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BIOLOGY OF THE FLORIDA RED SCALE IN FLORIDA

By WILLIS MATHIS

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DISTRIBUTION

The Florida red scale is widely distributed over the world, especially in tropical and subtropical regions. In the United States it has been found in practically every State, but in the Northern States it occurs chiefly on plants in greenhouses. In Florida, where it is the most abundant and destructive, the distribution is general over the State, but the heaviest infestations occur along the lower east coast, where the temperatures are most favorable for continuous development. In the northern part of the State, where citrus trees are occasionally defoliated by freezes, it is not so abundant, and when a tree is defoliated, infestations may be practically eliminated.

HISTORY OF THE SPECIES IN FLORIDA

The Florida red scale *(Chrysomphalus aonidum* (L.)) was first described in 1758 by Linné *(5)* under the name *Coccus aonidum* from specimens collected in India. He gave nondeciduous trees as hosts and mentioned *Camellia* specifically. In 1879 Ashmead *(1)* received citrus leaves infested with the Florida red scale in a letter from Orlando, Fla. He sent some of these to C. V. Riley, then entomologist of the Department of Agriculture in Washington, who gave the manuscript name *Chrysomphalus ficus* to the species, and informed Ashmead that the insect had been collected previously from *Ficus nitida,* now *F. retusa,* but that he had published no description of it. Ash-

[1] Acknowledgments are due Herbert Spencer for planning the first methods of study and assisting in the collecting of historical data, Max R. Osburn for advice and suggestions throughout the work, and F. M. Wadley for assistance in presenting the statistical data.

mead described the eggs, the crawling larvae, and the covering of the female from additional specimens from Florida, and recorded his correspondent's remedy of strong salt water applied just before the growing season, which was an effective control, since it caused defoliation of infested (and uninfested) leaves. There is no reference in the paper to the earlier description by Linné, and it was probably overlooked by Riley and Ashmead.

In 1880 Comstock *(3)* added many details to the Ashmead description and gave the microscopic characters from the last abdominal segment of the mature female and a drawing of the pygidial fringe. His characters for the male and its scale covering are excellent, and he gave useful drawings of infested orange leaves, male and female scales, newly hatched larvae, and the formation of the dorsal scale over a newly settled larva. He reared the insect through five generations on potted orange plants in Washington, D. C., and from his work surmised that in Florida there would be at least six generations per year. After thorough searches in orange groves of California and Florida, he found this scale present at that time only in the Florida grove near Orlando, from which specimens had been sent to Ashmead, and he traced this infestation to the shipment of a sour orange tree from Havana, Cuba, in 1874. The conclusion of his paper was prophetic: "The species is certainly one that is greatly to be feared, and there is no doubt that it would be a good investment for the orange growers of Florida to eradicate the pest, even if in doing so it is found necessary to purchase and destroy all infested trees. This could be done now easily, but if delayed a few years the species will doubtless become permanently established." In a short paper in 1881 Comstock *(2)* called attention to the differences between the Florida red scale and the California red scale, which he described as *Aspidiotus citri,* now *Aonidiella aurantii* (Mask.). He stated that the species *Chrysomphalus ficus* (Riley MS) Ashmead was simply an *Aspidiotus* and should be called *Aspidiotus ficus,* and that it was not present in California. Comstock *(3)* stated that up to 1883 he had obtained specimens only from Cuba and Florida, and in this paper referred the species to the genus *Aspidiotus* Bouché.

Although the Florida red scale has been present in Florida for more than 60 years, very little has been published on its biology in this state. The economic importance of this scale has increased in recent years, especially on the lower east coast, and studies on its biology were conducted at St. Lucie, Fla., from 1939 to 1943, in order to be better able to investigate control measures.

Methods of Spread:

In investigations conducted at St. Lucie, settled larvae were found as far as 19 inches from the mother scale on a citrus tree, and the crawlers probably could have traveled farther, if necessary, to find a suitable place for settling. They may also be distributed within a tree by being blown from leaf to leaf. It is doubtful, however, whether many that fall to the ground get back to the tree through their own locomotion. Other insects may aid in the distribution of the crawlers, but ants probably have less to do with the distribution of this scale than they do with some other insects, since no honeydew is secreted by the scales to attract the ants. Heavily infested leaves that fall may be blown about in a grove, and low branches that come in contact with the ground may be a source of infestation. Scales may also be distributed on infested host plants that are carried into uninfested areas, and on equipment that is moved from grove to grove.

ECONOMIC IMPORTANCE

In Florida this species is classed as one of the most destructive pests of citrus (*8*, p.5) and it also infests many other plants. On citrus, after a Florida red scale has been on a leaf for some time, a yellow spot appears under the scale, and as the infestation increases the entire leaf turns yellow. Heavily infested leaves eventually fall, and a severe infestation will almost defoliate a tree, lowering the vitality and the yield of the fruit. Fruits infested with this species have an unattractive appearance, inasmuch as the contrast in color makes the scales very noticeable, and infested fruits do not color uniformly. This results in a lowering of the grade and a reduction in returns to the grower. Heavily infested fruits are sometimes refused at canning plants, because of the difficulty of removing the scales during washing, and the possibility of their being incorporated into the finished product.

HOST PLANTS IN FLORIDA

Records of occurrence of the Florida red scale in Florida were made available by G. B. Merrill, entomologist of the State Plant Board. In the preparation of the following host list from these records, valuable assistance in classification was given by Mr. Merrill and Erdman West, mycologist at the Florida Agricultural Experiment Station.

SCIENTIFIC NAME (Species and Family)	COMMON NAME
Acacia sp. (Leguminosae)	Acacia
Acrocomia sp. (Palmaceae)	Acrocomia palm
Agave sp. (Amaryllidaceae)	Agave
Agave americana L. (Amaryllidaceae)	Centuryplant

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Aleurites moluccana Willd. (Euphorbiaceae)	Candlenut-tree
Allamanda sp. (Apocynaceae)	Allamanda
Aloe sp. (Liliaceae)	Aloe
Aloe vera L. (Liliaceae)	True, or Barbados aloe
Annona sp. (Annonaceae)	Annona hybrid
Annona muricata L. (Annonaceae)	Soursop
Annona squamosa L. (Annonaceae)	Sugar-apple
Aralia sp. (Araliaceae)	Aralia
Araucaria araucana Koch. (Pinaceae)	Monkeypuzzle tree
Archontophoenix sp. (Palmaceae)	Archontophoenix palm
Archontophoenix cunninghamiana Wendl. & Drude (Palmaceae)	Seaforthia palm
Ardisia sp. (Myrsinaceae)	Ardisia
Areca aliciae Muel. (Palmaceae)	
Areca madagascariensis Mart. (Palmaceae)	
Areca triandra Roxbg. (Palmaceae)	
Arecastrum romanzoffianum Becc. (Palmaceae)	Plumy coconut palm
Artabotrys sp. (Annonaceae)	Artabotrys
Artabotrys odoratissimus R. Br. (Annonaceae)	Climbing ylang-ylang
Asparagus plumosus Baker (Liliaceae)	Asparagus fern
Aspidistra sp. (Liliaceae)	Aspidistra
Azalea spp. (Ericaceae)	Azaleas
Balaka sp. (Palmaceae)	Balaka palm
Bauhinia sp. (Leguminosae)	Mountain ebony
Belamcanda chinensis DC (Iridaceae)	Blackberry-lily
Bischofia sp. (Euphorbiaceae)	
Bougainvillea sp. (Nyctaginaceae)	Bougainvillea
Butia capitata Becc. (Palmaceae)	Pindo palm
Calophyllum inophyllum L. (Guttiferaceae)	Kamini
Calycanthus sp. (Calycanthaceae)	
Camellia spp. (Ternstroemiaceae)	Camellias
Camellia japonica L. (Ternstroemiaceae)	Camellia
Cananga odorata Hook. f. & Thoms. (Annonaceae)	Ylang-ylang
Canna sp. (Cannaceae)	Canna
Carissa sp. (Apocynaceae)	
Carya pecan Ascerts. & Graebn. (Juglandaceae)	Pecan
Caryota sp. (Palmaceae)	Fishtail palm
Casimiroa edulis Llave & Lex. (Rutaceae)	White sapote
Castanospermum australe Cunn. (Leguminosae)	Moreton Bay chestnut
Cassia sp. (Leguminosae)	
Cedrela odorata L. (Meliaceae)	West Indian cedar; Spanish cedar
Ceiba pentandra Gaertn. (Bombacaceae)	Silk-cotton tree
Chamaedorea sp. (Palmaceae)	Chamaedorea palm
Chrysalidocarpus sp. (Palmaceae)	Areca palm
Cinnamomum camphora Nees & Eberm. (Lauraceae)	Camphor-tree
Cinnamomum zeylanicum Breyn. (Lauraceae)	Cinnamon tree
Citrus aurantifolia (Christm.) Swingle (Rutaceae)	Lime
Citrus aurantium L. (Rutaceae)	Sour orange
Citrus grandis Osbeck (Rutaceae)	Grapefruit
Citrus limonia Osbeck (Rutaceae)	Lemon
Citrus mitis Blanco (Rutaceae)	Calamondin
Citrus nobilis var. *deliciosa* (Tenore) Swingle (Rutaceae)	Tangerine
Citrus nobilis var. *unshiu* (Mak.) Swingle (Rutaceae)	Satsuma
Citrus sinensis (L.) Osbeck (Rutaceae)	Orange
Coccolobis uvifera Jacq. (Polygonaceae)	Seagrape
Cocos nucifera L. (Palmaceae)	Coconut palm
Codiaeum sp. (Euphorbiaceae)	Croton (ornamental)

SCIENTIFIC NAME (Species and Family)	COMMON NAME
Crotalaria sp. (Leguminosae)	Crotalaria
Cycas circinalis L. (Cycadaceae)	Queen sago palm; fern palm
Cycas revoluta Thunb. (Cycadaceae)	Sago palm
Dictyosperma sp. (Palmaceae)	Dictyosperma
Dictyosperma album Wendl. & Drude (Palmaceae)	
Dictyosperma album var. *rubrum* (Palmaceae)	
Dictyosperma alexandra (Palmaceae)	
Diospyros kaki L. f. (Ebenaceae)	Japanese persimmon
Dizygotheca elegantissima Vig. & Guill. (Araliaceae)	
Dracaena sp. (Liliaceae)	Dracena
Duranta sp. (Verbenaceae)	Duranta
Elaeagnus sp. (Elaeagnaceae)	Elaeagnus
Elaeagnus angustifolia L. (Elaeagnaceae)	Russian-olive
Epibaterium sp. (Menispermaceae)	Coral bead
Eriobotrya japonica Lindl. (Rosaceae)	Loquat
Erythea armata Wats. (Palmaceae)	
Eucalyptus sp. (Myrtaceae)	Eucalpytus
Eucalyptus rudis Endl. (Myrtaceae)	Desert gum
Eugenia sp. (Myrtaceae)	Syzygium
Eugenia jambos L. (Myrtaceae)	Rose apple
Eugenia uniflora L. (Myrtaceae)	Surinam-cherry
Euonymus sp. (Celastraceae)	
Euphorbia pulcherrima Willd. (Euphorbiaceae)	Poinsettia
Ficus sp. (Moraceae)	Fig
Ficus benjamina L. (Moraceae)	Weeping laurel
Ficus elastica Roxb. (Moraceae)	Rubber plant
Fortunella sp. (Rutaceae)	Kumquat
Gardenia sp. (Rubiaceae)	Gardenia
Gladiolus sp. (Iridaceae)	Gladiolus
Glycosmis pentaphylla (Retz.) DC. (Rutaceae)	
Gordonia lasianthus (L.) Ellis (Ternstroemiaceae)	Bay
Grevillea robusta Cunn. (Proteaceae)	Australian silk-oak
Hedera sp. (Araliaceae)	Ivy
Hedera canariensis Willd. (Araliaceae)	Algerian ivy
Hedera helix L. (Araliaceae)	English ivy
Hibiscus sp. (Malvaceae)	Hibiscus
Howea sp. (Palmaceae)	Kentia palm
Hydriastele wendlandiana Wendl. & Drude (Palmaceae)	Hydriastele palm
Hyophorbe sp. (Palmaceae)	Hyophorbe palm
Ilex spp. (Aquifoliaceae)	Holly
Illicium sp. (Magnoliaceae)	Anisetree
Iris sp. (Iridaceae)	Iris
Ixora sp. (Rubiaceae)	White ixora
Jasminum sp. (Oleaceae)	Jasmine
Jasminum humile L. (Oleaceae)	
Jasminum primulinum Hemsl. (Oleaceae)	
Jasminum pubescens Willd. (Oleaceae)	
Jasminum sambac Soland (Oleaceae)	Arabian jasmine
Lagerstroemia indica L. (Lythraceae)	Crapemyrtle
Latania sp. (Palmaceae)	Latania palm
Laurus nobilis L. (Lauraceae)	
Ligustrum sp. (Oleaceae)	Ligustrum
Ligustrum lucidum Ait. (Oleaceae)	
Lilium sp. (Liliaceae)	Lily
Lilium longiflorum Thunb. (Liliaceae)	White lily
Linum sp. (Linaceae)	Flax
Liriope sp. (Liliaceae)	Liriope

SCIENTIFIC NAME (Species and Family)	COMMON NAME
Litchi chinensis Sonn. (Sapindaceae)	Litchi
Livistona sp. (Palmaceae)	Livistona palm
Livistona australis Mart. (Palmaceae)	
Magnolia sp. (Magnoliaceae)	Magnolia
Magnolia soulangeana Soul (Magnoliaceae)	
Magnolia virginiana L. (Magnoliaceae)	White bay
Mammea americana L. (Guttiferae)	Mamey apple
Mangifera indica L. (Anacardiaceae)	Mango
Maranta sp. (Marantaceae)	Maranta
Melaleuca leucadendra L. (Myrtaceae)	Cajeput-tree; punk tree
Meratia praecox Rehd. & Wils. (Calcycanthaceae)	
Michelia fuscata Blume (Magnoliaceae)	Banana-shrub
Monstera deliciosa Leibm. (Araceae)	Ceriman
Moraea iridioides L. (Iridaceae)	
Morus sp. (Moraceae)	Mulberry
Muehlenbeckia sp. (Polygonaceae)	Muehlenbeckia
Musa sp. (Musaceae)	Banana
Myrtus sp. (Myrtaceae)	Myrtle
Myrtus communis L. (Myrtaceae)	
Nerium oleander L. (Apocynaceae)	Oleander
Ochrosia parviflora Hemsl.	
Olea sp. (Oleaceae)	Olive
Ophiopogon sp. (Liliaceae)	Ophiopogon
Osmanthus sp. (Oleaceae)	European osmanthus
Osmanthus fragrans Lour. (Oleaceae)	
Pachysandra sp. (Buxaceae)	
Paurotis wrightii (Griseb. & Wendl.) (Palmaceae)	
Persea sp. (Lauraceae)	Avocado
Phoenix sp. (Palmaceae)	Phoenix palm
Phoenix canariensis Chaub. (Palmaceae)	Canary date palm
Photinia serrulata Lindl. (Rosaceae)	
Pittosporum sp. (Pittosporaceae)	Pittosporum
Podocarpus sp. (Taxaceae)	Podocarpus
Pritchardia sp. (Palmaceae)	Pritchardia palm
Prunus spp. (Rosaceae)	Cherry, plum
Prunus caroliniana Ait. (Rosaceae)	Cherry-laurel
Prunus laurocerasus L. (Rosaceae)	English-laurel
Psidium sp. (Myrtaceae)	Guava
Pyracantha sp. (Rosaceae)	Firethorn
Pyrus malus L. (Rosaceae)	Apple
Rapanea guianensis Aub. (Myrsinaceae)	Myrsine
Ravanela madagascariensis Gmel. (Musaceae)	Travelers-tree
Rosa sp. (Rosaceae)	Rose
Roscheria melanochoetes Wendl. (Palmaceae)	
Roystonea regia O. F. Cook (Palmaceae)	Royal palm
Sabal sp. (Palmaceae)	Palmetto, Sabal palm
Sabal palmetto Lodd. (Palmaceae)	Cabbage palmetto
Schaefferia frutescens Jacq. (Celastraceae)	Boxwood
Scindapsus sp. (Araceae)	Pothos
Senecio mikanioides Otto. (Compositae)	German ivy
Serenoa repens Sm. (Palmaceae)	Saw palmetto
Severinia sp. (Rutaceae)	Severinia
Spiraea sp. (Rosaceae)	Spirea
Strelitzia sp. (Musaceae)	Bird-of-paradise
Syringa sp. (Oleaceae)	Lilac
Tabernaemontana sp. (Apocynaceae)	Tabernaemontana
Tamala sp. (Lauraceae)	Redbay
Ternstroemia sp. (Ternstroemiaceae)	
Thea sinensis L. (Ternstroemiaceae)	Tea plant
Thrinax sp. (Palmaceae)	Thrinax palm

SCIENTIFIC NAME (Species and Family)	COMMON NAME
Trachelosperum sp. (Apocynaceae)	Rhynchospermum
Trachelospermum jasminoides Lem. (Apocynaceae)	Starjasmine
Trachycarpus fortunei H. Wendl. (Palmaceae)	Fortunes palm; windmill palm
Trevesia palmata Vis. (Araliaceae)	
Viburnum sp. (Caprifoliaceae)	Virburnum
Viburnum tinus L. (Caprifoliaceae)	Laurestinus
Vinca major L. (Apocynaceae)	
Washingtonia sp. (Palmaceae)	Washingtonia palm
Wisteria sp. (Leguminosae)	Wisteria
Zamia sp. (Cycadaceae)	

In addition to these host plants, the following have been found in St. Lucie County:[2]

Bidens pilosa radiata Sch. Bip. (Compositae)	Beggarticks
Carica papaya L. (Caricaceae)	Papaya
Croton glandulosus L. (Euphorbiaceae)	Croton (wild)
Smilax tamnifolia Michx. (Liliaceae)	Smilax

DESCRIPTION OF THE STAGES

Egg:

The egg is oval in shape, lemon yellow in color, and has a smooth chorion that is slightly sticky. The color remains about the same from the time the egg is oviposited until it hatches. The first noticeable change in the shape is a considerable flattening and widening, which occurs immediately before hatching. One hundred eggs, measured before any change in shape occurred, averaged 0.18 mm. in length and 0.10 mm. in width.

First Instar:

The active larva, or first instar, is bright yellow, broadly oval in outline, and widens toward the anterior end of the body. The antennae are 5-jointed, and two very short setae are found on the posterior end of the body. One hundred active larvae averaged 0.20 mm. in length and 0.15 mm. in width. The dorsal scale of the settled larva is dark gray with a white tip (the remains of the white cap) in the center. No change, except growth, occurs in the body of the larva from the time it settles until the first molt. As the larva enters the first molt, the body becomes tightly stuck to the dorsal scale, the color of which changes to a light brown.

Second-Instar Female:

The larva sheds its legs, setae, and antennae during the first molt. The upper portion of the cast skin is incorporated with the dorsal scale, and the lower portion forms the first part of the very thin ventral scale. The dorsal scale in this stage has two distinct rings, the inner one being light brown and the outer one much darker. As in the first instar, the body becomes tightly stuck to the dorsal scale immediately before the second molt, and the color of the dorsal scale becomes reddish brown.

[2] Identification of these plants was made by the Bureau of Plant Industry, Soils, and Agricultural Engineering.

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Adult Female:

The cast skin from the second molt of the female is incorporated with the dorsal and ventral scales, as in the first molt. The dorsal scale is circular and convex, and has three distinct rings. The innermost one, which is nearly central, is light brown, the second is reddish brown, and the third varies from a dark reddish brown to black, with a thin gray margin. The third ring is wider than the other two combined. The measurements of 100 dorsal scales averaged 2.1 mm. in diameter. Ferris (*4*, SII - 201) gives the following description of the female body:

"Length about 1.1 mm. Derm at full maturity membranous or at times with very slight sclerotization in the cephalothoracic region. Pervivulvar pores present in five groups of three to six pores in each. Pygidium short and broad, the apex quite obtuse. Three pairs of well developed lobes present, these all of about the same size and shape; fourth lobe indicated merely by a rounded projection. Beyond the fourth lobe the margin is sclerotized and is twice notched. Plates from the meson to the third lobe all finely and evenly fimbriate at the apex, those beyond the third lobe of a different form, the first two normally showing two large and somewhat club-shaped processes, the third with one club and a varying number of variously shaped fimbriations. Marginal scleroses or paraphyses distributed in the manner described for the genus, [From the description of the genus by Ferris: (*4*, SII - 198) 'Slender scleroses or paraphyses arise from the bases of the median to third lobes and from the margin in the intersegmental areas . . .'] there being none beyond the third lobe. Dorsal ducts of the pygidium of two sizes. Three or four stout ducts arise from pores between the median and second lobes and extend to about the center of the pygidium. From near the bases of the third and fourth lobes there extend zones of small pores from which arise long and slender ducts, the anterior-most of which extend beyond the anterior margin of the pygidium. These bundles of slender ducts are conspicuous features of the species. In the zones of pores the striations of the derm tend to lie transversely. A conspicuous, submarginal cluster of small, short ducts is present on the dorsum of what is here considered to be the second abdominal segment, other than these there being not more than one or two small ducts on any segment anterior to the fifth. Thoracic spur well developed, acute, sclerotized. Anal opening."

The body of the female decreases in size as the eggs are oviposited, and if the oviposition period is completed, the remains of the body are practically clear and very much shriveled.

Second-Instar Male Larva:

Under field conditions, no distinction can be made between the sexes until 3 or 4 days after the first molt, when the second ring of growth, which is in the process of being formed, becomes noticeably darker in the male than in the female. As growth continues, the scale covering of the male becomes more convex than that of the female. As the larva nears the end of the second period of growth, purple eye spots are formed which are retained through all the succeeding immature stages, eventually becoming eyes in the winged adult. The eye spots can hardly be seen at first, but become very conspicuous as development continues. After they are formed, the last external change occurs, in which a thin gray lip is formed at the posterior end of the scale covering. The pygidial characteristics and color are the same for the two sexes during this stage.

Male Prepupa:

After the second molt the male enters the prepupal stage. In this stage the width of the body at the anterior, middle, and posterior parts is almost the same, and the tip of the abdomen is very blunt, except for two small spines. The color is about the same as that of the larva, and by the time the growth for this stage is completed, the outlines of the antennae and wings can be seen. One hundred prepupae averaged 0.62 mm. in length and 0.40 mm. in width.

Male Pupa:

The pupa has the general shape of the adult male, and the outlines of the wings, antennae, style, and legs can be seen clearly. The color varies from a bright yellow to a yellowish brown. One hundred pupae averaged 0.72 mm. in length.

Adult Male:

The adult male is a delicate, two-winged insect, light orange-yellow in color, with a dark-brown band around the thorax, purplish-black eyes, and vestigial mouth parts. The average length of the male, including the style, was about 0.74 mm., and the wing expanse was 1.36 mm.

LIFE HISTORY AND HABITS

The Egg:

The eggs are deposited underneath the dorsal scale of the female, where they remain until they hatch. Since no observations could be made under natural conditions because of the dorsal scale, it was lifted from females that were on fruits, and observations were made on those found ovipositing. Females continued to oviposit for a time after the scale covering was removed, and under this condition the eggs were laid in chains, being lightly stuck together end to end. During the summer months the rate of oviposition was fairly rapid, as 2 eggs were laid by a female in 1 hour, and 334 crawlers were removed from an isolated female on a fruit in a 51-day period.

The length of the incubation period at various temperatures was determined from tests in which ovipositing females were held in a constant-temperature cabinet. With one group of 70 eggs held at 90° F. the first egg hatched in less than 1 hour; with a group of 37 eggs held at 80° the first egg hatched after 3 hours and the last one after 26 hours. The last egg from a group of 14 held at a mean room temperature of 67° hatched after about 48 hours.

After the egg flattens, the covering splits at the anterior end, and the larva gradually works the skin back over its body. During the summer months the hatching is very rapid, and the larva may be seen crawling before the cast skin is completely off, but during cool weather the crawler may remain partially hatched for several days.

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In order to determine the minimum and maximum temperatures at which they would hatch, eggs that had been removed from ovipositing females were held in groups of 50 at different constant temperatures and left until some hatched or it was apparent that none would hatch. This procedure was repeated until the highest and lowest points at which any eggs hatched were reached. The minimum point was 53° ± 1° F. Only 1 out of 50 eggs hatched at 107.5° ± 2.5° F., and the larva died without moving after casting its skin. Other eggs appeared to flatten, preparatory to hatching, but never completed the process. No hatching occurred from a group of 50 eggs held at 110.5° ± 1.5°, and after 24 hours the eggs appeared to be shriveled.

The percentage of eggs that hatched was determined by removing them from ovipositing females, placing them on filter paper in a petri dish, and leaving them at room temperatures until they hatched or became discolored. From these tests conducted during the winter and spring months, 99 per cent of 980 eggs hatched. This high percentage of hatching was also borne out in the records taken under grove conditions, as very few discolored eggs were found under females unless signs of predators were noticed.

Active Larva:

The percentage of crawlers found alive under females ranged from 40 in March to 100 in June. In February and March, when the percentages were lowest, many predaceous mites were found under the scales with the dead crawlers. The lowest percentage of living crawlers found in any of the other months was 78. In most cases where the female had apparently completed its normal life cycle, large numbers of cast skins were found, and all larvae had emerged or settled under the old scale covering. One female was observed to have 14 immature scales under it. No accurate method was found for determining what percentage of the crawlers under an ovipositing female emerge. From the foregoing counts, however, the indication is that the dorsal scale of the ovipositing female does not hinder emergence, since very few females were found with large numbers of dead crawlers under them unless some signs of predaceous enemies were evident.

The distance traveled by active larvae was determined in tests made in the screened insectary. Crawlers were placed on smooth paper and on grapefruits, their movements were traced with a pencil, and the distances traveled were measured with a map measurer. From observations made over 2-hour periods it was found that the average distance traveled by six crawlers on smooth paper was 38 inches when the mean temperature was 86° F., and by four crawlers, 20.6 inches at a mean temperature of 69°. All crawlers were still alive at the end of the 2-hour periods. The distances five crawlers traveled on a grapefruit ranged from 1.5 to 9 inches, and the time required before settling ranged from 15 minutes to 1 hour.

In an experiment where larvae were placed on dry sandy soil they had great difficulty in traveling. Two hours was the minimum time observed for a crawler to travel from the center to the edge of a 6-inch circle of such soil. The minimum temperature at which crawlers made any effort to move about was 55°. Movement was very slow until the temperature reached 60°.

The ability of a larva to live without food on slightly moistened filter paper ranged from 6 to 13 days, as compared with 3 to 4 days on dry filter paper. Crawlers that were transferred to leaves after living for 4 days on slightly moistened filter paper were able to settle, but those kept on the paper longer were not. Living crawlers were found up to the 25th day on leaves picked during the winter months and placed in petri dishes without additional moisture. By this time all ovipositing females had died and all eggs had hatched.

Observations made during this study indicated that crawlers will settle as readily on leaves as on fruits, and will settle on leaves or fruits of any age, with the exception of very immature fruits. Some scales were found on green wood, but rarely unless the infestation was extremely heavy. No scales were found on gray wood.

A larva, upon being placed on a leaf, usually moves over both the upper and lower surfaces. After this activity has continued several minutes, it moves very slowly over a selected area and inserts its mouth parts. The body moves considerably while the mouth parts are being inserted. The first waxlike threads of the scale covering appear on the posterior end of the body, and as they are being secreted the body is slowly rotated, the mouth parts being used as a pivot, until it is turned completely around, and then the movement is retraced. About 30 minutes is required for a scale to make a turn of 360°. This rotating continues as long as the body can be seen. During the movement some contractions of the body and movement of the legs are visible. The first waxy covering is easily removed; from one scale six coverings were removed as soon as each was completed, before the scale died. After the larva is completely covered with the wax, it is considered to be in the white-cap stage. At this stage the covering is round and the sides are vertical. A thin gray ring is then formed around this central nipple. From data secured during the summer months, when the temperature ranged from 72° to 91° F., the average time from emergence to settling was 95 minutes, from settling until the white-cap stage was 100 minutes, and the time spent in the white-cap stage was 21 hours and 20 minutes.

Data on the percentage of the crawlers that settled were obtained by placing eggs in gelatin cylinders on fruits at room temperatures and leaving them until they hatched and the crawlers settled. Under these conditions 76.5 percent settled of 443 larvae that were observed. Wind, rain, predaceous enemies, and extreme temperatures are some of the hazards encountered in settling under grove conditions.

First Instar:

Artificial infestations were started in 1939 for a study on the length of time the scale spends in each instar under grove conditions. The infestations were made by fastening leaves heavily infested with the Florida red scale to uninfested leaves and fruits. In warm weather many crawlers had transferred to the clean surfaces within 2 days, and the leaves that were the source of infestation were removed; in cool weather the leaves were left on for about 4 days. The newly settled larvae were then circled with India ink for identification. Each individual was examined every 2 days when possible, and its stage of development recorded. A hygrothermograph was operated in the screened insectary in the grove for temperature and humidity records during this study, and the data on the duration of each stage of development were correlated with temperature.

During the first part of this work new infestations were started monthly, but later they were started twice each month to obtain more data. In the 64 infestations made over a 3-year period 12,603 scales were marked for study, but only 4,942 completed the first instar. Some were removed for microscopic examinations, and some were destroyed by premature dropping of leaves from frequent handling. When these had been deducted, mortality in the remaining larvae ranged from 76 percent in December to 37 percent in September.

From data from these infestations it was possible to calculate the effect of seasonal variations in temperature upon duration of development of the first instar. The time required for development for each infestation was inverted to obtain the rate of development. These rates were correlated with the temperature, the regression equation being $Y = -75.6246 + 1.6633X$, and the correlation coefficient $r = 0.9526$. The rates estimated from the regression equation were inverted to give estimated times of development which, when plotted, gave a smooth hyperbolic curve (Fig. 1).

The length of the instar was calculated from the time the infestation was made until the scale was considered to be through the first molt.

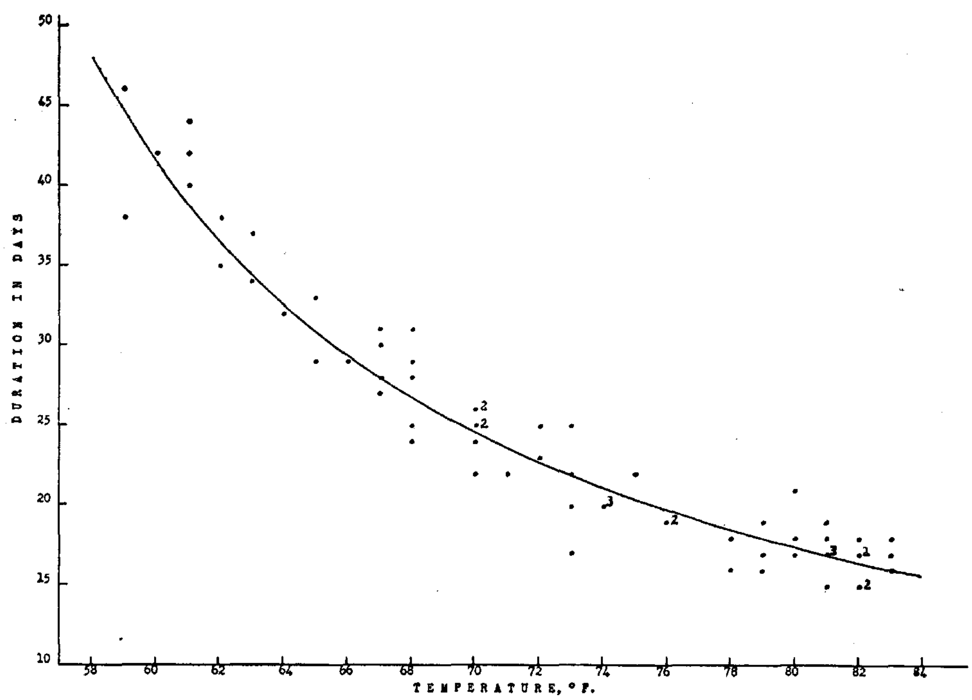

Figure 1.—Relation between temperature and the time required for development of the first instar of the Florida red scale.

Considerable variation in development occurred at the same temperatures, but many factors could have caused this. The time required for completion of the instar ranged from 46 days at 59° F. to 15 days at 82°. The optimum temperature for development was between 78° and 83°, but there was little difference in the rate of development between these points, although below 78° the time required for development was increased.

Second-Instar Female:

After the scales had completed the first molt, examinations were continued to determine the length of the second instar. From these infestations 3,325 females were observed, of which 877 completed the second instar. Owing to the high mortality from November through March, female scales were able to complete the second instar in only 51 of 64 infestations. The development of the male and female differs after the first instar, and data on only the females are included in Figure 2, which gives the number of days required for the completion of the second instar correlated with the mean temperatures for the period. The curved line represents the expected time required for completion of the instar at any given mean temperature between 61° and 83° F. This line was plotted in the same way as the one for the first instar, the regression equation in this case being $Y = -101.1596 + 2.1046X$ and the correlation coefficient $r = 0.9258$.

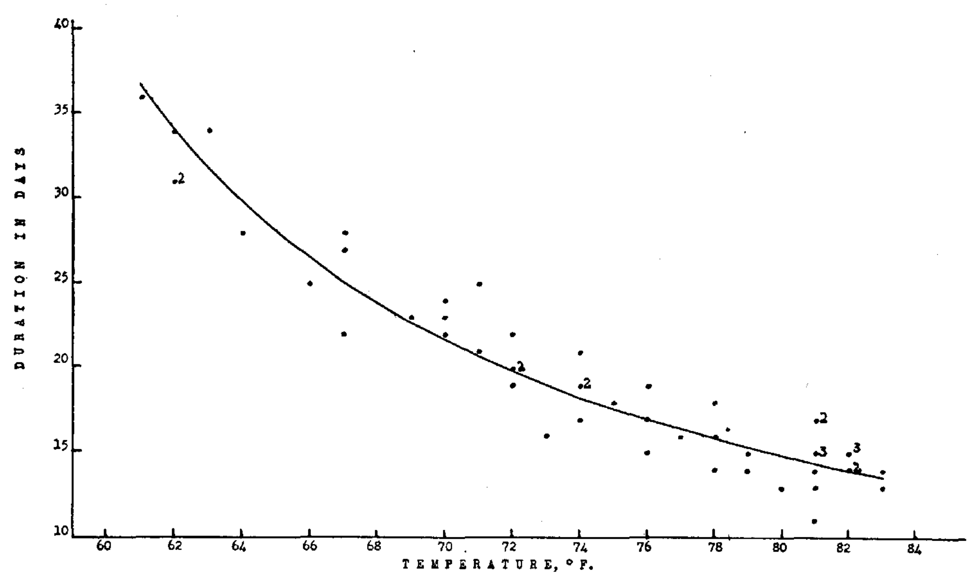

Figure 2.—Relation between temperature and the time required for development of the second instar of the female Florida red scale.

The length of the instar ranged from 36 days at 61° F. to 11 days at 81°. The variation between the actual number of days recorded and the expected number of days was not so great in this instar as it was in the first. As in the first instar, the optimum temperature for development was between 78° and 83°. It was found that temperature affected the development of the second instar less than it did the first, and that the greatest difference in time occurred at 69°.

The natural mortality during each month, computed as for the first instar, ranged from 96 percent in March to 51 percent in September. It varied considerably from month to month, but was obviously higher during the winter months. Natural mortality was unusually high in the grove where the work was conducted. From infestations made in the fall and winter months, when the parasites were the most effective, very few of the marked scales reached maturity.

During January, February, and March 1942, examinations were made to secure additional information on the number of parasitized second-instar females. Each month 50 leaves picked at random from 10 trees in the laboratory grove were examined under a binocular microscope. Of 5,039 second-instar females examined, 40, 50, and 55 percent were found with parasites in the respective months. The percentage of living scales ranged from 13 in January to 3 in March. A scale was considered to be parasitized if the parasite's body or any portion of it was found in the scale's body, or if the dorsal scale showed the characteristic round emergence hole with the shell-like body of the scale under it. Most such females had entered the second molt before the parasite had developed enough to kill them, and very few ever completed the molt.

Adult Female:

Very little definite proof has been obtained on how or when fertilization occurs, but it is believed to occur at night shortly after the female completes the second molt, as the males of the same age emerge at this time. Inasmuch as Schweig and Grunberg *(6)* proved that fertilization by the male is necessary for reproduction, no experiments were made along this line, although additional evidence was obtained in a few cases when females isolated for reproduction records failed to reproduce, evidently having been isolated before fertilization occurred. The time from the completion of the second molt until the first eggs were deposited ranged from 2 to 4 weeks; the oviposition period ranged from 1 to 8 weeks.

Reproduction records were obtained in a screened insectary from adult females isolated in gelatin cylinders on leaves of potted citrus plants and on fruits picked from trees in the grove. If crawlers or settled larvae were found in a cylinder within 3 days after isolation in summer, or within 5 days in winter, the female was discarded because of the possibility that it was already reproducing when isolated. The remaining cylinders were examined at intervals, and all newly settled scales or active larvae were counted and removed. When no crawlers were found in a cylinder for several days, the female scale was turned over, and the number of scales that had settled under it was recorded. In this way the total number of crawlers produced by each female was obtained.

The number of crawlers produced by each of 30 females on fruits ranged from 32 to 334, with an average of 145; the number produced by 25 females isolated on leaves ranged from 21 to 156, with an average of 80. Not only did the females isolated on fruits produce more young than did those on leaves, but they did so in a shorter period of time. The total number of crawlers produced was the same in cool and warm weather. The minimum time from infestation to oviposition was 45 days and the maximum was 153, the latter occurring during abnormally low temperatures. Very few of the females deposited all their eggs, as some could still be seen in their bodies after death.

Immature Stages of the Male:

Inasmuch as temperature proved to be the main factor that determined the rate of development of the immature stages of the female, it was assumed that the same would be true of the male scale. However, one infestation was made in 1940 to secure data on the changes that occur in the male and on the time required for the completion of each change. On August 3, 840 scales on the upper surfaces of leaves were marked for identification. Every 2 to 4 days after the first molt was completed about 15 males were examined to determine the stage of development.

It was found that about 5 days after completion of the first molt the eye spots could be seen, 5 additional days were required for the lip to be formed on the dorsal scale, and after 3 more days the prepupal stage was reached. The prepupal and pupal stages so overlapped that it was difficult to determine their length, but each is very short, as winged adults were found 15 days after completion of the first molt. The body of the male does not stick to the dorsal scale in any molt except the first, and the cast skins of the second, third, and fourth molts are pushed out under the lip of the dorsal scale.

Adult Male:

To determine the duration of the developmental period of the male — that is, the time from artificial infestation to the end of the pupal stage — the dorsal scales of many individuals were carefully removed. When a winged adult was found, the time from infestation to that date was calculated. If prepupae or pupae were found, they were placed in petri dishes on moistened filter paper to complete their transformation into winged adult males, and then the number of days from infestation to the time the last molt was completed was calculated. The time required for development was correlated with the mean temperature for each infestation (Fig. 3). The curved line, which represents the estimated rate of growth, was calculated as for the first- and second-instar females, the regression equation in this case being $Y = -49.2057 + 1.0164X$, and the correlation coefficient $r = 0.9798$. In the examinations 106 winged males were found, and the period of development ranged from 78 days at 61° F. to 28 days at 83°.

Some variation in the rate of development at the same temperature occurred, but this was expected as the numbers were small and the dates on which males were found could have been either the earliest or latest days for completion of development and not the average. It was found, however, that the calculated rate of development of the male corresponded closely with the calculated time required for the female to complete the second molt at the same temperatures. At no temperature was the variation greater than 3 days. After a male emerges, its life is very short, as no food is taken. The longest period that one was kept alive was 4 days.

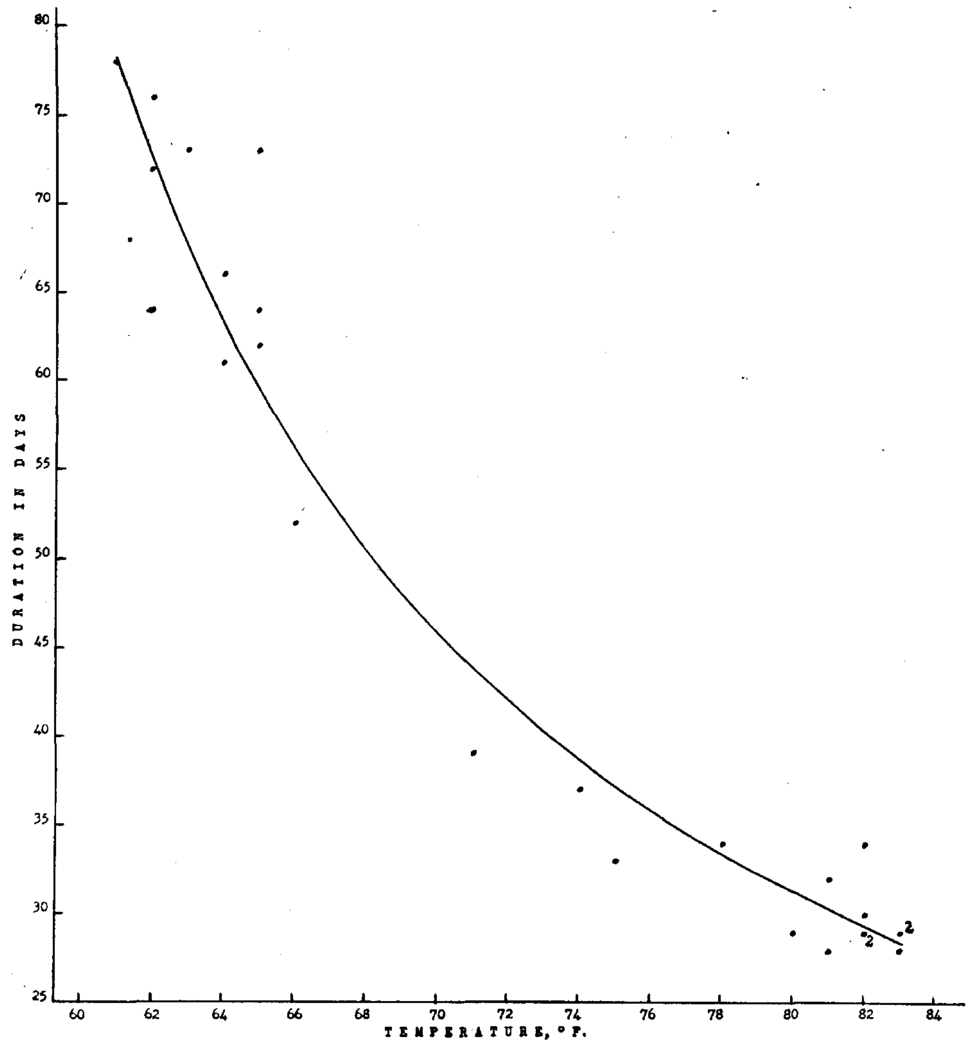

Figure 3.—Relation between temperature and the time required for the development of the male Florida red scale.

Number of Generations a Year:

To determine whether an adult female has reached the ovipositing period, the dorsal scale must be lifted. After females of the artificial infestations reached the adult stage, such examinations were made at irregular intervals, and when a female that had apparently just entered the oviposition period was found, the time that had elapsed since the infestation date was recorded. It was found that five or six generations would occur over a period of 12 months at a mean temperature of 74° F. Schweig and Grunberg *(6)* state that three to four generations were produced in Palestine at a mean yearly temperature of 19.3° C. (67° F.) and five generations at a mean temperature of 22.5° C. (73° F.).

Ratio of Males to Females:

Each month when the seasonal-history counts discussed in the following section were made, the males and females were recorded separately if their development had reached a point where the sexes could be distinguished. Of the 15,738 scales so recorded during a 12-month period, 59 percent were females, the range being from 52 to 68 percent.

Distribution of Males and Females on Leaf Surfaces:

From the same seasonal-history counts records were also kept of the numbers of males and females found on the upper and lower surfaces of the leaves. It was found that 96 percent of the males and 13 percent of the females were on the upper side of the leaves. It was thought that light or gravity might be factors influencing this distribution. If this were true, scales that settle in the absence of light should have an equal distribution. In the case of gravity, the distribution of the sex should be reversed if the leaf surfaces were reversed.

To determine the influence of absence of light on the distribution, infestations were made on potted citrus plants in a photographic dark room by clipping infested leaves onto the clean leaves of the plants, just as was done in making the artificial infestations in the grove. Several days later the clipped-on leaves were removed, but the plants were left in the dark for an additional day to give all the crawlers time to settle before the plants were removed from the dark room. The scales were then allowed to develop until their sex could be determined, and counts were made of the males and females on the upper and lower surfaces of the leaves. To determine the effect of gravity on the distribution, potted citrus plants were suspended in an inverted positon and infested. Table 1 gives the results of these experiments.

TABLE 1.—DISTRIBUTION OF MALES AND FEMALES OF THE FLORIDA RED SCALE FOUND ON UPPER SURFACE OF CITRUS LEAVES.

Date of Infestation	Males (Percent)	Females (Percent)
In the Absence of Light		
1940		
May	90	58
June	54	40
1942		
May	83	50
	77	68
	78	35
Average	76	50
On Inverted Plants, to Test Effect of Gravity		
1942		
May	56	34
June	58	45
Average	57	40

In the experiments in which the crawlers settled in the absence of light, the females were evenly distributed between the two surfaces, whereas 76 percent of the males settled on the upper leaf surfaces. In the experiments to determine the effect of gravity, a fairly even distribution was secured for each sex. The experiments indicated that light is one of the most important factors influencing the distribution of the females, but no definite indications were secured for the male although, while it seems that both light and gravity affect their distribution, evidently other factors also exert influence.

SEASONAL HISTORY

Once each month from April 1942 through March 1943 a sample of 5 leaves was picked at random from each of 80 orange trees, and the numbers of scales in each stage were recorded. Table 2 gives the number of living scales and of ovipositing females found at each examination.

TABLE 2.—SEASONAL DISTRIBUTION OF THE FLORIDA RED SCALE ON CITRUS.

Date of Examination	Number of Scales on 400 Leaves	
	Living	Ovipositing
1942		
April	1,071	37
May	868	14
June	316	13
July	788	31
August	1,413	42
September	1,743	38
October	1,286	19
November	620	17
December	538	11
1943		
January	378	13
February	309	12
March	216	6

The number of living scales appears to be unusually high in April, but no explanation can be given for this. The number decreased in May and June, and this is believed to have been caused partially by the falling of the old, infested leaves. In June it was impossible to secure a randomized sample of fully matured leaves, because there was so much new growth, and probably the distribution of the scales was not general over the new growth. The number of living scales increased from June to September, when the peak was reached, and thereafter decreased each month.

The number of ovipositing females followed the same trend as the number of living scales, except that the peak was reached in August.

The percentage of parasitized scales was calculated from the number of settled scales, exclusive of those in the first instar, since only two first-instar scales were found with visible parasites in them. The percentage of

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The percentage of parasitized scales was calculated from the number of settled scales, exclusive of those in the first instar, since only two first-instar scales were found with visible parasites in them. The percentage of parasitized scales ranged from 7.4 in August, to 20.0 in November. The percentage of parasitization was also calculated separately for the males, for second-instar females, and for third-instar females. More males were parasitized than either instar of the females, 32.5 percent in November. Very few third-instar females were found with parasites, the highest parasitization being 5.6 per cent in February.

FACTORS INFLUENCING SCALE ABUNDANCE

Cultural Practices:

In recent years it has been the opinion of many investigators that the general condition of a grove influences the abundance of scales. Schweig and Grunberg *(6)* reported that a grove well supplied with water and fertilizer was likely to have a heavier infestation of scales than a poorly kept grove. Thompson *(7)* reported that populations of the purple scale were higher in groves in which the mineral deficiencies had been corrected, as more green leaves were produced and were retained longer.

Results of preliminary work at this laboratory seem to support these statements. In 1942 a comparison was made of Florida red scale infestations found on citrus trees growing in areas which were clean cultivated or contained a cover crop. The experimental arrangement consisted of 8 plots, each approximately 6 trees by 14 trees. Half of these plots were disked at intervals to keep them clean of all vegetation, and in the other half a cover crop was maintained and no cultivating was done. The first cultivating was done in March and the last in September. At monthly intervals from April through December, 200 leaves from each treatment were examined for scale infestations. Only the living, settled scales were used in comparing the infestations in the two treatments. The results of these examinations are summarized in table 3.

TABLE 3.—EFFECT OF GROVE CULTIVATION ON FLORIDA RED SCALE ABUNDANCE IN 1942.

Month	Average Number of Living Scales per Leaf	
	Cultivated Plots	Cover-Crop Plots
April	2.4	2.9
May	2.4	1.9
June	.9	.7
July	2.3	1.6
August	5.0	2.0
September	6.2	2.6
October	5.0	1.3
November	2.5	.6
December	2.1	.6

In April the average number of scales per leaf was practically the same in the two treatments, being only slightly higher in the cover-crop plots. In May and for the remainder of the year the average was slightly higher in the cultivated plots. When the data were analyzed statistically, parasitized scales ranged from 7.4 in August, to 20.0 in November. The percentage of parasitization was also calculated separately for the males, for second-instar females, and for third-instar females. More males were parasitized than either instar of the females, 32.5 percent in November. Very few third-instar females were found with parasites, the highest parasitization being 5.6 per cent in February.

FACTORS INFLUENCING SCALE ABUNDANCE

Cultural Practices:

In recent years it has been the opinion of many investigators that the general condition of a grove influences the abundance of scales. Schweig and Grunberg *(6)* reported that a grove well supplied with water and fertilizer was likely to have a heavier infestation of scales than a poorly kept grove. Thompson *(7)* reported that populations of the purple scale were higher in groves in which the mineral deficiencies had been corrected, as more green leaves were produced and were retained longer.

Results of preliminary work at this laboratory seem to support these statements. In 1942 a comparison was made of Florida red scale infestations found on citrus trees growing in areas which were clean cultivated or contained a cover crop. The experimental arrangement consisted of 8 plots, each approximately 6 trees by 14 trees. Half of these plots were disked at intervals to keep them clean of all vegetation, and in the other half a cover crop was maintained and no cultivating was done. The first cultivating was done in March and the last in September. At monthly intervals from April through December, 200 leaves from each treatment were examined for scale infestations. Only the living, settled scales were used in comparing the infestations in the two treatments. The results of these examinations are summarized in table 3.

TABLE 3.—EFFECT OF GROVE CULTIVATION ON FLORIDA RED SCALE ABUNDANCE IN 1942.

Month	Average Number of Living Scales per Leaf	
	Cultivated Plots	Cover-Crop Plots
April	2.4	2.9
May	2.4	1.9
June	.9	.7
July	2.3	1.6
August	5.0	2.0
September	6.2	2.6
October	5.0	1.3
November	2.5	.6
December	2.1	.6

In April the average number of scales per leaf was practically the same in the two treatments, being only slightly higher in the cover-crop plots. In May and for the remainder of the year the average was slightly higher in the cultivated plots. When the data were analyzed statistically, it was found that the treatments were significantly different only in December, despite the fact that the greatest difference in the averge number of living scales per leaf occurred in October.

The differences in the infestations from the two treatments on the same dates are believed to be due to the physical condition of the trees. In July, after the trees in the cultivated treatment had been disked three times, the difference in the appearance of the trees in the two treatments was apparent, as those in the cultivated areas had much greener leaves and much more flush growth than those growing in the cover-crop areas.

Weather:

Immediately after a period of low temperatures in January 1940, examinations were made of scales in two groves, one where the temperature was freezing or below for three nights in succession with a minimum temperature of 27.5° F., and the other where the temperature was freezing or below for five nights in succession with a minimum temperature of 23°. All examinations were made from leaves, and only third-instar females that were alive or that appeared to have died recently, supposedly from the cold, were included.

From the count of 506 adult females from the first grove 68 percent were killed, and from the second grove 84 percent of the 510 examined were killed. Yothers *(9)* stated that 94 percent of the Florida red scales examined on a camphor tree at a minimum temperature of 22° in 1917 were killed. In 1934, with the same minimum temperature, Yothers and Osburn *(10)* found that approximately 70 percent of the mature females were killed on grapefruit fruit, slightly more on oranges, and 94 on grapefruit foliage.

A tropical storm on August 11, 1939, with 60-mile winds and 2 inches of rain in 24 hours, eliminated 90 percent of a lot of 178 scales that had settled and been marked the week before. Many crawlers that had emerged but had not settled were undoubtedly destroyed by wind and rain.

Parasites and Predators:

The following parasites and predators of the Florida red scale were collected in St. Lucie County during the period of this study: *Aspidiotiphagus lounsburyi* (Berl. and Paoli), *Chilocorus stigma* (Say.), *Chrysopa lateralis* Guerin, and *Hemisarcoptes malus* (Shimer).[3]

Pseudhomalapoda prima Gir.[4] was collected in Orlando, Fla. Only the first two are of any importance. *Aspidiotiphagus lounsburyi,* a hymenopterous parasite, is abundant in some groves during the fall and winter months. It seems to attack only the immature stages of the scale, especially those of the male and the second instar of the female. Only a few mature females have been found parasitized by this or any other species. *Chilocorus stigma,* the twice-stabbed ladybeetle, is also numerous in some groves during the latter part of the winter, and both the larvae and adults

[3] Determined, respectively, by A. B. Gahan, E. A. Chapin, A. B. Gurney, and H. E. Ewing, all of the Bureau of Entomology and Plant Quarantine.

[4] Determined by A. B. Gahan.

feed on all stages of the Florida red scale. When this ladybeetle cannot pull the covering off the scale, it chews a hole through the dorsal scale and devours the body.

The larva of *Chrysopa lateralis* is a voracious feeder. One larva was fed 12 mature females in 1 hour. It pulls at the dorsal scale until it is loose, and then inserts its mandibles under the scale. *Hemisarcoptes malus* is a predaceous mite that is occasionally found under mature female scales. When this mite is found under an ovipositing female, many dead crawlers are usually present. Watson and Berger *(8)* state that the larvae and especially the crawlers are preyed upon by ladybeetles and aphislions and that the scale is destroyed by *Epitragodes tomentosus* (Lec.) and trash bugs.

Several other insects undoubtedly feed on crawlers and newly settled larvae, but not enough control is exerted by the entire group to be depended upon alone, for they usually appear after the scales have reached their peak and have done most of their damage.

Other Factors:

Some natural control is secured when the fruit that is infested is picked, and also by the falling of the old, infested leaves.

SUMMARY

The Florida red scale *(Chrysomphalus aonidum* (L.)*)* has become one of the most destructive pests of citrus in the State. In St. Lucie County this scale continues its development throughout the year, and all stages can be found at any time. Temperature is the main factor that determines the rate of development.

Eggs are deposited under the dorsal scale, and the crawlers emerge and settle on fruits and leaves in a short time during the warmest seasons. When heavy infestations occur, the vitality of the trees and the yield and grade of the fruit are lowered.

Two molts occur in the development of the female and four in the male. The time required to complete these molts, at mean temperatures of 83° to 61° F., ranged from 28 to 78 days for the male and from 26 to 76 days for the female. Fertilization of the female, which is necessary for reproduction, is believed to occur shortly after completion of the second molt. The females on fruits produce more young than those on leaves, and five or six generations occur each year, the development for a generation requiring from 45 to 153 days in the tests conducted.

Of the scales found on leaves, 59 percent were females, and 96 percent of the males and 13 percent of the females were found on the upper surfaces. Gravity and light seem to be predominating factors affecting this distribution, gravity having the greatest effect on the males, and light on the females.

The largest number of ovipositing females was found in August, and the peak of living scales (all stages) was reached in September. The lowest for each was found in March. Preliminary work indicated that the physical condition of the trees influences the scale population, and that trees in the best physical condition are likely to have the most scales.

Parasites and predators were most effective during the winter months. Only one parasite, *Aspidiotiphagus lounsburyi* (Berl. and Paoli), was found in any numbers, and it usually attacked the immature stages. The most abundant predator was *Chilocorus stigma* (Say.), of which both the larvae and adults fed on the scales. However, neither the parasites nor the predators gave effective control, for they were most abundant after the peak of scale infestation had occurred and most of the damage had been done.

LITERATURE CITED

(1) ASHMEAD, W. H. 1880. On the red or circular scale of the orange *(Chrysomphalus ficus* Riley ms.). Amer. Ent. 3:267-269.

(2) COMSTOCK, J. H. 1881. Notes on Coccidae. Canad. Ent. 13:8-9.

(3) COMSTOCK, J. H. 1880. Report on scale insects. *In* Report of U. S. Commissioner of Agriculture, 1880, pp. 276-349. Reprinted in 1916, N. Y. (Cornell) Agr. Expt. Sta. Bul. 372:425-603, illus.

(4) FERRIS, G. F. 1938. Atlas of the scale insects of North America. *Chrysomphalus*, Ashmead, S. II-198. *Chrysomphalus ficus* Ashmead, S. II-201. Stanford University, California.

(5) LINNÉ, C. 1758. Systema naturae, regnum animale. Ed. 10, p. 455.

(6) SCHWEIG, C., and GRUNBERG, A. 1936 The problem of the black scale *(Chrysomphalus ficus* Ashm.) in Palestine. Bul. Ent. Res. 27:677-717.

(7) THOMPSON, W. L. 1939. Cultural practices and their influence upon citrus pests. Jour. Econ. Ent. 32:782-789.

(8) WATSON, J. R., and BERGER, E. W. 1937. Citrus insects and their control. Fla. Agr. Ext. Serv. Bul. 88, 135 pp., illus.

(9) YOTHERS, W. W. 1917. The effects of the freeze of February 2-4, 1917, on the insect pests and mites on citrus. Fla. Buggist 1: 30-35, 38-40.

(10) YOTHERS, W. W., and OSBURN, M. R. 1935. The effects of the freeze of December 12 and 13 on citrus pests in Florida. Fla. State Hort. Soc. Ann. Proc. 48: 122-126.

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