PSYCHE.

EXPERIMENTS FOR THE DESTRUCTION OF CHINCH BUGS BY INFECTION.

BY FRANCIS H. SNOW, LAWRENCE, KANSAS.

[Annual address of the retiring president of the Cambridge Entomological Club, 12 February, 1892.]

I regret my inability to be present at the annual meeting of the Club on the 8th inst.* I, however, forward the following account of my experiments for the destruction of chinch bugs in the field by the artificial introduction of contagious diseases. This may serve as my annual address as president of the Club. One of your former presidents, Prof. S. A. Forbes of Illinois, adopted a similar subject for his annual address.

At the outset, I desire to call your attention to the difference between my own experiments and those of Prof. Forbes. The latter has been working for several years in the line of communicating contagious diseases to chinch bugs by means of artificial cultures of the microscopic plants which produce disease. He has not, however, thus far, been successful in communicating disease to chinch bugs in the fields by means of artificial cultures. In my own experiments, continued now for three years, I have proceeded upon a different basis. Recognizing the failure of previous attempts to destroy chinch bugs by the application of artificial cultures of disease germs, I conceived a very simple idea of making the chinch bug himself the vehicle for the communication of disease in the field.

Dr. Otto Lugger of the Minnesota Agricultural Experiment Station in the autumn of 1888 distributed in certain fields infested with chinch bugs the dead bodies of bugs that had died in other fields from disease which was naturally present. Dr. Lugger, however, was in doubt as to whether disease was actually communicated in the field by these dead bugs, thinking that perhaps the disease after all might have reached the fields in which he distributed his material by the natural progress of the disease from field to field. So far as I know, Dr. Lugger did not further continue these experiments, and made no investigations in the laboratory with reference to preserving the infection through the winter and experimenting in the following season with infection thus preserved.

In June, 1889, I obtained the first material for my experiments from a farm in Morris County, Kansas. This material consisted of Empusa, deter-

*The address reached the Club too late for the meeting of 8 January.

mined as *Empusa aphidis* by Dr. Thaxter, and doubtless identical with the Entomophthora of Prof. Forbes's presidential address.

With this material I was able to test my theory that chinch bugs from the field having been made sick by contact with the dead bodies of bugs killed by disease in the laboratory, if turned loose in the field would communicate the disease to the field bugs. I found that in the laboratory exposure of healthy bugs to bugs dead from disease, was invariably followed by the death of the exposed bugs in from eight to twelve days. A similar operation in the field led to the same result.

I have thus experimented with all three diseases now known as fatal to chinch bugs: — the *Sporotrichum globuliferum* of Spegazzini which I have called the "white fungus" disease; the *Empusa aphidis* of Hoffman which I have called the "gray fungus" disease; and the *Micrococcus insectorum* of Burrill, which is a bacterial disease. The *Sporotrichum globuliferum* (thus determined by Dr. Thaxter) is identical with Botrytis referred to by Prof. Forbes in his address.

I have been able to keep two of these diseases alive through two successive winters in my laboratory, and have been able to supply farmers with infection upon demand in the following season. My experiments have shown that the two fungus diseases, Sporotrichum and Empusa, are more destructive in damp weather than in dry, while the bacterial disease (Micrococcus) is most destructive in hot, dry weather; thus in 1890, which was a very dry year in Kansas, the crops being seriously injured by drouth in all parts of the State, the fungus diseases had very little effect in the destruction of the chinch bug, while the bacterial disease was exceedingly destructive. During the year 1891, which was a wet year in Kansas up to the end of July, the fungus diseases sent out from my laboratory again resumed their destructive effect in the fields; the bacterial disease becoming most destructive after the close of the wet weather in July.

Considerable prominence having been given to the subject of my experiments during the year 1890, the legislature of Kansas in February, 1891, made a special appropriation of $3,500 to enable me to continue my investigations upon a larger scale than had previously been possible. By means of this appropriation I have been able to equip a bacteriological laboratory and obtain the apparatus necessary for thorough study of the subject. I have also been able to propagate infection upon a large scale, in order to meet the large demand from the farmers of Kansas and other States for infected chinch bugs.

During the year 1891 infection has been furnished to about 2,000 farmers, chiefly in Kansas, but also including all the western States exposed to the ravages of the chinch bug. I have received 1,390 reports from farmers stating the results of their experiments. Of these field experiments 1,050 have been successful, 187 unsuccessful, and 153

doubtful. Stated in another form 75.6 per cent of the experiments have been successful; 13.4 per cent unsuccessful; and 11 per cent doubtful. These field experiments have been distributed among the various States as follows: Kansas, 1,222, (successful, 953, unsuccessful, 140, doubtful, 129); Illinois, 40, (successful, 17, unsuccessful, 15, doubtful, 8); Texas, 26, (successful, 13, unsuccessful, 6, doubtful, 7); Wisconsin, 29, (successful, 13, unsuccessful, 13, doubtful, 3); Oklahoma Territory, 26, (successful, 20, unsuccessful, 4, doubtful, 2); Missouri, 13, (successful, 11, unsuccessful, 2); Iowa, 15, (successful, 9, unsuccessful, 5, doubtful, 1); Minnesota, 8, (successful, 3, unsuccessful, 2, doubtful, 3); Indian Territory, 2, (successful, 2); Nebraska, 6, (successful, 6); Indiana, 1, (successful); Arkansas, 1, (successful); Mississippi, 1, (successful).

In order to assure myself of the actual condition of the experiments in the field, I have personally visited a large number of fields during the past season while the experiments were being performed, and have kept a field agent constantly in the field during a large part of the time. He has made a thorough examination of eighteen Kansas counties and has assisted me materially in determining the true character of the field experiments, corroborating in a great majority of instances the reports of the farmers as to the working of the infection in their fields.

In this address I cannot enter extensively into the subject of these experiments, but will give a brief statement of the principal points connected with the laboratory work with each of the two fungus diseases.

On May 23d we began our experiments with Sporotrichum. We distributed some fungus-covered bugs from the field of Mr. Mattocks in six infection jars. Into the jars had been put soil taken from the yard, and green wheat. Fresh chinch bugs sent by the farmers were put into the jars — enough to thickly cover the bottom. The jars were covered with cheese cloth and set into a glass case containing moist sand. The soil in the infection jars was not watered, so that the bugs were in a humid atmosphere but not in contact with water. We were in this way able to secure the best conditions for the development of the fungus. When the bugs died in the jars new bugs from the field were put in — the date of restocking being also a record of the time when the bugs in the jars had nearly all died. The following is the memorandum for the six jars started May 23d:

May 23, June 4, June 20.
May 23, May 27, June 4, June 15.
May 23, June 4, June 15.
May 23, May 27, June 4, June 15, June 20.
May 23, May 27, June 4, June 15, June 20.

Seven jars were started May 25th. Their record is as follows:

May 25, June 4, June 19.
May 25, June 4, June 15.
May 25, June 4, June 15.
May 25, June 4, June 15.

May 25, June 2, June 11, June 20.
May 25, June 4, June 15.
May 25, June 2, June 11, June 19.

Four jars started May 27 have the following record:

May 27, June 6, June 15.
May 27, June 11, June 15, June 20.
May 27, June 6, June 15.
May 27, June 6, June 15, June 21.

Thirteen jars started June 2nd, each jar being infected with four fungus-covered bugs from the preceding jars, are recorded as follows:

June 2, June 11, June 20.
June 2, June 11, June 19.
June 2, June 11, June 19.
June 2, June 7, June 15.
June 2, June 11, June 15, June 20.
June 2, June 11, June 19.
June 2, June 11, June 19.
June 2, June 11, June 20.
June 2, June 15.
June 2, June 11, June 19.
June 2, June 11, June 19.
June 2, June 11, June 15, June 20.
June 2, June 11, June 15, June 20.

One jar started June 4 ran:

June 4, June 11, June 20.

One jar started June 5 ran:

June 5, June 15, June 20.

Four jars started June 6 are recorded:

June 6, June 15, June 20.
June 6, June 15, June 19.
June 6, June 15.
June 6, June 19.

The bugs put into the jars on the several dates were from all parts of the chinch bug district of the State of Kansas. They were for the most part just received from the mail and were in vigorous condition. They were kept supplied with green wheat. While the bugs in the infected jars were dying at intervals of five to ten days, bugs from the same lots in isolated check jars remained alive and vigorous.

By June 20th the demand for infected bugs was so large that the jar method of infection required more attention than we were able to give it. The results of our separate lots were so uniform and the Sporotrichum so vigorous and ever-present that the further watching of separate lots seemed useless. Accordingly June 20th a large glass case was arranged with damp sand three inches deep over the bottom. About ten dead bugs covered with Sporotrichum were scattered over the sand and large quantities of live bugs from the field were put in, with plenty of green wheat. In nine days the bottom of the case was thickly sprinkled with white fungus-covered bugs and in thirteen days only a few live bugs remained and the case was restocked. The infection continued to work so rapidly in this case that we found no trouble in filling from it twenty-five to one hundred orders daily. Vast numbers of young red chinch bugs were put into the case together with the adults and they too were an easy prey to the disease. Minute points of white made their bodies conspicuous among the larger flecks of white where the adult bugs lay covered with Sporotrichum.

On June 28th *Empusa aphidis* was first noticed in the infecting case. Up to this date it had not made its ap-

pearance in our laboratory in 1891. From this time till the middle of August it multiplied its victims in the infecting cases. For a short time it became more conspicuous than Sporotrichum and then subsided.

On July 4th we began experimenting with common shallow dry goods boxes for infecting cases. The inside of the boxes was sprinkled and the bottoms thickly covered with green wheat. A few fungus-covered bugs were sprinkled over the wheat and new bugs from the field were put in in large numbers. Within a week the white fungus-covered bugs were thickly spread over the bottoms and in places the white bugs were literally in heaps. Continued experiments showed that damp wooden boxes offered the best conditions for the development of the fungus and the glass cases were no longer used. Sporotrichum, like most fungi, thrives best in a moist atmosphere, but an excess of water, such as occurs in a wet soil or along the sides of a glass case where the vapor often becomes condensed, is detrimental to its development. In the wooden boxes the atmosphere was abundantly humid; but water that was sprinkled in from time to time or that became condensed on the sides of the boxes was at once absorbed by the wood.

During July and August Sporotrichum continued to spread through successive lots of fresh bugs from the fields. Empusa was always present but was not so conspicuous in its ravages as Sporotrichum. In the first weeks of September the diseases began to subside and by the middle of October neither Sporotrichum nor Empusa appeared to be spreading further. Nor is it at all probable that the diseases are lost. The observations on the life history of these fungi which follow show that provision is made for a period of rest.

June 28th the spores of Sporotrichum were transferred by means of a sterilized needle from the dead body of a chinch bug to fifteen culture plates. The culture medium was a mixture of beef broth and Irish moss; enough of the mucilaginous decoction of the moss being added to the beef broth to give a solid medium at 80° F. Within forty-eight hours the spores had germinated and branching mycelia could be seen spreading through the medium. Within three days spores were produced in abundance, but only one spot on one of the fifteen plates was found to be a pure culture, Aspergillus mucor and bacteria being mixed with all the other growths of Sporotrichum. From the one pure spot spores were transferred to three new plates, and the resulting growths were all pure.

The germinating spore puts forth a mycelium which branches as it grows. At intervals mycelial branches shoot upwards and grow over the surface of the culture medium. Conidiophores arise from these; the conidiophore sends off branches and the spores or conidia are abscissed from these branches in clusters. The average diameter of twenty spores thus produced was 2.3 micromillimeters. It is by means of

these minute spores that the fungus is so rapidly disseminated throughout a field infested with chinch bugs. These spores, however, soon lose their vitality (spores one month old would no longer germinate in our laboratory) and the fungus must make provision for its self-preservation during protracted periods of weather unfavorable to the development of conidial spores.

Culture plates in our laboratory, covered with pure cultures of Sporotrichum planted July 9, show the mycelial branches within the culture medium to be swollen at intervals to a diameter of 3.9 to 8.8 micromillimeters; the average diameter of the unswollen mycelial branches being about 2.5 micromillimeters. It seems more than probable that the function of these hyphal bodies is to carry the fungus through the cold of winter or the drought of summer. Experiments have been started in our laboratory to test the germinating power of these bodies, but too late to give the results in this paper.

Resting spores are also found on the culture plates having a diameter of 20 micromillimeters, and a thickness of cell wall of 1.8 micromillimeters. Similar spores are found in the crushed bodies of chinch bugs covered with Sporotrichum. While it was found that pure cultures of Sporotrichum could easily be obtained, repeated attempts to inoculate chinch bugs from these pure cultures were unsuccessful.

As heretofore stated *Empusa aphidis* was first noticed in our infection case June 28. Eight or ten bugs were found covered with a vigorous growth of this fungus. This disease had probably been sent in from some field where it naturally existed. Empusa continued to multiply in the infection cases and by July 12th it rivalled Sporotrichum in the number of its victims. Active bugs without external signs of disease in the afternoon would be found hanging to the wheat blades the following morning covered with a vigorous growth of Empusa. If the fungus were left undisturbed it would keep on growing at the expense of the tissues of the bug until nothing were left save bits of the chitinous integument.

Attempts were made to obtain pure fruiting cultures of Empusa, but without success. At first bugs covered with Empusa were placed on the surface of the culture medium in the hope that the spores would be thrown, as is the habit with this fungus, and the growth of these spores would give a pure culture. The spores were thrown in a ring about the bug to a distance of a quarter of an inch, but a rapid growth of bacteria from the bug broke down the culture medium and the Empusa spores did not develop.

To keep the bacteria from reaching the medium a cover glass was heated over a Bunsen burner until it became very much convexed. This was then placed on the culture medium, convex side up, and upon this were placed three bugs covered with Empusa. A mycelial growth was obtained in this way uncontaminated with bacteria; but no spores were produced. We have

been unable, then, to attempt the inoculation of chinch bugs with pure cultures of Empusa. That the fungus has power to rapidly spread from one *bug* to another the experiments in our infection cases have clearly shown.

A chinch bug covered with Empusa seems to be studded with minute gray beads. A thin section cut through the body of a bug in this condition shows the body cavity to be crowded with the mycelial growth and protruding through the integument are vast numbers of broad conidiophores each bearing a single conidium.

It is by the sudden rupture of the conidiophore due to turgescence that the conidia are thrown to some distance.

Where the fungus continues its growth to the complete destruction of the chinch bug the whole mycelial mass breaks up into bodies varying from 16 × 29 micromillimeters to 23.5 × 27.4 micromillimeters.

In one instance resting spores, apparently, were found. These were round bodies with granular contents and thick walls and varying in diameter from 21 to 25 micromillimeters.

A chinch bug that died of Empusa about the middle of July was confined in a moist atmosphere on a sterilized plate October 10 and on Oct. 13 the entire body was thickly covered with a new growth of Empusa. It seems then that the entire mass of this fungus may break up into a resting condition and be capable, whenever the atmospheric conditions will permit, of springing in to new growth.

Careful experiments will be made in our laboratory this winter to test the capabilities of germination and duration of vitality of the spores and hyphal bodies of Sporotrichum and Empusa.

I append the following as samples of the reports received from the farmers.

ALFRED DOIDGE, SOLOMON CITY, DICKINSON CO., KANSAS.

Infection sent May 8. Experiment successful as reported July 27.

"I experimented with the infected chinch bugs you sent me last May. They were the first bugs you sent out, and it was very wet weather. After I infected them I turned them out in a twenty acre field of wheat. The bugs were very numerous at that time, and hatching. The old ones soon began to die and the ground was white with them. Very shortly after there were no old bugs left in the field, but the wheat was red with young ones. It did not seem to take hold upon them. After cutting the wheat they went into five acres of oats. I concluded that it would not pay to harvest the oats. They were black and red from top to bottom. I never saw the like before. About one week from then I went into the oats and to my surprise the ground was white with dead bugs and the others were sluggish. In eight inches square I believe I could have picked up 1000 dead bugs. They were all in bunches. My five acres of oats were saved by using the infection. I do not think I lost two bushels in the whole crop. I find that the infection is a success in all that you claim for it."

Under November date reported as follows:

"The infected bugs saved me fifty bushels of wheat, four hundred bushels of corn, and two hundred bushels of oats."

C. B. MCALLISTER, BELLE PLAINE, SUMNER CO., KANSAS.

Applied for aid June 20. "The bugs are passing from the wheat into the corn by the million."

Infection sent June 22. Experiment successful as reported October 17.

"It was a success in my case. I followed your advice, putting diseased bugs in the corn. On the fifth day I could find no dead bugs. On the sixth day we found some dead ones, and the live ones were very lonely. The tenth day I could shake a handful of dead bugs off one hill of corn. In fifteen days they were all dead in the corn where I placed the infected bugs. I am very thankful we received the diseased bugs, as I believe it saved us 1600 bushels of corn. If I had sent sooner I would have saved 200 bushels of wheat."

W. W. CORMICK, ANTHONY, HARPER CO., KANSAS.

Applied for aid June 21st. "My corn is run over with bugs."

Infection sent June 24th. Experiment successful as reported October 19th.

"I followed directions closely, and on the seventh day I found dead bugs just the color of the first lot you sent me which were of a white furry appearance. The ground in a few days became pretty well covered with dead bugs. I then received a second lot, the dead bodies of which were black. Where I put black infected bugs the ground was covered with black bugs, and where white infected bugs were put I found the dead bugs to be white. I divided with my neighbors and they reported to me that it was a success. One man said that he could scoop up the dead bugs in great quantities after eight or ten days; he is convinced that the infection did the work. I am convinced that the two varieties carry death with them and each marks its victim peculiar to itself, and in conclusion I will say: should I ever be troubled again, I would lose no time in writing for bugs."

Reported in November:

"The infected bugs saved 900 bushels of corn in my field."

H. H. COLLINS, BELLEVILLE, REPUBLIC CO. KANSAS.

Applied for aid July 9th. "Bugs are leaving the wheat and are going into my cane, millet and corn. Please send infected bugs by return mail."

Infection sent July 11th. Experiment successful as reported December 25th.

"The observations that I made were as follows: 1st, — There were no dead bugs in field when I placed infected bugs in; 2d, — I found the first dead bugs on the fourth day — just a few — and on the seventh day I found that the bugs were all piling up in piles on the ground, and another thing I noticed was a white fungus on the ground where the bugs were dying; 3d, — The bugs did not seem to do any harm to the growing grain after they began to pile up on the ground; 4th, — I found that the disease spread one-fourth of a mile in about ten days. It was late in the season when I received infected bugs. The people up this way think that the infected bug is the greatest discovery of the age."

M. MONSON, KACKLEY, REPUBLIC CO., KAN.

Infection sent June 23. Experiment successful as reported October 23d.

"The diseased bugs were scattered in an eight acre field of wheat three days before the wheat was harvested. After ten days I found dead bugs in piles so that I could heap my hand full from a spot not larger than my hand. At the same time I found dead bugs in a field where no diseased bugs had been placed one half mile from mine. Bugs were now travelling from wheat to an adjoining

corn field. Six days after the bugs commenced travelling to the corn, the bugs covered three feet of every stalk about ten rods into the field. On the seventh day I noticed there were not so many bugs on the stalks. I then noticed that the bugs got less in numbers every day until the tenth day when I could scarcely find a bug on the stalks. As the bugs were not more than half grown, it seemed to me a strange act that they left the corn entirely without killing it.

I wondered what became of the bugs and I turned over some lumps of dirt and out flowed piles of dead bugs and live ones also. By taking close notice I found that the bugs had not left the field but had crawled down in the dirt to die. Half of the bugs were at that time dead. In a few days there came a heavy rain which baked the ground. I have not seen a bug there since."

In making their reports as to the benefit received from the use of the infection, 495 of the 1050 successful experimenters gave their own estimates of the number of bushels of grain saved by the experiment. The sum of these estimates amounts in cash value to $89,176.65 or an average of $180.00 for each farmer. It is fair to presume that this average may be safely applied to the remainder of the 1050 successful experiments. This gives an aggregate saving of $189,000. This amount saved by the farmers means additional profit for the railroads and the millers, so that $200,000 is a very conservative estimate of the actual value of the experiments in 1891.

CONCERNING THE "BLOOD-TISSUE OF THE INSECTA.—II.

BY WILLIAM MORTON WHEELER, WORCESTER, MASS.

Among the Pterygota oenocytes are of very general, perhaps universal occurrence. Wielowiejski found them in Rhynchota, Aphaniptera, Coleoptera, Lepidoptera, Hymenoptera and Diptera. They had previously been noticed by Graber in Orthoptera, Coleoptera and Trichoptera. I have found them in a number of orders in which they have not hitherto been observed and here subjoin a brief account of my observations together with a few notes on oenocytes in some of the orders in which they have been studied by others.

ORTHOPTERA. The oenocytes of Blatta and Xiphidium are very similar and may be regarded as typical for this order. Arising, as above described, by immigration from the ectoderm just caudad to the abdominal stigmata, they remain at their place of origin throughout embryonic life, but later some of the anterior cells wander into the thoracic cavity. In the adult the metameric arrangement seems to be lost and the oenocytes lie irregularly scattered along the pleural and sternal walls. The separate elements never show any ten-