PROGRESS REPORT ON THE FUNGUS DISEASES OF SCALE INSECTS ATTACKING CITRUS IN FLORIDA

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THE "FRIENDLY FUNGI"

Since 1897 when Rolfs (6) published "A Fungus Disease of the San Jose Scale," Sphaerostilbe coccophila Tul., and several other fungi have been credited with being of great value in controlling scale insects attacking citrus in Florida. Numerous investigators (1, 2, 7, 8, 9) following Rolfs have published papers on the efficacy of the fungus diseases; however, throughout the available literature, no one has reported seeing one of the "friendly fungi" actually growing on a living scale insect. Without evidence of the parasitism of these fungi their economic importance to the grower is in question.

It has been noted by the authors that purple scale (Lepidosaphes beckii Newm.) populations often decrease very rapidly. Holloway and Young (4) have indicated that the scarcity or abundance of entomogenous fungi has no influence on the rate of total mortality of these insects. If this be true, then some other factor must be responsible for the periodic epizootics.

THE "FRIENDLY FUNGI"—The term "friendly fungi" is generally used to include the following fungi associated with scale insects, as listed by Watson and Berger (9): Red-Headed Scale Fungus (Sphaerostilbe aurantiicola (Berk. & Br.) Petch), Pink-Headed Scale Fungus (Nectria diploa Berk. & Curt.), White-Headed Scale Fungus (Podonectria coecicola (Ell. & Ev.)

1 According to T. Petch (Brit. Myc. Soc. Trans. 7: 109-129. 1921) the correct name for this fungus is S. aurantiicola (Berk. & Br.) Petch.
2 Nectria diploa Berk. & Curt. and Sphaerostilbe aurantiicola (Berk. & Br.) Petch.

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Petch), Black Scale Fungus (*Myriangium floridanum* Hoehm.), and Cinnamon fungus (*Verticillium cinnamomeum* Petch).

During 1947 and 1948 the red-headed and the pink-headed fungi have been found in abundance, whereas the other "friendly fungi" were found occasionally, but they were not common. This paper will deal with *Sphaerosistilbe aurantiicola* (Berk. & Br.) Petch and *Nectria diploa* Berk. & Curt. both of which are incorporated under the general term, red-headed scale fungi.

**INOCULATION EXPERIMENTS WITH RED-HEADED SCALE FUNGI.**—All attempts to inoculate red and purple scale insects (respectively, *Chrysomphalus aonidum* L. and *Lepidosaphes beckii* Newm.) which were reared in the laboratory on grapefruit have failed. Spores, both from cultures and from mature fruiting bodies, in water suspensions were sprayed on first, second, and third stages of both red and purple scale insects. Some of the grapefruit were maintained under ordinary laboratory conditions while others were in a moisture chamber. In a series of five experiments in the laboratory there was no mortality of the insects which could be attributed to the red-headed scale fungi.

In two experiments, young pineapple orange trees which were infested with purple scale insects were sprayed with a water suspension of spores from mature fruiting bodies. There was no resulting mortality.

**RED-HEADED FUNGUS COUNTS.**—Evidence has been found that it is possible for the red-headed fungi to act as saprophytes. These fungi frequently have been observed growing entirely on the armors of dead scale insects, and also on the armors of insects which were alive and healthy.

In conjunction with spraying experiments, counts of purple scale insects and red-headed fungi were made to determine the length of time required for the fungi to begin their saprophytic growth on the dead insects. Table 1 shows a comparison of three spraying treatments and one non-sprayed plot in terms of percentages computed from counts made on June 5, 1947, five weeks after spraying. Each plot consisted of five trees.

In Table 1 the saprophytic growth of the red-headed fungi is illustrated by the large number of fungi per 100 living scales in plot 1 which received an oil-emulsion spray. In comparison with plot 1, plot 2, sprayed with copper-oil-emulsion, had a smaller percentage of fungi. This might be attributed to a larger percentage of living scale in plot 2, and to the fungicidal
action of the copper. There seem to be no significant differences, in the number of fungi per 100 living scales, between the copper-zinc-lime-wettable sulfur spray (plot 3) and the non-sprayed control (plot 4). All four plots are comparable in the average number of fungi per 100 dead scales. In the percentage of fungi which were associated with dead and living scales, plot 1, which received an oil-emulsion spray, and plot 2, which received a copper-oil-emulsion spray, had a higher percentage of fungi than did the copper-zinc-lime-wettable sulfur (plot 3) and the non-sprayed control (plot 4).

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Percentage of Fungus Associated with Dead and Living Scales</th>
<th>Average Number of Fungi per 100 Dead Scales</th>
<th>Average Number of Fungi per 100 Living Scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oil-emulsion</td>
<td>3.31</td>
<td>73.5</td>
<td>81.02</td>
</tr>
<tr>
<td>2</td>
<td>Copper-oil-emulsion</td>
<td>17.14</td>
<td>65.55</td>
<td>83.29</td>
</tr>
<tr>
<td>3</td>
<td>Copper, zinc, lime, and wettable sulfur</td>
<td>47.95</td>
<td>45.96</td>
<td>91.72</td>
</tr>
<tr>
<td>4</td>
<td>Control</td>
<td>42.14</td>
<td>41.40</td>
<td>88.27</td>
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</table>

CHYTRIDIOSIS OF SCALE INSECTS

An economically important disease of purple scale insects is caused by the endoparasitic chytrid, *Myiophagus* sp. Thaxter. Karling (5) has termed this disease chytridiosis. As far as is known, this chytrid was first found parasitizing purple scale insects on citrus in Florida by W. L. Thompson in the fall of 1934 at Rabson Park. At that time the parasitized insects were abundant. Although the fungus has been plentiful during the intervening years, identification attempts failed until 1946 when, with the aid of Dr. Ernst A. Bercy, it was identified as a species of *Myiophagus* by Fisher (3).

Distribution of Chytridiosis.—In Florida the distribution of chytridiosis is widespread and is known to occur throughout the interior citrus belt, as far south as Lake Placid and as far
north as Palatka and Mandarin, and in the Indian River section.

HOST RANGE.—The following hosts have been recorded in Florida: purple scale (Lepidosaphes beckii Newm.), red scale (Chrysomphalus aonidum L.), chaff scale (Parlatoria perigandii Comst.), and long scale (Lepidosaphes gloverii Pack.).

Karling (5) lists Myiophagus ucrainicus (Wize) Sparrow as being parasitic in: the larvae and pupae of Cleonus punctiventris and Anisoplia austriaca in the Ukraine (Wize); dipterous pupae, Kittery Point, Maine (Thaxter) and Yorks, England (Fetch); Lepidosaphes beckii and L. Newsteadi, Bermuda (Waterston); L. ulmi, Ontario, Canada (Waterston); L. beckii in Louisiana, U. S. A. (Karling); and the artificial inoculation of Pseudococcus longispinus and P. citri in New York (Karling).

THE LIFE HISTORY OF Myiophagus sp.—Purple scale insects with chytridiosis are easily recognized in the early stages of the disease while the insects are still alive. The first indication of the disease is a slight color change of the body which is normally white to a pale, coral-pink tint. Later, as the disease progresses and the insect dies, the zoosporangia develop internally giving the scale a bright orange color. After the insect is dead, the zoosporangia mature, and the insect’s body becomes a powdery mass of golden-yellow zoosporangia. If resting zoosporangia are present, all or part of the body may be brick-red in color.

When sufficient moisture is present to wet the leaves thoroughly, the zoosporangia in the dead scales germinate producing swimming zoospores which swim in the film of water until they come into contact with a healthy scale, and then produce germ tubes which penetrate the integument (5) of the insect. In this manner healthy scales become infected and all subsequent growth of the parasite is internal. Zoosporangia are again produced, at the expense of the insect’s life, and the subsequent release of zoospores completes the life cycle of the fungus.

RATE OF MORTALITY CAUSED BY CHYTRIDIOSIS.—The life cycle of Myiophagus sp. makes it readily apparent that not only is the fungus directly dependent upon the density and distribution of the scale population, but also upon moisture without which infection of the scales is impossible. Especially in the summer months when purple scale populations are increasing and rains are frequent, high mortality of the scales may be caused by
chytridiosis. During 1947 and 1948 weather conditions were favorable for this disease.

In Grove W (Figure 1), which is a typical example of several orange groves on a non-spraying program, purple scales apparently were effectively controlled by chytridiosis. Counts have been made in this grove over a period of 19 months. Scale
<table>
<thead>
<tr>
<th>Month</th>
<th>Plot 1 Mortality Ratio</th>
<th>Plot 1 Per Cent of Quarter Leaves Infested</th>
<th>Plot 2 Mortality Ratio</th>
<th>Plot 2 Per Cent of Quarter Leaves Infested</th>
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<td>7.79</td>
<td>23.3</td>
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<td>June</td>
<td>4.21</td>
<td>60.0</td>
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<td>August</td>
<td>38.81</td>
<td>19.3</td>
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<td>September</td>
<td>90.16</td>
<td>6.7</td>
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<td>November</td>
<td>78.23</td>
<td>6.7</td>
<td>79.70</td>
<td>7.3</td>
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Population counts were based on an examination of 1/4 of the leaf surfaces of each of 50 leaves per tree and were recorded as the average percent of quarter leaves infested. Identifiable males were not counted in either the scale infestation counts or in computing chytridiosis incidence. During the latter part of August, 1947, scale mortality reached its highest point of the summer. At that time, on scale counts of 30 heavily infested leaves, there were 434 diseased scales per 100 healthy scales; a mortality percentage of 81.28. The following month there was a decrease in the scale population. In general, Figure 1 shows that periods of scale population decrease or low incidence were usually preceded by or coincident with a high degree of chytridiosis. Low scale populations were usually followed by decreases in chytridiosis incidence. Thus, an increase in the number of scales parasitized by Myiophagus sp. appeared to cause a decrease in the scale population, and as the scales died, the amount of mortality due to chytridiosis decreased. However, in October and November, 1948, a marked increase in the number of scales with chytridiosis did not result in a further decrease of the scale population, but actually the scale

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*The percentage of mortality was computed by dividing the total number of diseased scales plus the total number of living scales into the total number of diseased scales, and multiplying the resulting figure by 100.*
population showed a slight increase. This discrepancy emphasizes the fact that a more complete understanding of the effect of scale population density on subsequent incidence of chytridiomycosis and other related factors is essential before completely accurate interpretation can be made of the available data.

Table 2 shows a comparison of the purple scale populations and the rate of mortality caused by *Myiophagus* sp. in two non-
sprayed control plots at the Citrus Experiment Station, Lake Alfred, Florida. Plot 1 did not receive any spraying treatments during 1947 or 1948. Plot 2 was not sprayed during 1948. Each plot consisted of five pineapple orange trees.

From April through November plot 1 and plot 2 (Table 2) are comparable. In August and September, plot 1 had a smaller per cent of infested leaves, and a larger percentage of scale mortality than did plot 2. The rate of mortality caused by chytridiosis, in both plot 1 and plot 2, during August does not seem to be sufficient to explain the decrease of the per cent of infested leaves. In these two plots it must be concluded that some factor other than chytridiosis was partially responsible for the decrease in the total number of infested leaves between June and August.

MORTALITY CAUSED BY CHYTRIDIOSIS COMPARED WITH THE NUMBER OF RED-HEADED FUNGI ATTACKING PURPLE SCALE INSECTS.—Figure 2 shows a comparison between the number of purple scales attacked with chytridiosis and the number of purple scales attacked by the red-headed fungi during the summer of 1947 in two plots at the Citrus Experiment Station, Lake Alfred, Florida. In the copper-zinc-lime-wettable sulfur sprayed plot the number of red-headed fungi closely followed the number of scales with chytridiosis. In the oil-emulsion sprayed plot the number of red-headed fungi reached its highest point five weeks after spraying while the number of scales attacked with chytridiosis was very low throughout the summer. The oil-emulsion spraying so effectively controlled the purple scale infestation that there were only a few living scales remaining for Myiophagus to attack.

*Hirsutella* sp.

It has been observed by the authors that occasionally large numbers of purple scale crawlers, *Lepidosaphes beckii* Newm., become yellow in color and a high mortality follows. Crawlers which were exhibiting this off-color and apparently living have been examined and found to contain yeast-like bodies. In examinations of dead crawlers only one fungus has been found consistently associated with the yellow-colored crawlers. This fungus has been tentatively identified as a species of *Hirsutella* Pat. Whether or not the mycelium of *Hirsutella* sp. growing out of the dead crawlers originates from the yeast-like bodies found inside of the living crawlers remains to be proved.
SUMMARY

For a number of years a diversity of opinion has existed as to whether or not some of the so-called "friendly fungi" (Sphaerostilbe aurantiicola (Berk. and Br.) Petch. and Nectria diploa Berk. and Curt.) actually parasitize scale insects. During 1947 and 1948 no evidence has been found that the red-headed fungi do parasitize red or purple scale insects. It has been established that these fungi have the ability to act as saprophytes, but their ability to act as parasites has not been proved.

The endoparasitic fungus, Myiophagus sp. Thaxter, which causes chytridiosis of scale insects has been found widely distributed throughout the citrus belt in all purple scale (Lepidosaphes beckii Newm.) infestations which have been examined. In 1947 and 1948 this disease has been of greater importance in purple scale populations than it has in red scale (Chrysomphalus aonidum L.) populations.

Although there are some groves in which the purple scale insects appeared to be effectively controlled by chytridiosis, biological control of scale insects by dependence solely upon Myiophagus sp. is not advocated. Not only is the fungus directly dependent upon the density and distribution of the scale population, but also upon moisture without which infection of the scales is impossible. Further study is necessary in order to determine methods which may be used to increase the efficacy of these diseases in coordination with the artificial control measures.

A fungus associated with dead purple scale crawlers has been tentatively identified as a species of Hirsutella Pat.

LITERATURE CITED


AN ANNOTATED BIBLIOGRAPHY OF NORTH AMERICAN THYSANOPTERISTS: PART II

By STANLEY F. BAILEY
University of California, Davis, California

It is always a great temptation to describe new species instead of doing the more difficult revisional and basic work. Unless this latter type of work is done, the systematics of many genera of thrips will reach an impasse. Zimmerman (Insects of Hawaii, V. 2, page 392, 1948) pertinently remarks "The Thysanoptera are largely in a state of taxonomic chaos, and the group is a most difficult one to work with systematically. There is not yet available a classification which can be considered adequate or natural. The basic concept of what constitutes the various categories of classification appears more often than not to have been lost sight of. Few authorities agree as to what constitutes a genus, subfamily, family or superfamily."

On the other hand, it is necessary to describe the species that come to hand in order that the diversification in a genus as well as the relationships of genera may be seen. It is only then that the higher groups may be arranged in proper sequence. In many other orders of insects, a large number of systematists have brought this desired condition about earlier than in the Thysanoptera. The burden of describing thrips has fallen largely upon a few individuals from whose efforts future workers will profit.

We cannot overestimate the value of carefully made illustrations when new species of thrips are described. Those of Hood are among the very best and are of the greatest value. Hood (1932c) so well stated this point that he should be quoted: "Finally, it should be stated that in no group of insects are carefully executed, accurate illustrations of new forms more to be desired than in the Thysanoptera. No two workers agree exactly in their selection of structures to be described, and a