Fungi to Control Forest Insect

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Index

Introduction ---------------------------------------- 1

History of forest entomology --------------------- 2

Damage done by insects -------------------------- 3

Insect control -------------------------------------- 6

Insectivorous parasites as a control method ------- 8

Definition of fungi ---------------------------------10

Origin of the fungi ---------------------------------10

Classification of fungous diseases -----------------11

Key to the genera Entomophthoraceae ---------------11

Description of important fungi genera -------------12

Typical life history ---------------------------------16

Examples of fungi work ----------------------------16

Summary of insect epidemics controlled by fungi ---21

Artificial culture -----------------------------------22

Summary --------------------------------------------24

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## Introduction

The purpose of this thesis is to point out the possibilities of raising and liberating fungi parasitic to harmful forest insects.

The insect damage of the forest spreads very rapidly and today exceeds the lumber cut and fire damage combined. Although the insects can be controlled, at present the possible methods of control are usually not economically possible.

The disease of fungal origin were probably the first diseases of insects to be studied, and with the exception of the bacterial disease of locust, are the only ones whose artificial large-scale propagation has been attempted. If attempting to create an epidemic by the introduction of a fungus into a region where it does not occur naturally, the results are usually poor, but where the fungus exist normally there seems to be some evidence that epidemic can be evoked by artificial means.

This thesis gives a general description of insect problems and the possible controls of such pest with a detailed description and possibilities of fungi as a control of forest insects.

History of Forest Entomology

In as much as Germany was the first country to develop forestry, it is natural that in that country forest entomology should have had its inception. The ravages of insects became increasingly important as the value of trees became more and more appreciated. The outbreak of a forest pest was something with which the early foresters were unable to cope, and so they were forced to call on outside help. The purpose behind most of these early studies of forest insects was the development of methods by which a certain pest or the pests of a certain tree might be controlled. Previous to 1800, forest entomology, as such, did not exist and there were no specialist in this subject. The first attempt to gather together all available information concerning forest insects was in 1805, and it was the only general work available on the subject for the next thirty years. Germany was still in the leadership of valuable pioneering work on forest insects in 1840 when a German entomologist, Ratzeburg, appeared as a specialist in forest entomology and made many insect studies that have never been surpassed in excellence and scope.

Since the beginning of the twentieth century a decided change has been taking place until now in the modern period leaders in forest entomology, instead of being centered in a single country, are to be found throughout those parts of the old and new world where forests are economically important. During the early periods in America the emphasis was placed on shade-tree insects. Virgin forest were still supplying an abundance of wood products, and the practice of forestry was practically unknown, because it was unnecessary. This situation has continued until very recently. In Europe, the emphasis, since the earliest development of the science, has been placed on insects of the forest. This has been the result of economic conditions, characteristic of densely populated communities, where a scarcity of wood has made the practice of forestry a necessity. The modern viewpoint of forest entomology is quite different however. As forestry has developed in America there has been an ever-increasing need for information concerning the influence of forest insects upon the forest. Where in the past there were almost no men spending their entire time upon forest insect problems, there are now many capable men employed in this work. These men are interested both in the insects themselves and in the forest, but their primary interest is in the influence of insects upon the forest. ******

## Damage done by Insects

Insects that injure and kill trees are always present and probably always have been a part in the life of every forest. There are about 600,000 known insects in the world, 200,000 of which attack trees. Their abundance, however, is transient and ever changing. Under normal conditions insect numbers are held in check by their many enemies and the unfavorable factors in their environment. But this normal, balanced condition in a forest is by no means a stable one, and at times certain species of insects may suddenly multiply their numbers and kill a very high percentage of the forest in the period of a few years. In the wild forest lands of the country even the epidemic condition may not be a serious matter in the general scheme of nature. It is only when a forest in its existing condition takes on a definite usefulness to man that we begin to regard these insects outbreaks as an economic evil. Our forest must be protected from the devastation of the ravages of insects if we are going to have an opportunity to practice forestry. During every stage in the growth of wood, from the seed to the finished product, important insect problems are continually presenting themselves. To the forester their importance may be measured if we refer only to the loss of increment both by killing the growing trees which compose the ultimate crop and by destroying the final wood product after it has been manufactured. But forestry is also concerned with other values inherent in the forest which are much less easily measured, such as its usefulness for watershed cover and for public recreational purposes and the aesthetic importance attached to trees that are a feature of great natural areas such as the national parks. Insects, like any other tree-destroying agencies, may affect any of these values. The most serious losses that affect the lumberman are those occuring in accessible stumpage which is to be marketed within a decade or two. There is little possibility that severe losses due to insect epidemics will be replaced by natural growth within this period, so that practically every tree taken by the insects is lost to the sawmill. Not only the loss of stumpage itself, but the increased overhead of logging cost in heavily thinned stands, must be charged against the infestation, as well as the community loss due to reduction of the product sold from the region.

Sustained yield from a given area, the goal of forest management, is an impossible attainment where insects or other causes interfere with the length of rotation and reduce or degrade the output upon which the forester has carefully planned his program. The control of insects that attack forest seed crops has been given little attention up to the present time. It is evident, however, that certain types of this damage, as well as that occurring in seedling and very young trees, will have to be minimized controlled as the restocking of cutover and denuded areas becomes more of a factor in the production of future timber crops.

Insect epidemics usually leave in their wake an accumulation of dead material which in dry periods adds tremendously to the inflammability of the cover. Increased cost of fire suppression and increased fire damage are the effects which remain long after the insect outbreaks that caused the snags have subsided.

It is undoubtedly true that in North America more wood has been destroyed by insects, fungi, and fire than has ever been cut and used. Estimates have placed the total loss of forest resources due to insects at more than $200,000,000 annually. Forest insects destroy enough timber each year to build 300,000 average American homes. It has been estimated that the losses of timber from forest fires in all of the national forests of the United States from 1905 to 1908, inclusive, averaged $165,062 annually. Taking the timbered area of this country as a whole, it is safe to say that the average annual loss caused by forest insect is at least five times the loss inflicted by fire. The probability of error in such estimates depends necessarily upon interpretation of values and the applicability to the entire country of the actual examples that were studied by the estimator. Incomplete and unsatisfactory as these statistics may be, they are, at least, sufficient to indicate the insects are an important economic factor in our forest industry and should receive an important place in our plans for the protection of our forest and forest products.

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## Insect Control

Insect control is the regulation of insect activites in the interest of man. It is generally recognized that it is practically impossible to exterminate any forest pest. The aim of the forest insect control is not extermination, therefore, but is to keep the pest within reasonable bounds. It has been shown that outbreaks of forest insects occur as the result of a disturbance of the biotic balance, and that as long as the balance can be maintained outbreaks are impossible.

In managing a forest and applying insect control the material saved by the application of control measures must justify the expense involved. The cost of control must be materially less than the loss that would have occurred had no protective measures been applied. The lower the value of the trees or wood products to be protected or the smaller the margin of profit, the smaller will be the amount which can justifiable be expended for protection. The value of partially manufactured products justifies a greater expenditure than does standing timber. Trees may have very real values in checking soil erosion, or for esthetic purpose. These indirect values must be taken into consideration along with commercial values in planning for their protection. Where trees are used to prevent the erosion of soil on steep slopes and watersheds, their destruction not only means a loss of a certain amount of wood but, also, may result in damage through erosion of soil, and silting of reservoirs, to such a degree that by comparison the loss in wood might appear infinitesimal. Under such conditions, large expenditures for protection are justifiable while not in timber forest. Likewise, park and shade trees have an esthetic value far in excess of their value for wood. The control measures must, therefore, be suited to the conditions under which it is to be applied, and under each different condition we may be forced to use a different method of control even for the same insect.

<u>Classification of control measures:</u>

A. Direct control - Operations aimed directly at the insect for the purpose of immediate suppression.

1. Mechanical methods:

   Collecting, trapping, destroying infected materials, barking to destroy broods and heating.

2. Biotic methods:

   Predators and parasites.

3. Chemical methods:

   Dusting, spraying, fumigating, using poisonous bait.

B. Indirect control - Operations designed to modify environmental factors to secure ultimate limitation of insect numbers.

1. Chemical and mechanical methods:

   Modifications of food supply, moisture conditions, and temperature conditions.

2. Biotic methods:

   Competition, parasites, and predators.

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Insectivorous Parasites as a Control Method

Some of the types of insect diseases caused by entomophagous micro-organisms are bacterial diseases, fungous diseases, and protozoan diseases. Epidemics of bacterial insect diseases usually occur only when the host is extremely abundant. This is probably because they are, for the most part, infectious in character, and it is only when the population of the host is quite dense, with the resultant frequent contact between the individual insects, that conditions for infection are at their best. Some of the most serious bacterial diseases of insects gain entrance into the digestive tract along with the food. There they multiply and attack the host tissues. The method of entrance in many instances is unknown. These disease organisms may attack insects in any stages, but those that we now consider as being most important are the cause of larval diseases. The symptoms of the diseases vary somewhat. As a rule, however, the first symptom appears to be a loss of appetite on the part of the affected larvae. Later, these larvae cease to eat and finally die. Previous to and following death, changes in color usually occur. Often this color change is first indicated by a fading and yellowing of the natural larval colors. Later, usually after death, the larvae become much darkened. After death has occurred, a rapid disintegation of the internal tissues take place until finally the skin is filled with a dark liquified material. Frequently, the insects suffering from one of these parasitic diseases will continue to hang to the plant on which they were feeding, even after death.

The polyhedral diseases of insects are very similar to some of the most dreaded diseases of man and other mammals; hydrophobia, smallpox, and trachoma, for instance. They are characterized by the presence of granular bodies in the blood and in certain tissues. In insects, these bodies are called "polyhedra." Although their true nature is not known, these diseases are among the most effective parasites in the natural checking of outbreaks of certain Lepidopterous insects. Up to the present time, the polyhedral diseases have never been found attacking insects other than representatives of the Lepidoptera.

Entomophogous fungi are not at all uncommon among insects and may be largely responsible for checking an outbreak. The effectiveness of the diseases depends upon the abundance of saprophytic growth, which in turn depends largely upon moisture conditions.

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Definition of Fungi

Fungi are chlorophyll-less thallophytic organisms typically consisting of coenocytic or cellular filaments, but including also encysted or amoeboid one-celled organisms which reproduce by some type of motile or non-motile spore; excluding the bacteria and such chlorophyll-less organisms, which, by their structure, are with definiteness assignable to recognized orders of algae.

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Origin of the Fungi

There are two well known opposing theories as to the origin of the fungi. One of these treats the group as an aggregation of relatively unrelated parts, which have degenerated along different lines from widely separated subdivisions of the algae. The other maintains that the fungi have arisen from non-chlorophyll bearing organisms lying below the level of the lowest of the present day fungi.

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## Classification of Fungous Diseases

Class - Phycomycetes, translated literally, means algal fungi. It was first applied by early investigators, who recognized that members of the group resembled strikingly in essential features of green algae.

Order - Entomophthorales; forms chiefly parasitic and entomogenous, a few forms saprophytic, a few others parasitic on plants; zygospores borne typically within the host; asexual reproduction almost always by conidia borne at the ends of specialized conidiophores and shot away at maturity.

Family - Entomophthoraceae; this family is the most important source of parasitic fungi.

Class - Ascomyceteae; characteristic spores endogenous ascospores. Order - Laboulbeniales

Class - Schizomycetes or Bacteria (Fission Fungi)

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## Key to the Genera of Entomophthoraceae

I Mycelium not entomogenous (i.e., not living in insects).

A. Mycelium profusely developed, not intracellular.

1. The asexual reproductive cell finally forming endogenous spores, hence termed a sporangium, apical portion of sporangiophore immediately be-

low the sporangium differentiated as a peculiar conical "basidium", which is shot away with the sporangium; saprophytes. Basidiobolus

2. The asexual reproductive cell functioning as a conidium; a specialized "basidium" absent; conidium freed from the conidiophore completely as an Empusa; parasites or saprophytes. Conidiobolus

B. Mycelium only slightly developed, intracellular, parasitic in fern prothallia. Completoria

II Mycelium entomogenous.

A. Conidia borne within the body of the host, and freed by its disintegration, not shot away, verrucose. Massospore

B. Conidia borne on the surface of the host, smooth-walled, discharged forcibly from the conidiophore. Empusa

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Description of Important Parasitic Fungi Genera and Order

Genus Massospora:

Vegetative growth of the fungus is confined to the softer tissues in the posterior segments of the body of the host. Although half the body of the insects has disintergrated or fallen away, they remain alive for a considerable period and may crawl about among its fellows. This process of sloughing off of the body of the insect is unknown in other genera of the Entomophthoraceae and is here concearned in spore dispersal. In Massospore the conidia are neither borne over the surface of the host nor ejected forcibly from the tips of the conidiophores. They are formed within the body of the insect, and though delimited on the conidiophore in the manner usual in this group, are held in the approximate position in which produced, finally cohering with one another to form a powdery mass of spores. They are exposed by the disintegration of the intersegmental abdominal membranes of the host, and falling away gradually, are disseminated by the wind. The conidia, unlike those of other genera, are markedly verrucose instead of smooth. In later phase of development, hyphal bodies are present, and give rise to conidiophores and resting spores. The latter are spherical, slightly brownish, and have beautifully reticulated walls. Each resting spore arises as a bud from a hyphal body and is asexually produced.

Genus Empusa:

The members of this genus are all entomogenous, and were long thought to be obligate in their parasitism. In recent years several species have been induced to grow saprophytically on artificial culture media and it is probable that others will be obtained in culture when the proper conditions are provided. In nature, infection of the host results when a germ tube from the conidium penetrates the outer covering of the insect and enters the body cavity. In the host the infection thread usually does not develop a profusely branching mycelium. Instead it forms short thick segments which break apart from one another, and undergo a process of division and budding. These segments are termed hyphal bodies. The process is continued until the body cavity is almost wholly filled with them. Meanwhile, powerful enzymes are excreted which quickly dissolve the various internal structures of the host until practically nothing remains but the outer coat. Under unfavorable environmental conditions the hyphal bodies may assume heavier walls, and enter a period of rest as chlomydospores. On the return of favorable conditions they germinate quickly and proceed at once to the formation of conidiophores. In the more normal development chlomydospores are lacking and the conidiophores arise from the thin-walled hyphal bodies. They penetrate the outer covering of the host and form conidia in the air. In some species the primary hypha, without branching, abjoints terminally a single conidium. In others considerable branching may occur, each ultimate branch becoming a conidophore. In either case the conidium is formed as a bud at the apex of the clavate termination of the conidiophore. As the conidium approaches its mature size its contents and those of the conidiophore absorb water rapidly, Finally the pressure exerted is so strong that the outer of the two walls enclosing the conidium ruptures transversely in a circle about its base, and the conidium is discharged violently into the air and carried a considerable distance. Should it fail to strike an insect host it may put out a germ tube, and on this, form a secondary conidium which is in turn discharged. This process may be repeated until the the vitality of the protoplasm is exhausted or a susceptible host encountered. Other more abnormal variations, in which secondary conidia bud directly from the primary or in which thicker-walled resting conidia are formed, occur under unfavorable conditions. In most species the conidiophores emerge in great numbers from the host through the less resistant portions of its surface and form tufts or definite palisade layers evident to the unaided eye as felt-like masses, powdery with conidia. The color is usually white, but may vary to some shade of gray or green. Occasionally sterile hyphae protrude beyond the layer of conidiophores. These have been termed paraphyses by some authors and by others cystidia. As the host sickens and dies hyphae are sometimes pushed out from its body to anchor it firmly to the substratum. These are termed rhizoids. The genus Empusa is an important parasite of many insects, some which are of considerable economic importance.

Order Laboulbeniales

They are minute, almost microscopic parasites upon insects. They develop mostly externally upon the host. The fungi vary from plants only a few cells in number and considerable less than 0.1 mm. in height to forms of hundreds of cells and 2 to 3 mm. tall. The cell walls are usually thick and firm, often dark in color. Laboulbeniales include several species, all of which, excepting only the yeasts, possess a well-developed mycelium of branched and septate hyphae. The plant may consist essentially of a row of cells which gives off laterally some branched filamentous appendages and a female reproductive branch.

The female reproductive branch usually consist of a row of three cells. After fertilization these cells divides into more cells. These fungi are found on beetles (Coleoptera), Hymenoptera, Diptera and various other orders of insects.

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## Typical Life Cycle

The infection in insects can occur only through the bodywall and enter directly into the blood. Development after the initial growth in the blood, is most rapid in the fat-body and the associated oenocytes. The fungus penetrate the large thin-walled cells with great ease, destroying the tissue by enzymic action. The tissue next to be destroyed after the glands are the muscles. The nervous system is most resistant and remains unharmed when most ot the other tissues of the insect yield to the parasite. The host is now in a very soft, floccid condition, in which the slightest touch may rupture the weakened cuticle and allow the content to flow out. It is during these last stages of disintergration that the fungus ceases vegetative development and turns to its reproduction phase. The average time necessary for the fungus to complete its life cycle, from inoculation to conidial production, is about seventy-two hours.

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## Examples of Fungi Work

Pelbrine - This fungus belongs to the Schizomycetes class.

Of the contagious diseases of insects, Pebrine, a consequence of a fungus, of the silkworm is the best known example. It is a plague that is rapidly and easily conveyed by contamination of the food, and exceedingly liable to hereditary transmission through ingection of the forming egg in the ovary. Its most evident symptoms are, externally, the black specking of the skin. The internal appearance of similar black spots on the organs. The characteristic pathological features are the more or less extensive disorganization of the gastric epithelium, within whose cells the parasites begin their development, and the general invasion of nearly all the internal tissues by these parasites and their spores, which also become abundant in the blood. After death it mummifies without decay. The food of healthy insects may become infected by the discharges of diseased larvae, or even, at a considerable distance, by the dust of their excrement. The "germs" of the disease may also be introduced by means of accidental punctures of the skin, as larvae crawl over each other with claws soiled with their spore-laden excrement.

Genus Empusa of the Phycomycetes class.

The aphid (Aphis spiraecola) on citrus in Florida rapid reproduction has been checked each summer by a fungus disease belonging to the genus Empusa. This fungus causing the Empusa disease leads to the death of the aphid in from two to five days after infection.

Empusa musce

This species affects various flies which causes the abdomen to be distended and presenting alternate black and white bands, while around the fly at a little distance is a white powdery ring, or halo. The white intersegmental bands are made by threads of the fungus and the white halo by countless asexual spores which may infect another fly upon contact. In recent years this species has been induced to grow saprophytically on artificial media and it is possible that others will be obtained in culture when the proper conditions are provided.

Empusa aphidis

This species affect plant lice ~~by~~ causing the body to swell and become discolored.

Empusa grylli

Attacks crickets, grasshoppers, caterpillars and other forms.

Cassospora cicadina of the class Phycomycetes.

This fungus attacks and kills Perodical cicada (seventeen-year locust) which is sometimes of considerable economic importance. This locust lays eggs in slits in branches or twigs of trees often killing branches; the young when hatched drop to the ground, make their way to the roots where they feed for seventeen years; the young nursery stock suffers the most. Both types of reproductive bodies, resting spores and conidia, were found on the host but not at the same time on an individual host. The fungus seemed to be largely though not exclusively confined to the male insect. The fungus is confined to the vegetative growth to the softer tissues in the posterior segments of the body of the host, ultimately destroys such tissues, including the flexible intersegmental membranes of the abdomen in this region. The sloughing off process takes place progressively, beginning with the last segment and continues until four or more have been dropped. The conidia are violently ejected from the conidiophores only after the host is dead and therefore stationary. In the fungus vegetative growth prior to the production of resting spores, the fungus destroys the intersegmental abdominal membranes of the host, as it does in the conidial phase of the development just considered, and there is similar sloughing off of the abdominal segments. These bodies are less coherent in the mass than are the conidia, and as a result they are scattered about by the movements of the host much more freely.

Entomophthora sphaerosperma

The development of Entomophthora sphaerosperma upon Rhopobota vacciniana. This host is the same species as that of an European insect whose larvae feed upon holly. Although the holly is a minor forest product at the present, it may develop into a primary forest crop in the future. This fungus in artificial culture offered incomparable opportunities for controlled studies of infection and development. The infection in Rhopobota can occur only through the bodywall and enter directly into the blood.

Isaria farinosa

Isaria farinosa attacks the Larch saw fly by being responsible for the death of a very large percentage of the cocooned larvae. Isaria fungus lives, as does a saprophyte, on moss beneath the trees and its spores are capable of infecting larvae that crawl over the infected moss. These organisms multiply be division of yeast-like cells. The effectiveness of this fungus depends upon the abundance of saprophytic growth which in turn depends upon moisture conditions.

Cordyceps clavulata

Cordyceps clavulata fungus is found on scales of the genus Lecanium. This fungus of fungus is found on scales infesting various trees. Each individual fungus grows over a single insect and, as a rule, not only hides it completely but consumes the whole of it so that there is no trace of the insect left within the stroma. Attempts have been made to control the scale insect pest by means of economic fungi in Florida. Control of white flies in citrus trees has been tried with varied results.

Entomophthora aulicae

Browntail moth larvae experiment in Massachusetts suceeded in destroying sixty percent of the larvae by artificial infesting them with Entomophthora aulicae fungi.

Sporotrichum globuliferum

Sporotrichum globuliferum have been used extensively as a means of spreading infection among chinch-bugs and grasshoppers with, however, but moderate sucess, as yet. Sporotrichum spreads within the body of the host and at length emerging to form on the body of the insect a dense white felt-like covering, this consisting chiefly of myriads of spores which infect healthy insects.

Class Phycomycetes as a whole:

The class Phycomycetes fungi have been found in one or more of their stages, spontaneous or as a consequence of experiment, on various insects of Homenoptere and Lepidoptera. Some of the Homenoptere insects that are attacked by this fungus are ants, the Hawk moths, and Papilio rutulus which defoliates willow and populars. The Owlet moth of the Lepidoptera is also attacked and killed.

Yeast fungus of the class Schizomycetes.

A remedy for insect pests, offering several prominent advantages, could be found in the application of the yeast fungus. Further, this remedy could probably be used against the famous Colorado grasshopper, for which the Government has appointed a commission and appropriated $75,000 for its use. It has been proved that mould sowed on mash produces fermentation and the formation of a yeast-fungus, which kills insects as well as the fungus of the house fly. The use of this type of mould has fomerly been the secret of brewing certain kinds of a strong beer. Healthy insects brought in contact with mash and fed with it are directly infested by the spores of the fungus with fatal consequence. The most different insects, such as flies, mosquitoes, caterpillars, all showed the same results. Beer mash or diluted yeast should be applied either with a syringe or with a sprinkler; and the fact that infested insects poison others with which they come in contact is great help.

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Summary of Insect Epidemics Controled by Fungi

Fawcett in 1908 mentioned six species of fungi, all

Ascomycetes, that destroyed the larvae of the citrus white fly, Aleyrodes citri, in Florida. Folsom in 1909 spoke of Entomophthora sphaerosperma as the worst enemy of the clover-leaf weevil, Hypera punctata. Majmone wrote of an epidemic at Portici, near Naples, Italy, in 1909, in which Empusa elegans caused such devastation among the larvae of the Brown-tailed moth that the next year the insect had almost disappeared from the whole province. Mattirola in 1898 observed a severe epidemic among aphids in the vicinity of Florence, caused by Entomophthora planchoniana. Burges and Swain in 1918 described a new species of Entomophthora, which destroyed over ninty percent of the walnut aphids in Southern California during the summer of 1917. Speare in 1922 described Entomophthora fumosa, parasitic upon citrus mealy bugs (Pseudococcus citri) in Florida, and estimated that this and other entomogenous fungi saved the citrus growers of Florida several million dollars annually.

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## Artificial Culture

The media which have been used most are swordfish, pork, and potato, which need no special preparation except sterlization. Liquid nutrient media favor luxuriant mycelial growth, but solid media favor the production of hyphal bodies and reproduction phases. It was found that carbohydrates and fats are not essential to the growth of these fungi, however the substratum must contain proteins, upon which the fungi are able to develop their complete life cycle. The hydrogen-ion concentration of the host should be about 6.5 to be most favorable to the development of these forms in artificial culture; growth may occur over a considerable range on either side of this point. Atmospheric humidity does not influence growth or reproduction, but too much moisture in the substratum inhibits the latter; conidia will not germinate below a relative atmospheric humidity of about 70 percent at 21°C and the maximum temperature is 34°C; the exact minimum has not been determined, but the conidia may be frozen in ice for several days and still germinate upon return to room temperature. The artificial cultivation of members of fungi is important, for thereby better material may be available for study and for economic usage.

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## Summary

Almost every insect has at least one parasitic fungous disease which is present all the time, however, the fungus is only of importance in insect control when certain conditions are present. The present information of these conditions is very incomplete. The controlling factors seem to be the climatic condition and the number of insects present in large numbers of epidemic. The artificial cultivation of parasitic fungi has been proven possible in some cases but has had only moderate sucess in controlling insects.

Attempts to cultivate these types of fungi are worth while for sucess in artificial cultivation would insure a ready and abundant supply of fungus in all stages of development, which would not only greatly facilitate detailed morphological study and the more definate determination of taxonomic relations in this group, but also, by furnishing unlimited material for infection in the field, might provide an important means for the control of undesirable insects. The artificial cultivation of these fungi may have an economic value, for the devastating effects of fungi on insects are well shown in natural epidemics. Nature uses always to attain its purposes the most simple and most effectual ways; therefore it is always the safest way to follow nature.

The most logical recommendation at the present time, while fungi control of insects is in the experimental stage, probably is the enlargement of experimental funds for this type of work by the government and private timber owners.

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## Bibliography


Atkinson, G.F., Artificial cultures of an Entomogenous fungus. Bot. Gaz., Vol. XIX, pp. 122-145, 1894.

Berger, E.W., Sitrus insects and their control. Florida Ag. Expt. Sta. Bul. 183, 1926.

Cooper, J.F., Friendly fungi help citrus growers. State plant board of Florida Monthly Bul., May 1928, Vol. XII, No. 11.

Doane, Forest Insects.

Dustan, The control of European apple-sucker by means of a parasitic fungus. 60th. Ann. Rpt. Fruit Growers Assoc. Nova Scotia.

______, A study of the methods used in growing Entomophthorous fungi in cages prior to their artificial dissemination in orchards. 55th. Ann. Rpt. Ent. Soc. Ontario.

Fitzpatrick, Lower Fungi.

Fobes, S.A., Memorands with regard to contagious diseases of caterpillars. Am. Nat., Vol. XVII, pp. 1169-1170.

Folsom, Ent. with reference to its bilogical and econ. aspect. pp. 200-202.

Gilbert, E.M., Some diseases and Aphis spiraecola. State plant board of Florida, quarter Bul. Vol. X, 1926.

Glaser, R.W., Status of fungus diseases of insect. Jr. Econ. Ent., Vol. VII:473-476, 1914.

Graham, Principles of forest ent., pp. 279-280.

Leconte, F.L., Fungous disease upon insect. Can. Ent., July, 1880, Vol XII, pp. 125-128.

Lesley, L.F., The destruction of insect pest. Nature, Vol. XXI, pp. 447-448.

Lintner, J.A., The seventeen-year locust destroyed by a Fungus. 2nd. Ann. Rept., N.Y. State Entomologist, 1885.

Lugger, O., Fungi which kills insects. UN. of Minn. Ag. Exp. Sta., Bul. 4, 1888.

Petch, Ent. Fungi and their use in controlling insects. Ceylon Bull. 71:1-40, 1925.

Pettit, R.H., Artificial culture of fungi. N.Y. Ag. Exp. Sta. Bul. 97.

Sawyer, W.H., Observations on some entomogenous members of the Enlomonphthoraceae in artificial culture. Am. Jr. of Bot., 16:87-121, 1929.

___________, Destroying fungus. Mycologia 23:411-432, 1931.

Skaiffe, The locust fungus, Empusa grylli and its host. So. African Jr. Sci., 1925.

Thaxter, R., The Entomophthoreae of the U.S. Mem. Bost. Soc. Nat. Hist., Vol. IV, Ap. 1888.

Wardle, Problems of applied Ent. pp. 106-108.

Speare, A.T., A fungus parasite of the Periodical cicada.