U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 102.

L. O. HOWARD, Entomologist and Chief of Bureau.

NATURAL CONTROL OF WHITE FLIES IN FLORIDA.

BY

A. W. MORRILL, Ph. D.,

AND

E. A. BACK, Ph. D.

Issued September 14, 1912.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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FUNGUS ENEMIES OF WHITE FLIES.

Upper figure, the yellow fungus (*Aschersonia flavocitrina*); middle figure, the red fungus (*Aschersonia aleyrodis*); lower figure, the brown fungus (*Ægerita webberi*). Three-fourths natural size. (Original.)

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Citrus and Subtropical Fruit Insect Investigations.

C. L. Marlatt, *in charge.*

A. W. Morrill,[1] E. A. Back, R. S. Woglum, W. W. Yothers, E. R. Sasscer, J. R. Horton, Reginald Wooldridge, P. H. Timberlake, H. L. Sanford, *entomological assistants.*

[1] Resigned.

ADDITIONAL COPIES of this publication may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 20 cents per copy

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., November 3, 1911.

Sir: I have the honor to transmit herewith for publication as Bulletin 102 of the Bureau of Entomology a report on "Natural Control of White Flies in Florida," by Drs. A. W. Morrill and E. A. Back, both of whom were formerly employed as special field agents in this bureau.

The control of the citrus white flies in Florida by natural means, most important among which are the fungous diseases of these insects and natural insect enemies, is a subject of much importance to the Florida citrus grower. In connection with the investigation of the white fly in Florida a good deal of time has been devoted to this special subject, and the results are here summarized. This investigation has been under the general direction of Mr. C. L. Marlatt, assistant chief of this bureau, and has been carried out by the authors named with the assistance and cooperation of Mr. E. L. Worsham, now State entomologist of Georgia, and Mr. W. W. Yothers.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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NATURAL CONTROL OF WHITE FLIES IN FLORIDA.

INTRODUCTION.

The control of the citrus white fly (*Aleyrodes citri* R. & H.) by means of the natural enemies already established in Florida has long been a subject concerning which there have been many diverse opinions and insufficiently supported conclusions, but very little definite knowledge. Opportunities for extended investigations of the subject were first offered in 1906 when the work was taken up independently by the Bureau of Entomology—as one phase of the white-fly investigations begun in July of that year—and by the Florida Agricultural Experiment Station. While the field work conducted in the two investigations has been largely along somewhat parallel lines, the duplication of work in the case of such a difficult and important problem is of great advantage in advancing our knowledge upon which final conclusions must be based.

It is not feasible to present in this publication more than a small selection from the large amount of data which have been secured in connection with the investigations of natural control, but it has been the purpose here to present such data as are necessary properly to support important conclusions. The nature of the more important conclusions is such as to render unnecessary complete discussions of minor topics, which would be necessary under other circumstances.

The investigations of the parasitic fungi were conducted by the senior author during the season of 1906; by the senior author, by Mr. E. L. Worsham, now State entomologist of Georgia, and by the junior author during the season of 1907; by the junior author during 1908, and by the senior and junior authors jointly during 1909. Mr. W. W. Yothers has aided at various times in connection with field work and has furnished certain data, as hereinafter specifically credited, in connection with the "white-fringe fungus." Mr. Worsham has been specifically credited where his results have been utilized. Practically all of the experimental results included herein are based on the work of the seasons of 1908 and 1909.

Thanks are extended to Prof. P. H. Rolfs, Dr. E. W. Berger, and Prof. H. S. Fawcett, of the Florida Agricultural Experimental Station, for the many courtesies extended during these investigations. Acknowledgment is also made of assistance rendered by Mrs. Flora W. Patterson, mycologist of the Bureau of Plant Industry, to whom many specimens of fungi have been submitted for examination and for information. The colored plate is the work of Mr. J. F. Strauss, of the Bureau of Entomology.

PARASITIC AND PREDATORY ENEMIES OF WHITE FLIES.

So far as known, there is no true insect parasite of the citrus white fly (*Aleyrodes citri* R. & H.) or of the cloudy-winged white fly (*Aleyrodes nubifera* Berger) in this country. Dr. Howard, however, has recently recorded [1] the finding at Lahore, India, by Mr. R. S. Woglum, of this bureau, of the exit holes of true parasites. In the examination of specimens of parasitized white flies, verified as *Aleyrodes citri* by Prof. A. L. Quaintance, Dr. Howard has found dead specimens of a minute aphelinine which he has described as a new species under the name of *Prospaltella lahorensis*.

During the course of these investigations, two species of Prospaltella—*P. aurantii* How., and *P. citrella* How.—and two species of Encarsia—*E. luteola* How., and *E. variegata* How.—have been quite thoroughly tested with abundant material as to their ability to parasitize the citrus white fly.[2]

In addition to the outdoor attempts at colonization in the event of successful parasitism, laboratory observations were made upon the behavior of many specimens of the first three species in the presence of larvæ and pupæ of the citrus white fly in all stages of development. Only one incident of especial interest was noted. One female specimen of *Prospaltella aurantii* showed a peculiar interest in a plump white-fly (*A. citri*) pupa, and in addition to carefully examining it she spent several minutes in attempting to force her ovipositor through the skin of the aleyrodid, apparently without success.

With the exception of *Encarsia variegata* How., the parasites mentioned have not been tested as to their ability to parasitize the cloudy-winged white fly. *Encarsia variegata* seems to confine its attentions entirely to *Paraleyrodes perseæ* even when the citrus white fly and the cloudy-winged white fly are present in greater abundance.

In case the Indian white-fly parasite (*Prospaltella lahorensis*) fails to become established in Florida or proves unable successfully to attack either of the two species of white fly under the conditions prevailing in the Gulf coast region, the work of testing all procurable aleyrodid parasites should be continued. Owing to the danger of introducing hyperparasites, suggested by Dr. Howard's studies [3] of material reared from *Aleyrodes coronata* Quaintance, it appears advisable to conduct work of this kind in greenhouses far from citrus-growing regions.

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[1] Journ. Econ. Ent., vol. 4, pp. 131–132, February, 1911.

[2] The first two species were reared from *Aleyrodes coronata* Quaintance, collected by Mr. E. M. Ehrhorn in California and sent to the Orlando Laboratory through Dr. Howard. The third species was reared from *Aleyrodes fernaldi* Morrill, collected at Amherst, Mass., and sent to the Orlando Laboratory by Dr. H. T. Fernald. The fourth species of parasite is of common occurrence in Florida, where it has an important economic rôle in holding in check a citrus-infesting white fly, *Paraleyrodes perseæ* Quaintance.

[3] Proc. Ent. Soc. Wash., vol. 10, nos. 1–2, p. 65, 1908.

Mr. Woglum has found two coccinellids in India at Saharampur which attack the citrus white fly,[1] which have been determined as *Verania cardoni* Weise and *Cryptognatha flavescens* Motsch. In Florida three ladybirds, *Chilocorus bivulnerus* Muls., *Cycloneda sanguinea* L., and a very small black species, *Scymnus punctatus* Melsh., have been observed to destroy white-fly eggs and larvæ, but have never been found to be effective in controlling the white fly to a noticeable degree. The same may be said of a capsid bug, which attacks adult white flies, and two or three species of lacewing flies or chrysopids. These latter might become of considerable importance were they not so subject to attack by several hymenopterous parasites which destroy the greater part of them in the pupal stage, and in addition a species which destroys their eggs. Several species of spiders are predaceous upon adult white flies; several species of ants destroy the larvæ, pupæ, and adults, and a species of thrips destroys the larvæ and pupæ. This last-mentioned insect, described by Dr. H. J. Franklin[2] as *Aleurodothrips fasciapennis*, has, according to the observations of the authors,[3] proved more effective than any other of the native insect enemies of the citrus white fly.

The combined attacks of all of these natural enemies, however, have thus far proved of no noticeable benefit in reducing the white flies, with the exception of a few rare instances where the thrips referred to appeared to accomplish some good in supplementing other factors of natural control.

The testing of all procurable species of ladybirds as possible white-fly enemies would seem to offer the most hopeful field for future work with predatory enemies aside from the work of foreign exploration recently undertaken. There are comparatively few species of this beneficial group whose tastes are so well known that it would be safe to predict that they would not attack either the citrus white fly or the cloudy-winged white fly in the egg, the larval, or the pupal stage.

SNAILS THAT FEED ON SOOTY MOLD.

It was observed in 1903, by Mr. F. D. Waite, of Palmetto, Fla., that a snail[4] was of considerable value in one grove in removing the sooty mold (*Meliola* sp.) from citrus leaves and fruit. Since then it has been found in many hammock groves in the State of Florida, more especially in Manatee and Lee counties. Without artificial protection in the attempt to encourage their multiplication these snails rarely reduce the sooty mold appreciably on more than a few trees at a time. When abundant, however, well-blackened trees may

[1] Journ. Econ. Ent., vol. 4, no. 1, p. 131, February, 1911.
[2] Ent. News, vol. 20, pp. 228–231, 1909; Proc. U. S. Nat. Mus., vol. 33, p. 727, 1908.
[3] Ent. News, vol. 23, pp. 73–74, 1912.
[4] Determined for Dr. E. H. Sellards by Dr. W. H. Dall as *Bulimulus dormani*.

be entirely cleansed of sooty mold, leaving the fruit rinds and upper surface of the leaves bright and glossy. Straw on the ground around the base of the trees and pieces of burlap hung in the crotches of the main branches protect the eggs of the snails to a certain extent, but birds and probably other natural enemies prevent their attaining a position of reliable economic importance. Live white flies in any stage are not eaten by the snails to any appreciable extent, the destruction of a few being entirely incidental. Strictly speaking, therefore, snails are not factors in the natural control of the white flies, but in their effects they may appropriately be mentioned in this connection. The species referred to above has been given the common name of "Manatee snail" by Dr. E. H. Sellards, who has published an account of its habits.[1] Additional notes have been published by Dr. Berger, who has also referred to another species of similar habits, the "Miami snail," introduced into Manatee County from Miami, Fla., by Prof. Rolfs.[2]

CLIMATIC CONDITIONS.

An examination of climatic records for points in California where both the citrus white fly and the cloudy-winged white fly have been temporarily established shows conclusively that these destructive insects are dangerous under any climatic conditions in the United States where citrus fruits are grown. The citrus white fly thrives on privets (*Ligustrum* spp.) and Cape jessamine (*Gardenia jasminoides*) out of doors in sections where winter temperatures are too severe for citrus trees. Freezing temperatures therefore have no effect in citrus-growing sections except through the shedding of the leaves of citrus. In proportion to the thoroughness with which this occurs both species of white flies are reduced in numbers, sometimes being entirely exterminated locally. In cool March weather heavy winds accompanied by beating rains have been observed to destroy practically all the adults of the first broods. During March and April there often occurs in Florida a rather high rate of mortality among the overwintered pupæ, which may be tentatively ascribed to weather conditions. Apparently associated with the mortality mentioned is the lower daily mean humidity and the greater daily range in humidity than occurs at other seasons of the year. Strong drying winds seem especially to characterize these periods of unusually high mortality. (Plate II, upper record.) According to the observations made, mortality among the overwintering pupæ during the first emergence period of the year ordinarily ranges from 19 to 38 per cent. In one instance, however, this mortality amounted to about 92 per cent, with a strikingly beneficial result in the grove where observed.

[1] Science, n. s., vol. 24, pp. 469–470, 1907; Fla. Agr. Exp. Sta., Press Bul. 59, pp. 1–4, Jan. 15, 1906.

[2] Bul. 88, Fla. Agr. Exp. Sta., p. 69, January, 1907; Rep. Fla. Agr. Exp. Sta. for fiscal year ending June 30, 1909, p. xliii.

UNEXPLAINED MORTALITY.

Early in the present investigations it became evident that mortality among larvæ and pupæ resulting from unrecognized causes was the most important element of natural control affecting the species of white flies herein considered. To this the authors have applied the term "unexplained mortality." This mortality has never been taken into consideration in previous publications, and in the past no little confusion has existed owing to the failure to distinguish between the benefits derived from it and those from fungous parasites, and attempts at artificial control by ineffective insecticides or other futile means.

White flies dying from unexplained causes ordinarily have the same characteristics as insects that have been killed by fumigation or by some sprays. After dying the insects turn light brown and in the course of several weeks generally become more or less whitened. The dead insect sometimes becomes infected with the saprophytic "white-fringe" fungus. There is very little unexplained mortality among overwintering pupæ, unless the mortality occurring during the period of emergence of the adults in the spring be properly classed as such, instead of being considered as due to climatic conditions.

In a previous publication[1] the senior author has recorded an instance where entire credit for the temporary freedom from white-fly injury was commonly given to fungous parasites when mortality from other sources was concerned to an unknown degree. The instance referred to was that in Manatee County, Fla., in the summer of 1906. Observations during the past two years have led the authors to consider that the unusual reduction in the numbers of the citrus white fly in Manatee County in 1906 was accomplished by the combination of two important factors—fungous diseases and unexplained mortality; also, that the former probably by themselves could not have produced the conditions which existed, while the latter unaided might have done so.

These two conclusions are based on the general studies of the effectiveness of fungous parasites, in the first case, and on a knowledge of the possible effectiveness of unexplained mortality in the second. The effectiveness of fungous parasites is discussed elsewhere. The possible effectiveness of unexplained mortality is shown by one of the most remarkable instances on record of the temporary checking of the citrus white fly and the cloudy-winged white fly by this natural-control influence, which occurred during the summer and fall of 1906. The effect was most noticeable in Orange County near Orlando, in a district where the senior author was quite generally conversant concerning the grove conditions.

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[1] Bul. 76, Bur. Ent., U. S. Dept. Agr., pp. 64–65, 1908.

Occurring coincidently with one of the most unusual periods of drought ever recorded in Florida, the reduction of white flies throughout the city limits of Orlando and in the majority of the infested citrus groves in the vicinity was at first thought to be due to the weather conditions. An analysis of the available data concerning the weather conditions in different locations where the white flies have become successfully established indicates that with little doubt this idea was erroneous.

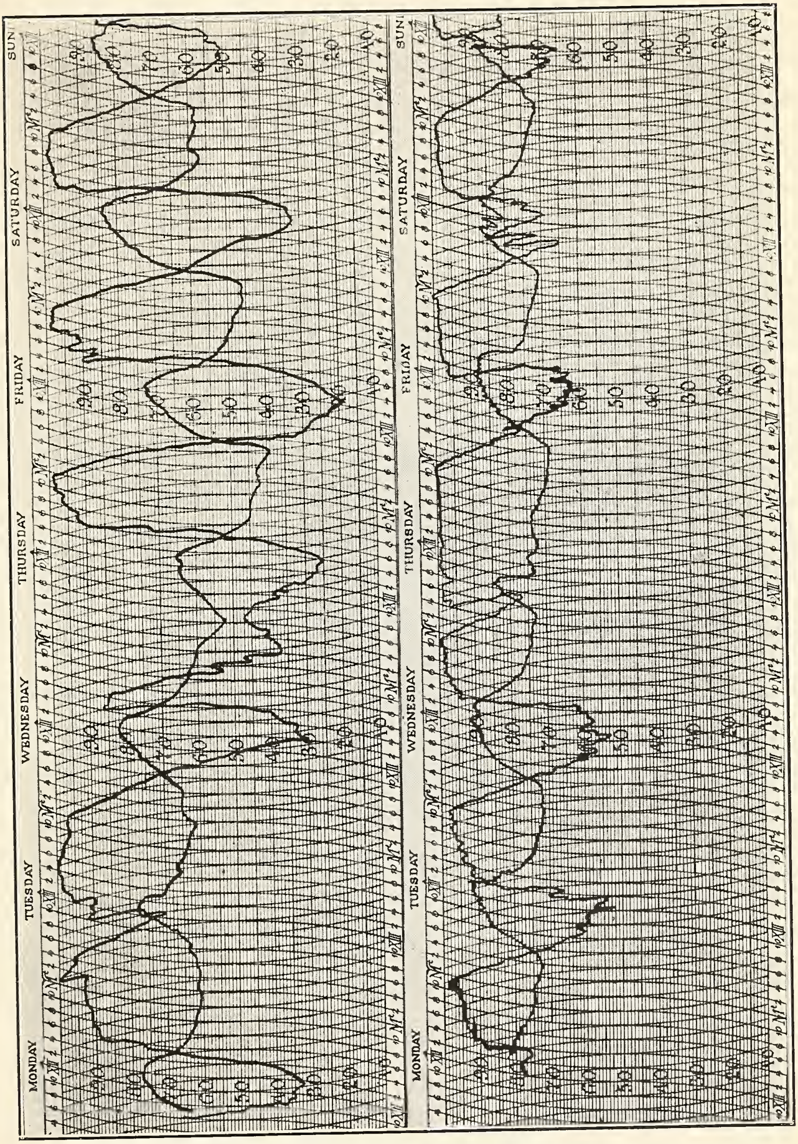
Fungous parasites were thought by some to have been responsible for the situation here considered. While such a conclusion might have been drawn in 1906 from observations in a few selected groves, the white-fly conditions in 1907 in these same groves offered positive proof that the fungous parasites exerted an insignificant, if appreciable, influence toward the general reduction in the numbers of white flies. The brown fungus appeared to be effective in one small grove of about 100 trees located near the center of the city of Orlando. Aside from this, no instance of effectiveness of fungous parasites in the locality referred to was known to the senior author, who is responsible for the observations. A comparison of the conditions during 1906 and 1907 in representative groves and in yards in and near Orlando will show the status of fungous parasites with relation to the situation. (See Table I.)

TABLE I.—*White-fly conditions in and near Orlando, Fla., during 1906 and 1907.*

Grove No.	Varieties.	White flies, 1906.	Parasitic fungi, 1906.	Foliage.	
				1906.	1907.
1	Mostly grapefruit; a few oranges and tangerines.	Both A. citri and A. nubifera in about equal numbers.	Traces of yellow; no red. The former abundant on a few trees.	Slightly blackened.	Clean.
2	Grapefruit, oranges, and tangerines.	......do..............	Yellow and red considered together more abundant than elsewhere in locality.	Varying from slightly to moderately blackened.	About same as in 1906.
3	Mostly oranges; a few grapefruit and tangerines.	Mostly A. citri; a few A. nubifera.	Red very abundant in one section. Traces of brown.	In general very black.	Clean.
4	Oranges entirely.....	All A. citri, so far as observed.	Traces of red.........	Slightly blackened.	Clean.
5	Oranges entirely.....	Mostly A. citri; very few A. nubifera.	Absent, so far as observed.	Blackened....	Clean.
6	Oranges, grapefruit, and tangerines.	.....do..............	Red abundant in certain places, traces in other places, and absent in others. Traces of brown.	Generally blackened.	Clean.

Grove No. 1 is that belonging to Capt. J. S. Jouett and is located near the north end of Orange Avenue in Orlando.

Grove No. 2 is that of Mr. C. B. Thornton and is located near Orange Avenue, a few hundred yards southeast of grove No. 1. The condition in this grove (No. 2) is especially significant, since, notwithstanding the comparative abundance of the parasitic fungi



HUMIDITY AND TEMPERATURE RECORDS MADE BY COMBINED HYGROGRAPH AND THERMOGRAPH AT ORLANDO, FLA.

Left-hand record, illustrating unusual conditions which appear to be associated with high rate of spring mortality affecting overwintered pupæ of white flies; right-hand record, midsummer record during period of unusual fungous activity. (Original.)

in 1906, white flies were more abundant in 1907 in this grove than in any other grove or section in or near Orlando.

The white-fly laboratory was located in grove No. 3 during 1906 and 1907. This grove, the property of Hon. J. M. Cheney, is located immediately south of No. 2. The red Aschersonia was more abundant on a certain group of trees in this grove than on any other trees in the locality covered by these observations. The white flies were most abundant in this section of the grove in 1907, while in other sections, where only traces of the fungus occurred, the insects had become very scarce before September 1, 1906, and were least numerous in 1907.

Grove No. 4 is the "Wilcox Grove," located immediately south of Mr. Cheney's grove (No. 3). The foliage in this grove was only slightly blackened at the time it first came under the observation of the senior author in August, 1906, the insects even then being on the decline in point of numbers. In this grove the fly was so effectively reduced that it did not multiply to the point of slightly blackening the foliage until the fall of 1908.

Grove No. 5 was known as the "William Dennen Estate Grove" and is located about one-half mile south of the city limits, immediately south of the Atlantic Coast Line Railroad. This grove was so seriously injured in 1905 and looked so unpromising in the winter of 1905–6 that it was considered inadvisable by those in charge to go to the expense of fertilizing until some satisfactory method of control was discovered. In the spring of 1906, during an unfavorable period, the grove was sprayed twice, the adults being then on the wing. In this instance spraying was at first believed to be responsible for the cleaning up of the grove, but examination in several groves of the effectiveness of the applications made by the same spraying outfit, and the experience of the authors in their experimental work, eliminate beyond doubt the possibility that the two applications of sprays were responsible for the scarcity of white flies. Mr. E. H. Walker, chairman of the Orange County horticultural commission, who had general charge of the extensive spraying carried on in the Orlando district in 1906, agrees with the authors in considering that the spraying, whatever its effectiveness may have been by itself, could not have produced such striking results. The first trace of red fungus was found in this grove in the fall of 1908 by the senior author. By this time the white fly had increased to the extent of slightly blackening the foliage of a few trees. The greater effectiveness of the unexplained mortality in this grove (No. 5) as compared with the effectiveness of this factor throughout the city of Orlando was due to the absence of china-trees (*Melia azedarach*) and umbrella china-trees (*Melia azedarach umbraculifera*) in the immediate neighborhood. These trees, as explained in previous publications,[1] are

[1] Bul. 76, Bur. Ent., U. S. Dept. Agr., 1908 (see Chinaberry); Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911 (see China-tree).

important aids to the citrus white fly in regaining its normal abundance after it has been reduced by any cause.

Grove No. 6 in Table II represents the general condition of trees in yards in Orlando aside from the groves 1 to 5. The important point shown by this is that whether the parasitic fungi were present or absent, the general condition in 1907 was practically the same throughout the city.

The foregoing general observations led to a more detailed investigation of mortality from unexplained causes, and a large amount of data concerning the subject has accumulated. For the most part these data cover too great a range of conditions to be briefly summarized for this report. One series of observations, however, was made especially with a view to securing records under uniform conditions and sufficiently extensive to enable certain definite conclusions to be reached concerning this important subject. The data presented in Table II are based upon the examination of about 275,000 insects found on 1,155 leaves. All but No. 6 represent citrus groves in Orange County selected on account of the comparative abundance of fungous parasites, or because common reports placed a particularly high estimate on the effectiveness of the fungous parasites in them. In several cases it had been generally reported that the fungous parasites had brought the white fly into complete subjection. No. 6 includes a mixed lot of leaves from seven different points in the city of Orlando, representing town conditions. The first record was made by the senior author on October 19, 1908, and the others were made by the junior author in December, 1908. The leaves were 1908 growth, and mostly midsummer growth of that year. For convenience in the discussion the records in Table II are arranged in order of the percentage of unexplained mortality.

TABLE II.—*Study of causes of mortality of white flies near Orlando, Fla., in 1908.*

Grove No.	Number of leaves examined.	Total number white-fly forms counted.	Leaf averages.				Percentages of totals.						
			Killed by fungous parasites.	Unexplained mortality.	Emerged (pupa cases).	Alive.	Red Aschersonia.	Yellow Aschersonia.	Brown fungus.	Cinnamon fungus.	Total percentage killed by fungous parasites.	Unexplained mortality.	Surviving: Alive and matured.[1]
1	85	8,813	24.5	24.5	5.6	49.1	9.5	0.05	14.1	0.0	23.6	23.6	52.8
2	100	6,541	27.1	34.0	.7	3.6	.0	41.2	.0	.0	41.4	52.0	6.5
3	100	10,832	1.7	72.6	2.0	32.0	.0	1.6	.0	.0	1.6	67.0	31.4
4	100	13,257	19.2	89.9	3.4	20.0	4.0	10.4	.0	.1	14.5	67.8	17.6
5	100	22,922	29.6	157.2	6.5	35.9	.38	12.5	.0	.0	12.9	68.6	18.5
6	85	36,841	29.8	306	17.8	80.6	6.2	.06	.08	.6	6.9	70.5	22.6
7	100	11,944	16.4	91.8	1.9	9.3	.4	13.3	.0	.0	13.7	76.8	9.5
8	100	59,728	80.9	469.5	16.4	30.6	12.5	.05	.03	.9	13.5	78.7	7.7
9	100	28,242	43.9	228.5	1.7	8.4	5.8	1.6	7.9	.2	15.5	80.9	3.6
10	100	46,935	84.2	380.6	2.8	1.7	10.1	2.1	5.2	.5	17.9	81.1	.95
11	100	14,702	17.9	119.2	2.4	7.5	2.7	9.4	.0	.1	12.2	81.1	6.5
12	85	19,540	9.7	210.8	1.1	8.3	.7	2.1	.6	.9	4.2	91.7	4.1

[1] Represented on leaves examined by empty pupa cases.

An examination of the data in the last three columns of the above table shows a striking relationship between the unexplained mortality and the insects which survived. In the case of the fungous parasites, however, there seems to be no striking relationship of this kind. In order to make this point clear the six records (Nos. 1 to 6, inclusive) with the lowest percentages of unexplained mortality and the six records (Nos. 7 to 12, inclusive) with the highest percentages of unexplained mortality are here summarized and compared with a similar summary with regard to fungous parasitism rearranged from the same data:

Unexplained mortality:
- 6 lowest percentages averaging 58.2 per cent, 24.9 per cent survived.
- 6 highest percentages averaging 81.7 per cent, 5.4 per cent survived.

Fungous parasitism:
- 6 lowest percentages averaging 8.5 per cent, 15.1 per cent survived.
- 6 highest percentages averaging 21.1 per cent, 15.2 per cent survived.

It appears from the above summary that a difference of about 24 per cent in unexplained mortality in two groups of groves was associated with a difference of about 20 per cent in the insects which survived. On the other hand, a difference of about 13 per cent in the deaths due to fungous parasites was associated with no appreciable difference in the proportion of insects which survived.

In December, 1910, Mr. S. S. Crossman, at the suggestion of the junior author, made a series of records to correspond with 10 of the 12 included in Table IV. A summary of the 10 records for the two years is given in Table III.

TABLE III.—*Status of white flies in 10 groves at ends of seasons 1908 and 1909.*

Year.	Total number white fly forms examined on 1,000 leaves.	Leaf averages.			Percentages of totals.		
		Killed by fungus.	Unexplained mortality.	Alive and matured.	Per cent of fungous infection.	Per cent of unexplained mortality.	Per cent surviving; alive and matured.
1908	259,054	34.0	203.1	33.5	12.4	73.7	13.9
1909	107,191	16.3	76.5	14.5	15.4	71.0	13.7

In five groves a larger percentage of surviving insects was found in 1909 than in 1908, in four groves a smaller percentage of surviving was found in 1909 than in 1908, and in one grove there was no appreciable difference in this percentage, as shown by the two examinations. Unexplained mortality ranged from 23.6 to 91.7 per cent in 1908 and from 61.8 to 78.8 per cent in 1909. The following is a summary for 1910 based on arrangements of the data to show relation between unexplained mortality and fungous diseases to the number of insects surviving.

Unexplained mortality:

5 lowest percentages averaging 66.1 per cent, 15.7 per cent survived.
5 highest percentages averaging 76.1 per cent, 11.7 per cent survived.

Fungous parasitism:

5 lowest percentages averaging 10.2 per cent, 14.7 per cent survived.
5 highest percentages averaging 20.5 per cent, 12.6 per cent survived.

In the above summary the comparatively small difference between the five highest and five lowest records in each case makes the results less striking than are the results of the previous year. However, it is noteworthy that a difference of 10 per cent in unexplained mortality shows a corresponding difference of 4 per cent in the number surviving, while a difference of 10 per cent in the fungous parasitism shows a difference of 2.1 per cent in the number surviving.

A fair estimate of the results produced by either unexplained mortality or fungous diseases must include a consideration of the increased degree of benefit from each if it had been the only factor concerned with the mortality of the larvæ and pupæ on the leaves. This point has been discussed elsewhere as to fungous diseases. Assuming that, in the 10 groves considered in Table III, the 12.4 per cent recorded as infected by parasitic fungi in 1908 and the 15.4 per cent in 1909 were actually destroyed by the fungi,[1] a large part of those infected by fungi would have died from unexplained causes if the fungi had not been present. Eighty-eight of every one hundred larvæ and pupæ were not infected by fungi in 1908 and 85 of every 100 were not infected in 1909. Of these 84.1 per cent (73.7/87.6) and 83.8 per cent (71.0/84.7), respectively, died from unexplained causes. It must therefore be assumed that if no fungous parasites had been present 84 and 83.8 per cent of the 12.4 and 15.4 per cent recorded in Table III would have died from unexplained causes, giving a total efficacy for unexplained mortality of 84.1 per cent and 83.9 per cent, respectively, for the years 1908 and 1909. This efficacy, combined with the effects of fungous diseases and overcrowding, did not result in a condition of satisfactory control in the average grove in 1908, with an average of about 24 live pupæ per leaf, nor in 1909, with the average reduced to 11 live pupæ per leaf. In each year there was a satisfactory condition of control in two or three of the groves under observation or a promise of such a condition the following season. In the opinions of the authors the data here given, representing a small selection of the large amount of similar data at hand, covering all sections of the State of Florida, conclusively show that the fluctuations from year to year in the proportion of white flies dying from causes as yet unexplained are of first importance in the periodical "cleaning up" of infested citrus groves.

More attention should be given to a study of the cause or causes contributing to the unexplained mortality herein discussed. Attempts

[1] As shown elsewhere, the brown fungus is known to infect dead as well as live insects.

to separate pathogenic bacteria from material sent to the Bureau of Animal Industry have not thus far been successful. There is certain evidence that some organism is directly concerned. As a rule unexplained mortality is greater in heavily infested groves than in lightly infested groves, although it is not dependent upon this point to a great degree after the insects have once become well established. The data in Table II, illustrating ordinary conditions in groves long infested, are here summarized:

Average number of forms per leaf:
- 6 lowest, averaging 112.7, 61.3 per cent unexplained mortality.
- 6 highest, averaging 368.3, 78.5 per cent unexplained mortality.

It should be noted that unexplained mortality was from 2.3 to 12.5 per cent greater in the case of record number 11, averaging 147 forms per leaf, than in the case of either record numbers 5, 6, or 8, averaging 229, 434, and 597 forms per leaf, respectively. Of the twelve records the one showing the highest unexplained mortality ranks seventh in point of average number of forms per leaf.

In newly infested groves or in groves where the white fly has been temporarily greatly reduced from any cause, unexplained mortality as a rule is comparatively low. Grove No. 1 in Table VI, that of Hon. J. M. Cheney, previously referred to as to its condition in 1906 and 1907, shows a condition which may follow the reduction of the white fly to a negligible quantity for a season. Table IV gives the results of the examination of white flies in six newly infested groves, no fungous diseases, so far as could be detected, being present in any case:

Table IV.—*Conditions with regard to unexplained mortality of white flies in newly-infested groves.*

Grove No.	When examined.	Number leaves examined.	Total number of forms counted.	Average number white fly forms per leaf.	Percentage of unexplained mortality.
1	Dec. 4, 1906	27	5,503	20.4	12.0
2	Sept. 13, 1907	100	150	1.5	15.3
3	Oct. 15, 1907	10	2,094	20.9	30.5
4	Aug. 16, 1908	100	1,222	12.2	24.2
5	Dec. 8, 1908	41	233	5.7	12.4
6	Dec. 2, 1909	25	12,801	51.2	10.9

Both species of white flies herein considered are affected by mortality from unexplained causes, but the effect on the cloudy-winged white fly (*Aleyrodes nubifera* Berger) seems to be more pronounced as a matter of control, since the absence of food plants other than citrus tends to prevent the rapid increase in infestation which results in the case of the citrus white fly when its useless food plants are neglected. In the foregoing records both species were present, the citrus white fly greatly predominating.

DROPPING FROM LEAVES.

Daily observations made on marked larvæ from date of settling to emergence of adults, in connection with life-history studies, proved that a small proportion of larvæ loses hold upon the leaves and drops, especially at molting periods. Of 231 marked larvæ, 20 (or 8.6 per cent) dropped before reaching maturity. This dropping occurred in nearly every case after the larvæ had passed several days in the plump condition preceding molting and were in no way pressed for room. While dropping is largely restricted to the earlier instars, one pupa has been known to drop after having shown developed eye-spots for nine days. Where infestation is excessive, dropping is more frequent than noted above, but is then due more directly to overcrowding, as shown under the following heading.

MORTALITY DUE TO OVERCROWDING.

The excessive overcrowding of leaves with eggs always results in the death of practically all the larvæ that hatch, as it either becomes a physical impossibility for them to find suitable places for attachment, or, because of the closeness of the eggs, such spaces as they do find are far too limited to permit development to the pupal stage.

TABLE V.—*Effect of overcrowding upon development of the citrus white fly.*

Leaf No.	Number of eggs deposited.	Number live larvæ.	Number live pupæ.	Number pupal cases.	Per cent alive.
1	13,882	0	2	0	0.01
2	14,000	0	0	4	.03
3	2,000	0	0	0	.0

The data in Table V illustrate the inevitable outcome of over-deposition. The leaves on which these data are based were heavily infested with eggs, No. 3 being a very small leaf. Unfortunately this wholesale mortality is not so important a factor in the development and spread of the citrus white fly as in the case of the cloudy-winged white fly, since the habit of the female leads her to scatter her eggs over the older as well as over the more tender growth. With the former species on more than one occasion effective control has been observed to follow certain favorable conditions as to the relative abundance of the adult insects and new citrus growth. It has been computed that the larvæ hatching from the 13,882 eggs deposited on Leaf No. 1, would require about 25 times the surface of that leaf in order to reach the pupal stage should they settle with the view of utilizing the least possible space. Since the larvæ do not show such discrimination in locating themselves, an even larger amount of leaf surface would be required.

Because of this lack of discrimination in settling, it will be readily seen, death due to overcrowding is not, strictly speaking, always the result of overdeposition, but frequently results from the overlapping of larvæ and pupæ during growth on leaves only moderately infested. Since, after settling, the immature stages do not change their location, specimens having ample room during the early larval stages become so large in the pupal stage, if not before, that they may overlap each other at the molting period, with disastrous results to the individual beneath. Partial overlapping of the posterior portion of a pupa does not always result in its death, but death invariably follows the overlapping of the anterior or head end of the body.

EFFECT OF CURLING AND DROPPING OF LEAVES FROM DROUGHT.

Data collected during an unusual period of drought extending throughout the fall and winter of 1906–7 show that curling of leaves as an effect of drought has little effect on the vitality of the fly at this season. In March, 1907, pupæ of the citrus white fly were observed on leaves which had been curled and dry from the effects of droughts for more than three months. The leaves were so dry that they felt and tore much like paper, but they soon regained their normal texture after the beginning of the rains. The emergence of the adults on trees affected as here described was delayed for several weeks as compared with unaffected trees, but aside from this there was no apparent effect on the insects.

Although the curling of the leaves of citrus trees as a result of drought has not, so far as observed, resulted in checking the white flies, the dropping of the leaves may be decidedly effective in this respect. When citrus trees suffer from the effects of drought to the extent of shedding a considerable part of their foliage, the resulting reduction in the numbers of white flies rarely proves of sufficient advantage to offset the injury to the trees, and the insects as a rule resume their normal status fully as rapidly as the trees recover.

BACTERIAL DISEASES.

While no bacterial disease has been recognized as such in producing the very high rate of mortality often occurring among the larvæ and pupæ of both species of white flies, there are indications that bacteria play a more important rôle in this connection than has been suspected, and are at times more beneficial in holding the fly in check than are the fungi. The fluctuating effectiveness of the unexplained mortality heretofore discussed, without the visible appearance of any fungous parasite which might be responsible, seems to indicate that some parasitic organism is directly concerned.

FUNGOUS DISEASES.

THE RED FUNGUS.

(*Aschersonia aleyrodis* Webber.)

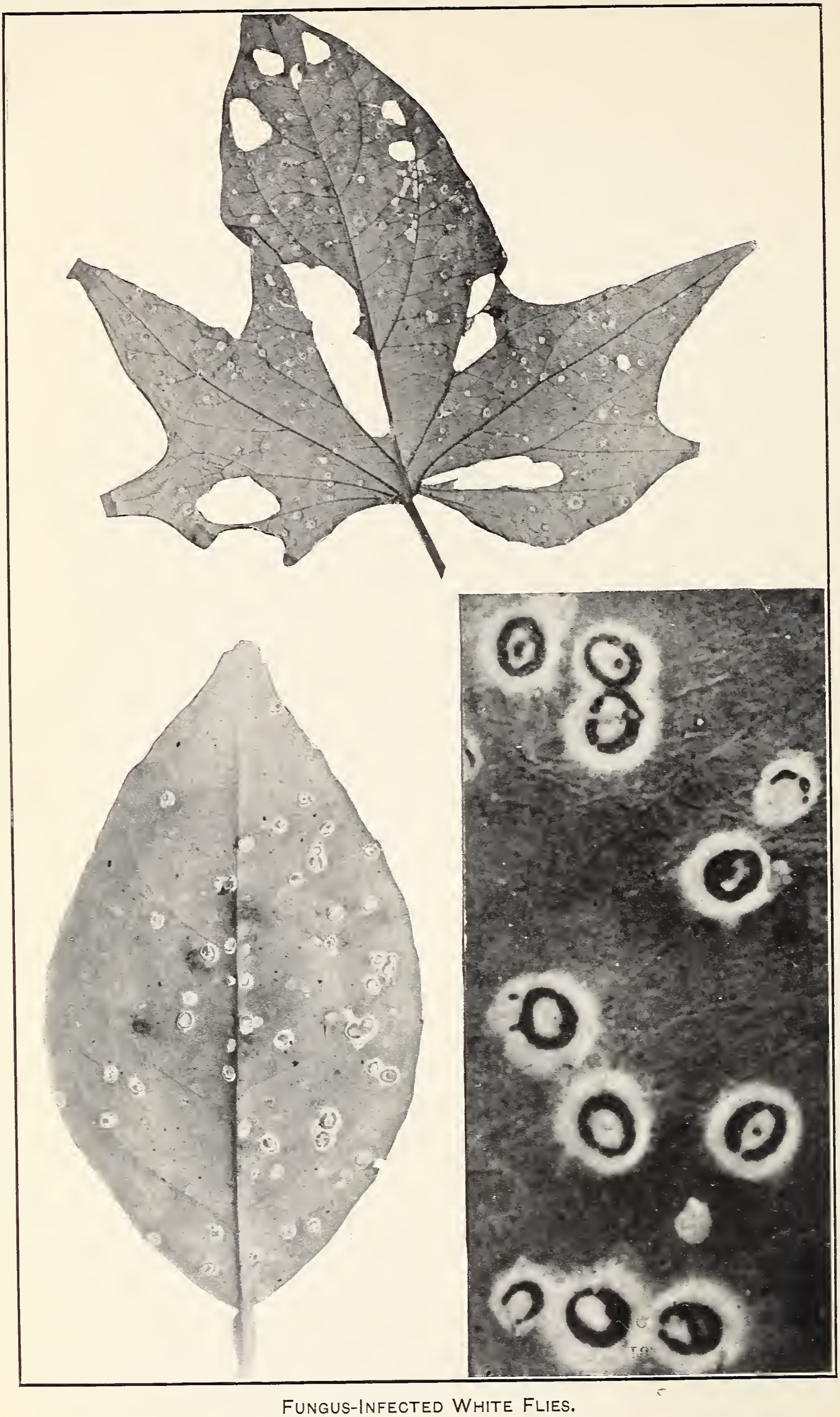
HISTORY.

The red fungus was first discovered at Crescent City, Fla., in August, 1893, in the grove of Mr. J. H. Harp, by Dr. H. J. Webber, then of the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, who, in a preliminary notice [1] of its entomogenous nature, referred it to the closely allied species *Aschersonia tahitensis* Mont. In 1896, under the same name, he mentions it in the bulletin "The Principal Diseases of Citrus Fruits in Florida." [2] Upon further study, however, he found it to be a distinct species, and in 1897, in his bulletin on the "Sooty Mold of the Orange and its Treatment," [3] described it as *Aschersonia aleyrodis,* and illustrated it with 14 line drawings and 2 colored figures. It is interesting to note that at the time Prof. Webber first reported this species attacking white-fly larvæ and pupæ no species of the genus Aschersonia had been known to attack insects, although several entomogenous species have since been discovered. In the last-mentioned bulletin the author, besides discussing at length the development of the red fungus on the white fly, the probable methods of spore dissemination, and methods of introduction into noninfested groves, states that he had found fungus only at Crescent City, Citra, Gainesville, Panasoffkee, Bartow, Manatee, and Fort Myers, Fla., while no fungus was seen in white-fly groves at Ocala, Orlando, Evinston, and Ormond. He further states that the fungus was very abundant in groves at Panasoffkee and that while in 1893 no trace of it could be found in the grove at Citra, it had been reported by growers as being quite abundant there in certain localities at the time of the first freeze, which occurred December 28, 1894. Since the publications mentioned above, the yearly reports and numerous bulletins of the Florida Experiment Station and the Transactions of the Florida Horticultural Society have contained the principal contributions to the literature of this species of fungous parasite. Special mention should be made of the work of Dr. E. W. Berger and Prof. H. S. Fawcett. From a technical standpoint the most important contribution to our knowledge of this fungus since Webber is contained in Prof. Fawcett's paper on "The Fungi Parasitic upon *Aleyrodes citri,*" [4] in which the author gives the description, history, methods of introduction, distribution, and

[1] Journal of Mycology, vol. 6, no. 4, p. 363, 1894.
[2] Div. of Veg. Phys. and Path., Washington, D. C., Bul. 8, p. 27, 1896.
[3] Div. of Veg. Phys. and Path., Washington, D. C., Bul. 13, p. 21, 1897.
[4] University of the State of Florida, Special Studies, No. 1, pp. 10–17, 1907.

ORANGE TWIG . ɛSTED WITH CITRUS WHITE FLY, SHOWING A SUCCESSFUL INFECTION OF RED FUNGUS.

[Hundreds of white flies may develop to maturity on a twig as well infected numerically as this one, or the mortality may be complete. (Original.)]



FUNGUS-INFECTED WHITE FLIES.

[Red Aschersonia developing on *Aleyrodes inconspicua* infesting sweet-potato leaves (top); red Aschersonia infecting the cloudy-winged white fly (*Aleyrodes nubifera*) (lower left); red Aschersonia pustules, enlarged, showing mycelium and pycnidia (lower right). (Original.)]

valuable data on cultural methods and on the introduction of artificially grown spores. Dr. George F. Atkinson, of Cornell University, was successful in growing cultures of this fungus during the summer and fall of 1907 from material sent him by Mr. Worsham, at that time an agent of this bureau, and under date of September 30, 1907, sent the authors at the Orlando Laboratory cultures from which infections were secured in the grove.

DESCRIPTION.

A glance at Plate I, middle figure, would give one unfamiliar with this fungus a sufficiently correct idea of its appearance and make possible its identification in the grove. (See also Plates III and IV.)

Dr. Webber's original technical description is as follows:[1]

Stroma hypophyllous, depressed hemispherical, pinkish buff or cream colored, coriaceous, 1–2½mm. in diameter; mycelial hypothallus grayish white, forming a thin membrane closely adhering to the leaf and extending about 1 mm. beyond the stroma; perithecia membranaceous, at first superficial, later becoming irregular, reniform or orbicular in mature specimens, and opening by small, round, or elliptical pores or slits; basidia crowded, filiform, slender, continuous, 28–40μ long, 0.94–1.5μ in diameter; paraphyses abundant, slender, projecting beyond the basidia, 65–100μ long, ¾–1μ in diameter; sporules fusiform, continuous, mucilaginous, hyaline, sometimes obscurely 3–4 guttulate, 9.4–14.1μ long by 0.94–1.88μ wide, very abundant and erumpent, forming conspicuous coral-red or rufous masses. (Parasitic on *Aleyrodes citri* R. & H., infesting citrus leaves in Florida.)

Dr. Webber further states that peculiar darkened cells occur at irregular intervals in the paraphyses which are quite characteristic of this species of fungus.

DEVELOPMENT.

If in the process of dissemination the spores find a favorable resting place and the weather conditions permit, they soon germinate or grow by sending out rootlike processes known technically as hyphæ or mycelial threads. Should one of these succeed in finding a vulnerable spot in a white-fly larva or pupa, the growth of the fungus becomes very rapid and the insect is soon killed. The following description of the development of the fungus within the insect has been taken, with slight changes, from that of Dr. H. J. Webber,[2] which in the main has been verified by the authors.

The first indication of the effect of the fungus on the larva of the white fly is the appearance of slightly opaque, yellowish spots, usually near the edge of the larva. In the early stages of infection the larva becomes noticeably swollen and appears to secrete a greater abundance of honeydew than normally. As the fungus develops, the internal organs of the larva appear to contract away from the margin, leaving a narrow circle, which then becomes filled with the

[1] Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 21, 1897. [2] Idem, pp. 23–24, 1897.

hyphæ or mycelium. This circle becomes opaque and whitish, presenting a very characteristic appearance. Shortly after this the hyphæ burst out around the edge of the larva, forming a dense marginal fringe. This may form all around the larva at about the same time, or may develop at one portion of the margin sooner than at the others. The body of the larva at this time is plainly visible, but it is opaque and yellowish throughout. Death usually ensues, it is believed, before the hyphæ burst out. The fungus does not spread over the leaf to any great extent, but grows upward in a mass, gradually spreading over the larva. It is not uncommon to find the perithecia, with their bright coral-red masses of sporules, formed in a circle around the edge of the larva while it is yet visible. As the Aschersonia develops, the hyphæ spread over the larva, forming a dense, compact stroma, which ultimately entirely envelops the larva. The stroma in this stage is thin and disklike, the fructifications being usually borne in a circle near the edge. The hymenium at this time is spread out on the surface of the stroma, or but slightly sunken, the sporules projecting in a conical coral-red or rufous mass. As the fungus develops the stroma becomes thickened and hemispherical and the hymenium gradually becomes immersed. The hyphæ which make up the main mass of the stroma are from 3.5 to 7.5 micromillimeters in diameter. Within the body of the insect and near the perithecia they are somewhat smaller.

Data collected in connection with experimental work in the field have shown that well-developed pustules can mature within 15 days after artificial spreading of the infection. Ten shoots on the outside of a tree which were sprayed on June 25, 1909, had developed by July 10 numerous well-developed pustules (red Aschersonia). Check shoots produced no fungus growth. The range in temperature during this period was from 70° to 95° F. (average daily mean, 80.5° F.) and frequent showers fell. Fungus introduced by spraying on July 27, 1907, had produced pustules by August 17, or 21 days later. During this period the temperature ranged from 70° to 98° F. (average daily mean for period 80.8° F.), with numerous showers. In both of these instances no earlier examinations were made. In another instance a larva of *A. citri*, noted to have died on October 15, 1908, began to develop a whitish appearance on October 23, or 8 days later, and while the fungous growth was daily observed the characteristic reddish color of the spore masses of red Aschersonia did not appear until November 4, or 12 days after the fungus first began to be visible to the eye and 20 days after the larva was recorded as having died. During the 20-day period the temperature ranged from 45° to 85° F. (with an average daily mean of 70.4° F.) and there was no rain. The average daily mean humidity for the three periods was 92.3, 89, and 90 per cent, respectively.

Prof. H. S. Fawcett[1] has found that this fungus requires from 30 to 40 days to mature a pustule and produce pycnidia when grown on a 5 to 10 per cent glucose agar in the laboratory.

DISSEMINATION OF SPORES.

Various agencies, such as rains and dews, crawling and adult white flies, and other insects, have been considered as probable means of spreading fungous spores. Notwithstanding the fact that its spores have been described as mucilaginous, and therefore would not seem to be subject to being blown about by winds, laboratory tests have shown that after water solutions of spores have been dried on a hard surface the spores can be loosened and blown away by the aid of an electric fan or lung power. While complete success did not attend these experiments, it was demonstrated that spores can be and doubtless are blown about by winds to a considerable extent after once being freed from their mucilaginous matrix by rains and dews, and it is believed by the authors that winds are the most valuable agents in spreading the fungus from tree to tree and to the more isolated groves in a fungus-infested district. However, when once the white flies in a tree have become infected, rains and dews appear to be the most valuable agents of distribution throughout the individual and closely adjoining trees. The fact that the pustules are largely borne on the underside of the leaves is no argument against this view. While the pustules thus located are for the most part protected from the direct wash of beating showers, examination of citrus trees, especially oranges and tangerines, will show that many of the leaves are more or less slightly curled so that their underside is easily wetted, either entirely by direct rainfalls or in spots by splashing from closely growing leaves, while the newer growth, upon which infestation is usually very heavy, because of its more flexible nature is soon beaten or weighted down by the rain so that the underside of its leaves receive innumerable splashings and drippings from the pustule-bearing leaves above.

After several showers of moderate duration and force, an examination of trees in the laboratory grove showed that about 90 per cent of the leaves were either thoroughly or partly wetted on the lower surface, and during the progress of ordinary showers drippings from leaves above have been seen to bound off from lower leaves to which they had fallen and strike the exposed underside of leaves 3 feet to one side, or to splash obliquely upward as high as 1 foot. This upward spattering accounts not a little for the upward spread of fungus. It requires only a microscopic examination of drippings from fungus-laden trees, caught during a heavy shower, to prove that

[1] Special Studies, No. 1, Univ. of the State of Fla., p. 13, 1908.

spores are not only spread about by rain but that many are washed to the ground.

It is probable that dews, and especially the heavy dews of fall, are of greatest value in moistening the pustules, thus aiding in the dissolving out of the spores from their mucilaginous matrix, so that they may be more readily transported by other agencies. After heavy dews the matrix containing the spores is so soft that portions of it will adhere to any body brought into contact with it, and not infrequently such a quantity of spores is dissolved out of the pycnidia that they spread out over the leaf for one-fourth of an inch from the pustule, as shown by the reddish coloring matter of the matrix. Because of the adhesive nature of the matrix thus moistened, it is possible, and even probable, that insects play a part in spore dissemination; yet the failure of this fungus to increase to any extent during an unusually dry period in midsummer or after the summer rains cease, even though the insects remain abundant, is regarded by the authors as significant and leads them to conclude that insects, in general, play a minor rôle in spore dissemination.

Microscopic examination of washes from the bodies of adult white flies collected on trees bearing much fungus has not disclosed the presence of the spores. Of still greater importance as direct evidence is the frequently repeated observation that leaves upon which adult flies collected from similar places have been caged, and which have been protected from rain drippings, have seldom developed fungus pustules. In this connection it is also worthy of note that water-shoots, even though more heavily crowded with adults than outside new growth, develop only a slight amount of fungus as compared with the outside growth if not so located as to be easily drenched with rains. It has been generally observed by growers as well as by the authors that rapid dissemination of spores is concurrent with summer rains, and if these fail to fall the fungi are not spread rapidly, no matter how abundant the adults may have been.

SPECIES OF WHITE FLIES ATTACKED.

While the red Aschersonia is most effective in its attack upon the citrus white fly and is of economic importance largely in connection with this species, it is frequently found growing upon several other species of white flies. On numerous occasions it has been observed at Orlando and other points in Orange County attacking the cloudy-winged white fly, upon which it develops into unusually large pustules. Thus far, however, attempts at introduction into groves infested only with the cloudy-winged white fly have met with failure from an economic standpoint, although in each instance an infection was secured. During the summer and fall of 1907 such a luxuriant growth of fungus upon *Aleyrodes inconspicua* Quaintance was discovered at

Orlando, on the underside of sweet potato leaves, that several bushels of leaves of this plant were picked as the easiest way of procuring a supply of fungus for experimental purposes. Mr. W. C. Temple, of Winter Park, also noted a similar attack upon a sweet potato aleyrodid, probably the species above mentioned, in July, 1909. The senior author has several times seen pustules on *Aleyrodes floridensis* Quaintance on guava at Orlando and Manatee, and on another, as yet undetermined, aleyrodid attacking Spanish mulberry at Orlando, while in 1908 Messrs. M. T. Cook and W. T. Horne reported it attacking *A. howardi* Quaintance as well as *A. citri* in Cuba.[1] The junior author has found a rank growth of this fungus on a white fly (*Aleyrodes abutilonea* Hald.) at Orlando.

DISTRIBUTION.

In Florida the red Aschersonia occurs in all the leading orange-growing sections infested with the citrus white fly. The fact that Dr. Webber reported it from such widely separated places as Gainesville, Bartow, and Fort Myers, is sufficient evidence to warrant the conclusion that even then its distribution was wider than known. It is being continually reported from or introduced into new localities, and at present may be said to occur in greater or less abundance in Florida in all sections infested by the citrus white fly. It is most widely distributed in Manatee, Lee, and Orange Counties.

Outside of Florida the red Aschersonia now occurs in different points in Louisiana, having been introduced by agents of the Louisiana Crop Pest Commission. In 1905 Mr. F. S. Earle[2] reported this fungus on *A. citri* in Cuba. In 1906 Mr. J. Parkin[3] mentioned finding in Ceylon an Aschersonia closely resembling *aleyrodis* on several undetermined species of Aleyrodes. Dr. Berger has identified this species of fungus on citrus leaves infested with *Aleyrodes citri* from Japan,[4] and the junior author found it attacking *A. howardi* in 1910 in both Cuba and Mexico.

HYPERPARASITIC FUNGI.

Thus far the red Aschersonia has not been subjected to widespread attack by hyperparasitic fungi. In sheltered places during the late summer and in the fall the pustules sometimes become overgrown by the species of Cladosporium mentioned more fully under the hyperparasitic fungi of the yellow Aschersonia. In a grove at McIntosh, Fla., examined in December, 1907, it was estimated that fully 50 per cent of the red-fungus pustules were overgrown by this hyperparasite. Old worn-out pustules are often entirely overrun late

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[1] Bulletin 9, Cuban Experiment Station, p. 31.

[2] Primer Informe Annal de la Estacion Central Agronomica de Cuba, 1904 and 1905, p. 169, 1906.

[3] Annals Roy. Bot. Gard. Peradeniya, vol. 3, pt. 1, p. 36, 1906.

[4] Ann. Rept. Fla. Agr. Exp. Sta. for year ending June 30, 1909, p. xxxvi.

in the season by a rank growth of sooty mold (*Meliola* sp.), but this usually occurs after the fungus has ceased spreading rapidly and on pustules the majority of which would fall from the leaves before spring. On the whole these two fungi are of no practical importance in checking the spread of the red Aschersonia or in reducing its efficacy.

THE YELLOW FUNGUS.

(*Aschersonia flavo-citrina* P. Henn.)

HISTORY.

Specimens of a white-fly parasite from the grove of Mr. J. F. Adams, of Winter Park, Fla., sent to Mrs. Flora W. Patterson, Mycologist of the United States Department of Agriculture, in September, 1906, by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, were identified by Mrs. Patterson as the yellow fungus (*Aschersonia flavo-citrina*). Previously this had been discovered occurring on leaves of the guava (Psidium) at Sao Paulo, Brazil, in October, 1901, and described in 1902 by P. Hennigs. No insect was mentioned associated with it on the guava leaves.

Since its discovery in Florida as a parasite of *Aleyrodes nubifera* and *A. citri* it has been found in several new localities and has been introduced into others. Reports and bulletins of the Florida Agricultural Experiment Station and the Transactions of the Florida Horticultural Society contain the only references to data concerning the yellow fungus as a parasite of white flies. Prof. Fawcett has published the most important contributions to our more technical knowledge and has successfully grown artificial cultures on various mediæ. Prof. George F. Atkinson, of Cornell University, has also successfully grown cultures from which infection has been secured in the grove by the junior author in early October, 1907.

DESCRIPTION.

The yellow Aschersonia in general form closely resembles the red Aschersonia, but is at once separated from it by the rich yellow instead of pink or red color of its well-developed pustules. A sufficiently clear idea of its appearance may be had by referring to Plate I, upper figure. (See also Plates V and VII.) During the early stages of infection it is impossible to separate these two fungi by ordinary examination; it is only after the pycnidia, with their characteristically colored spore masses, are formed that they can be readily distinguished. Prof. H. S. Fawcett states [1] that the pustules of *A. aleyrodis* under similar conditions average less in diameter, that the pycnidial cavities

[1] Fungi parasitic upon *Aleyrodes citri*, University of State of Florida, Special Studies, No. 1.

are usually more sunken than in *A. flavo-citrina,* and that its spores are smaller. The original description follows:

Aschersonia flavo-citrina P. Henn. Stromatibus carnosis, hypophyllis, subdiscoideo-pulvinatis vel hemisphaerico-depressis, citrinis, 2–2.5 mm. diameter, pruinosis, superne punctulato-pertusis, intus subaurantiis, subiculo membranaceo, flavo; pycnidiis immersis oblongis, paraphysibus filiformibus, flexuosis, hyalinis, 140–180x1–1.5 micr., continuis; conidiis fusoideis, utrinque acutis, continuis, hyalinis, 12–18x2 micr.; conidiophoris brevibus, hyalinis, fasciculatis.

The manner of development of the yellow Aschersonia upon the larvæ and pupæ is so like that already described for the red Aschersonia that no further mention of it need be made here.

The method of spore dissemination, so far as can be determined, is also similar to that of the red fungus.

BIOLOGY.

The yellow Aschersonia, except when artificially introduced, has never been found in groves infested only by the citrus white fly and so far as observed thrives only on the cloudy-winged white fly. Dr. Berger[1] reports having caused the infection of a few larvæ of *citri,* but states that this fungus did not increase in his experiments. The same experience has been had by the authors at Bradentown, Fla. It has been noted by the senior author attacking a scale insect on the leaf of sweet gum (*Liquidambar styraciflua*) at Winter Park, Fla.

DISTRIBUTION.

Up to July, 1909, this fungus has been found growing naturally at Altamonte Springs, Maitland, Mims, Oneco, Orlando, Oviedo, Wildwood, and Winter Park, Fla., and has been introduced into Buckingham, Gainesville, Lakeland, Lake City, Largo, Lemon City, Manatee, Miami, New Smyrna, Sutherland, St. Petersburg, and in the vicinity of Turkey Lake in the western portion of Orange County, Fla. Its occurrence in Brazil has already been noted.

HYPERPARASITIC FUNGI.

The yellow Aschersonia is subject to widespread parasitism by a greenish-brown hyperparasitic fungus identified in March, 1907, by Mrs. Patterson as *Cladosporium* sp. The attack of the latter upon the yellow Aschersonia was first noticed by the senior author in the summer of 1906. During the winter of 1906–7 it was estimated to have overrun 95 per cent of the yellow pustules in certain groves at Winter Park and Orlando, and has since been noted wherever the yellow Aschersonia occurs. The destruction of more than 90 per cent of the supply of yellow Aschersonia spores during the fall and winter must necessarily have a retarding influence on the spread of the fungus at the beginning of the next season for its normal spread. Frequent observations and experiments at both Winter Park and

[1] Bul. 97, Fla. Agr. Exp. Sta., p. 53.

Orlando have demonstrated, however, that ordinarily the overrunning of from 20 to 90 per cent of the pustules does not prevent the fungus from spreading rapidly when the weather conditions are favorable. The Cladosporium spreads most rapidly during dry weather and upon leaves bearing many pustules of the Aschersonia.

The yellow Aschersonia pustules in all ages and conditions are subject to the attack of the Cladosporium. (See Pl. VI.) The former is frequently so closely followed by the latter that even when spreading rapidly practically all of the Aschersonia pustules show the beginning of the hyperparasitic attack before they reach more than one-fourth of their normal size.

During 1907 and 1908 the Cladosporium was especially active in August and October. In 1907 its spread was unusually rapid between October 17 and 31, during very dry weather, and by November 15 of the same year had so overgrown the yellow fungus in one nursery at Orlando that 92.6 per cent of the pustules were affected. This estimate is based on the examination of 50 leaves upon which there were 3,110 pustules of the yellow Aschersonia. Again, between August 6 and 13, 1908, when no rain had fallen since July 28, it spread with such rapidity as to render useless numerous experiments started in July at Drennen. During the summer of 1909, when the rain was more abundant than during 1907 or 1908, the Cladosporium did not spread with such rapidity in any of the groves at Orlando.

THE BROWN FUNGUS.

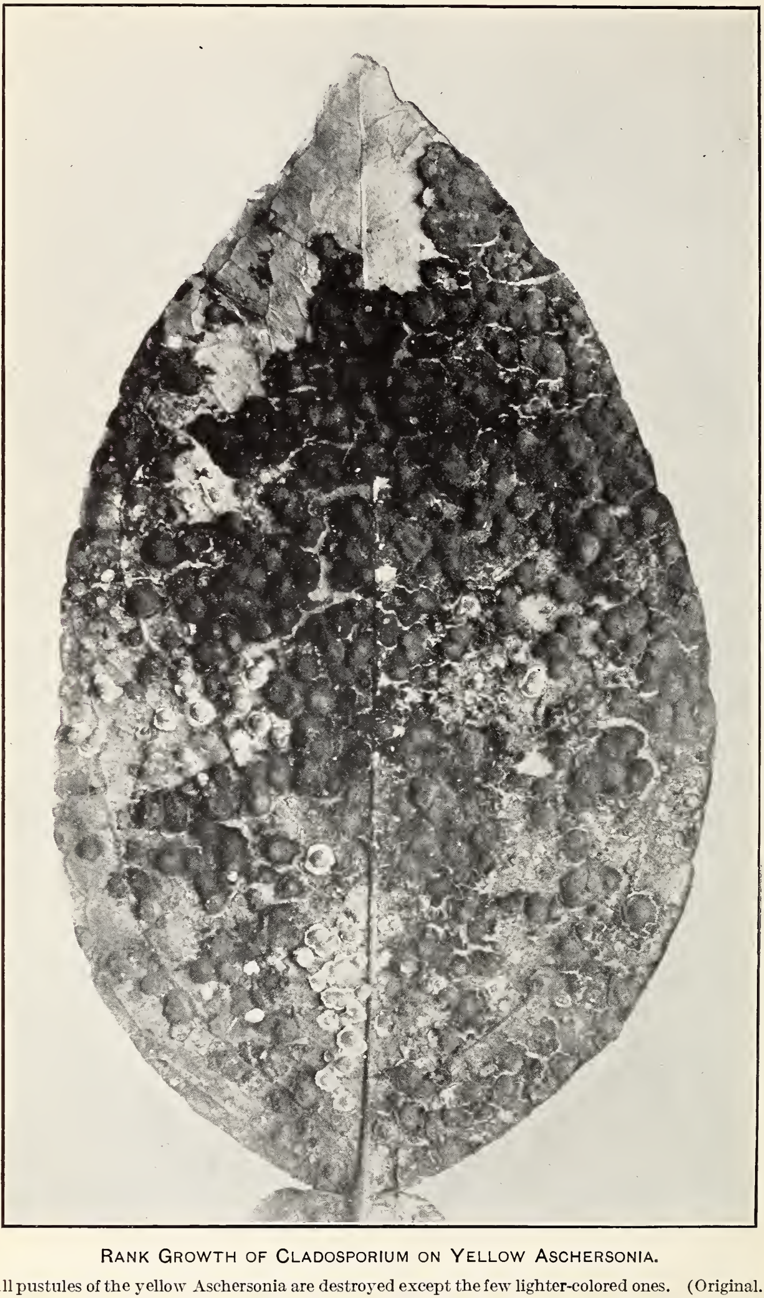
(*Ægerita webberi* Fawcett.)

Dr. H. J. Webber, then of the United States Department of Agriculture, first discovered the brown fungus, parasitic upon the immature stage of the citrus white fly, in March, 1896, in the grove of J. H. Viser, Manatee, Fla. Dr. Webber states that while the spread of the fungus was phenomenal from March to December of that year and killed so many larvæ and pupæ that the fruit was clean, he was unable to discover it in any of the surrounding groves heavily infested with the fly. Although a thorough study of the fungus was made by its discoverer at several seasons of the year, no trace of fructification was found; hence it was impossible to determine its relationship. The fungus was, therefore, popularly named the brown mealywing fungus, or, as it is now more commonly called, the brown fungus.

During the past three years the authors have noted the frequency of the occurrence of patches of minute brownish spores on leaves infected with this fungus, arising apparently from its ground mycelium As these spore patches occurred only upon leaves infested with the fungus and upon no other leaves no matter how heavily coated with sooty mold, it was concluded that they must be the fruiting bodies of the fungus. A specimen leaf was sent to Mrs. Patterson, the mycolo-

GRAPEFRUIT LEAF, SHOWING YELLOW ASCHERSONIA INFECTING THE CLOUDY-WINGED WHITE FLY.

[The parasitic fungous pustules are overgrown in spots by sooty mold and sooty mold is also shown developing around the edges of infected pupæ. More, rather than less, sooty mold usually accompanies as extensive an infestation by the yellow fungus as that shown on this leaf. (Original.)]



RANK GROWTH OF CLADOSPORIUM ON YELLOW ASCHERSONIA.

[All pustules of the yellow Aschersonia are destroyed except the few lighter-colored ones. (Original.)]

gist, who, under date of November 2, 1907, wrote: "The specimen has a fruiting stage connected with the brown fungus." In a publication dated October 1, 1908, Prof. Fawcett[1] announced that he had noted what appeared to be the spores of the brown fungus, and that these spores were then germinating in hanging drop cultures of sugar solutions, and were producing hyphæ that seemed identical with those of the brown fungus. Since then, however, Prof. Fawcett has been most successful in not only growing the characteristic brown-fungus mycelium from the spores, but infecting healthy white-fly larvæ with the mycelia thus grown and in securing the characteristic pustules of this fungus, to which he has given the name *Ægerita webberi*.[2]

DESCRIPTION.

The pustules of the brown fungus, which vary in size according to the size of the larva or pupa infected, are seal-brown in color and when fully developed entirely conceal the insect attacked. The pustules are round or slightly elliptical, and, as compared with the pustules of the red Aschersonia, are more flattened, thus resembling the Florida red (or circular) scale (*Chrysomphalus ficus*) (see Pl. I, lower figure; also Pl. VII.) Dr. Webber gives the following general description:[3]

The mature stroma is compressed hemispherical, frequently having a slight depression in the apex over the center of the insect, where the hyphæ come together as they spread from the edges of the larva in their development. The size varies greatly according to the stage of development of the insect attacked. In many young larvæ it is from one-fourth to one-half a millimeter in diameter. The thickness or height also varies in like manner, specimens on mature larvæ or pupæ having usually from 175 to 260 microns while those on young larvæ are much thinner. * * * The stroma is commonly seal brown, with a shade of chestnut, but becomes slightly darker with age. It adheres closely to the leaf, but no indication has been found that the hyphæ penetrate the latter. The hyphæ which make up the body of the stroma are light brown, very tortuous, and but slightly branched.

Those in the body of the insect are of similar character, but a much darker brown. From the base of the stroma a ground mycelium, or hypothallus, spreads out in all directions on the surface of the leaf, forming a compact membrane near the stroma, but becoming gradually dispersed into separate filaments. * * * The hyphæ of the hypothallus are colorless, sparingly branched, mostly continuous, having only an occasional septa, and are from 5 to 7 microns in diameter. In some places in the hypothallus, when the hyphæ are apparently somewhat amassed and knotted, they become light brown, similar in color to the isolated hyphæ of the stroma. *

When there are but a few pustules on a leaf, the threadlike mycelium spreads as separate strands on the underside of the leaf for as far as 2 or 3 inches and may be seen with the aid of a lens. The mycelium also often extends to the upper surface of the leaf. When the pustules are abundant, however, the mycelial

[1] Univ. of the State of Florida, Special Studies No. 1.

[2] An important entomogenous fungus. Mycologia, vol. 2, no. 4, July, 1910.

[3] Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., pp. 28-30, 1897.

threads interlace to form a dense papery membrane covering the lower surface of the leaf, and mycelial threads growing down the petioles and along the branch to the next leaf are often so numerous as to form a like coating on these. The authors have on many occasions seen watershoots 5 feet long with the undersides and petioles of the leaves, and the stems of the shoot, wholly coated with this dense mycelial growth. In one instance there were brownish sporelike bodies, above mentioned, scattered over the entire mycelium on the stem of the watershoot and along the edges and upper surface of the leaves. (See Pl. VII.)

DEVELOPMENT.

The development of the brown fungus on the larvæ and pupæ does not differ materially from that of the red and yellow Aschersonias already described, with the exception that after the hyphæ have filled the insect body and have broken out around the edges, the stroma which then forms does not produce fruiting bodies but from them there grow out slender mycelial filaments which extend to a greater distance than those of the Aschersonias and partly take the place of the spores of the latter in infecting other larvæ and pupæ. As with the other fungi, insects may be killed without the formation of the characteristic complete stroma, or the stroma may be restricted in its growth to the margin of the insect. Often when several insects close together are infected, one large irregular stroma will develop over them all.

The junior author has followed from day to day the growth of the mycelium of the brown fungus toward dead pupæ, and the subsequent development thereon of the characteristic stromas. This fungus is therefore definitely known to be partially saprophytic. This was previously suspected, since on leaves infected by it nearly all specimens within reach of the mycelium are overgrown and the usually large percentage of specimens dead from unknown causes is not apparent. The stroma frequently does not develop normally except around the margin, leaving the greater part of the body of the insect and the segmentation easily distinguishable. This condition is probably due in some cases to the effect of dry weather on the growth of the fungus, but it is considered by the authors to be due more often to the development of the fungus on the body of a dead insect.

DISSEMINATION.

Although Dr. Webber was unable to discover any fruiting bodies of the brown fungus, his observations led him to believe that the mycelial filaments, spreading out over the surface of the leaf from larvæ already infected, have the power to infect other larvæ and pupæ with which they come into contact, and that it seemed probable that the spread of fungus from tree to tree was effected through fragments of the mycelium carried by wind or birds. It has been conclusively demonstrated by means of a series of marked specimens that Dr. Webber's observations as to the power of infection possessed by the mycelial filaments is correct. In several instances infection was noted to occur only so far as the mycelial growth extended. In this respect the mycelia of the Aschersonias is different; living pupæ have frequently been noted to touch developing pustules of both red and yellow Aschersonia without becoming infected.

While it is very likely that winds, birds, and insects do spread this fungus by carrying small pieces of mycelium on their bodies, the experiments of the authors and of Dr. Berger have fully demonstrated that the fungus can be spread from grove to grove by means of broken pieces of mycelium. It has been frequently observed that the fungus appears on trees to which no attempt has been made to introduce it. As yet no success has followed the attempt on the part of the authors to spread the fungus by means of the spores already mentioned, but considering the abundance with which they are developed, especially after the middle of July, it is considered probable that they play an important, though as yet unknown part in its dissemination.[1] Although it probably will be proved that the brown fungus is most widely disseminated through the agency of the small spores, it is apparent that after becoming well established on a branch its spread is due chiefly to infection started by the spreading mycelium. As noted elsewhere, these mycelial filaments have been traced from one leaf down its petiole, along the branch to the next leaf, thence along its petiole to start an infection on its underside. It is not a rare occurrence to find all the leaves on a watershoot or small branch thus connected by mycelial growths.

SPECIES OF WHITE FLIES ATTACKED.

The brown fungus thrives best on the citrus white fly and has never been observed in any amount in a grove infested by any other species. However, slight infections of the cloudy-winged white fly have been noted in various places.

DISTRIBUTION.

The brown fungus has been introduced into or reported from the following places in Florida: Lake City, St. Augustine, Hawthorn, McIntosh, Boardman, Leesburg, Orlando, Oviedo, Winter Park, Bartow, Lakeland, Largo, St. Petersburg, Bradentown, Manatee, Oneco, Palmetto, Sarasota, Alva, Buckingham, and Fort Myers. In addition it has been introduced into various places in Louisiana

[1] Since this was written Prof. Fawcett has been able to infect larvæ with mycelium grown from these spores, thus removing all doubt that they are a means of disseminating this fungus.

and Texas through the offices of the entomologists of the experiment stations of those States. Its recent discovery in India by Mr. R. S. Woglum, of the Bureau of Entomology, has been noted by Dr. Howard.[1]

HYPERPARASITIC FUNGI.

A greenish hyperparasite of the brown fungus was noted by the senior author in April, 1907, in Manatee, Fla., where an examination of leaves shed by the cold of the previous winter in one grove showed that fully 95 per cent of the pustules of the brown fungus had been parasitized. Since then it has been observed at various times in many of the groves in Manatee, Oneco, and Palmetto. In September, 1907, it was noted by the senior author at Lake Charles, La., where its occurrence was directly traceable to importation of nursery trees from Manatee County, Fla.

Prof. H. S. Fawcett has identified this hyperparasite as *Coniothyrium* sp. It forms a dense, dark-greenish, hard growth over the pustule of the brown fungus and presents a surface roughened by numerous pustular elevations as shown in Plate VII.

As only the stromata of the brown fungus appear to be affected, it is doubtful if the Coniothyrium has any practical influence in checking the spread of the mycelium of the brown fungus. In fact, it has been repeatedly noted that even when its parasite was present the brown fungus was spreading as rapidly and doing as effective work in controlling the fly as when it was not parasitized. In January, 1909, the junior author noted that the Coniothyrium was rare in groves in and about the Manatee hammocks, even where it was observed to be most abundant in 1907, and in all these groves the brown fungus was doing effective work in controlling the fly.

FUNGI OF LITTLE OR NO VALUE AS WHITE-FLY PARASITES.

THE WHITE-FRINGE FUNGUS.

(*Microcera* sp.)

The white-fringe fungus (*Microcera* sp.) is so inconspicuous that it is easily overlooked. It forms no distinct pustules as do yellow and brown fungi. (See Plate IX, lower figure). Larvæ and pupæ infected turn whitish, then red, often pinkish, and from their margins bursts forth a delicate fringe of white mycelial growth from which the fungus derives its name. There subsequently appear at various points along the margin and through the vasiform orifice the fruiting bodies, which are pink in color and vary in number in different specimens infected. After the specimens infected are dried or after the mycelium has been long developed, the characteristic fringe dries up and disappears, so the best lasting evidence of the presence of this fungus is its pink fruiting

[1] Journ. Econ. Ent., vol. 4, p. 130, 1911.

LEAF SHOWING BROWN FUNGUS WHICH HAS DEVELOPED ON LARVÆ AND PUPÆ OF THE CITRUS WHITE FLY; FILM OF MYCELIUM PARTLY TORN FROM LEAF AND STEM.

[Lower figure shows Coniothyrium on brown fungus. (Original.)]

bodies. Those desiring a fuller description are referred to Press Bulletin 68, issued October 14, 1907, by the Florida Agricultural Experiment Station, by Prof. H. S. Fawcett, in which appears the original description. In June, 1908, Prof. Fawcett[1] published a more technical description, together with data on successful cultural methods and introductions secured in the field with artificially grown cultures. The apparent effectiveness of this fungus and methods of introducing it are discussed by Dr. Berger[2] in a publication bearing the date of February, 1909.

The authors' experiences with this fungus date from the fall of 1906. Under date of November 26 of that year the senior author noted the presence at Orlando, in a grove infested with the cloudy-winged white fly, of an "unknown pink fungus especially prevalent on pupæ killed by a spray." While no data as to the relative abundance of infected pupæ on the sprayed and unsprayed trees were collected, the number of infected specimens on the sprayed trees was unmistakably greater. Examinations made showed that from November 26 to December 10 there was no spread of fungus to previously marked healthy pupæ from infected pupæ touching them. Later in the same year this fungus was seen at Hawthorn developing upon the citrus white fly. Under date of August 27, 1907, Mr. Worsham reported the *Microcera* quite abundant in Manatee, Hillsboro, and Orange Counties, saying that at that time it was present in greater abundance in every grove visited in Manatee County than on July 19. Under the same date Mr. Worsham reported it very abundant in the groves of Mr. F. L. Wills and Mr. C. W. Hicks, at Sutherland, and in several groves at Orlando. On November 1, 1907, an examination of leaves from Mr. Hicks's grove gave the following results: Flies reaching maturity and emerging, 46.8 per cent; living larvæ and pupæ, 4.9 per cent; dead larvæ and pupæ, 4.2 per cent; dead larvæ and pupæ infected with the white-fringe fungus, 44 per cent. Under date of November 11, 1907, a grower at Largo reported that this fungus had killed 95 per cent of the fly in his grove, but an actual count of the leaves sent to the Orlando laboratory with this statement showed that 12.9 per cent had reached maturity and had emerged, 52.7 per cent were still alive on the leaves, and 34.3 per cent were dead from fungus and unexplained mortality, no attempt being made to find the percentage of white-fringe fungus, which was noted as being very slight.

On October 3, 1907, many pupæ of *Aleyrodes nubifera* were killed by mechanical injuries in applying as a smear a culture of yellow Aschersonia; on October 31 the junior author noted that many pupæ had been killed by the application of the culture, and on November

[1] Fungi parasitic upon *Aleyrodes citri*. Univ. of State of Florida, Special Studies, No. 1.
[2] Bul. 97, Fla. Agr. Exp. Sta., pp. 54-55.

11 that these same dead pupæ had developed the characteristic growth known as white-fringe fungus. During 1908 and the summer of 1909 the authors found the fungus in every grove visited in various parts of the State.

Since the observations made on November 26, 1906, this fungus has been regarded by the authors as entirely or largely saprophytic, and all data and observations since obtained have strengthened this belief. Three series of observations have been conducted in connection with fumigation experiments. The data obtained are presented in Tables VII and VIII. Specimens of the fungus under observation were submitted to Prof. H. S. Fawcett, who verified the authors' determination of the species. The data in Table VI are based upon the examination, by the senior author and Mr. W. W. Yothers, of leaves picked promiscuously from adjoining fumigated and unfumigated rows of nursery trees. The trees were fumigated on September 26, 1908, and the examination was made on October 8, 1908.

TABLE VI.—*Relative abundance of white-fringe fungus on fumigated and unfumigated leaves.*

Leaves.	Number of leaves examined.	Live pupæ.	Dead pupæ.	Pupæ infected with white-fringe fungus.		
				Total.	Average per leaf.	Per cent.
Unfumigated	20	2,154	1,031	29	1.4	0.9
Fumigated	20	19	4,432	302	15.1	6.8

In Table VII are given data collected by Mr. Yothers showing the development of the fungus over a period of one month on fumigated leaves, as compared with the same on unfumigated leaves. Five selected leaves were under observation in each case.

TABLE VII.—*Development of white-fringe fungus on fumigated and unfumigated leaves.*

Fumigated October 12, 1908.[1]				Unfumigated.[2]			
Leaf No.	Pupæ infected on—			Leaf No.	Pupæ infected on—		
	Oct. 13.	Oct. 26.	Nov. 9.		Oct. 13.	Oct. 26.	Nov. 9.
1	0	1	2	6	0	0	0
2	1	4	12	7	3	4	4
3	4	8	8	8	1	3	3
4	1	13	20	9	0	0	0
5	0	1	29	10	1	4	4
Total	6	27	61	....	5	11	11

[1] Leaves 1 to 3 on one nursery tree with a total of 400 dead and 2 living pupæ. Leaf No. 4 on similar tree and with same number dead and living pupæ. Leaf No. 5 on similar tree but with 1 living and 400 dead pupæ.

[2] Leaves 6 to 10 with average of about 40 living pupæ and numerous dead larvæ and pupæ per leaf.

In the third series of observations the junior author selected leaves on which all living pupæ had been killed by fumigation. It is probable that fungus had already infected a few dead pupæ but had not broken out around the margin previous to fumigation; yet, considering the comparatively few pupæ becoming infected on unfumigated leaves as compared with the unusual number infected on fumigated trees, there is no doubt that the fungus developed for the most part after the pupæ were killed by the gas.

TABLE VIII.—*Development of white-fringe fungus on leaves fumigated Sept. 26, 1906.*

Leaf No.	Pupæ alive.	Pupæ dead.	Pupæ infected with white-fringe fungus on—					
			Sept. 30.	Oct. 8.	Oct. 14.	Oct. 21.	Oct. 28.	Nov. 5.
1	0	200	0	10	32	57	57	57
2	0	600	0	0	2	21	40	40
3	0	200	0	0	8	21	48	48
4	0	400	0	0	1	10	22	22
5	0	100	0	0	1	6	6	6
Total	0	1,500	0	10	44	115	173	173

Concerning the reported practical results in reducing the white flies, it may be said that the occurrence of a very high percentage of the dead larvæ and pupæ, especially of the cloudy-winged white fly, as already noted in the grove of Mr. C. W. Hicks, where over 91 per cent of the dead insects were infected, has no bearing on the parasitic nature of this fungus, since an equally high rate of mortality occurs in groves infested with the same species where very little white-fringe fungus can be found. Its prevalence is evidently only an indication of the extent of the occurrence of unexplained mortality. The data here presented are regarded by the authors as satisfactory evidence that the Microcera develops almost entirely or exclusively on larvæ and pupæ already dead from other causes and should be disregarded as a factor in the control of the white fly.

SPOROTRICHUM.

The Sporotrichum is either closely related to or identical with one of the diseases of the chinch bug which attracted so much attention from entomologists a number of years ago. As a white-fly parasite it has been under observation since September 8, 1906, and is largely limited in its spread to the fall of the year, when, under favorable weather conditions, it spreads with astonishing rapidity among adults of both the citrus and cloudy-winged white flies then crowding the new growth. This fungus does not form pustules like the red Aschersonia. Adults killed by it remain attached to the underside of the leaf, their bodies become shriveled, and in a short time the grayish mycelial threads of the fungus break through the body of the fly and produce countless spores. To the casual observer the flies appear merely to die and shrivel up on the leaf as shown in Plate IX, upper figure.

In connection with this fungus the authors' observations have been limited to the vicinity of Orlando, but Prof. Fawcett, to whom credit is due for its determination, has seen it several times working in different parts of the State since August, 1908. While it has been reported by Dr. Berger [1] as attacking the larvæ of the citrus white fly, and has been seen by the authors attacking the eggs of the same species, it must be regarded, so far as now known, as primarily a parasite of the adult.

Notwithstanding the very large number of adults it is capable of killing when spreading most rapidly during the fall, it can not be said that it has proved itself of any value in checking the progress of fly infestation for the reason that a sufficiently large number of adults escape to deposit as many eggs as the new growth can well support. During September and early October, 1908, when this fungus was spreading very rapidly and there were in places from one to several hundred dead flies per leaf and it appeared that much good was being accomplished, careful examination of the leaves of the new growth showed that they were heavily infested with eggs. In a grove near Turkey Lake, 8 miles west of Orlando, where the Sporotrichum was even more virulent in its attack upon the cloudy-winged white fly, the surviving adults so overcrowded the leaves with eggs that on many shoots not a larva was able to mature. These observations have been mentioned to show that, if anything, the killing of an even comparatively large number of the fall brood of adults may act as a stimulus rather than a check to the progress of infestation, inasmuch as it seeks to prevent that overdeposition of eggs, which, in itself, as explained elsewhere, is an important element of self-control with this species.

Thus far the authors have not been successful in attempts at spreading the Sporotrichum artificially. During September, 1908, many thousand infected flies were collected for experimental purposes. On October 8, when the fungus was spreading less rapidly than during September, two watershoots were rubbed with infected flies, and although adults of both species fed on the leaves for two weeks none became infected. One hundred adults caged on a leaf smeared with a paste made of 100 infected flies and water did not become infected, neither did adults confined on leaves sprayed with a solution of 100 infected flies in one-fourth of a cup of water. Experiments with the same material on May 29 and August 17, 1909, gave equally negative results, although adult *citri* were abundant on the treated leaves. Leaves of china tree and orange were dipped and sprayed with a water solution of infected flies, were rubbed with a paste made of flour and

[1] Bul. 97, Fla. Agr. Exp. Sta., p. 56, 1909.

CINNAMON FUNGUS, SHOWING PUSTULES AND THE DENSE WHITISH MYCELIUM FORMING IN PLACES A FELTLIKE COVERING ON UNDERSIDE OF LEAF. (ORIGINAL.)

UPPER FIGURE, SPOROTRICHUM FUNGUS INFECTING ADULT WHITE FLIES, CAUSING THEM TO REMAIN ATTACHED TO UNDERSIDE OF LEAF, INSTEAD OF DROPPING AS IS USUAL.

LOWER FIGURE, LARVÆ AND PUPÆ OF THE CITRUS AND CLOUDY-WINGED WHITE FLIES KILLED BY FUMIGATION AND LATER DEVELOPING THE WHITE-FRINGE FUNGUS. (ORIGINAL.)

infected flies, and, both wet and dry, were dusted with a mixture of infected flies and flour applied with a blowgun. No fungus developed on checks kept on these experiments.

THE CINNAMON FUNGUS.

(*Verticillium heterocladum* Penz.)

History.—The cinnamon fungus (*Verticillium heterocladum*) was first described by O. Penzig in 1882 attacking the soft scale (*Lecanium*) *Coccus hesperidum* L. on lemon leaves in Italy. In 1905 Dr. E. H. Sellards, then entomologist of the Florida Experiment Station, found it growing on *Aleyrodes citri* at Palmetto, Fla., on leaves also bearing numerous pustules of the brown fungus. As no fruiting bodies of the latter had ever been found, for several years it was thought possible that it might be the spore-bearing stage of the brown fungus. However, it has since been proved distinct by Prof. H. S. Fawcett, who has referred it to Penzig's species, and in 1908 published the results of his studies begun in 1905, giving an account of its history, its description, and biological notes.

Description.—The pustules of this fungus are brownish-gray or cinnamon colored and are surrounded by a whitish feltlike growth spreading out over the leaf for a short distance around the pustule. In general appearance, when not growing luxuriantly, this Verticillium superficially resembles the brown fungus. The following technical description is quoted from Prof. Fawcett:[1]

> The pustules, which are cinnamon colored, are powdery on the surface. Under the hand lens they appear brushlike in form, bristling with hyphæ. From the edge of the pustules there grows out a creeping layer of white, delicate, interwoven hyphæ. From these colorless hyphæ, as well as from the top of the pustules, there arise upright conidiophores. These may have either a simple series of whorls, two to four branches in each, or the branches of the whorls may again be whorled. The conidia are borne on the ends of the ultimate branches. The conidiophores are quite delicate, slender, hyaline, 150 to 240 microns by 3 to 4 microns, several times septate. The conidia are oblong, hyaline, 4 to 6 micorns long by 1.5 to 2.5 thick. The main body of the cinnamon-colored stroma when mature becomes powdery in appearance, and under the microscope it is found that the hyphæ have broken up into short pieces irregular in shape and length with rounded ends, some of them quite closely imitating spores. These have thicker walls than the conidia, and probably act as reproductive bodies in carrying the fungus through a period of dry weather.

The resemblance to the brown fungus mentioned above is most striking when the pustules are very scattering and only partially developed. However, when very abundant, as shown in Plate VIII, the similarity between the two fungi disappears. Leaves have been found in which the underside was entirely concealed beneath the feltlike mycelial growth surrounding the pustules. This running together of the mycelial growths of the several pustules is shown in

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[1] Special Studies No. 1, Univ. of Florida, p. 23, 1908.

places in Plate VIII. When weathered the pustules lose their powdery appearance and their surface appears pitted. This fungus attacks both the larval and pupal stages of both the citrus and cloudy-winged white flies, and has been observed by the junior author to spread to and develop pustules on larvæ and pupæ known to be previously dead. It is therefore saprophytic as well as parasitic.

Effectiveness.—The authors have frequently observed this fungus in various places in Lee, Manatee, Orange, and Marion counties since 1906, but in only one instance, on a few nursery trees in a very moist spot at Orlando, did it appear to give promise of ever being of value in holding the fly in check. The pustules are usually very scattered, being most abundant in the lowest and most shaded portions of the grove. Considering the almost negligible good accomplished by it, it has not been the subject of serious study in the course of these investigations except in noting its spread on certain trees to both living and dead marked larvæ and pupæ. Prof. Fawcett has successfully grown cultures on various media, and both he and Dr. Berger have secured infections in the grove with these cultures.

Distribution and insects attacked.—The cinnamon fungus has been reported as infecting *Aleyrodes citri* at Gainesville, Citra, McIntosh, Orlando, Winter Park, Apopka, St. Petersburg, Palmetto, Bradentown, Manatee, Oneco, Bartow, Fort Myers, Buckingham, and Alva. Its attack is not restricted to the citrus white fly. Prof. Fawcett states that it has been found in Florida on the following five scale insects: *Lepidosaphes gloveri* Pack., Gainesville; *Diaspis* sp., on leaves of *Euonymus americanus*, Gainesville; *Lepidosaphes beckii* Newm., Palmetto and Citra. In Italy it attacks soft scale (*Coccus hesperidum*) on lemon leaves, and in Africa and the Antilles it has been reported on unknown host insects.

THE REDHEADED SCALE FUNGUS.

(*Sphærostilbe coccophila* Tul.)

The red-headed scale fungus (*Sphærostilbe coccophila*) is here recorded among those fungi of minor importance attacking the white fly only because it has been repeatedly associated with it in this connection. It was first noted as a parasite on *Aleyrodes citri* at Orlando in 1903 by Prof. H. A. Gossard. While it has a world-wide distribution and is very effective at times as a parasite of scale insects, being reported on no less than 15 species, its value as a parasite on the citrus and cloudy-winged white flies is absolutely nil. Probably not more than one white-fly larva or pupa in a million is killed by it. In not a few cases, where it has been thought on casual observation to be attacking the white-fly larva, careful examination with a lens has shown that its bright red fruiting bodies originated not in the fly larva itself but in a purple scale, *Lepidosaphes beckii* Newm., partially or completely concealed by it.

NATURAL EFFICACY OF FUNGOUS PARASITES.

Under this heading are discussed subjects relating to the actual degree of control of which fungous parasites have shown themselves capable, without regard for the possibilities of increasing that degree of efficacy by artificial means. These two subjects are frequently confused, although a clear distinction is necessary for a proper understanding of the economic value of the parasitic fungi.

CREDIBILITY OF COMMON REPORTS.

It is a well-recognized fact among economic entomologists that wherever predaceous insects or parasites of any kind are conspicuous enemies of an insect pest, popular reports are greatly exaggerated in regard to the efficacy of the natural enemy. The amount of control influence exerted by the natural enemy can not be approximated by casual observation, by the record of parasitism of a comparatively small number of specimens of the insect pests, or even by the seemingly practical results as shown by the condition of the host plant. A casual observation summarized by a statement that 50, 75, or 90 per cent of the insects are destroyed by fungous parasites is usually worthless and misleading. Even an experienced entomologist could not make a statement of value in this respect without first making extensive counts of specimens, recognizing the influence of unexplained mortality and the effect this has upon the apparent percentage of parasitism. The experience of the authors in the course of the investigations reported herein shows that thousands of insects rather than hundreds, and these on leaves picked absolutely at random without previously making any note of their condition, can be regarded as the only satisfactory basis for approximate estimates of the efficacy of fungous parasites. Even reports based on seemingly practical results of fungous parasites, with the white flies greatly reduced and with clean leaves and fruit, should not be credited without being authoritatively confirmed.

Experience has shown such reports too frequently to be incorrect for either of two reasons: The first is due to a misunderstanding of the factors influencing fluctuations in numbers of the insects; the second is the absolute lack of any actual foundation for the popular report of the character referred to. These reports are traceable to a feature of human nature which is found everywhere. One can not become well acquainted with the white-fly situation without noting instances of persistent and emphatic reports in regard to the complete efficacy of fungous parasites in certain sections or in certain groves which upon investigation are found to be entirely erroneous.

It is desirable that citrus growers become acquainted with all important facts in regard to the white flies and the methods of their control, but due weight should be given to the authoritativeness of common reports. Otherwise the confusion which arises becomes a decided hindrance to progress.

OLDER ESTIMATES OF THE NATURAL EFFICACY OF FUNGOUS PARASITES.

In some respects the subject of the natural efficacy of the fungous parasites of white flies is the most important subject dealt with in this bulletin. Common reports concerning this matter are so frequently erroneous or misleading, as has just been explained, that in addition to the specific observations and records to be given under another heading it is considered advisable to present here quotations from previous publications showing the status of the fungous parasites at different periods since their discovery and the views expressed by various writers concerning their efficacy.

In a publication previously referred to, submitted for publication in March, 1897, Dr. H. J. Webber makes the following statement:[1]

> The writer believes it may safely be assumed that the spread of *Aschersonia aleyrodis* and the brown mealy wing fungus will ultimately materially check the ravages of the mealy wing (white fly) and sooty mold.

According to the publication mentioned, Dr. Webber knew of two instances of apparently satisfactory control resulting from the red Aschersonia and one such instance resulting from the brown fungus. Owing to the comparatively brief period of his observations and to the checking of both the white fly and its parasitic fungi by the freezes of December, 1894, and February, 1895, the fact that the parasites did not maintain a uniform state of control apparently had not come under Dr. Webber's observation at the time of writing the report from which the quotation is taken. However, as a prediction his statement was doubtless fully warranted by the circumstances.

The next investigator to give attention to the matter of the efficacy of the fungous parasites was Prof. H. A. Gossard. After more than four years of more or less continuous investigations and observations, noting the fluctuations from year to year in the abundance of the insects and of the parasites, he arrived (1903) at the following conclusion:[2]

> I repeat emphatically that while I have no word of condemnation for the man who with intelligence and skill directs nature's agencies so that he secures results from most insects equal to the best (and we have some such in Florida), I believe that white fly is an insect that should be fought by everybody by insecticides from the day it is discovered in a grove. I admit that there is no spray that will kill white fly and not at the same time inflict injury to the trees, but I am satisfied that the injury is far less than white fly causes, except during exceptional periods when fungous diseases are unusually active. Infested trees that are properly sprayed through many years and

[1] Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 34, 1897.
[2] Bul. 67, Fla. Agr. Exp. Sta., p. 626, 1903.

are correctly treated in other respects I believe will live longer, yield better, and give much larger net profits than they will do if fungi alone are relied upon for protection.

After three years largely devoted to investigations of the white flies affecting citrus in Florida, giving particular attention to their fungous diseases, Dr. Berger[1] (1909) summarized his observations concerning natural efficacy of the fungous parasites as follows:

When left without assistance the fungi will practically destroy the white fly in a grove, on the average, once every three years; thus reducing the injury due to the white fly by at least one-third. The destruction is not complete, so that the insects increase again during the two succeeding years; but this is accompanied by rapid increase of the fungi, until the white fly is again overwhelmed. This is the course run by the white fly and the fungi when unassisted in those sections which have been longest infested, such as Manatee County, Fort Myers, and Orlando. At Orlando the fungi were in the ascendency during the summer of 1906, and this resulted in so far reducing the white fly that an uncommonly large and clean crop of citrus fruit was marketed in 1907.[2]

Mr. C. L. Marlatt, assistant chief of this bureau, after visiting various sections of Florida in the fall of 1907 and discussing the white-fly situation with numerous well-informed citrus growers, described the natural efficacy of the red and brown fungi as follows:[3]

In Manatee County, where the fungi are fully established, they are able practically to exterminate the white fly once in three years, so that every third year the fruit is clean and requires no washing. The following year the insect again flourishes because the white-fly fungi have disappeared, having during the clean year nothing on which to develop. Toward the end of this year, however, the fungi again begin to operate, but not sufficiently to prevent the complete blackening of the foliage and fruit during the following or third year. Nevertheless, during this year the fly is again reduced to practical extinction, so that the year following is a year of clean foliage and fruit.

The senior author of this bulletin, writing in the fall of 1907[4] after a little more than one year devoted exclusively to white-fly investigations, discussed the natural efficacy at some length, in part, as follows:

Data obtained from many orange growers and personal observation by the writer and other entomologists connected with the Bureau of Entomology indicate that the fungi, without artificial aid, reduce the injury from the white fly about one-third. * * * One year in three, it is the experience of the growers in this county (Manatee), the fungi have so thoroughly cleaned up the pest that the fruit is clean and requires no washing. * * * Considering the county as a whole in 1906, fully three-fourths of the groves were so free from sooty mold as to require no washing of the fruit. It was generally considered that this condition had never before been equaled since the white fly first obtained a foothold in this county. * * * As a natural consequence of the lack of abundant food for the fungous parasites in 1906, the situation in 1907 showed a complete reversal, with more than three-fourths of the groves thoroughly blackened by sooty mold. It is not uncommon to find that individual groves vary considerably from the average condition of the groves in the county as a whole.

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[1] Bul. 97, Fla. Agr. Exp. Sta., p. 50, 1909.

[2] See explanation of this condition on p. 11.

[3] Proc. Ent. Soc. Wash., vol. 9, nos. 1-4, p. 124, April, 1908.

[4] Bul. 76, Bur. Ent., U. S. Dept. Agr., p. 64, issued October, 1908.

From the foregoing quotations it is seen that there is practical agreement among the various writers as to the natural efficacy of the fungous parasites.

OBSERVATIONS AND RECORDS CONCERNING NATURAL EFFICACY.

Under the subject of unexplained mortality it has been shown that even where fungous diseases are most effective mortality from this source is secondary in importance to that from unexplained causes. The recognition of this fact does not in any way detract from the actual value of the fungous parasites, but should be regarded as a necessary step in the proper estimate of that value.

The theoretical efficacy of white-fly fungous parasites may be determined by a similar method of calculation as that employed on page 16, in estimating the efficacy of unexplained mortality. Instead of 12.4 and 15.4 per cent for the years 1908 and 1909, the efficacy would become 47.6 and 53.2 per cent if there had been no unexplained mortality. Considering the normal rate of increase of the white flies as shown in a previous bulletin of this bureau, mortality among the larvæ and pupæ to the extent of the foregoing calculations (47.6 per cent and 53.2 per cent) obviously would be of no practical advantage as an average condition. The insects could continually maintain themselves at the maximum of injurious abundance even if the mortality were 25 or 30 per cent higher. Theoretically considered, therefore, the fungous diseases were entirely ineffective in either 1908 or 1909 for the average of the 10 groves under observation.

There is another phase of the subject to be considered, however. With unexplained mortality present in all groves it is not necessary for fungous diseases or any other known cause of mortality to increase to a point of independent efficacy in order to be of distinct value. The most important question to be considered here, therefore, is: To what extent do fungous parasites effectively supplement all other causes of mortality to the direct and practical advantage of white-fly infested citrus groves?

For practical purposes in this bulletin, fungous parasites are said to have worked effectively or to have cleaned up a grove when they appeared to have worked effectively on the insects not succumbing to unexplained causes of mortality, bearing in mind that the same rapidity of spread and multiplication and the same percentages of infection do not produce similar effects in different cases. This absence of standards of efficacy is plainly shown in the data presented in Table II and also in the following table in which the records concerning eight of the groves included in Table II are extended to show the status of the white flies and their fungous diseases at the end of the season of 1909.

TABLE IX.—*Status of white flies and their fungous parasites in eight groves, December, 1908, to December, 1909.*

Grove No.[1]	Examination, December, 1908.			Examination, July, 1909, 100 leaves picked at random from each grove; condition as to sooty mold.	Examination, December, 1909.		
	Average number forms per leaf.	Average number live forms per leaf.	Average number forms killed by fungus per leaf.		Average number forms per leaf.	Average number live forms per leaf.	Average number forms killed by fungus per leaf.
1	103.7	49.1	24.5	All leaves thoroughly blackened.	170.0	0.5	56.6
3	108.3	32.0	1.7	79 per cent moderately blackened.	124.4	13.0	12.4
4	132.6	20.0	19.2	60 per cent moderately or slightly blackened.	106.2	6.8	14.0
5	229.2	35.9	29.6	64 per cent thoroughly, 34 per cent moderately blackened.	218.5	13.8	26.0
8	597.3	30.6	80.9	None blackened..................	82.3	11.9	13.4
9	282.4	8.4	43.9	Traces of blackening.............	48.7	4.9	3.1
10	469.4	1.7	84.2	None blackened..................	56.8	3.9	11.6
12	229.9	8.3	9.7	8 per cent moderately blackened, remainder showing traces.	27.8	2.5	3.6

[1] See Table II.

As regards blackening of the fruit and foliage, which is the most important element of injury by the white flies, groves 1, 3, 4, and 5 were not benefited by the work of the parasitic fungi during either 1908 or 1909. By the 1st of July, 1909, these groves were at least as black as the average infested grove in which no fungous parasites were established. Moreover, there were sufficient live insects present to continue this condition regardless of any unusual climatic conditions which might favor the multiplication of the fungous diseases. As regards the reduction of the insects themselves, the fungous diseases were decidedly effective in grove No. 1, promising a condition of freedom from white-fly injury in 1909. The condition of groves Nos. 3 and 5 did not give promise of such condition, since any number of live white flies (pupæ) above 10 per leaf in December is strong indication that the insects will multiply sufficiently the following spring to cause a decidedly injurious blackening of the foliage and fruit before climatic conditions will give the fungous parasites an opportunity to check them. Without interference by adults migrating from other groves, an average of 12 overwintering insects per leaf has been noted to produce a general blackening (moderate) of new spring growth of foliage by June 15, while an average of 2.6 live insects per leaf in December was noted to result in a very heavy infestation one year later with excessive blackening of the foliage. As is often the case, in this latter instance the foliage appeared entirely clean up to midsummer, most of the blackening appearing in September and October.

On the July examination of No. 4 it was found that the average number of forms per leaf representing the insects which produced the condition noted consisted of 26 dead larvæ and pupæ, 8.8 live larvæ and pupæ, and 1.9 pupa cases. No. 8 was in a satisfactory condition in July, but in December the average number of dead larvæ and pupæ was found to be 61, live larvæ and pupæ 11.9, and pupa cases 5.1. This would indicate at least a slight blackening of the leaves by the end of the year, judging from the effects of a lighter infestation in the case of No. 4 as noted above. To a casual observer this fairly satisfactory condition might appear to have resulted from fungous diseases. As a matter of fact the fungous diseases had no appreciable effect. A fairly high average number matured per leaf in the spring of 1909, but very few eggs were deposited on the citrus trees. This appeared to be due to the emergence of the insects before the appearance of new growth on the citrus trees and as a consequence the attraction of the adult white flies to other food plants, persimmon and China trees, having new foliage. An examination of a persimmon tree growing in the midst of the citrus trees on this property showed 8 times more larvæ and pupæ per leaf than on the leaves from surrounding citrus trees. If fungous diseases had been concerned in the reduction of the infestation of the citrus trees the July examination of the spring growth would have shown this. The examination of 100 leaves picked at random showed that an average of 0.37 white flies of the first generation had matured and that of this generation an average of 0.15 per leaf showed infection by fungous diseases. These, with a very small average of less than 1 per leaf dying from unexplained causes, represented the entire first generation as shown by the examination of the leaves.

The July examination of No. 9 showed that an average of 0.2 white fly per leaf of the first generation had matured and that 0.46 per leaf was infected with fungous diseases. This low average of infection could not have had any appreciable effect on the normal increase of the insects, and it is obvious that in this grove the comparative freedom of the foliage from blackening was not due to the fungous diseases.

The very excellent condition as to white-fly infestation of grove No. 10 during the season of 1910 may be properly credited to the effective work of the fungous diseases after midsumer in 1909. The trees suffered so severely during 1909 from the excessive infestation that their unthrifty condition was noted at the time of the examination in July, 1910.

In No. 12 it was found, on July 1, that an average of 0.2 per leaf of the first generation had matured, while 0.74 forms of this generation showed fungous infection. As shown by Table II, the reduction in the number of the insects in this grove in 1908 was due almost entirely to an excessive rate of mortality from unexplained causes, fungous diseases being comparatively insignificant. As regards the cause for the failure of the live insects found in December, 1909, to multiply normally, No. 12 must be classed with No. 9. In both these cases the explanation is probably similar to that in the case of No. 8.

When the data in Table IX are examined with due consideration of circumstances known to the authors, it appears that the fungous diseases in the eight groves were ineffective in 1908, but produced a condition in that year resulting in satisfactory freedom from the insects and blackening of the foliage in one grove in 1909 and with prospects for such a condition in at least one grove in 1910. As the investigation of fungous diseases was discontinued in 1909, there are no records as to the condition of the groves the following season. Since the actual cause of the temporary freedom from injurious attack is often obscure, as the foregoing records show, it is evident that less detailed observations, such as have formed the basis of the estimates of the authors of previous publications (including the senior author of the present publication), have favored the fungi rather than otherwise in crediting them with complete efficacy to the extent of one year in three.

During 1906, 1907, 1908, and 1909 a large number of records were accumulated in regard to the efficacy of fungous diseases during those years in about 25 citrus groves located in different sections of Florida, mostly in Lee, Manatee, Hillsboro, and Orange counties. In several instances authentic information has also been secured in regard to the efficacy of the fungi in previous years, as shown by the necessity for washing the fruit to remove sooty mold.

More than one-half of the total number of records are concerning hammock groves and the list includes the majority of groves in Florida where the fungous diseases have been exceptionally effective during the period under observation. In two instances groves have been noted or authentically reported as free from blackening for two successive years after being well freed from the insects by fungous diseases. These are offset, however, by several instances of groves showing no benefit whatever for three or more years after the fungous diseases have become well established. In the case of one grove in Manatee County, unfavorably located with respect to a general nursery with citrus, China trees, privets, and other food plants, it had been necessary for the owner to wash the fruit every year for a period of more than 10 years, except for less than one-half of one crop. Although the red and the brown fungi were always found present in abundance at each of the several examinations made by the authors, the trees were always found to be more or less blackened and in one instance noted as being as thoroughly blackened as any grove seen in Florida.

The hammock groves of Manatee and Lee counties have offered the best opportunities for observations of the fungous diseases under the most favorable conditions. During 1906 and 1909 the majority of the Manatee hammock groves were practically free from blackening by sooty mold, but the crop of 1907 in these same groves was as thoroughly blackened as any to be found in the State and in 1908 was only slightly improved. In Lee County the hammock groves located near the Caloosahatchee and Orange Rivers have been much less uniform than hammock groves in Manatee County as regards the efficacy of the fungous parasites. It has been more frequent to find very effective work by the fungi in one section of a grove, while another section of the same grove has been heavily infested and thoroughly blackened. On the whole the average condition in these groves in Manatee and Lee counties has conformed entirely to the estimates given in previous publications; in effect, that the efficacy of the fungi amounts to about one-third of a complete remedy.

In the interior of the State, in high pine land groves, the natural efficacy of the fungous parasites appears to be somewhat less than in the hammock groves referred to. Prof. Gossard mentioned the presence of the red and the brown fungi at Orlando in his annual report for the year ending June, 1901.[1] According to an authentic report, the grove of Hon. J. M. Cheney (grove No. 3 of Table I, and No. 1 of Tables II and IX) at Orlando was one of the earliest in that section to become infected with the red and the brown fungi. This introduction was not later than 1901. In 1907 the grove was entirely free from sooty mold, as noted in the discussion of unexplained mortality. This was the first year that the fruit had not been generally blackened since the introduction of the fungi, and the fungous diseases in this case were not responsible. In 1908 and 1909 the trees and fruit were very black, while by the end of the latter season the insects had been reduced in an entirely satisfactory manner. While we have no record concerning the condition of the crop for 1910 in this grove, it may be said without hesitancy that if not clean it was due to the interference with the efficacy of the fungi by adult white flies migrating from other groves or from China and umbrella trees. Without doubt China and umbrella trees have seriously interfered with the natural efficacy of the fungous parasites in Orlando and other cities and towns in Florida, but at the most the natural efficacy of the fungous parasites at Orlando and at similar locations apparently will not equal the natural efficacy in the hammock groves of Manatee and Lee counties.

COMPARATIVE EFFICACY OF DIFFERENT SPECIES OF PARASITIC FUNGI.

In the preceding topics, under the general heading of natural efficacy, the brown, red, and yellow parasitic fungi have been discussed collectively. All other species so far reported as white-fly parasites are of negligible value, as shown elsewhere. The brown fungus has long been considered as more effective than the red fungus against the citrus white fly. This estimate is in accordance with our obser-

[1] Rept. Fla. Agr. Exp. Sta., p. 65, 1901.

vations. An examination of 100 leaves picked at random in 5 typical groves in Manatee County and 5 in Lee County in January, 1909, showed a ratio of 14 red-fungus pustules to 32 brown-fungus pustules in groves which had all been infected with both species for several years previous. In 9 of the 10 groves the total number of pustules of brown fungus counted exceeded the total number of red-fungus pustules. The single exception was a grove in which both species of fungous parasites were present in almost negligible amounts. In Orange County the brown fungus has also as a rule shown greater natural efficacy than the red wherever the two species have both been present in the same grove and both have become well established. For example, in grove No. 1 of Tables II and IX the average number of red and brown fungus pustules per leaf was found to be 9.9 and 14.5, respectively, in December, 1909, and 3.7 and 52.9 in December, 1910.

The natural efficacy of the yellow fungus against the cloudy-winged white fly is about the same, according to the authors' observations, as the natural efficacy of the red fungus against the citrus white fly. The fact that the red and brown fungi have shown very little adaptability to the cloudy-winged species has been mentioned elsewhere.

HAVE THE FUNGOUS PARASITES INCREASED IN NATURAL EFFICACY SINCE THEIR FIRST DISCOVERY?

The statement sometimes heard to the effect that the fungous diseases are more effective now than formerly is unquestionably without the slightest foundation, and it is unnecessary to devote any space to a discussion of the subject.

ARTIFICIAL MEANS OF SPREADING FUNGOUS DISEASES.

HISTORY OF WORK IN THIS LINE.

Dr. H. J. Webber, who first discovered the red Aschersonia and the brown white-fly fungus, was also the first to undertake experiments with artificial methods of spread.[1] The methods tested included mixing the spores of the Aschersonia with water and spraying the infested leaves with an atomizer, hanging branches with pustules of the Aschersonia and brown white-fly fungus above branches infested with the white fly in groves where the fungous parasites did not occur, and transplanting young trees with parasitized white flies. The first method is reported to have failed to give satisfactory results. The second method was tested several times, but results were obtained in only one instance in the case of the red Aschersonia and once in the case of the brown fungus. The season of the year when these tests were made is not stated. The transplanting of young trees seemed the most reliable method, and this was recommended in estab-

[1] Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., pp. 26 and 30, 1897.

lishing the red Aschersonia and the brown fungus in groves where these white-fly enemies did not occur.

Prof. H. A. Gossard[1] tested pinning fungus-infected leaves onto leaves infested by the white fly, as also spraying with spores of the fungus and fragments of its mycelium suspended in water. These and certain other methods of less practical interest Prof. Gossard states "have been tried by various experimenters, myself included, without marked success." He adds: "However, an infection is sometimes started by these methods." With the knowledge concerning the fungous parasites obtained up to the time of writing (1903) Prof. Gossard recommended the transplanting of young trees as the most reliable method of spreading the parasites.

At the beginning of the present investigations in July, 1906, spreading the white-fly fungi by pinning the infected leaves onto uninfected trees was the method commonly employed. This method was successfully used, together with the so-called tree-planting method, in introducing the red Aschersonia and the brown fungus into a grove in Orlando as long ago as 1898 or 1899.

Dr. Berger has recorded experiments in pinning leaves infected with red Aschersonia in June and July, 1906, and in spraying the spores in a water solution in July and August, 1906. Results of pinning leaves infected with brown fungus and of spraying water solutions of brown-fungus mycelium incidental to experiments with red Aschersonia have also been noted by the same author. Dr. Berger was the first experimenter to obtain results in spraying water mixtures of the spores, justifying the use of this method in preference to the tree-planting method or leaf-pinning method. He was also the first to recommend that the spraying method be used to spread red and yellow Aschersonias in groves already infected in order to aid artificially in their multiplication and in the increasing of their efficacy.

EXPERIMENTAL METHODS.

In connection with the present investigations extensive experimental work has been conducted to determine the best methods and most favorable conditions for introducing the fungous parasites into groves where they do not exist, as well as to determine to what extent practical benefit can be derived through artificial methods of spread and encouragement of the growth of these fungi in groves where they already are present and well distributed. During 1906, 1907, and 1908 a total of about 3,500 trees was included in the experimental work. In addition, fully as many trees sprayed with water mixture of spores by citrus growers as independent experiments have been carefully examined and extensive data concerning the results obtained.

[1] Bul. 67, Fla. Agr. Exp. Sta., pp. 624–625, 1903.

During 1909 about 2,000 trees were included in the experimental work conducted.

Various methods have been employed in experimental work in the artificial dissemination of the fungous diseases. The tree-planting method recommended by Dr. Webber and Prof. Gossard and the leaf-pinning method commonly employed previous to 1907 have both been tested as checks on other methods. Spraying water mixtures of spores of the red and yellow Aschersonias, which, as heretofore stated, was first successfully used and recommended by Dr. Berger, has been most extensively used, as this method has proved the most satisfactory for use on a large scale. Preliminary tests of using water mixtures of spores in September, 1906, by the senior author seemed to show that the spores were affected by pressure in passing through an atomizer or spraying nozzle.[1]

Consequently, two other methods were used which, so far as known, had not been previously tested. These methods, with their various modifications, have been called the dipping and the brushing methods.

Aside from the tree-planting and leaf-pinning methods and the methods mentioned in connection with the dissemination of fungous infection by means of water mixtures of spores and mycelia, the authors have tested and in correspondence recommended for use the rubbing of the underside of infected leaves against the underside of the leaves of uninfected trees. This has been done both with single infected leaves and with twigs with several infected leaves attached. It has also been tested with dry and wet leaves. The rubbing method has been most extensively used in experiments in the dissemination of the brown fungus.

PINNING AND RUBBING INFECTED LEAVES.

The pinning of infected leaves in introducing the Aschersonias, being obviously an inferior method, has been used by the authors principally in the form of checks on other methods tested. Infection was not secured in more than 50 per cent of the experiments, and when secured was a more local infection than those following spraying. Better results followed when the upper surface of the fungous leaf was brought into contact with the underside of the leaf to which it was pinned, although good infections have followed when the fungus pustules have been placed against the leaf. In all instances where infection followed pinning, fungus developed either on the leaf to which the fungous leaf was pinned, or more often on leaves immediately below, and occasionally on leaves so located that they might have been brushed against the fungous leaf by winds. In view of the greater abundance of infections occurring immediately below the

[1] Later experience indicates that the unsatisfactory results obtained were due to lack of suitable weather conditions.

fungous leaf, the authors conclude that showers and abundance of larvæ and pupæ are conditions most favorable to successful pinning. Good infections have been secured at times when there were no adults on the leaves.

While there are cases on record where very good results in introducing fungus have followed the pinning method, this must be regarded as second in importance to the introduction of spores in water mixtures, especially when Aschersonias are concerned. On the other hand, infections with the brown fungus have been secured with more certainty by pinning than by spraying, although with no more certainty and in a less widespread manner than by the dipping of infested shoots into ground brown-fungus leaves and water as described elsewhere. Infections with brown fungus by pinning have been secured as late in season as November 6 (1908).

Infections secured by rubbing fungus-infected leaves, as described under experimental methods, have proved of more value in connection with the brown fungus. Although success has attended the introduction of the Aschersonias by this method, they are too easily introduced by water mixtures to warrant attempts at introducing them by rubbing. Under favorable weather conditions the rubbing method is many times superior to the pinning. At most, rubbing, even for brown fungus, is a very uncertain method, as only a very small percentage of leaves rubbed become infected. In a hammock grove at St. Augustine, Fla., in August, 1907, the senior author rubbed about 1,200 leaves on four trees, the leaves averaging about 75 *citri* larvæ and pupæ. Infection resulted only on about two twigs. Later in the season slightly better results have been obtained. When only a few brown-fungus-infected leaves are obtainable, they can best be used for rubbing and then pinning. Frequently leaves that appear to have been rendered worthless by rubbing have caused infections when pinned. Fungous leaves should be kept wet or moist during rubbing by frequently dipping in water. Good infections with brown fungus have been secured as early as June 5, 1907, and as late as October 31, 1908, although September and October have proved more favorable months than the three preceding. While Prof. Fawcett reports[1] success in obtaining infections by means of the brownish sporodochia, which are found dusted over the surfaces of the infected leaves, several similar tests by the authors made at various times since June, 1907, have all been without results.

WATER MIXTURES OF SPORES AND MYCELIA.

Preparation of mixture.—Whichever of the three most promising methods of introducing the fungi in water mixtures is to be followed, viz, spraying, dipping, or brushing, the initial steps in the preparation of the mixture, with few exceptions, are the same. The "fungous

[1] Science, vol. 31, no. 806, p. 913, 1910.

leaves," as leaves[1] bearing fly larvæ and pupæ infected with fungi are popularly called, are placed in water, allowed to soak a varying length of time, and then shaken or stirred vigorously for from three to five minutes in order that the spores may be washed from the pustules, or, if brown fungus is used, that in addition small pieces of the mycelia may be separated from the leaves. After the leaves have been thoroughly agitated by shaking or stirring, the mixture is carefully strained, if it is to be applied as a spray, like ordinary insecticides; or, if the dipping or brushing methods are to be followed, merely poured into the final receptacle, together with the leaves and fungus. This stock mixture is then diluted to the desired strength.

In securing infections with the brown fungus, infections have been secured by using ground fungous leaves. In preparing water mixtures of the mycelia in this way, the leaves are first passed through an ordinary meat grinder or similar instrument. During this process the leaves are thoroughly ground into small particles. The ground leaves may be shaken in a jar, then poured into a bucket, thoroughly stirred, and the resulting mixture used for dipping the ends of white-fly infected branches.

As the spores are very readily gotten into solution, no special apparatus is necessary. The authors have found an ordinary 2-quart fruit jar very convenient when no more than 3 or 4 gallons of solution are desired at any one time. The fungous leaves are placed in the jar previously half filled with water, the top screwed on, and the contents shaken the desired length of time. In making larger amounts of spray, an ordinary washtub is a convenient retainer; the leaves being thrown into the tub half filled with water and vigorously stirred with a stick or board. The solution is then strained through a wine strainer into the spray pump and is ready for application.

Means and methods of applying water mixtures of spores.—For those who have only a few trees into which they wish to introduce fungi and do not care to go to the expense of purchasing spray pumps, very satisfactory results will be obtained by the use of an ordinary wooden bucket half filled with spore solution into which the badly infested outer shoots of the tree are dipped. In using the brushing method an ordinary whisk broom, or even a bunch of leafy twigs, in addition to the bucket, is all that is necessary.

In spraying the spores into the trees, the authors have used ordinary knapsack sprayers, compressed-air sprayers, and barrel pumps. There is little choice between these sprayers from the standpoint of infection secured, and the sprayer used has depended largely upon the

[1] The danger of introducing by means of fungous leaves either the citrus or cloudy-winged white fly into sections or groves where both do not occur is very great. When a grove is infested by only one species, the danger of introducing the other by this means may be obviated by scraping the red and yellow Aschersonia pustules from the leaves or by crushing the leaves, particularly those infected with brown fungus, in a meat chopper.

preference of the grower and the amount of work to be done. The compressed-air sprayer has a capacity of 3 gallons, and besides having the advantage of being somewhat lighter has a valve by the use of which the spray can be instantly cut off by the operator, thus preventing loss of solution in passing from tree to tree. It has the disadvantage of requiring frequent pumping up, and having been in use for some time, this feature is apt to become a serious drawback. Knapsack sprayers and barrel pumps, new or thoroughly cleaned, were found less likely to cause delays in work.

The method of procedure in the grove has differed but little from that by which insecticides are applied, and is very simple. In using knapsack or compressed-air sprayers it has been found very convenient to have as many jars on hand as there are sprayers. After the fungous leaves have been shaken the solution is strained directly into the tank and then diluted to its capacity. The jars are then refilled with another supply of leaves and water and allowed to stand until the contents of the first tank have been sprayed out. After the first shaking, the leaves have been used to advantage a second time when the supply was limited, but when an abundance of fungous leaves was available it was found to be a better policy either to throw them away or add fresh leaves for reasons mentioned elsewhere. Where three or four sprayers were in use it was found to be of advantage to have an additional man to keep the water supply replenished, shake the fungus, and change the base of supplies, so as to save time in traveling back and forth.

When using a barrel pump, in view of the larger amounts of water necessary, it is more essential that the tub or other retainer be placed near a larger supply of water. After the spore solution had been prepared and strained into the barrel, the latter was filled and the solution sprayed. Meanwhile the tub was again partially filled and more leaves added to soak and be stirred in readiness for the next barrelful of solution.

In spraying with knapsack or compressed-air sprayers, or in brushing, best results were obtained by directing the spray onto the underside of the leaves of the outer, more heavily infested, shoots. Experiments have shown that better infections were obtained on the outer portions of the tree than on water shoots. With a barrel pump two leads of hose were used to advantage, the halves of two rows being sprayed as the wagon passed between the rows.

The dipping method was first used as a check on experiments with other methods, but as it has been found to have a practical usefulness under some conditions, it has been frequently recommended by the authors to citrus growers. The water mixture is prepared as already described. A clean bucket half full of the unstrained mixture is held with one hand and arm in such a manner that with the other hand the ends of the branches of the white-fly-infested tree can be momentarily immersed. This method is especially desirable where there are only a few trees to infect with the fungus and no satisfactory spray pump is available; also when only a few fungus-infected leaves can be obtained—as is frequently the case—and the greatest economy in the use of the water mixture is needed. The branches and twigs most heavily infested with the insects should be selected. For the dissemination of the brown white-fly fungus this is probably as satisfactory for general use as any method now known, the mixture being prepared as hereafter described in a slightly different manner than in the case of the mixtures of Aschersonia spores.

The brushing method consists in dipping a whisk broom or a substitute in the unstrained water mixture and brushing the underside of the leaves of the trees to be infected as far as within reach and throwing the water by means of the brush against the underside of the leaves higher up in the trees. This method, like the dipping method, can sometimes be employed with advantage in the case of the red and yellow Aschersonias and is especially useful in the case of the brown fungus, where unstrained solutions are naturally more desirable.

MISCELLANEOUS EXPERIMENTS AND OBSERVATIONS.

As infection was almost invariably secured in favorable seasons with fresh fungus material when spores of either the red or yellow Aschersonia were introduced by spraying, dipping, or brushing, it became apparent that the problem to be solved in connection with the introduction of fungi was not that of how to secure an infection, but by what means the ordinary infection secured by haphazard work could be increased by careful attention to the details. The results, however, of over 500 experiments conducted by the authors, together with those of growers, have been so variable that, at the end of three years of experimentation, little has been added to our practical knowledge of how to insure satisfactory infections. These same statements apply to the brown fungus, although the securing of an infection with this fungus is at no time so certain as with the red or yellow Aschersonias.

Results of straining water mixtures of spores through cloth strainers.—In straining the solution before spraying, the authors have found a fine-wire strainer (about one-sixteenth-inch mesh) of most value. Under no circumstances should cotton cloths be used as strainers, for microscopic examination of strained and unstrained solutions shows that a large percentage of spores fails to pass through the cloth. Mr. E. L. Worsham found, as a result of 36 microscopic examinations of solutions strained and unstrained, that about one-third of the spores were lost when ordinary cheesecloth was used as a strainer.

Examinations by the junior author have shown that even a larger percentage of spores may be lost. It was found that a closely woven cheesecloth removed as high as 73.8 per cent to 92.8 per cent of the spores, while an ordinary coarse towel removed 41 per cent. In obtaining these results one-tenth cubic centimeter of solution of red Aschersonia spores and water was placed on a glass slide marked off into one-tenth millimeter squares, and the counts made beneath a compound microscope. While the results thus obtained were subject to much variation, they all demonstrate that cloths should be avoided as strainers. Similar examinations of solutions strained through fine-wire strainers showed that practically no spores are lost.

Amount of fungus to use.—Experiments to determine the most economical amounts of fungus to use per gallon of water have given such varying results that no dependence can be placed upon the data obtained. Even under identical and apparently most favorable weather conditions, in experiments conducted at the same time and on trees equally well infested and favorably located, frequently as good infections have resulted from the use of 200 pustules as from 4,000 pustules per gallon of water. This is equally true of results obtained when only a few or a larger number of trees were included in the experiments. Within reasonable limits, the amount of pustules to use, therefore, depends entirely upon the amount of fungus obtainable. In all of the experiments herein reported, unless otherwise stated, 200 or more pustules have been used to each gallon of water.

Advantages of soaking fungous pustules before shaking or stirring.—A series of experiments in which the fungus was allowed to soak for different periods between 5 minutes and 48 hours showed that it is immaterial how long the fungous pustules remain in the water before shaking, provided, of course, that they are not left soaking an unreasonable length of time. Experiments have furnished no data to even warrant any soaking of the fungous leaves if they are comparatively fresh, except such as takes place during shaking or stirring. As good infections have been secured repeatedly when pustules were shaken as soon as placed in the water as when soaked several hours.

Number of times fungous pustules can be used to advantage.—Several experiments have been conducted to determine this point with definite results. Twelve hundred and 1,800 pustules of red Aschersonia in different experiments were shaken with a quart of water in a 2-quart glass jar for a period of five minutes. After pouring off the water used in the first shaking, fresh water was added and shaken as before, repeating up to four times. The quart of water used in each successive shaking was diluted to make 4 gallons of spray and applied to a given number of trees. In every test the third and fourth shakings gave only the slightest trace of an infection or none at all, while the second shaking in four different experiments gave 20, 70, 4, and less than 1 per cent as much infection as the first shaking. The second shaking is, therefore, very unreliable as compared with the first. These field experiments have been supplemented by a microscopic examination of spore solutions.

Two hundred red Aschersonia pustules freshly picked in January were shaken five minutes in 1 quart of water, the solution poured into a clean dish, and the same pustules shaken again in a similar way three times. The solutions of the successive shakings were likewise poured into separate dishes. Each solution, in turn, was thoroughly stirred and the number of spores present in one-tenth cubic centimeter of solution (a very small drop) were counted by means of a slide marked into one-tenth square millimeters. The count gave the approximate numbers of spores in the successive solutions to be 9,188, 2,100, 274, and 19, respectively; or 79.3, 18.1, 2.4, and 0.2 per cent, respectively.

Effect of copper sprayers on vitality of spores.—It is a well-established fact that fungi are susceptible to the effects of solutions containing very small quantities of copper. Consequently, in purchasing spray pumps or retainers of any kind for work with white-fly fungi, it has been considered advisable on general principles to avoid copper and brass parts as far as possible. Numerous experiments have conclusively shown that equally good infections can be secured whether a copper or a galvanized-iron knapsack sprayer is used, provided the spore solution is not permitted to remain in the tank longer than is necessary to spray it into the trees. Throughout the summer of 1908 the authors used a copper and a galvanized tank in numerous duplicate experiments on different occasions, including nearly a thousand trees, and in all these no difference in infection secured could be detected. As good infections were secured when the copper tank was used as when the spore mixture was applied by means of a barrel pump, and as good as resulted in check experiments using the dipping and brushing methods where the spore solution was carried in a wooden bucket. Unsprayed trees developed no fungus except where the natural spread was rapid.

Effect of nutrients added to water mixtures of spores.—Experiments to determine what benefits, if any, accrue from the addition of nutrients to the ordinary water solutions of spores were begun in 1906, and were continued throughout 1907 and 1908. Agar, glucose-agar, glucose, and gelatin were used in varying amounts, and the solution allowed to stand varying lengths of time before application. As Prof. Fawcett has found a 5.10 per cent glucose-agar solution the best medium for the germination of the spores of the red Aschersonia, and that germination usually takes place in a little over 24 hours. field experiments were conducted with the view to showing the effect of applying spores brought nearly to the point of germination in this medium. In this and other series of experiments the solutions were applied under favorable weather conditions, but no difference could be observed between the infection secured with nutrient solution and ordinary solutions used as checks. In some instances better infections were secured where no nutrient was added. Similar experiments with glucose as the nutrient have been reported by Dr. E. W. Berger [1] who also obtained negative results.

Effect of sulphur waters on spores.—Experiments to determine what effect sulphur water has upon securing infections with water solutions of spores have been conducted only in the grove. Artesian water from Manatee County was used. An equal number of red Aschersonia pustules (400) were soaked in sulphur water and in lake water for one-half hour, shaken thoroughly, and the solutions used for dipping on June 25, 1909. By July 10, on the six shoots dipped in sulphur-water solution, representing an aggregate of 54 leaves, 180 pustules had developed, while on the four shoots dipped in lake-water solution with a total of 28 leaves, 89 pustules developed. For each solution 3.3 and 3.2 pustules per leaf, respectively, were obtained. Check shoots developed no fungus. The results obtained gave no evidence of any injurious effect of the sulphur water on the spores of the fungus.

LENGTH OF VITALITY OF SPORES.

Field tests only have been made by the authors in determining the length of vitality of spores of white-fly fungi. No definite infections resulted from the use of fungi, either the Aschersonias or the brown fungus, collected from September to December, 1907, and applied in various ways during the following summer months. Infections were secured with fungus dropped by the cold in January, 1906, during the following June, although far better infections at the same time followed the use from freshly picked fungus, as a check. In all, the authors have used in their experiments about a barrel of fungus-infected leaves, collected during the early winter months, without success. In several instances a very minute infection, one or two pustules, was detected, but under such conditions that it was more than probable that the infection came from other sources. Special attention has been given to these experiments in order to determine the value of picking fungus-infected leaves in the fall so that much of the fungus that falls from the leaves during the winter months might be saved for spring infections. The results above mentioned would indicate that such fungus pustules are valueless unless some more successful method be devised for preserving the fungus-infected

[1] Rept. Fla. Agr. Exp. Sta. for year ending June 30, 1908, p. 111.

leaves than the usual drying process followed by the authors. In summer and fall, fungus left remaining on leaves, as well as when scraped off and kept in bottles, has produced infections as long as two months after picking.

RELATION OF WEATHER CONDITIONS TO FUNGOUS INFECTIONS.

While it is an established fact that good infections of the red and yellow Aschersonias are occasionally secured as early as April and May, and as late as early October, experiments have shown that weather conditions during these months are too subject to variation for even reasonably reliable results. Unless due regard be given to existing conditions, more failures than successes follow introduction at this season. Considering the difficulty with which fungus can be secured so early in the season, the tendency toward unfavorable weather conditions, and the better infections secured later in the season in return for the same expenditure of time and money, the authors do not recommend the introduction of fungi before June or, at least, until the summer rains begin. All experiments have shown that it is useless to force nature; that fungi can not be successfully introduced unless the weather conditions are such that the fungi are spreading naturally in infected groves. At Orlando this did not occur till June in 1907 and 1908, but in 1909 occurred by the middle of May. While infections of red and yellow Aschersonias have been secured as late as early October during the past three years, it is recommended that introductions of these fungi be completed during the summer rainy season. Our records show that numerous attempts by various means to introduce the brown fungus earlier than the 1st of September have frequently been failures, while previous to that time the slight infections secured have spread very slowly.

During the rainy season itself, all experiments to determine just what combination of humidity and temperature would give the best infections have, as a whole, been thoroughly negative. No difference in resulting infections has been observed whether the spore solutions were applied on bright, sunny days or on cloudy, muggy days; on ordinary days, days with frequent showers, or directly after such showers; at various times in the day from 5 a. m. to 6 p. m., with the temperature high and the humidity low, or vice versa.

It would appear that applications have been made under every conceivable combination of weather conditions, and from the entire mass of experiments nothing can be learned aside from the fact that it apparently makes no practical difference at what time of the day or under what conditions of humidity, temperature, prevalence of showers, etc., the spores are applied, so long as typical Florida summer weather prevails.

RELATION BETWEEN ABUNDANCE OF WHITE FLIES AND RESULTS IN SPREADING FUNGOUS INFECTIONS.

While theoretically introduction of fungi should begin as soon as the presence of the white fly is discovered in a grove, the authors have met with such poor success with all attempts at such introductions that they have recommended the waiting until the white fly becomes abundant enough to cause a very slight blackening of foliage. Attempted earlier introductions have proved practical failures. It is contrary to natural laws governing the relation between host and parasite to expect to keep the fungus abreast of the fly all the time, and all experiments and observations during the past three years have failed to bring out a single instance where the fungus has spread, artifically or naturally, in a newly infested grove soon enough or fast enough to prevent the blackening of foliage. One can reasonably hope for success in holding down the fly in slightly infested groves only by careful attention to the direct remedial measures.

SUSCEPTIBILITY OF DIFFERENT STAGES OF HOST INSECTS.

Experiments have shown that the presence of no one instar of either species of white fly is essential to successful infections, or that any one larval stage is more susceptible to fungous attack than another, or than the pupal stage. Considering the large number of larvæ that hatch and the high rate of mortality that greatly reduces the number of forms in each successive instar, it is only natural that such leaves sprayed with spore solutions when the larvæ are very young should develop a large percentage of pustules on young larvæ. It has been found equally true that a much larger percentage of pustules develops on advanced larvæ and pupæ when introductions are made when the fly is largely in these later stages. A count of 40 leaves of various ages, picked promiscuously and with the citrus white fly in all stages, gave the percentages of red and yellow Aschersonia pustules developed on the first, second, and third larval, and on the pupal stage as 33, 32.1, 22.2, and 12.7, respectively. Another count following introduction of the fungus in experimental work gave in percentages of the total number of pustules developed: Pupal stage 36.5 per cent, third larval stage 34.5 per cent, and first and second larval stages 29 per cent. Examination showed that the various stages of fly were present in about this proportion at the time of the application of the fungous spores.

COST OF INTRODUCING AND SPREADING PARASITIC FUNGI.

The very low cost of introducing fungi into white-fly infested groves has influenced many to resort to this method of control, hoping to get much for little. Men who have taken up the matter in a commercial way furnish the supply of fungus and spray trees with water mixtures of spores for about 2 cents a tree. At this price there is, of course, a fair margin of profit. The authors, with knapsack sprayers, and with the assistance of laborers at $1.50 per day, have been able to spray 3 trees for 1 cent. One grower, by using a barrel outfit, with the aid of a boy at the pump, sprayed 100 trees with 50 gallons of solution in one hour. If one has to purchase fungus-infected leaves the cost is correspondingly higher. The very low cost of spraying fungous solutions can not fairly be compared with that of spraying insecticides or of fumigation if one considers the results obtained. Certain expenditures for either of these last methods of control may be expected to produce definite results that can be figured in dollars and cents if the remedy is properly applied. The returns for money spent in spraying fungus are never assured; if there is no infection in the grove at the time of the first application, the spraying may result in a temporary fungous control within three years, or it may ultimately cost the grower, through failure of the fungi to spread properly, much of his foliage and bearing wood as a result of secondary scale attack, to say nothing of a sharp falling off in the bearing of his trees, and other losses incident to white-fly infestation.

DEGREE OF INFECTION OBTAINABLE.

In field experiments it is impossible to distinguish the extent of direct infections with certainty, since natural spread usually takes place before the entire direct infection manifests itself. Even under the most favorable climatic conditions for fungous spread, only a very small percentage of the immature white flies which are exposed to spores from freshly matured pustules of red and yellow Aschersonias becomes infected. Many field tests have been made on a small scale, in which one or more branches heavily infested with white-fly larvæ and pupæ have been dipped or drench-sprayed with concentrated mixtures of Aschersonia spores.[1] In no instance has the resulting infection amounted to more than 5 per cent of the number of insects alive at the time of the introduction, and the apparently direct infection has rarely exceeded 1 per cent. In ordinary spraying on a large scale the direct infection on the parts of the tree reached by the spray is usually but a very small part of 1 per cent.

The brown fungus has proved much more difficult of spread artifically, as regards the degree of infection which it is possible to obtain by the methods tested as described elsewhere. During September and October, the most favorable season for brown fungus, introduction and infection are rarely secured on more than 1 per cent of white-fly-infected leaves[2] which have been dipped in water mixtures of

[1] Tests with red Aschersonia for the citrus white fly and with the yellow Aschersonia for the cloudy-winged white fly are particularly referred to.

[2] Since the brown fungus generally destroys all of the white flies on a leaf upon which it becomes established, it appears to the authors that the number of leaves infected is a better standard than is the actual number of insects infested.

spores and mycelia. The best general infection by brown fungus which has come under the observation of the authors was one secured in a grove[1] of Mr. W. C. Temple at Winter Park, by Mr. Frank Sterling of Deland. The ordinary method of spraying spores was used. The spraying was done between October 2 and 16, 1908. Doubtless there was more or less secondary spreading in the fall, but there was no appreciable spread in 1909 before April 23, when the records were made. At that time brown fungus was found to be present on 7 per cent of the leaves, averaging 23 pustules per infected leaf or 16 pustules for the entire lot of 100 leaves examined.

As regards the extent of infection attainable by methods herein discussed, the authors consider the results far from satisfactory. The dipping of white-fly infested branches in water mixtures of spores of Aschersonia and ground-up leaves infected by brown fungus would appear to represent a maximum of favorable influences so far as practicable methods of introduction or spread are concerned, and the failure to secure more than a slight infection, comparatively speaking, under any conditions indicates the relative insignificance of human efforts as compared with natural methods of spread.

PRACTICABILITY OF INCREASING THE EFFICACY OF FUNGOUS PARASITES.

The efficacy of the fungous parasites may be said to be increased, in a broad sense, whenever they are introduced or even spread naturally into white-fly-infested citrus groves in which they previously did not exist. The subject to be considered here, however, relates to the ordinary meaning of the expression "increasing the efficacy" after the initial introduction has already been accomplished. Apparently there are only two opportunities for effort in this direction. The first consists in producing conditions more favorable for the development of the fungous parasites and the second consists in artificially spreading the infection.

IMPROVEMENT OF CONDITIONS FAVORING THE DEVELOPMENT OF FUNGOUS PARASITES.

A line of work which naturally suggests itself in connection with an investigation of this kind is the improvement of conditions favoring the development of fungous parasites. Preliminary work in spraying trees with clear water in the absence of regular rainfall gave no promise of benefit. Common observations made in hammock groves in Lee and Manatee counties are sufficient to prove the futility of

[1] No examination of this grove was made prior to Dec. 8. 1908, but since no brown fungus was found in several surrounding groves, since none was known to occur nearer than 5 miles, and since no previous attempt had been made to introduce it, it was presumed that this fungus was introduced by Mr. Sterling. On the other hand, yellow and red fungi sprayed at the same time were presumed not to have been successfully introduced or spread by this application, since on the opposite side of the road a grove in which no artificial introduction had been made was found to have an average of twice as many red-fungus pustules and six times as many yellow-fungus pustules per leaf.

attempting materially to increase the efficacy of fungous parasites by artificially increasing the humidity. Even were it possible to secure a high percentage of humidity on high pine land in the counties mentioned and in the interior of the peninsula comparing favorably with the humidity in the most humid hammock lands, the accomplishment would avail nothing of practical importance.[1] If the conditions in these very hammock lands of Lee and Manatee counties were improved so that the work of the fungous parasites were sufficient to keep the crop of fruit free of sooty mold one year in two instead of, as at present, one year in three, the injury from the white fly would still be sufficient to demand more satisfactory means of control than natural enemies afford. Notwithstanding the apparently self-evident impracticability of efforts in this line, the careful investigation of the subject would be of much interest and possibly of usefulness in connection with the investigation of other fungous parasites affecting insect pests. In a small investigation conducted within reasonable time limit, however, the elimination of unpromising lines is necessary.

INCREASING THE EFFICACY BY SPREADING THE INFECTIONS.

The most important subject in connection with the investigation of white-fly fungous parasites is that of increasing their efficacy by artificially spreading the infection. At the time of this writing the only published record of the results secured by an attempt to spread infections where the fungous parasites already exist, and properly classifiable as a result of this kind, has been made by Dr. Berger.[2]

The authors' field investigations of this subject consist of personally conducted or cooperative experimental work in six groves in addition to more general observations in a few other groves where work in this line was taken up commercially. Altogether more than 1,500 trees were included in the experimental blocks in these groves, not including the untreated trees left as checks.

(1) *Gettysburg Grove, near Orlando, Fla. Estimated 94.8 per cent citrus white fly, 5.2 per cent cloudy-winged white fly.*—To determine what effect one introduction of spores of the red Aschersonia might have on the abundance of fungus in a grove already slightly infected,

[1] Since the preparation of this report the investigation by Prof. H. S. Fawcett, of the Fla. Agric. Exp. Sta., of a new disease of citrus fruits, known as "stem and rot" (Fla. Exp. Sta. Bul. 107, 1911), has shown that humid conditions in orange groves which are considered an advantage in favoring the white fly parasitic fungi are a serious disadvantage in also favoring the destructive disease of the fruit.

[2] Rept. Fla. Agr. Exp. Sta. for fiscal year ending June 30, 1909, p. xli. "On Aug. 17, 1909, red fungus was reintroduced into six trees in the Heathevat grove in order to compare, at a later date, the amount of fungus in these trees with those not treated again. On Mar. 2, 1909, these trees were estimated by Mr. Jos. E. Kilgore and the Entomologist to have 10 times as much fungus in them as six trees in either row next to them, showing clearly that fungus should be introduced frequently, if necessary to get the best results."

blocks of trees in this grove (fig. 1) were sprayed as indicated with a spore mixture made by using about 1,200 pustules of red Aschersonia to each 4 gallons of water.[1]

On August 21, almost before the introduced fungous spores had had an opportunity to mature into pustules, 27.6 per cent of the 185 trees sprayed August 10 were visibly infected with red Aschersonia, and 18.6 per cent of the 354 trees sprayed on August 11, while 15.5 per cent of 252 check trees showed the presence of fungi. A fungous inventory of this grove made during the following December showed the general infection represented in figure 1. A study of the distribution and comparative abundance of the fungus as indicated shows that it had no relation to the trees sprayed and that the spread from the middle of August on was entirely independent of any practical influence of the introduced spores. In fact some of the very best infections were on trees that were not sprayed.

A count of leaves picked promiscuously from the trees on April 30, 1909, gave data included in Table X.[2]

TABLE X.—*Red Aschersonia; averages per leaf on sprayed and unsprayed blocks.*

Rows.	1–3 check.	4–11 sprayed.	12–14 check.	15–20 sprayed.	21–23 check.	24–27 sprayed.	28–30 sprayed.	31–33 check.	Check rows.	Sprayed rows.
Live pupæ	0.7	0.5	0.4	0.1	0.4	0.1	0.4	0.3	0.4	0.3
Pupa cases (adults emerged spring of 1909)	17.1	24.8	12.7	21.9	16.0	9.2	2.5	3.1	12.2	14.6
Spring mortality among pupæ	3.7	1.3	2.6	2.2	2.0	3.3	1.3	1.4	2.4	2.0
Red Aschersonia infection	9.0	17.7	8.6	6.3	7.2	2.6	.9	1.0	6.4	6.9

In Table X the forms recorded, aside from fungous infections, represent the total number of white flies surviving the winter. The spring mortality referred to is mostly the same as that discussed under the head of climatic conditions. The predaceous thrips mentioned elsewhere was also concerned in this mortality to some extent. It is evident from the data presented that absolutely no tangible benefit resulted from the attempt to spread the infection. A grove immediately south of the experimental grove, similarly infested with red fungus but in which no attempt was made to spread the infection, developed even more fungus than did the sprayed trees. An examination of 100 leaves picked at random in this grove showed

[1] Spraying began in the afternoon of Aug. 10, 1908. About 2 inches of rain fell during the morning and the afternoon was cool; the temperature for afternoon and night ranged from 74 degrees to 71.5 degrees F., while the humidity ranged from 92 degrees to 82 degrees and up to 99 degrees, where it remained close to 100 until 7 a. m., Aug. 11, when it gradually dropped to 63 degrees by 1 p. m., then rose suddenly to 94 degrees by 4 p. m., remained between 94 and 95 degrees for about one hour, suddenly dropped to 90 degrees, and then rose to 99 degrees and remained at 100 during the night of Aug. 11. The temperature at 4 a. m., Aug. 11, was 71.5 degrees F., gradually rose to 89 degrees F. by 12 m., and remained there until 2.30 p. m., then suddenly dropped to 74 degrees F. by 3.30 p. m., and then slowly dropped until 71 degrees F. was reached at 4.30 p. m. On Aug. 12 temperature rose to 92 degrees F. by 2 p. m. Subsequent conditions were very favorable for the spread of fungus.

[2] One hundred leaves were picked from each block, or 800 in all. The leaf averages are proportionally lower than in the records in Table II, since leaves were taken from all growths at random.

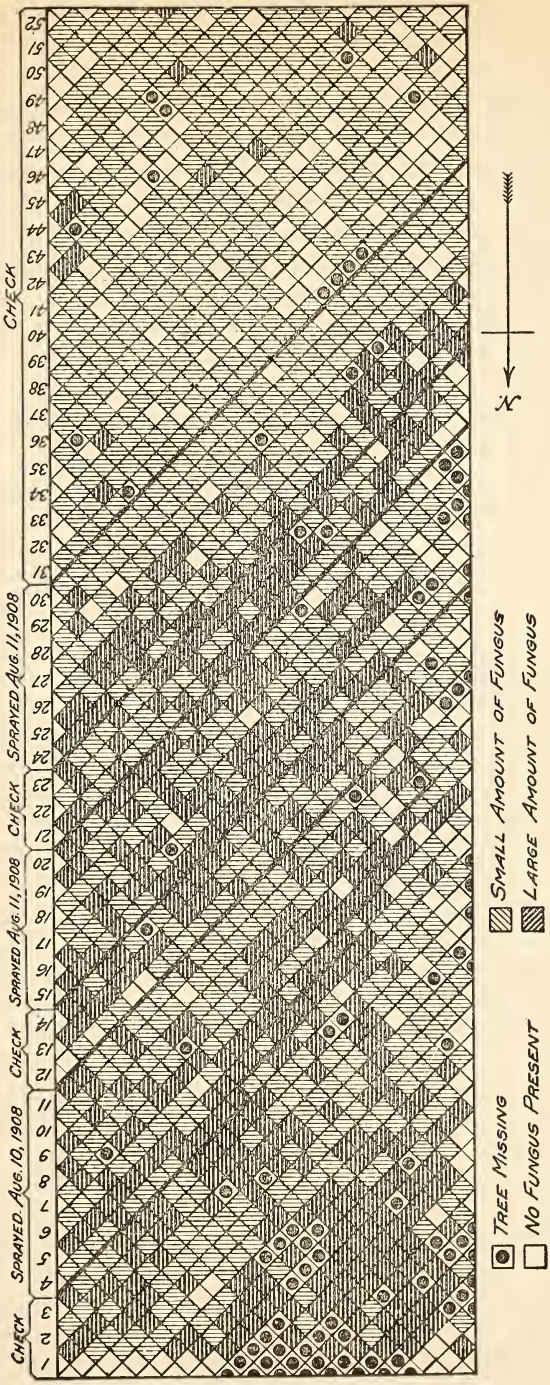

FIG. 1.—Diagram of Gettysburg Grove; experiment in spreading red-fungus infection in an attempt to increase its efficacy. (Original.)

an average of 29.8 red-fungus pustules per leaf, the degree of white-fly infestation agreeing quite closely with rows 4 to 11 (Table X) of the experimental grove.

(2) *Swindley grove, near Orlando, Fla. More than 80 per cent citrus white fly; less than 20 per cent cloudy-winged white fly.*—In this grove of 900 seedling oranges experiments were conducted during the summer of 1908 to determine what advantage might follow two introductions during the same season, and incidentally, one introduction on each of two successive years. About one-fourth of the trees were sprayed with no fresh red Aschersonia,[1] one-fourth with fresh red-fungus mixtures varying to strength (300 to 625 pustules per gallon) during July, and another fourth in a like manner during July and August. The remaining fourth, which had been sprayed during July, 1907, was again sprayed in August, 1908. The results are given in Table XI.

TABLE XI.—*Red Aschersonia: Results of experiments in spreading the infection.*

Block No.	Fungous introductions.	Leaves examined.	Pupa cases per leaf, average.	Red Aschersonia infection, average per leaf.
1	Unsprayed check	120	9.8	0.01
2	Sprayed once, July, 1908	120	6.2	6.1
3	Sprayed twice, July and August, 1908	120	6.7	7.3
4	Sprayed twice, July, 1907, and August, 1908	120	6.0	2.9

While the data presented show that more fungus developed on the trees sprayed twice in one season, the spread of the fungus on all trees during the season of 1909 was so rapid that it became impossible to tell which trees had been sprayed once, twice, or not at all. All developed an equally large amount of fungus which, supplementing unexplained mortality, so held the fly in check that the fruit in the grove was practically clean by the following fall. By the following spring much of the fungus had fallen off and there were more specimens of the fly in the grove during 1910 than the owner had noticed for many years, and the trees became thoroughly sooted.

(3) *Drennen estate grove, near Orlando, Fla. The citrus and cloudy-winged white flies present, the latter comprising 0.8 per cent, according to an estimate made in June, 1909.*—In this experiment a solid block of six rows of eight trees each was divided into two series, one comprising the even and one comprising the odd numbered trees of the six rows. Only a trace of red fungus (no yellow or brown) had been found in this grove and none had been discovered near the experimental block. After the first introduction, therefore, the experiment is properly one of increasing the efficacy by spreading the infection. An attempt was also made to introduce and spread the yellow and brown fungi by including their spores and mycelial

[1] This fourth was composed of trees either not sprayed or sprayed with dried pustules of the Aschersonias later determined to be valueless.

fragments with the red-fungus spores, but no results worth noting were secured.

Series A was sprayed 11 times between May 7 and October 19, using from 300 to 600 pustules per gallon of water.[1] The applications were made on the following dates: May 7, May 26, June 25, July 24, August 27, September 11, September 18, September 25, October 2, October 9, October 19.

Series B was sprayed only once, May 7.

Eight examinations, each based upon 300 leaves picked promiscuously from the trees of each series, gave the records shown in Table XII.

TABLE XII.—*Average number of red-fungus pustules per leaf at successive examinations.*

When examined (1909).	June 10.	June 30.	July 9.	July 24.	Aug. 14.	Aug. 27.	Sept. 11.	Oct. 26.
Series A, sprayed 11 times	0.22	0.5	1.2	3.5	5.1	10.1	20.1	21.5
Series B, sprayed once	.15	.3	.5	.8	2.4	6.0	8.8	9.5

A check lot of leaves picked promiscuously from unsprayed trees within three rows of the experimental block showed an average of two red-fungus pustules per leaf on October 26.

The rainfall and the comparative humidity[2] for each week during the six months covered by the sprayings are shown by the data in Table XIII, being based upon the mean of the maximum and minimum relative humidity records for each day by a Friez recording hygrograph located at the standard Weather Bureau shelter near the Orlando laboratory.

TABLE XIII.—*Rainfall and relative humidity records, Orlando, Fla., May to October, 1909.*

Week beginning—	Daily mean humidity.	Weekly rainfall.	Week beginning—	Daily mean humidity.	Weekly rainfall.
	Per cent.	*Inches.*		*Per cent.*	*Inches.*
May 3	76	.58	August 2	78	.9
10	82	.0	9	84	3.39
17	78	1.83	16	91	2.76
24	80	.0	23	86	.57
31	77	2.01	30	83	.73
Monthly mean	78.6		Monthly mean	84.5	
June 7	83	.05	September 6	84	.77
14	77	.0	13	82	.99
21	76	.59	20	86	1.65
28	77	8.23	27	87	.0
Monthly mean	78.2		Monthly mean	84.7	
July 5	91	1.03	October 5	81	.0
12	86	2.34	12	78	.0
19	81	.0	19	80	.38
26	80	1.59	26	79	.92
Monthly mean	84.5		Monthly mean	79.7	

[1] As in all experiments, unless otherwise stated, the freshest fungous pustules obtainable, according to the season of the year, were used.

[2] These humidity records are not comparable to U. S. Weather Bureau records, which in Florida are taken at 7 a. m. and 7 p. m.

It appears that the great humidity, after the introduction of September 11, was not a condition which would promote fungous development. The increases in the average number of fungous pustules per leaf are, as a rule, inconsistent, in series A and B, whether the data be examined from the standpoint of the attempts made to spread the infection or from that of climatic conditions. One exception is found in the rapid increase between the examination of August 14 and that of September 11 for both series. This most important increase of the year appears to be entirely uninfluenced by the attempts to spread the infection, since the fungous pustules in series B increased at practically the same rate as in series A. The pustules in series A increased about 200 per cent between July 9 and July 24, when practically uninfluenced by artificial spreading of infection, while the pustules in series B increased only about 60 per cent. Between July 24 and August 14 the attempt to assist natural means of spread was followed by a 46 per cent increase, while without any effort in this direction the natural spread in series B amounted to a 200 per cent increase in the number of fungous pustules.

Notwithstanding the foregoing inconsistencies the records show that after the initial introduction the fungous pustules multiplied about 10 times (964 per cent increase) in series A and about 6 times (623 per cent increase) in series B. It is not impossible that such a difference as this in the rate of multiplication might be found in two arbitrarily selected groups of trees treated identically as regards fungous introductions. We may, however, fairly give the fungous diseases the advantage of the presumption that the difference noted is due to the artificial spreading of the infection. The question then arises, Did this difference result in any practical benefit to the trees?

On June 30 an examination showed an average of 59 live larvæ and pupæ per leaf in the experimental block; on July 24, 21.5 per leaf; on August 27, 43.7 per leaf on old mature growth and about 350 larvæ per leaf on the newer summer growth, and on October 26 an average of 27.8 live per leaf. The last estimate was based on 10 typical leaves which averaged 27.5 red-fungus pustules per leaf and 10.4 pupa cases. While this examination was not extensive enough to compare with those the results of which are given in Table X, a summary showing more live insects in the leaves showing the most fungous infection is noteworthy.

Five leaves with greatest number of red-fungous pustules, averaging 47.6 per leaf, 36 live per leaf.

Five leaves with least number of fungous pustules, averaging 7.4 per leaf, 19.6 live per leaf.

It is probable that more adults migrated from the surrounding trees to the experimental block and from trees of series A to series than vice versa, thus giving more live insects to those trees upon which the fungus spread best than they otherwise would have had. This, however, was an advantage so far as the increase in the average number of fungous pustules per leaf was concerned. On the other hand, the experimental block, which was heavily infested at the beginning of the season, began blackening by the 1st of June, and this heavy infestation would unquestionably have continued and a general blackening have resulted in spite of an increase in the number of fungous pustules to 21 or even 25 per leaf. From our data in this experiment and from our general knowledge of white-fly and fungous conditions, we conclude that no practical benefit to the orange trees resulted during 1909 from the repeated attempts to spread the infection of red fungus, and that from this standpoint the results would not have been affected if the trees of series A had been isolated. The only accomplishment of practical importance was in the introduction of the red fungus onto trees not previously infected.

(4) *Wills Grove, Sutherland, Fla. Grapefruit trees infested by cloudy-winged white fly only.*—In cooperative experimental work, in 1909, Mr. F. L Wills, of Sutherland, Fla., sprayed 49 trees in the middle of a block of 378 trees, all heavily infested with the cloudy-winged white fly, and already slightly infected with yellow Aschersonia, with mixture of yellow Aschersonia on May 18, June 11, July 8, August 9, and after the 1st of September until October 18 one-half of the sprayed trees every two weeks, the rest once a month. By July 17 a count of 185 leaves, picked promiscuously, showed that 173 were infected, with an average of 41 pustules per leaf, or nearly twice as many pustules as were present on leaves picked from check trees. On August 18 Mr. Wills noted that the fungus was spreading very rapidly and making its appearance over 20 acres of orange and tangerine trees adjoining. At the time there was an average of 90.7 pustules per leaf on the sprayed trees as compared with 51.8 pustules on the check trees. By September 22 a count of 200 leaves from the sprayed and from the unsprayed check trees showed the average abundance of pustules per leaf to be 118.4 and 137.5, respectively; in other words, by the middle of September, the natural spread in the entire block had been so rapid that there was more fungus in the check than in the sprayed tree. By the middle of November no difference could be noted on a general examination of the grove, and both the owner and the authors concluded that had no spraying been done the natural spread would have accomplished the same results.

(5) *Fairbanks Grove, Island Grove, Fla.—Orange trees infected with citrus white fly only; cooperative experiments arranged with Rev. J. J. Glass.*—The trees were fairly heavily infested and there was a

trace of red fungus present in the experimental block of 26 orange trees located in the midst of a 10-acre grove. An examination of 100 leaves of old growth picked at random from the experimental block showed that an average of 12.6 had matured in the spring of 1909 or were still alive on the leaves as pupæ. The new spring growth was beginning to become blackened by May 21 and was generally moderately blackened by June 15. The experimental block was sprayed by the foreman, Mr. John Engle, on May 17, June 9, July 2, August 2, September 2, and September 11, using about 2,000 pustules of red fungus for the first and about 4,000 pustules of red fungus for each later spraying. One hundred and fifty leaves picked at random on June 15 had an average of 7 pustules of red fungus per leaf; on August 21, 140 leaves had an average of 8.8 pustules, and on September 15, 50 leaves had an average of 19.6 pustules. On August 2 Mr. Engle wrote to the effect that the fungus seemed to be working as well in other sections of the grove as in the experimental block. At the end of the season no difference could be detected so far as showing the slightest advantage from the repeated applications. An examination of two lots of leaves from surrounding unsprayed trees on September 15 and October 18 showed an average of 41.3 and 14.3 red-fungus pustules, respectively, on lots of 50 and 100 leaves. In regard to the record of October, a misunderstanding is involved which in the opinion of the junior author renders the record valueless, but even if it be accepted the data show that more fungus developed on the check trees immediately surrounding the experimental block than on the trees to which the spore mixture was applied.

(6) *Keep Grove, Boardman, Fla. Orange trees infested with citrus white fly only; cooperative experiment with Mr. B. B. Keep.*—The degree of infestation in this grove was practically the same as in the Fairbanks grove, but there was no fungous infection. A small block of 36 trees was sprayed. On May 3, a lot of 25 spring-growth leaves picked at random from the experimental block showed an average infestation of about 50 larvæ in the first three stages. Red-fungus spores were sprayed as in the preceding experiments within the first 10 days of May, June, July, August, and September. On October 25 an examination of 125 leaves from the sprayed block showed an average of 2.2 red-fungus pustules per leaf while from the surrounding unsprayed trees an average of 0.3 pustules was found on 134 leaves. On September 25 it was noted by Mr. Yothers that 72 out of 143 leaves examined from the experimental block had considerable sooty mold while the remainder were only slightly blackened.

THE DISADVANTAGES ACCRUING TO CITRUS TREES THROUGH THE USE OF PARASITIC FUNGI.

DIRECT INJURY TO FOLIAGE.

Dr. H. J. Webber gave the subject of direct injury to foliage some consideration in connection with the brown fungus and reported as follows:[1]

Old leaves on which the larvæ have been dead for some time, and on which the fungus has been exposed for an extended period to the action of rain, etc., clearly show the slight damage to the leaf caused by this fungus. Leaves which were observed in March, 1896, to be badly infested with the fungus were found in December of the same year to show only the remains of the pustules, the hypothallus having been entirely washed away. That the fungus does some damage to the tree can not be denied, but this is clearly a secondary effect.

The secondary injury referred to by Dr. Webber has been noted by the authors. It may be considered as of slight importance. A more serious secondary injury frequently results from the prevalence of the yellow Aschersonia. Dr. Webber has noted[2] that sooty mold frequently surrounds and covers insects infested by the red Aschersonia. He states:

The honeydew collected around the infected insects furnishes nourishment for the sooty mold, which frequently springs up and makes a conspicuous growth. The growth of the sooty mold is more rapid than that of Aschersonia so that it sometimes happens that a rank growth of the sooty mold smothers both the insect and the Aschersonia.

The condition described is one which unquestionably interferes seriously with the respiratory functions of the infected leaf. The extent of the injury has never been estimated, so far as known to the writers. Fortunately this condition is not the usual one where the infection consists of the red Aschersonia. Such a condition is, however, quite typical when the yellow Aschersonia is abundant. Moreover, the yellow pustules themselves, being much larger than the red pustules developing on the citrus white fly, cover a correspondingly larger leaf surface. As has been indicated the secondary injury resulting from the yellow Aschersonia infection is of some importance and without doubt partly offsets the benefits resulting from the destruction of the white-fly larvæ and pupæ.

INDIRECT INJURY THROUGH THE DISUSE OF FUNGICIDES NEEDED TO COMBAT FUNGOUS DISEASES.

In Florida the control of diseases[3] of citrus by means of fungicides is seriously interfered with by the disadvantages and supposed disadvantages of the destruction of fungous parasites of destructive

[1] Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 29, 1897.

[2] Ibid., p. 23.

[3] The principal diseases preventable or partly controllable by means of applications of fungicides are known as melanose, die back, anthracnose, scab or verrucosis, withertip, and scaly bark. For the treatment of these diseases publications of the Bureau of Plant Industry of this department and of the Florida Agricultural Experiment Station should be consulted.

scale insects and white flies. In the case of fungous parasites which partially control the purple scale the disadvantage mentioned has been abundantly proved by the experience of many citrus growers. It is now recognized as necessary in most cases to follow up applications of a fungicide with applications of whale-oil soap or other insecticide suitable for checking the purple scale. Except in cases of extreme injury from plant diseases citrus growers of Florida are as a rule deterred from using fungicides on account of the indirect effect on the purple scale. A similar condition exists to a certain extent in white-fly-infested sections where the fungus parasites occur. That it is a mistake to allow hopes of possible benefit from fungous parasites of the white flies to interfere with the use of fungicides seems to the authors to be a clear deduction from the data herein presented regarding the efficacy of these diseases. Whenever the white flies are controlled by fumigation or by spraying the incidental control of the scale insects by the treatment primarily directed at the white flies will permit the more extended use of fungicides without fear of injurious secondary effects.

SUMMARY AND CONCLUSIONS.[1]

From our present knowledge of the effects of climatological conditions upon the citrus white fly and cloudy-winged white fly, it is necessary to conclude that climatic conditions offer no hope of holding these insects in satisfactory control in any citrus-growing region where they may be introduced.

No true parasites of these species of white flies are known to exist in this country and their numerous native predatory enemies are usually of no material assistance in their control.

Two factors of natural control—overcrowding and unexplained mortality—have heretofore not been recognized or have been confused with the results of attempts at artificial control or with the effects of fungous diseases. The two factors named are in effect a reaction from excessive infestation.

Bacterial diseases of the white flies are at present unknown but it is not improbable that they are the leading cause of mortality so far unexplained.

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[1] The conclusions of Profs. F. H. Billings and P. A. Glenn, from their recent studies of the well-known and highly overrated chinch-bug fungus, are of especial interest in connection with the investigations of white-fly fungous parasites. In Press Bulletin 40 of the University of Kansas they say:

"In fields where the natural presence of the fungus is plainly evident, its effect on the bugs can not be accelerated to any appreciable degree by the artificial introduction of spores.

"Moisture conditions have much to do with the appearance of chinch-bug disease in a field; artificial infection nothing.

"Advocating artificial infection or encouraging it by sending out diseased chinch bugs does not serve the best interests of the farmer, since his attention is thus diverted from other and truly efficient methods of combating the pests."

See also Bulletin 107, Bureau of Entomology, U. S. Department of Agriculture, "Results of the artificial use of the white-fungus disease in Kansas," by F. K. Billings and P. A. Glenn, 1911.

There is a wide margin in which natural enemies of the white flies may act, apparently with great activity, but with no practical benefit to the infested trees. The deceptive appearances thus explained have proved a serious hindrance to progress in white-fly control.

It is when several factors concerned in producing mortality among the insects are combined that the most satisfactory results are apparent.

Aside from unexplained mortality, fungous diseases are the most important agents of natural control. The brown fungus (*Ægerita webberi* Fawcett) and the red Aschersonia (*Aschersonia aleyrodis* Webber) are, in the order named, the most effective parasites of the citrus white fly. The yellow Aschersonia (*Aschersonia flavo-citrina* P. Henn.) is the most effective parasite of the cloudy-winged white fly. The cinnamon fungus (*Verticillium heterocladum* Penz.) and the Sporotrichum fungus (*Sporotrichum* sp.) are of comparatively little importance. The red-headed scale fungus (*Sphærostilbe coccophila* Tul.) is rarely parasitic upon white flies, while the white-fringe fungus (*Microcera* sp.) is with little doubt normally saprophytic.

The fungous parasites thrive only under suitable weather conditions during a period of about three months each year; generally speaking the summer months in the case of the two Aschersonias and the fall months in the case of the brown fungus.

Their efficacy in destroying white flies under natural conditions is dependent upon the abundance of the insects; a period of excessive abundance always precedes effective temporary control.

Much damage has resulted in the past from ill-advised attempts to check the spread of white flies in newly-infested localities by means of fungous parasites.

The control of destructive diseases affecting citrus trees and fruit has been interfered with by fungous diseases and much preventable loss thereby incurred. This interference is due to the fear that the fungicides recommended for the diseases referred to would, if applied to the trees, check the white-fly fungus parasites with injurious results.

Under natural conditions, without artificial assistance in spreading, the fungi have ordinarily, in favored localities, controlled the white fly to the extent of about one-third of a complete remedy through a series of years.

The most successful method so far devised for introducing the red and yellow Aschersonias into groves where they do not occur is the spore-spraying method, first successfully employed and recommended by Dr. E. W. Berger. For the introduction of the brown fungus the brushing or dipping and the rubbing methods first used by the authors are as successful as any yet discovered, but are not so reliable as the spore-spraying method for the Aschersonias. The infections secured by artificial means of introducing fungi, while successful in introducing the fungi, have thus far proved of little or no avail in increasing their efficacy after they have once become generally established in a grove. Experiments by the authors, and by citrus growers in cooperation with the authors, involving the treatment of thousands of trees with suitable "checks" or "controls" have shown that when fungus (red or yellow Aschersonia) even in small quantities is present in a grove there is no certainty that from three to six applications of fungous spores in water solution will result in an increased abundance of the infection on the treated blocks of trees by the end of the season. In some of the most important and carefully planned and executed experiments the fungus has increased more rapidly in sections of the groves which were not sprayed with spore solutions than in the experimental blocks. In no case has practical benefit been observed to result from efforts to increase the efficacy of the fungi in groves where they previously occurred. The above remarks apply especially to the Aschersonias. With the brown fungus, efforts to increase the efficacy have been equally disappointing from a practical standpoint.

As a result of the investigations reported herein and of observations and experience covering a period of four years the authors conclude that there are at present no elements of natural control herein dealt with which can be relied upon to give satisfactory results. Under present conditions it is unquestionably more profitable to depend upon artificial remedies.[1]

There are, however, certain circumstances under which fungous parasites may be used to advantage. First may be mentioned the comparatively few citrus groves located in hammocks, with trees growing without regularity and with conditions such that fumigation or spraying with insecticides would be impracticable.[2] Second are those groves which are so situated that the failure to more than partially control the white flies will not interfere with the control of the insects in other groves and which for any reason it is impracticable to place on the most profitable basis of productiveness.

While it is recognized that everything possible should be done to secure and to test every procurable and possible enemy of both the citrus white fly and the cloudy-winged white fly, citrus growers in Florida should not await the outcome of this work with inactivity

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[1] See Bul. 76 and Circular 111, Bur. Ent., U. S. Dept. Agr. Fumigation has already been dealt with in publications of the bureau. Spraying and other matters connected with artificial methods of control will be treated in later publications.

[2] Since the above was written the brown fungus has been so effective in controlling the white fly in certain very low-lying hammock groves in Lee County that it must be conceded this fungus has made artificial remedial measures unnecessary. Such groves, however, are an exception to the rule at the present time.

in the line of white-fly control. It should be borne in mind that even though an important and successful enemy should be discovered within the next two years, it would probably require several years before the practical results secured would justify the abandonment of artificial methods of control. On the other hand, in planning for the future the proportion of successes and failures of the past in obtaining successful natural enemies for various pests must be considered. Instances of such complete success as was obtained by the introduction of the Australian ladybird into California and later into Florida for the control of the cottony cushion scale are rare. Instances of only partial success or of entire failure are many. It is true that many failures have been due to the elementary condition of our knowledge of insect parasitology and that the failures of to-day and of the past may be overcome by advances in this line which may be made in the future. The field is almost unlimited in possibilities, and even the failure of the present foreign explorations should not lead to the abandonment of all hope of successful natural control.

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