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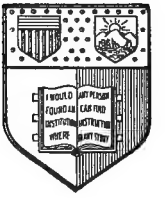

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BY PROF. A. N. PRENTISS.

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DESTRUCTION OF OBNOXIOUS INSECTS BY MEANS OF FUNGOID GROWTHS.

BY PROF. A. N. PRENTISS.

ENTOMOLOGISTS have been for a long time endeavoring to discover some available means for checking the ravages of obnoxious insects, and of late the possibility of employing fungoid growths for this purpose has been receiving considerable attention. The most important paper which has appeared upon the subject is a pamphlet by Dr. H. A. Hagen, of Harvard University, in which he advocates the use of the Yeast Fungus for the purpose in question. "Destruction of Obnoxious Insects, Phylloxera, Potato Beetle, Cotton-worm, Colorado Grasshopper and Greenhouse pests, by application of the Yeast Fungus." Cambridge, 1879. A proposition of this kind, emanating from so high an authority, is worthy of the most careful consideration.

It seems that the possibility of destroying insects by infesting them with fungi from spores artificially sown, attracted the attention of Dr. Bail, of Prussia, more than a dozen years ago. His experiments, however, were not conducted with reference to the point in question, but for the purpose of establishing the identity of certain forms of fungi which had been regarded as distinct. That Dr. Bail's conclusions do not follow from his experiments, for instance, that the house-fly fungus *(Empusa muscæ)* and the yeast fungus *(Saccharomyces cerevisæ)* are merely different developments of the same species—is an opinion, I think, that every mycologyst who has had experience in the growth of microscopic fungi will endorse. This, however, does not affect Dr. Hagen's main proposition, inasmuch as the identity of the fungus is of small importance so long as it proves fatal to insects and its application is practicable. Propositions of a similar nature to that of Dr. Hagen's have been made by other scientists, notably by M. Pasteur some years since, whose investigations upon the silk-worm disease led him to suggest to the French Commission du Phylloxera, the possibility of destroying the insect which had

committed such fearful ravages upon the grape-growing industry of France, by its inoculation with some microscopic fungus.

In this country, as long ago as 1874, the same idea was suggested by Dr. John L. LeConte.[1] He recommends that a careful study of the epidemic diseases of insects be made, especially those of a fungoid nature, hoping thereby that some sweeping remedy may be found by which man can rid himself of insect enemies.

Charles A. Peck, State botanist of New York, advanced the same idea in 1876, only, however, applying it to the destruction of obnoxious plants. He says,[2] "On the other hand, those fungi that infest noxious weeds and hinder their dissemination and multiplication must be regarded as the friends and allies of man. Thus, the thistle rust, *Trichobasis suaveolens*, an early stage of *Puccinia compositarum*, sometimes attacks the Canada thistle with great virulence, and so impairs its vigor as to prevent the development of the seeds, thereby checking the propagation and spread of this pestilent plant. So, also, the troublesome bur-grass, *Cenchrus tribuloides*, is sometimes infested by a smut fungus, *Ustilago syntherismæ*, which not only prevents the development of the seeds of the grass but also the annoying bur-like involucres. It may yet be found practicable to keep down this grass by the artificial dissemination of the spores of its parasitic fungus."

Among the facts pointing to a favorable issue of the proposed remedy against obnoxious insects, is the well-known fact that many insects living under wholly natural conditions are annually destroyed by fungi. Cook states that about twenty-five species of the genus Torrubia are known to be parasitic on insects.[3]

Mr. Peck, in his Annual Report on the N. Y. Museum of Nat. Hist. for 1878, says that, "the seventeen-year locust, *Cicada septemdecim*, which made its appearance in the Hudson River valley early in the summer, was affected by a fungus. The first specimen of this kind that I saw was taken in New Jersey and sent to me by Rev. R. B. Post. Examination revealed the fact that the Cicadas or 'seventeen-year locusts' in this vicinity were also

[1] "Proceedings of the American Association for the Advancement of Science," 1874, p. 22.

[2] Twenty-ninth Annual Report on the State Museum of Natural History (1876) p. 30.

[3] "Fungi, their Nature and Uses," p. 218.

affected by it. The fungus develops itself in the abdomen of the insect, and consists almost wholly of a mass of pale-yellowish or clay-colored spores, which to the naked eye has the appearance of a lump of clay. The insects attacked by it become sluggish and averse to flight, so that they can easily be taken by hand. After a time some of the posterior rings of the abdomen fall away, revealing the fungus within. Strange as it may seem, the insect may, and sometimes does, live for a time even in this condition. Though it is not killed at once, it is manifestly incapacitated for propagation, and, therefore, the fungus may be regarded as a beneficial one. In Columbia county the disease prevailed to a considerable extent. Along the line of the railroad, between Catskill and Livingston stations, many dead Cicadas were found, not a few of which were filled by the fungoid mass."

Mr. Peck again, in the same report, says, that "While in the Adirondack region, numerous clumps of alders were noticed that had their leaves nearly skeletonized by the larvæ of some unknown insect. The larvæ were nearly black in color and scarcely half an inch long. They were seen in countless numbers feeding upon the leaves and threatening by their numbers, even if but half of them should come to maturity, in another year to completely defoliate the alders of that region. Upon looking under the affected bushes for the pupæ of the insect, in order, if possible, to have the means of obtaining the species, what was my astonishment to find the ground thickly flecked with little white floccose masses of mold, and that each one of these tufts of mold was the downy fungoid shroud of a dead larva from the alders. Not a single living pupa could be found, but there were hundreds of dead and moldy larvæ, killed without doubt by the fungus, which is nature's antidote to an over production of the insect and nature's agency for protecting the alders from utter destruction."

The "pébrine," a disease which appeared in South France nearly thirty years ago and attacked the silk-worms with much virulence, is also a case in point. A popular account is given of this epizoötic in Huxley's Lay Sermons.[1]

This disease appeared in the rearing houses in great violence in 1854, although it had been occasionally seen previous to that date. The name "pébrine" was given to it because of the dark spots which appeared on the bodies of the infested larvæ.

[1] Lay Sermons, pp. 373–375.

The malady spread from year to year, until in 1858 the amount of silk produced was diminished to one-third of that which had been made previous to 1853. In brief, a microscopic fungus, preying upon the silk-worm and causing its destruction by thousands, prostrated the industries of the city of Lyons, and plunged its working class into idleness and want. What the total loss was, could not be determined, as all classes of industry suffered, but the direct loss was estimated at $250,000,000.

The fact that the insects mentioned by Dr. Hagen exist in great numbers, is most favorable to the rapid spread of any disease that may appear among them, and the remedy proposed, should it work at all, would probably prove powerful, rapid and insidious. The spread of the potato rot, *Peronospora infestans*, over the whole of the British Isles within two years after its introduction, is an example of how rapidly and thoroughly spores may permeate any region when all the conditions are favorable to their growth.

In examining the question as proposed by Dr. Hagen, many facts must be taken into account before deciding upon the probable results. It must be remembered that the air is at all times charged with the spores of fungi. Dr. Cunningham found that "spores and other vegetable cells are constantly present in atmospheric dust, and usually occur in considerable numbers; the majority of them are living and capable of growth and development."[1]

Dr. S. M. Babcock, in studying the chemical changes of cheese during the curing process, finds it impossible to avoid mold in the curd except by heat and anæsthetics (ether and chloroform). He states that the spores *seem* to be in the very milk used in the experiments.

In the Botanical Laboratory, at Cornell University, where molds and yeast are cultivated at certain times for experimentation, the air soon becomes charged with spores.

Growing in the same laboratory and rooms directly connected with it, are plants which require constant care lest they be overrun with their several insect pests. No disease appears to have attacked these insects. It may be said that they do not feed upon the yeast, and for this reason escape. It is not necessary that the

[1] "Microscopical Examinations of Air," from the "Ninth Annual Report of the Sanitary Commissioner." Calcutta, 1872.

spores be eaten by the insect in the case of the fly fungus (*Empusa muscæ*). Huxley says:[1] "It has been ascertained that when one of the spores falls on the body of a fly, it begins to germinate and sends out a process which bores its way through the fly's skin; this having reached the interior cavity of the body, gives off the minute floating corpuscles which are the earliest stages of Empusa. The disease is 'contagious,' because a healthy fly coming in contact with a diseased one from which the spore-bearing filaments protrude, is pretty sure to carry off a spore or two. It is 'infectious,' because the spores become scattered about all sorts of matter in the neighborhood of the slain flies."

In this connection it should be noted that while the insects which infest more or less the plants growing in the laboratory have not been affected in any way by the fungi or their spores, the plants themselves, in some instances, have been seriously injured. On one occasion, recently, some experiments which had been commenced with much care upon *Drosera rotundifolia*, were brought to a sudden end by a mold which completely overrun and destroyed the plant. That the air of the laboratory should become abundantly charged with spores, would, of course, be expected from the large number of experiments in the growth and propagation of microscopic fungi which at times are being conducted by the members of the classes in mycology. Indeed after a time the spores become so abundant that all apparatus has to be thoroughly cleansed and fumigation by sulphur resorted to in order that the experiments with the fungi themselves should not be defeated.

The abundance of these spores of many kinds, including those of the house-fly fungus, emphasizes the fact that aphides and other plant insects, seem to thrive in the midst of these spores without any diminution of their vigor or power of reproduction.

Although our whole experience in the cultivation of fungi, as might be inferred from the statements already made, as also nearly all observations made upon fungoid growths in general, indicate that the yeast fungus offers little promise of success as a remedy against obnoxious insects, nevertheless the matter has been deemed of sufficient importance to warrant a considerable amount of labor in the way of experimentation for the purpose of arriving, if possible, at some definite facts bearing directly

[1] "Lay Sermons, Addresses and Reviews," p. 372.

upon the subject. A brief account of the methods and results of this undertaking is here given. All of the experiments here described were made on plants growing in pots in the Botanical Laboratory, or in the adjoining rooms, or in a large conservatory window, where the conditions of light, heat and moisture were favorable to the healthful growth of the plants experimented upon.

In conducting the experiments I have been greatly aided by Instructor W. A. Henry, of the Botanical Department, who has also rendered much assistance in collating information relating to the whole subject.

Experiment No. 1.—A strong plant of strawberry geranium *(Saxifraga sarmentosa)* has been allowed to become infested with green aphides. They are mostly confined to the flower peduncles and young tips of the runners.

May 13.—The plant is thoroughly sprinkled with dilute yeast by means of a flat paint brush so that all parts, especially those covered with aphides, are fairly wet. The yeast used is fresh domestic yeast, diluted with two-thirds water. Torulæ are active, as is shown from the fermentation in progress. After being sprinkled the plant is placed by itself on a table and covered by a large funnel-shaped hood, made of thin white paper, slightly open at the bottom to admit air. A cup of actively fermenting yeast is placed at the side of the plant under the hood, so that any germs which may possibly escape from the yeast will be confined to the air immediately surrounding the plant. Some of the older leaves are infested with a number of scale insects.

May 15.—No dead aphides are to be found. Some cast-off skins from molting are seen.

May 18.—Peduncles and tips of runners are loaded with plump aphides. Many cast-off skins. No dead insects are found. The scale insects larger and apparently more numerous.

May 20.—All young parts completely covered with aphides.

June 3.—The plant is obviously injured from attack of aphides and scale insect. Some of the leaves are dead. The plant is out of flower and the peduncles are more or less withered. On these peduncles are a number of dead aphides. These might have starved for want of food, owing to the drying up of the juices of the peduncles. A number of dead aphides are examined under the microscope in a variety of ways, but in no case is there any

appearance of Torulæ or other fungoid growths. Numerous live aphides are found on the younger parts of the plant.

Experiment No. 2.—May 13.—A small geranium plant *(Pelargonium angulosum* var.*)*, infested with a considerable number of aphides, is sprinkled with domestic yeast (the same as in No. 1), and placed in a window in its ordinary position among other plants not infested.

May 15.—Aphides more scattered but apparently not less in number.

May 18.—Aphides plainly more numerous. Numbers of cast-off skins from molting. Some leaves of geranium with dark-brown spots obviously caused by drops of yeast; other plants of the same kind not treated with yeast show no spots.

June 3.—Aphides numerous and healthy. Quantities of cast-off skins. No dead aphides to be found. Foliage obviously injured by the yeast. Plant plainly enfeebled by the aphides.

Experiment No. 3.—May 10.—A calla lily has become infested with aphides and red spider. The whole plant is carefully washed with a sponge except a small spot on one leaf where twenty-seven aphides are left, and a similar spot on another leaf where about twenty red spiders are left. The whole plant is sprinkled with domestic yeast, care being taken to thoroughly drench both the aphides and red spiders. The plant is covered by a bell jar which rests upon a ring of cotton batting, so as to shut the plant off from the approach of insects or spores from without, and prevent the escape of those within. Under the bell jar are placed two cups of actively fermenting yeast.

May 14.—The plant carefully examined. No dead aphides to be found. A number of cast-off skins are seen. The aphides are well scattered over the plant, but more than the original twenty-seven can be counted. The red spiders are also scattered so that the number cannot be ascertained. Several living but no dead ones are seen. That the spiders should have decreased in numbers might be expected from the moisture of the yeast independent of the Torulæ.

Experiment No. 4.—April 8.—Selected a thrifty rose geranium, about ten inches high, that had by count seventy aphides upon it, collected mainly upon the tender shoots.

The yeast is prepared by dropping pieces of compressed yeast-cake, bought at the grocer's, into Pasteur's fluid with sugar. In

about twenty-four hours the yeast has become active as is shown by frothing and the budding of the Torulæ observed under the microscope. This active yeast is sprinkled all over the plant, care being taken to wet the bodies of as many aphides as possible. Over the plant is placed a bell jar to isolate it from others.

April 11. — No effects noticed. Sowed more of the same yeast.

April 18.—The soil in the flower-pot has been allowed to become quite dry. The larger leaves of the plant have turned yellow, and upon these are nearly all the aphides. Counting as carefully as possible, the number is found to be three hundred and fourteen. The glass cover is removed and nearly all the aphides are brushed off, and the plant allowed a few days to recuperate.

Experiment No. 5.—May 1.—Sowed yeast procured direct from the bakery upon the same plant as in No. 4. Upon the plant are fifty-five aphides, mostly small. The plant is placed in a close Wardian case where there is an abundance of moisture.

May 6.—A mold (Mucor) has made its appearance upon all parts where the yeast adheres. The aphides are nearly all dead or dying. One aphis is found alive held to the stem of the plant by a pasty mass of yeast.

May 16.—Only three aphides alive; the mold has seriously injured the plant.

Experiment No. 6.—May 26. — Sowed yeast from the same bakery as in No. 5 upon the aphides on a healthy young plant of same kind and size as No. 4. This time the plant was not treated differently from others in the same room except being thoroughly sprinkled with yeast.

June 3.—Aphides as numerous as ever. No dead ones seen.

Experiment No. 7.—To ascertain whether any fungoid growths could be developed from the dead aphides in No. 5, two of them are placed on a bit of clean, broken plant crock sufficiently moistened, which is covered with a small bell glass, the rim of which rests in a shallow vessel of water to isolate the experiment as completely as possible. The experiment commences May 5, at 2 P. M. On May 6, at 3.30 P. M., some mycelium is visible on the body of an aphis.

May 9. — A number of upright hyphæ have fruited; the quantity of fruit is very small and not sufficient to determine what the mold is with certainty, but it appears to be a Mucor.

Experiment No. 8.—This experiment is introduced as a test of No. 7.

May 11.—Two aphides are taken from a plant which has been treated with yeast. One is dead when found, the other is killed; both are placed as in No. 7. No mycelium or fungoid growth of any kind is developed in this experiment.

Experiment No. 9.—This experiment was introduced for the same purpose as No. 8.

May 11.—5.30 P. M. Three living aphides are taken from a plant not treated with yeast, and killed and placed as in No. 7.

May 13.—The room has been quite cool and no mycelium has appeared.

May 15.—On one of the aphides a few fruits of a mold can be discerned. None can be seen on the other two.

This experiment seems to show that the mold developed in experiment No. 7 on the body of the aphis which had died, has no connection with the fact that the plant from which the dead aphis was taken, had been treated with yeast.

The result of these experiments, as a whole, as also many others not here recorded which have a more or less direct bearing upon the subject under consideration, indicate plainly that yeast cannot be regarded as a reliable remedy against such insects as commonly affect plants cultivated in greenhouses, rooms and parlors. Moreover, it is more than probable that the yeast would injure many kinds of plants, especially those with delicate foliage by spotting and soiling the leaves, and inducing fungoid growths upon the jars or soil in which the plants are grown. Indeed, in most greenhouses at the present time, it is not so much a question of keeping down injurious insects, as it is the suppression of molds and mildews of various kinds. The verbena rust only need be named as an illustration of this point.

Nearly all recorded experiments with the yeast fungus as an insecticide, have been attended only by negative results. Among these may be mentioned those of Prof. J. H. Comstock, of the Department of Agriculture, who fed caterpillars in breeding cages with leaves wet with dilute yeast. They seemed to thrive as well as others not thus fed.

Mr. Wm. Trelease tried last August a number of experiments with yeast upon the cotton-worm, in the vicinity of Selma, Ala.[1]

These experiments were varied and carefully conducted. In

[1] "Report upon Cotton Insects." J. H. Comstock, Dept. of Agr. Washington, 1879.

some cases the cotton plants upon which the worms were feeding were thoroughly drenched with active yeast. In one instance a number of the larvæ were placed in a tin box and drenched for twenty-four hours with yeast; after this the surplus yeast was drained off and the larvæ kept in the same box and fed for a week without showing any symptoms of disease. They were then sent to the department at Washington, where they arrived safely, and never gave those receiving them cause to suppose that they had been thus treated. Similar results attended all the experiments tried by Mr. Trelease, and he was led to the conclusion that the proposed remedy could not be utilized for the destruction of the cotton caterpillar.

On the other hand, Dr. Hagen mentions some experiments made last summer by Mr. J. H. Burns, of Shelter Island, N. Y., on the potato beetle, as being successful. A quantity of beetles was divided into two parcels, one of which was sprinkled on successive days with dilute yeast.

On the eighth day those sprinkled began to die, and on the thirteenth all were dead. Of the unsprinkled parcel only a few had died. That this experiment is decisive can hardly be claimed, as it is probable that some other substance, as for instance, dilute flour paste, which would favor the growth of fungi, might have had the same effect as the yeast. At all events, the experiment must necessarily be tried upon the beetles as they are found in their natural state infesting the potato plants, before any definite conclusion can be drawn.

It is true that Dr. Hagen found spores in quantity in the large sinus of the wing of the dead beetles which had been sprinkled, but it does not appear that these were in any way directly connected with the Torulæ of the yeast. It should also be noted that Dr. Hagen states in the May number of the Canadian Entomologist, for 1880, that he has recently received a letter from Germany, giving an account of the use of the diluted (compressed) yeast upon aphides in a green-house, "which was successful to an exceeding degree;" but no details in regard to the experiment are given.

Possibly the kind of yeast used may make a great difference in the result, although it should be remembered that three different kinds have been used in the experiments detailed in this paper.

It is also worthy of note that yeast, as suggested by Prof.

Metschnikoff, might in some cases prove destructive to insects to which it had been applied, not because of the yeast itself, but because of impurities which it might contain, it being an established fact that yeast may and often does contain the living spores of more than one kind of fungus.[1]

One of the things which is always taken into account in the cultivation of fungi in the laboratory, is the fact that when we purposely sow the spores of a given fungus we are never quite sure that we are not at the same time unconsciously sowing the spores of some other fungus which may be floating in the air. While we expect and generally obtain an abundant crop of the fungus we may wish to cultivate, we are apt to find here and there one or more other forms mingled with those we are trying especially to grow. These may be compared to the weeds which the gardener is pretty certain to find among the plants he has sown in his seed bed.

The subtle nature of fungoid growths of every grade, and the peculiar dependence of fungi upon climatic conditions and other circumstances, which are often unknown and wholly beyond control, are very important factors in estimating the probabilities of success by the methods under consideration. We know that epidemics and epizoötics of various kinds may be largely destructive and fatal one year, and the next, although the germs of disease must now be scattered in abundance everywhere, the disease is lessened or is wholly gone. Again, rust and smut may one season abruptly invade our grain-fields; the next it is scarcely seen; or blights and mildews may devastate for a few years our orchards and vineyards, and then gradually or suddenly disappear. Nor are these characteristics confined to microscopic fungi alone. During last season certain of the larger species, as Boletus and Hydnum, were sought in vain in localities about the University, where ordinarily they were abundant. The fall had been unusually dry and in this probably lay the cause of their non-appearance. Perhaps for the same reason, not a house-fly could be found that was affected with the Empusa, though they were sought for with much care, especially about the Botanical Laboratory where the yeast fungus was being grown.

Nevertheless, inasmuch as it is possible to suppress injurious fungi which destroy our economic insects, as for instance, the

[1] See *Nature* for March 11, 1880.

Muscardine in the case of the silk worm, the theory seems plausible that we may in time learn on the other hand, how to suppress injurious insects by fostering the growth of parasitic fungi which would spread infection among them and carry with it disease and death.

Finally, it must be confessed that the main question at issue is by no means decided, perhaps not seriously affected by the experiments and conclusions which I have here recorded. Though the yeast fungus may not be destructive to the insects named, and under the given conditions, it may, nevertheless, be destructive to other insects, or even to these under other conditions, or if the yeast fungus should prove to be wholly worthless and unreliable, it does not follow that there are not other forms which may be successfully employed as insecticides to the very great advantage of our most important national industry.