

# Cobweb or Dactylium

Cobweb disease can be caused by a number of different but related fungi. *Cladobotryum dendroides* (syn. *Dactylium dendroides*) which is the conidial state of *Hypomyces rosellus* has historically been considered to be the commonest cause. *Cladobotryum mycophilum*, the conidial state of *Hypomyces odoratus*, is also commonly found in Europe, North America and South Africa. *C. mycophilum* produces a characteristic odour on agar, which has been described as being similar to that of turpentine. A form of the pathogen showing some characteristics of *C. dendroides*, but genetically closer to *C. mycophilum*, has been found in the UK and has been referred to as *C. mycophilum* type 2. So far, all isolates of this form are resistant to thiabendazole fungicides. *Hypomyces aurantius* (stat. conid. *Cladobotryum varium* syn. *C. variospermum*), *Cladobotryum multiseptatum*, and *Cladobotryum verticillatum*, have all been recorded as causes of Cobweb disease, but there is no information on their incidence or importance.

In recent years, Cobweb disease has become common and a serious cause of crop loss not only in Europe but also in the USA and Australia. Its increase has coincided with changes in cultural techniques, in particular casing type and watering. Control with fungicides has become increasingly more difficult because of the development of resistance to the benzimidazole fungicides, and a decreased sensitivity of some forms to prochloraz manganese.

## Symptoms

None of the various symptoms are associated with any one particular species of *Cladobotryum*. It is possible that all of the species involved do not produce all of the symptoms, which could account for some of the variation in appearance with locality.

One of the main symptoms of Cobweb disease is the cobweb-like growth of mycelium over the surface of mushrooms, hence the common name. The colonized surface turns pale brown (66). This discolouration, together with the presence of the off-white mycelium of the pathogen, is very diagnostic (67). Cobweb mycelium is able to grow over the surface of the casing in the absence of mushroom fruiting bodies, but not in the absence of mushroom mycelium. Patches of dense white powdery

mycelium, sometimes circular in shape, may appear on the surface of the casing (68). Many spores of the pathogen are produced from this mycelium. Occasionally when left on the bed, diseased mushrooms turn a red or yellow colour (69). Affected mushrooms eventually turn brown or black and rot. Cap spotting also occurs and can cause large crop losses. There are two types of spot. The commonest has dark brown spots characterized by a poorly defined edge. They are very similar in appearance to those caused by *Trichoderma aggressivum* (70). The spots develop in 3–4 days from spore germination. Extensive spotting of a flush can occur when inoculum concentrations are high and conditions for spore germination favourable. Spots can also develop after harvest. In the second form of spotting, more or less circular spots, light brown in colour, develop. The



66 Mycelium of *Cladobotryum dendroides*, Cobweb, on the surface of the casing and attacking developing mushrooms (*Agaricus bisporus*).



67 Cobweb mycelium discolouring mushrooms (*Agaricus bisporus*) as it colonizes their surfaces. The mycelial strands hanging from the affected mushrooms give the disease its common name as they resemble cobwebs.



68 (a) Dense white circular patches of Cobweb mycelium sometimes develop on the casing surface. When seen close up, the mycelium can be seen to be powdery and is a major source of the spores of the pathogen (b).



69 Pink-coloured mushroom tissue in a Cobweb patch.



70 Spots on a mushroom from a crop (*Agaricus bisporus*) with a severe attack of Cobweb. These spots are very similar to those of both *Aphanocladium* and *Trichoderma*.



**71** An unusual spot caused by *Cladobotryum*. These spots increase in size as the pathogen colonizes the surface of the mushroom (*Agaricus bisporus*).

spots appear to grow from a point source and radiate out until a large proportion of the cap is affected (71). Extensive colonization of harvested mushrooms may also occur after harvest when the crop is stored in damp conditions (72).

### The pathogen and disease development

The pathogen (*C. dendroides*) grows best at 25°C, at 90% RH and pH 5–6, but sporulation is most abundant at 25°C and 95% RH. Conidia are the only commonly occurring spore form of this pathogen, although there are research records of the occurrence of microsclerotia in laboratory cultures. It is not known whether or not these are significant in practice. The spores are relatively large and multicellular, but are very readily dispersed in air. Any physical disturbance of the air near to a patch of Cobweb will result in spores becoming air-borne. This is the main way in which the pathogen is distributed on farms, but perhaps also between farms. Air-borne spores may contaminate returnable plastic containers taken into an affected crop and, in this way, the pathogen could be spread from farm to farm.

Even the operation of covering diseased mushrooms with salt or a pot can result in significant spore dispersal. The spores can also be spread by water splash (which also makes them air-borne), in drainage water, and by pickers. In recent epidemics flies, in particular sciarids, have been implicated in spore spread, but as



**72** A container of Cobweb-affected mushrooms which have been stored for a few days in a warm place. It only needs one or two affected mushrooms for the whole quantity to be colonized in favourable conditions.

the spores are not sticky, it seems unlikely that flies or even pickers are a significant means of dispersal. In addition to these mechanisms, the pathogen can be distributed as small fragments of mycelium present on the surface of mushrooms or casing. Small pieces may be carried in air currents or be accidentally spread during harvesting and be part of the dust.

The pathogen has been found in soil and is known to attack some species of wild mushrooms. Possible initial sources include soil, contaminated casing, air-borne spores and/or mycelial fragments, contaminated dust and debris, flies, and contaminated workers. Harvested mushrooms that are moved between farms for packing can also be a very important initial source, as well as the returnable plastic containers they are in.

Most commonly, the first symptoms of the disease are seen in the later flushes, but once established on the farm, they may appear at any stage. Experimentally, it has been shown that mycelial fragments applied to casing result in the rapid development of Cobweb symptoms, whereas even large spore loads may not immediately induce disease. Spores quickly cause cap spotting. Symptoms in the third flush may therefore have resulted from spore contamination of the casing either before or shortly after it was applied. Unlike *Verticillium* and *Mycogone*, this pathogen is capable of growth on or through casing. In this respect it is possible that contaminated compost can also be a source.

Disease development, whether it is the Cobweb

symptom or spotting, is considerably influenced by the presence of water or very high humidities. When water does not evaporate from the casing or the surface of mushrooms, Cobweb is likely to be severe. Sometimes the slope of a growing room is sufficient to result in humidity differences along its length, with Cobweb developing in the colder wetter parts.

### Control

The use of wetter casing and the development of fungicide resistance have made this disease much more difficult to control. Surface wetness and a non-evaporating casing will encourage disease development. In order to help prevent epidemic development, the environment must be controlled to give continuous evaporation (*see p. 58*).

Effective steam cook-out is by far the best way to control Cobweb. Fresh spores are reported to be killed by a 30-minute treatment at 45°C, but are able to withstand much higher temperatures, even as high as 100°C when dry. Similarly fresh mycelium is killed at 40°C when this temperature is maintained for 15 minutes, but dry mycelium withstands 70°C for 15 minutes. On farms where it is not possible to achieve higher temperatures, cook-out at 50°C can eliminate many of the spores.

Spore dispersal resulting from watering-affected areas of crop, or careless application of salt to affected patches, is considered to be one of most important factors in recent outbreaks of the disease. Air-borne spores can contaminate any surface. For instance, returnable plastic containers used in an affected crop can easily become contaminated and must be cleaned before reuse (*see p. 44*). The same applies to any equipment or implements.

In order to minimize air-borne spores, affected mushrooms and areas of casing should be very carefully covered with a damp paper towel which is then covered with salt, starting at the outside of the patch and working inwards (*see p. 42 and 34*).

It is important to examine the layout of the farm to check whether it is possible for spores to move from an affected crop to a healthy one. Some form of filtration on incoming and outgoing air minimizes spread. Absolute filtration should not be required for growing rooms, but filters that will remove most, if

not all, of the air-borne spores, are needed. A 5-micron filter is usually adequate for this job. During picking of affected crops, the doors of houses should be kept closed as much as possible to prevent air moving from affected crops to nearby healthy ones. Positive air pressure used in cropping rooms can aid spore spread, especially at harvesting when the doors are open.

At crop termination, the spores may become air-borne and can then be transferred to a new crop (*see crop termination, pp. 46–48*). This is particularly the case during spray-off. If chemically terminated crops are taken through the farm it is vitally important to make certain that there are no untreated Cobweb patches on the cropping surface.

Before applying fungicides, it is important to know the sensitivity of the pathogen affecting the crop. Of the fungicides available, prochloraz manganese (Sporgon/Octave) and the benzimidazoles (Bavistin, Benlate, and Tecto) are effective, but not on all isolates. Some strains of the pathogen are moderately insensitive to prochloraz. Similarly, many strains are resistant to thiabendazole while being sensitive to benomyl or carbendazim. Some are resistant to all the benzimidazoles.

Chlorothalonil (Bravo) gives some control of all isolates but is not as effective as the other fungicides. Recently a natural product, Trilogy, has been recommended in the USA (*see p. 61*). Generally, the choice of fungicides is between prochloraz manganese and carbendazim.

### Action points

- Cover affected mushrooms and areas of casing very carefully as soon as they appear, using damp paper towels and salt (*see 34*).
- Never water or handle untreated areas of disease.
- Check harvesting procedures to minimize the chance of transfer of air-borne spore and mycelial fragments from one crop to another (*see pp. 43–44*).
- Do not harvest crops that have not been inspected and treated.

*Continued overleaf*

### Cobweb or Dactylium action points (*continued*)

- Fit air filters to input and exhaust ducts in cropping rooms.
- Test for fungicide sensitivity.
- Apply the appropriate fungicide.
- It is important to prevent long periods of cap wetness and to avoid poor evaporation from the casing surface (*see p. 58*).
- Check all aspects of crop termination to eliminate inoculum at the end of each crop (*see pp. 46–48*).
- All returnable plastic containers must be cleaned before being taken into a crop.

# False truffle

The False truffle fungus (*Diehliomyces microsporus* syn. *Pseudobalsamia microspora*) not only competes in the compost for food and space, but is believed to attack mushroom mycelium and cause mycelial death. There are very few recorded pathogens of mushroom mycelium and in this respect it is unusual. It is sporadic in occurrence and less common than it was, but when it occurs it can persist and be difficult to eradicate.

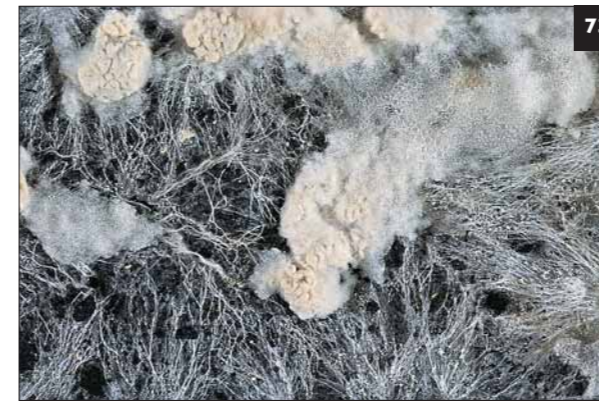
### Symptoms, the pathogen, and disease development

*D. microsporus* is a common soil dweller and severe outbreaks on farms often follow operations which involve soil movement. When soil was used as casing, False truffle was a much commoner problem. Where *Diehliomyces* mycelium grows, the mushroom mycelium disappears, and the compost is black, often wet, and is said to have a characteristic chlorine-like smell. For severe crop loss to occur, False truffle must be present in the compost at or during spawn-running, and then yield reductions can be as high as 75%.

The mycelium of *D. microsporus* is initially white, becoming cream to pale pink in colour, and it often grows in dense cotton-wool like wefts (73). Initially it can be virtually impossible to distinguish from the mycelium of the mushroom (*see Sectoring, p. 167*), but becomes distinct with age as it changes in colour

to red-brown (74). The False truffles (ascocarps) of the fungus form within the dense wefts of mycelium within 15–21 days, depending on the temperature, and are often the only indication of the presence of the mould, as they persist after the mycelium has disappeared.

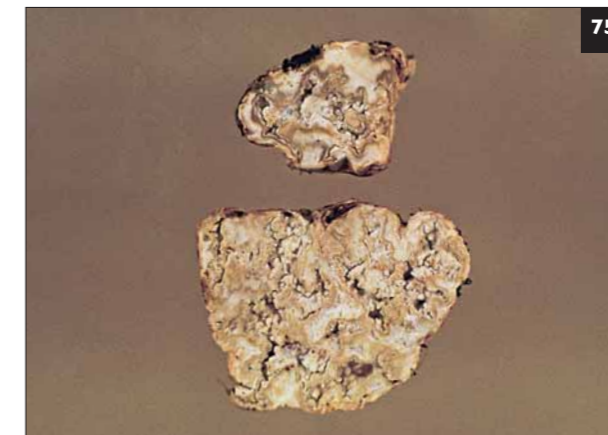
False truffle is often first found when non-cropping areas of bed are carefully examined. Small creamy-brown coloured corrugated lumps of tissue (ascocarps) may be found in the compost of these areas. Ascocarps vary in length from 3 mm to 40 mm, and although initially light in colour, turn ochre yellow to red-brown as they age. The exterior corrugation on their surface gives them a characteristic appearance, often said to resemble a shelled walnut or the surface of a brain (hence the once common name 'calves' brains', 75). The ascocarps most frequently form at the casing-compost interface (76), but also along the sides of trays or beds, or against the base of the bed, and



73 Dense white fluffy mycelium of the False truffle fungus in contrast to the whiter stringy mycelium of the mushroom.



74 Dense growth of red-brown mycelium of the False truffle fungus. The colour intensity increases with age.



75 A false truffle, the ascocarp of *Diehliomyces microsporus*, cut through showing the corrugations which account for one of the common names for this disease, 'calves' brains'.



76 False truffles of the fungus *Diehliomyces microsporus*, forming predominantly between the casing layer and the compost.

anywhere within the casing or compost, including on the surface of the casing (77). They form on the outsides of spawned blocks, or bags of compost, next to plastic covers. The ascocarps contain many small ascospores about 5 microns in diameter and following their breakdown by bacteria the ascospores are released into the casing or compost. Spread of the ascospores is most likely to occur in drainage water, and with debris.

The optimum temperature for the germination of ascospores is 30°C, although they will germinate at much lower temperatures (16°C). Spore germination is said to be stimulated by the presence of actively growing mushroom mycelium. A short initial period of 1–2 days after spawning at 30°C is enough to stimulate the development of False truffle. Such conditions can occur in hot weather, especially with bag or block compost, or in any crop where cooling is not adequate. Ascocarps do not form at 16°C, but compost is rarely this cold, with the possible exception of bag and blocked compost which has cooled during transit, especially in cold winter conditions.

Ascospores were once thought to be very heat- and chemical-tolerant, but this is not the case. False truffle, in contaminated compost, is eliminated when heated to 60°C for 2 hours. Treatment at lower temperatures or for a shorter time is not effective. In this respect, False truffle should not survive phase II, and the general improvement in phase II may account for the decreased incidence of this disease. A high level of gaseous ammonia at kill

(at least 450 ppm) is also important in the elimination of the fungus.

The most likely initial source of the pathogen is soil mixed with compost ingredients. An ineffective phase II would then allow spores to survive. Once established on a farm, the ascospores may be on any surface, but are most likely to be on containers such as trays and shelves, as well as in the dust on the floor of the growing room. *Agaricus bitorquis* can be seriously affected by False truffle; the higher growing temperature used for this species is a significant factor.

### Control

If False truffle is a persistent problem on a farm, the phase II process should be carefully examined, and temperatures checked throughout the compost. Poor phase II together with soil-contamination of phase I compost (often by water draining from nearby land), are major factors in the occurrence of the disease. The phase I area should have a smooth concrete surface to allow thorough power washing between batches of compost. Soil contaminated straw is also a possible source. Such contamination occurs as a result of storage on a soil surface, splash during periods of heavy rain before harvest, or harvesting with the roots of the plants attached.

Strict attention to hygiene, an effective phase II, and the use of filters (2 micron) in both the phase II spawning and spawn-running areas, will prevent False truffle occurring. A satisfactory level of gaseous



77 Ascocarps of *Diehliomyces microsporus* on the casing surface.

ammonia (450 ppm), measured 3 hours after the maximum kill temperature, is also very important. Covering the spawn-run with paper and regularly spraying it with Formalin (0.25% *see* p. 56) will minimize the risk of late contamination. High compost temperatures for periods of 24 hours or more during spawn-running must be avoided, as these will encourage the germination of ascospores.

All affected crops must be cooked-out or chemically treated. A temperature of 65°C maintained for 12 hours is adequate to kill ascospores, but it is important to make sure that this temperature is achieved throughout the compost. In

addition, trays and wood used to make shelves must be thoroughly cleaned by heat or with a disinfectant at the end of cropping. Lining trays with polythene, which is replaced for every new crop, can minimize the risk of carry-over. If heat is not available, Formalin fumigation of empty trays can be effective. Thorough net cleaning in shelf systems is also essential. Special attention should be given to disinfecting floors. There are no satisfactory fungicidal treatments of compost or casing either before or after the disease has occurred.

All *A. bisporus* spawns can be affected.

### Action points

- Correct phase II temperatures must be achieved.
- Aim for at least 450 ppm of free ammonia measured 3 hours into phase II.
- Prevent soil contamination of compost by ensuring that the compost yard is adequately cleaned between batches of compost, and that the straw is free from soil.
- Use absolute filters during phase II, at spawning, and during spawn-running.
- Avoid high temperatures of 30°C and above during spawn-running.
- Achieve an effective cook-out.
- Cook-out empty trays and shelves.
- Remove all debris from trays and shelves and chemically treat between every crop if cook-out is not available.
- Line trays with polythene.
- Thoroughly disinfect the floor of affected cropping houses if they have not been heat-treated.
- Do not leave newly spawned bags and blocks stacked for longer than is absolutely necessary, especially in summer, in order to minimize the risk of the compost overheating.