this stage secrete a very thin waxy pellicle over the dorsal surface, which probably helps protect them from sudden changes in temperature as well as from the rain. This pellicle becomes divided into quadrangular plates later in the spring (Pl. XIII, c). Growth in the spring coincides with the beginning of the sap flow in the trees. The first signs of development were noticed the last week of January, when the insects began feeding, increased in size and changed color slightly.

The male nymphs start secreting the characteristic test and enlarge, especially in length and height. As soon as the test is completed, the male enters a quiescent period or a prepupal stage during which no food is taken. After the second molt, the insect enters the true pupal stage, which is distinguished by the further development of the appendages. The secretion of the caudal filaments indicates the completion of the male development. The length of the true pupal stage is no more than 3 to 5 days, after which the mature insect backs out of the test and is ready for copulation. The first emergence was observed February 18, while the maximum emergence in the field was

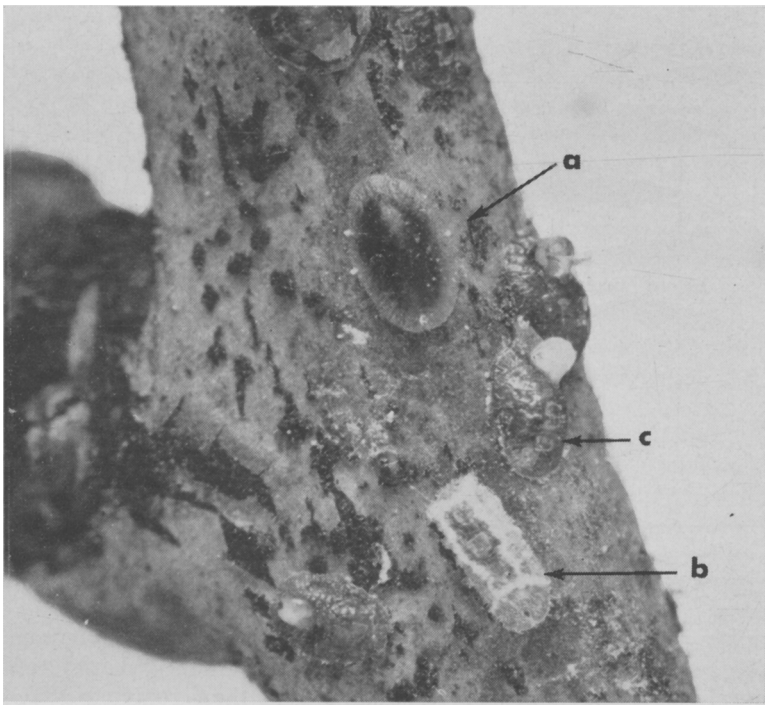

Plate XIII. Second nymphal instar of the Kuno scale. ×11.5. **a.** Parasitized second-instar female. **b.** Second-instar male under the the test. **c.** Healthy second-instar female.

about March 18. By April 16, all males had emerged. The average adult life span of the male is about 3 to 4 days, during which it may fertilize one or more early adult females.

The second-instar female casts its skin as early as February 15, without any change in position. After this molt, the insect increases rapidly in size and becomes globular, and dark markings appear on the dorsum. Honeydew begins to appear right after the first insect ends its hibernation and starts feeding in the early spring. The excretion of this sugary substance reaches its maximum about May 16. Meanwhile, the derm of the female becomes hardened and chestnut brown. Fertilization takes place during the early adult stage in March and early April, but mature eggs are not laid until

the last week of April. By the middle of May, the brood chamber becomes full of eggs which have an incubation period of about 1 to 3 weeks.

From the 2nd week of May until the second week of June, the first-instar nymphs hatch from the egg and stay in the brood chamber for 3 to 5 days until they make their way from under the scale. They crawl to the leaves, where they settle, usually on the underside, and insert their feeding tubes. This is the most important stage of dispersal by wind and other agents such as birds or insects. About the middle of the summer, these crawlers begin to cast their skin, losing the two major apical setae which distinguish them from the second instar.

The second-instar nymphs remain on the leaves until the fall when they begin migrating back to the twigs before the leaves drop to the ground. A good percentage of this stage fails to migrate to the twigs, however, and falls to the ground with the leaves and perishes. This is a most important factor in reducing the number of surviving individuals.

NATURAL ENEMIES AND PARASITES

From a comparison of the great number of eggs found under the body of the adult female at the end of the egg-laying period and of the much smaller number of scales which reached maturity, it is evident that there should be a dominant limiting factor. At all events, a considerable number of both sexes of all ages seem to die without any assignable cause, while their companions on the same twig remain healthy. The number of natural enemies which the writers were able to find was very limited, in spite of the abundance of Kuno scales and their habit in the nymph stage of feeding gregariously and unprotected on the surface of leaves and twigs.

Clausen (1932) states that *Lecanium kunoensis* is heavily attacked by the internal parasite *Encyrtus infidus* Rossi in Ch'osan, Korea. He has studied the biology of this parasite and found that an average of 6.4 *Encyrtus* individuals reaches maturity in each full-grown female scale. He reported also a striking phenomenon in which the larva of this parasite establishes a functional relationship with the tracheal system of the host.

The only parasite which the writers were able to find was a small chalcid, identified as *Coccophagus lycimnia* (Walker).[6] This parasite was found commonly on the specimens collected from Lafayette, where the trees were infested with both *Lecanium kunoensis* Kuwana and *L. corni* Bouché. The second-instar nymphs which were parasitized became very dark (Pl. XIII, a); only one parasite emerged from each scale after making a large hole in the dorsum. Later a female parasite was observed in the laboratory crawling on infested twigs and ovipositing eggs in female scales of the third instar.

The Kuno scale seems also to be subject to an unknown disease. Diseased scales shrink irregularly and harden in an abnormal way.

No other parasites were detected although a large number of specimens were examined.

Symbiotes. During the course of this study, the writers observed some specimens which dry up and harden for no apparent reason. In a search for

[6] Identified by R. L. Doutt of the Division of Biological Control, University of California, Berkeley.

the cause of disease, a few specimens were crushed and placed in wet mounts under the microscope, which revealed the presence of yeastlike symbiotes occurring singly or in pairs. The approximate dimensions were 2 to 3 by 10 to 15 microns. These symbiotes were described by Steinhaus (1955) for the first time. Attempts were made by the same author to cultivate the symbiotes on a variety of artificial media, but no definite success was obtained. So far, the role of this symbiote is unknown.

SUMMARY

The Kuno scale, *Lecanium kunoensis* Kuwana, which is an Asiatic species, was first reported from North Temescal, California, in 1894. It is still restricted in distribution to Alameda and Contra Costa counties in California.

The host list includes many deciduous fruits and a few ornamentals and native plants, but plum and prune are the favorite hosts.

The primary injury caused by the Kuno scale is the extraction of fluids from the host plants and the excretion of honeydew on which a fungus (sooty mold) grows abundantly covering the foliage and fruits.

Winter is passed in the second nymphal stage on twigs. Late in the winter the males become differentiated and secrete the white waxy test under which they complete their development. The adult males (described for the first time) are delicate and each has two large wings with halters. They emerge mostly during March but their life span does not usually exceed 3 days. The female second-instar nymphs begin shedding their exuviae as early as February 15 and increase rapidly in size, secreting a large amount of honeydew. Copulation takes place at this developmental stage. Maturity is reached mostly during the last half of March and the first half of April. At this time the females become globular and reddish-brown. At the same time they become hollow underneath, forming the brood chamber. Eggs are produced in great numbers beneath the scale, averaging about 1,200 per female. After an incubation period of 1 to 3 weeks, the eggs hatch and the first-instar nymphs crawl to the leaves where they settle on the underside. During the summer the first-instar nymphs molt and the second-instar nymphs migrate back to the twigs where they spend the winter in a quiescent stage.

The only two known internal insect parasites of the Kuno scale are *Encyrtus infidus* Rossi, which was reported to be common on this scale in Korea, and *Coccophagus lycimnia* (Walker), which was reared from specimens collected from Lafayette, California.

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LITERATURE CITED

ARMITAGE, H. M.
1947. Bureau of Entomology and Plant Quarantine. Insect pest surveys. California Dept. Agr. Bull **35**(4):195–198.
CLAUSEN, C. P.
1931. Insects injurious to agriculture in Japan. U. S. Dept. Agr. Circ. **168**. 115 p. (See especially p. 10.)
1932. The biology of *Encyrtus infidus* Rossi, a parasite of *Lecanium kunoensis* Kuw. Entomol. Soc. Am. Ann. **25**:670–687.
COCKERELL, T. D. A.
1909. The Japanese Coccidae. Canad. Entomol. **41**:55–58.
CRAW, ALEXANDER
1894. Insects, pests and remedies. California State Board of Hort. Bull. **68**:14.
ESSIG, E. O.
1941. Two little known scale insects. J. Econ. Entomol. **34**:590.
KUWANA, S. L.
1907. Synoptical list of the Coccidae of Japan. Imp. Cent. Agr. Expt. Sta., Japan, Bull. **1**(2):177–207.
MCKENZIE, H. L.
1951. Present status of the Kuno scale, *Lecanium kunoensis* Kuwana, in California. California Dept. Agr. Bull. **40**(3):105–109.
OSBORN, H .T.
1944. Federal port survey. California Dept. Agr. Bull. **33**(4):252–253.
PIERCE, W. D.
1917. A manual of dangerous insects likely to be introduced in the United States through importations. U. S. Dept. Agr. Manual. 256 p.
SANDERS, J. G.
1909. The identity and synonymy of some of our soft scale insects. J. Econ. Entomol. **2**(6):428–448.
SASSCER, E. R.
1920. Important foreign insect pests collected on imported nursery stock in 1919. J. Econ. Entomol. **13**:181–184.
1923. Important foreign insects collected on imported nursery stock in 1922. J. Econ. Entomol. **16**:152–158.
STEINHAUS, E. A.
1955. Observations on the symbiotes of certain Coccidae. Hilgardia **24**(8):185–206.
TYRRELL, M. W.
1896. The lecaniums of California. California Agr. Expt. Sta. Bien. Rept., 1894–95. 481 p. (See especially p. 262–270.)

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