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SOME MUSHROOM DISEASES AND THEIR CARRIERS

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The early history of mushroom cultivation in the United States contains no reports of serious troubles caused by fungous diseases.

A CASE OF BUBBLES

This is probably due to the fact that the growers were widely separated geographically, and that the diseases, while occurring to a limited extent, were not readily distributed.

[1] The first part of this circular, dealing with fungous diseases of mushrooms, was written by Vera K. Charles, and the second part, on insect contamination in mushroom houses, by C. H. Popenoe.

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"BUBBLES" DISEASE

Probably the most serious disease of the cultivated mushroom in this country is that commonly called "bubbles," due to a parasitic fungus of the genus Mycogone. Specimens of mushrooms with this disease were first received by the United States Department of Agriculture in 1909. Microscopic examination revealed the presence of Mycogone, the disease known in France as "la mole." The occurrence of this mushroom disease is now quite common in North America. This trouble has been recognized abroad as a serious disease for more than 40 years. It has caused extensive losses in England, France, and Germany and in severe cases has caused the abandonment of the business for a period of years or in extreme cases indefinitely.

Mushrooms affected with bubbles are deformed from the beginning of their growth. They are covered at first with a white cottony growth which later somewhat disappears, and the mushrooms become soft and rotten. The diseased mushrooms become greatly distorted, as is shown in the illustration on the title-page. Often the stem becomes swollen or bulbous or the entire mushroom presents a shapeless mass showing no differentiation of cap, gills, or stem. Where a cluster of mushrooms is attacked the entire cluster grows together into a misshapen mass. As the disease progresses, drops of a brownish fluid are exuded and the diseased mushrooms emit a very disagreeable odor.

It is generally believed that this disease was introduced with imported spawn. Certain phases of the disease in the beds are unknown. The mycelium is known to live in the wood of beds, especially when the wood is somewhat softened or beginning to rot, and particularly when the houses have not been fumigated thoroughly. Experiments in this office have shown that the fungous threads of the parasite Mycogone are present in the rotten wood and may retain their vitality for more than three years, showing that abandonment of a house for one year will not make it safe for growing a crop. The relation of Mycogone to the spawn is not exactly known. From the experiments and observations made, the presence of Mycogone does not prevent running of the spawn; the earliest evidence of the disease appears at the time the mushrooms begin to show.

Observations on the Mycogone disease in North America show it to be exceedingly variable as to its time of appearance and the severity of its attack. It may be noticed when the first mushrooms appear in a bed, or it may not develop until the season is about over. These two extremes are often seen, but ordinarily the disease is most destructive during the middle of the productive period.

The disease does not start at a single place in a bed. Diseased plants occur scattered among healthy plants, especially when the disease appears late.

In order to understand clearly how the disease is spread it is necessary to know the way in which the fungus causing the disease grows.

The usual method of plant propagation is by seeds. However, in fungi no true seeds are produced, but there are other bodies which

answer the same purpose. These are very small bodies called spores, thousands in number, each capable of starting a new plant and causing the disease. Mycogone or the bubbles fungus is doubly dangerous because it has two kinds of spores. One kind, which develops early, is produced on the cottony growth on the mushrooms. These spores are very thin walled and can not endure unfavorable conditions of temperature, humidity, or fumigation. The second kind of spore is two celled and thick walled, which makes it more resistant to unfavorable conditions such as heat and cold. The fungus in this stage is more difficult to destroy; consequently, it is important to collect and burn all diseased mushrooms as soon as they are observed, that is, when they show the velvety coat and before they have become soft and brown or smell bad.

In addition to spores, the fungus has a vegetative part, the mycelium, corresponding to spawn and consisting of a threadlike growth (hyphae) which works its way into the cracks or crevices of the wood of the beds and unless the houses are fumigated thoroughly will live over and start the disease again the next year.

CONTROL MEASURES

Two lines of attack—sanitation and fumigation—are absolutely essential in order to control the disease.

SANITATION

Sanitation is of primary importance, and without it fumigation is only half effective. As soon as a mushroom shows the bubbles disease it should be removed and burned. The practice of putting diseased mushrooms just outside the entrance to a mushroom house is of greatest danger, for the following reasons: (1) There are always air currents or wind which carry the spores into the houses; and (2) insects, especially flies, also carry spores. As shown by microscopic examination, the spores of the fungus cling to the wings, feet, and other parts of the body of the flies, and in this manner the disease is easily carried from an infected house to a healthy house, even to considerable distances. Another very easy way by which the disease is distributed is by mushroom pickers or other workmen who go from house to house attending to watering, ventilating, or other work. Soil containing spores of the fungus readily clings to tools, shoes, hands, or even clothing; therefore persons working in infected houses should not be permitted to go to a healthy house, or at least not before changing clothing or taking other precautions to prevent carrying spores from diseased mushrooms.

Where the method of ventilation includes opening the entire house, the danger from insect carriers of disease becomes very great. The screening of ventilator shafts and doors will materially lessen this source of infection.

The disposal of material from old beds is a very difficult matter, especially when mushroom establishments are near together. The manure from the beds is still of value as fertilizer and is easily disposed of to truck growers, but its utilization on near-by farms is one of the surest means of reinfection and spread of the disease. Some growers dispose of their manure very advantageously to golf

clubs, but this is safe only when the clubs are located at a considerable distance. Another important precaution in this connection is to fumigate thoroughly the trucks or carts in which the diseased material is carried before using these same trucks or carts for transporting the fresh manure for new beds. The same is true where freight cars are used.

Rigid sanitation and thorough fumigation may be practiced, but if care is not taken to select soil for casing which is free from all possibility of contamination, all of the work and expense, including collecting and burning the diseased material, house fumigation, and purchase of disease-free spawn, will be of no avail.

The extremely infectious nature of the fungus, the rapidity with which it grows, and the great vitality of the spores make the most painstaking care indispensable in prevention and control. The spores, as already pointed out, may be carried in the manure, in the casing soil, on boots and shoes, on tools and implements, and by wind, water, and insects. All diseased material must be removed, disinfected, and destroyed as soon as the disease appears, in order to prevent the reproduction and spread of the disease. Places where the fungus appears, the houses, the ground about them, the composting yard—wherever the disease might be carried—should be thoroughly sprayed or otherwise treated with a 2½ per cent solution of lysol or some other strong disinfectant (1 gallon of formalin to 45 gallons of water may be used).

As soon as the beds stop bearing the used compost should be put where the fungus which it contains can not return to the houses. As the disease does not attack other crops, the spent compost may be sold, but only to farmers who do not live near mushroom-growing establishments.

FUMIGATION

Fumigation with formaldehyde or sulphur or both has been found to be the most satisfactory means of control for the bubbles disease.

Certain successful growers use just sulphur. Where it is used as a combination fungicide and insecticide, the proportion of 5 pounds to 1,000 cubic feet of air space is used. Less will kill the fungi but will not control the insects.

Some years ago the department worked out a successful method of control by means of formaldehyde gas, which is described below.

To prepare for fumigation, remove completely all old bedding material from the house and dispose of the bedding as already described. Thoroughly spray the house with water and keep it warm and closed for about a week or 10 days. Select a warm, moist day for fumigation, as the gas is then more effective. To insure sufficient humidity, spray again with water the day before the fumigation is to be performed. Close and seal the house, making it as nearly airtight as possible by pasting paper over all cracks and filling up all openings to prevent the escape of gas. If leakage is allowed the fumigation may be ineffective.

Caution.—It is theoretically possible for formaldehyde to form explosive mixtures with the air; consequently, care should be exercised in its use and all flames kept away from the houses while they are being fumigated.

Fumigation by the chlorate method consists of mixing commercial 40 per cent formaldehyde solution with sodium chlorate and boiling water, the heat of the reaction acting to volatilize formaldehyde. The following materials are required: Formalin; sodium or potassium chlorate; boiling water; bags, paper, or cloth, of convenient sizes; receptacles, which should be of uniform size, deep enough so that the formalin will not boil over when the chlorate is added; they may be half barrels, washtubs, or iron or earthenware vessels, but they should not be of glass, as the heat evolved may break them. Ordinary galvanized pails are quite satisfactory and may be placed in pans, similar to dish pans, very wide so as to serve as trays for the formalin receptacles. Allow 1 pound of formalin for every 1,000 cubic feet of space and 5 ounces of sodium or potassium chlorate to every pound of formalin. If the house is of the usual size (24 by 100 feet), use at least three receptacles for generating the gas.

Weigh out the proper quantity of chlorate, divide it into as many parts as the number of vessels used, and put it into paper or cloth bags. Measure the proper quantity of formalin and divide it equally among the vessels. Place the vessels, each standing in a large flat pan, in their proper places in the building. The formalin should not be left standing uncovered very long in the house, as considerable discomfort may be experienced by the workers.

In houses of average size place the vessels in the center aisle. In larger houses one or more vessels should be placed in each aisle, as the gas must be evenly distributed to be effective.

Place a bag of chlorate beside each vessel. When everything is ready, beginning at the end of the aisle farthest from the door, place the chlorate in the formalin, and pour boiling water into the pan containing the vessel. Go quickly to the next vessel and repeat. After the chlorate has been added to each vessel, close the door at the end of the aisle and seal it with paper as quickly as practicable, as the action of the chemicals is rapid. It must be remembered that where there is one person to each aisle, the work of dropping the bags of chlorate into the formalin must be done at the same time, in order that all of the persons may get out at the same time and before the gas has become strong.

Keep the house closed for at least 24 hours. If possible do not open until just before the new beds are to be installed, thus preventing any chance of their being infected after fumigation. If the spent compost was piled near the house after its removal, under no circumstances open the house until this has been removed from the vicinity and the ground where it was placed thoroughly disinfected in the manner before described.

Approximately 1 pound of formalin per 1,000 cubic feet of air space is required for the boiling formalin method. In this method a tank containing the formalin is placed over a stove or a fire outside of the mushroom house. Pipes conduct the vaporized formalin into the mushroom house. This method is extremely cheap and highly effective.

The potassium permanganate method was advised by the department in the early studies of the disease, but the price of potassium permanganate became very high during the World War, and the substitute methods above mentioned have been found satisfactory and less expensive.

PLASTER-MOLD DISEASE

The plaster-mold disease has been known for many years in France, England, and Italy, where it has been the cause of great losses. The attention of the department was first called to it in 1920, when it appeared in the beds of a grower in California. This grower traced his trouble to spawn in which the fungus was introduced. This mold has been known to North American growers for some years, but it has never before attained the serious proportions which it has recently assumed. It is unlike the bubbles or Mycogone disease in all respects, as, for instance, time of appearance, method of injury, and appearance both to the naked eye and under the microscope. It is not a parasite on the mushroom, but runs through the manure, preventing or delaying the development of the spawn. If the fungus is abundant a loss of the entire crop may result. However, if the fungus is present in a more limited amount, mushrooms will develop later, but the crop will never be normal in quantity.

The plaster-mold fungus appears on the surface and sides of the beds as white patches which may be seen when the boards are raised. At certain stages in its development the fungus may also be seen by digging down into the beds, but it is generally dirty white or darker, according to the age of growth. When mature the white patches of the fungus are powdery. A microscopic examination shows the white areas to consist of thousands of colorless oval spores borne in chains. As the fungus matures, the chains break up and the spores separate. The spores are light and easily carried by wind; thus the disease is easily spread. Small insects, especially flies, may also spread the disease and are an unusually important factor in its distribution. As the fungus is present both in the manure and on the surface of the beds, insects come in contact with it at different stages of their development. Locating manure piles for refilling beds in close proximity to mushroom houses is a very dangerous practice, because the flies covered with spores gather around the doors and when they are opened the flies come out in great numbers and light on the nearest pile, shedding spores on the manure, which start a new growth of the fungus. In this manner the manure is often well infected with the fungus before it is taken into the house to make up new beds.

The study of control methods for this disease is being carried on, but no satisfactory means has yet been found. The disease is very difficult to control because the spores are so numerous and easily distributed by wind and insects. The danger of infecting new manure not yet brought into the houses is therefore very great, and every effort should be made to avoid introducing infection in that way.

INSECT CONTAMINATION IN MUSHROOM HOUSES

The presence in mushroom houses of the two diseases considered above renders it even more than ordinarily necessary to control various insect pests which attack mushrooms. Every grower is familiar with the small black mushroom flies which produce the maggots in the caps, and with the losses which they are at times capable of causing. He may not, however, appreciate their possibilities in the distribution of such diseases as plaster mold and

bubbles. In houses where these diseases occur mushroom flies have been examined which carried on their somewhat spiny bodies and legs hundreds of spores of these fungi. In addition to these, there are other flies much like them in appearance which feed in the compost and ordinarily do not injure mushrooms. They are, however, able to distribute the spores of these diseases in the same manner as the flies producing the injurious mushroom maggot. All of these flies move actively about through mushroom houses, both by walking and by flight, and are undoubtedly responsible for the rapid increase in the distribution of the diseases in large houses. Diseased mushrooms develop an odor likely to attract some of the larger carrion flies from outside, and these larger flies are capable of carrying much greater numbers of spores throughout the house. On this account particular attention should be paid to the proper screening of the houses. Springtails also are adapted by nature, through their fine, scaly coats of bristles and by their activities on the beds, to further the distribution of these diseases.

It has been noted that some growers are extremely careless in the disposal of diseased compost. Cases are known to the writers wherein compost cleared from beds in which serious loss from disease has occurred and full of fungous spores was merely piled outside the door of the house during the time the house was being refilled. This permits the carriage of the disease into the house and to the new compost both by the feet and clothing of the workers and by the myriads of flies leaving this disease-infected material to enter the house each time the door is opened. The house may be thoroughly cleaned and disinfected, but under such circumstances the crop is sure to be a loss through these diseases.

CONTROL MEASURES

In the event that either of the diseases described in this circular makes its appearance in a restricted portion of the mushroom house, its spread may be materially delayed by maintaining as great freedom as practicable from both flies and springtails. There is a present tendency toward the use of varieties of mushroom spawn which produce much better crops when maintained at temperatures in excess of 60° F. The increased temperature maintained in commercial establishments producing such mushrooms is likely to cause more rapid multiplication and consequently greater abundance of both mushroom flies and springtails and therefore to increase the rapidity of disease distribution. Much can be done, however, to offset these conditions by applying fumigation or other control methods against these insects so frequently that the adults will be killed practically as they emerge. It is the practice in large commercial greenhouses to apply nicotine or cyanide fumigations for certain insect pests even two to three times a week to attain this result, and a good crop of mushrooms equals in commercial value many of the greenhouse crops protected in this manner.

NICOTINE

The fact that nicotine is quite poisonous to flies of this type renders it possibly the most practicable fumigation material. It should be used from medium to heavy strength and either dusted through

the air of houses in the form of nicotine dust or evaporated from commercial solutions or nicotine paper which can be purchased from almost any seedsman or nursery firm. The commercial nicotine preparations vary in strength to such an extent that it is impracticable here to furnish detailed directions as to the dosage. It is therefore suggested that directions on the commercial package be followed in fumigating with this material. Nicotine will not in any respect damage the mushroom crop or prevent the running of the spawn.

Free nicotine is preferable to nicotine sulphate for use in mushroom houses, as it is rapidly volatilized and may be sprayed on the beds. Nicotine-sulphate solutions, on the other hand, are only slightly volatile and require the addition of an alkali to release the free nicotine and render the solutions fully effective. The soap ordinarily recommended for this purpose by the manufacturers is injurious to the growth of mushrooms when sprayed on the beds, so the use of air-slaked or hydrated lime at the rate of 1 pound to each 50 gallons of nicotine-sulphate solution is recommended as a substitute.

HYDROCYANIC-ACID GAS

Hydrocyanic-acid gas is used to some extent in mushroom houses as a fumigant. In practice it may be applied at either of two different times in the course of cropping. A number of growers fumigate the house with calcium cyanide at the rate of 1 pound per 1,000 cubic feet at the time of maximum heat before spawning and afterwards give it a thorough ventilation. The advantage of this method is that at that time the insects ordinarily concealed in the compost of the bed are driven therefrom by the heat generated by the manure, which at times reaches 150° F. They are then likely to be well exposed to the action of the fumigant, since they are congregated on the outside of the beds where the temperature is lower. A single fumigation applied at this time is particularly effective in destroying the majority of insects carried into the house in the compost or breeding thereafter up to the time of fumigation.

The practice of fumigating with light doses of calcium cyanide, applied two or three times a week over a period of two weeks, has also gained some headway with commercial growers. Some operators have recommended the use of 3 ounces of sodium or calcium cyanide to each 1,000 cubic feet of space, applied preferably after the gathering of the crop and while the atmosphere of the house is relatively dry. In the event that houses containing growing mushrooms are fumigated, care should be taken that the fumigation is conducted on a rising temperature, as otherwise the moisture precipitated upon the young caps may cause serious spotting and burning. The gas may be released in the evening and the house thoroughly ventilated before sprinkling down the following morning. The tightness and construction of the house will have a bearing on the dosage required, and the quantity mentioned above, i. e., 3 ounces to 1,000 cubic feet, should be considered as a maximum. Growers have found, however, that the process of fumigating at this rate is somewhat dangerous, as the margin of safety between effective fumigation and damage to the crop is relatively narrow, and undue concentrations of the gas in certain parts of the house may occasion browning or burning of mushrooms above the ground. If fumiga-

tion of the growing crop is attempted, applications varying from one-half ounce per 1,000 cubic feet upward to the limit mentioned above should be tested, the minimum quantity required for a satisfactory kill being used.

Caution.—Fumigation with hydrocyanic-acid gas is a process requiring considerable precaution in its application, as the gas is extremely poisonous to human beings. It is therefore recommended that Farmers' Bulletin 880 and Department Circular 380 [2] be obtained from the Department of Agriculture before undertaking this method. If growing mushrooms are fumigated with hydrocyanic-acid gas, they should receive a thorough airing over a period of some hours before being marketed, as the retention of such gas as might be absorbed by them or held in the gills during the process of fumigation constitutes a possible source of danger to the consumer.

INSECT POWDER

Many large growers depend on the use of pyrethrum or Dalmatian insect powder for the control of flies and springtails in mushroom houses. This method is entirely safe and reasonably satisfactory, and the insecticide may be used at a considerable strength without possible injury to the crop. The powder may be dusted over the beds or burned in the alleyways between them with equally good results. A dosage of 1 pound per 1,000 cubic feet of space, applied every other day during a period of two weeks, is the usual practice.

Pyrethrum extracts are on the market and are also useful in controlling insects. It is inadvisable, however, to use extracts prepared with mineral oils or soap for spraying upon the beds, as a deleterious deposit is thereby produced.

Pyrethrum of the highest grade, composed of ground pyrethrum flowers and packed in air-tight metal containers, should be used, as the lower grades are likely to prove unsatisfactory.

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[2] SASSCER, E. R., and BORDEN, A. D. FUMIGATION OF ORNAMENTAL GREENHOUSE PLANTS WITH HYDROCYANC-ACID GAS. U. S. Dept. Agr. Farmers' Bul. 880, 20 p., illus. 1917. WEIGEL, C. A. CALCIUM CYANIDE AS A FUMIGANT FOR ORNAMENTAL GREENHOUSE PLANTS. U. S. Dept. Agr. Circ. 380, 16 p., illus. 1926.

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