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Department of Agriculture
New South Wales

Agdex
271/630

Diseases of cultivated mushrooms

Agfact H8.AB.30, first edition 1984
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Mushrooms, like any other cultivated crop, are subject to attack by diseases. However, since commercial production is now carried out in a controlled environment at all stages from preparation of compost to final disposal of spent materials, growers can greatly reduce disease problems by careful management.

Control measures outlined here for virus, dry bubble and brown blotch diseases, as well as for weed moulds, are good examples of disease management by environmental manipulation. The close relationship between management practices and disease problems is most obvious with endemic diseases, such as dry bubble.

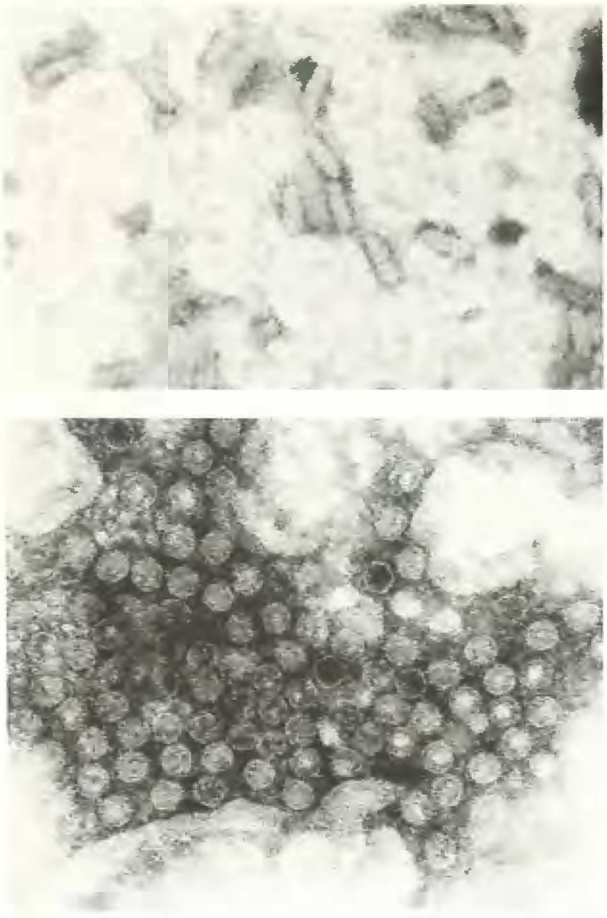
Three avenues of disease control are open to mushroom growers overseas:

- ecological—manipulation of environmental factors such as temperature, humidity and ventilation;
- biological—use of antagonistic organisms; and
- chemical.

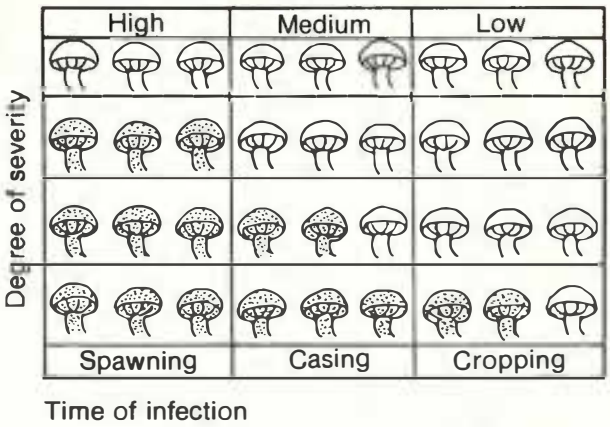
Often an integrated approach, combining ecological, biological and chemical measures, is needed to control mushroom disease. At the time of writing, there were no products registered for use in New South Wales as biological or chemical control agents against mushroom pathogens. However, as products are at present being assessed with a view to possible registration for these purposes, growers are advised to contact the Department for current recommendations (see details p. 11).

Healthy *Agaricus bisporus* mushroom. All commercially grown strains are susceptible to virus disease.

Virus infection in these mushrooms has caused "drumstick" formation. Other effects of virus disease are illustrated overleaf.



Virus particles seen under an electron microscope. Top: sausage shaped particles 19 × 50 nm; lower: 19 nm spherical particles.



How time of infection influences severity of virus-disease outbreak. Spotting on mushrooms indicates infection.

VIRUS DISEASES

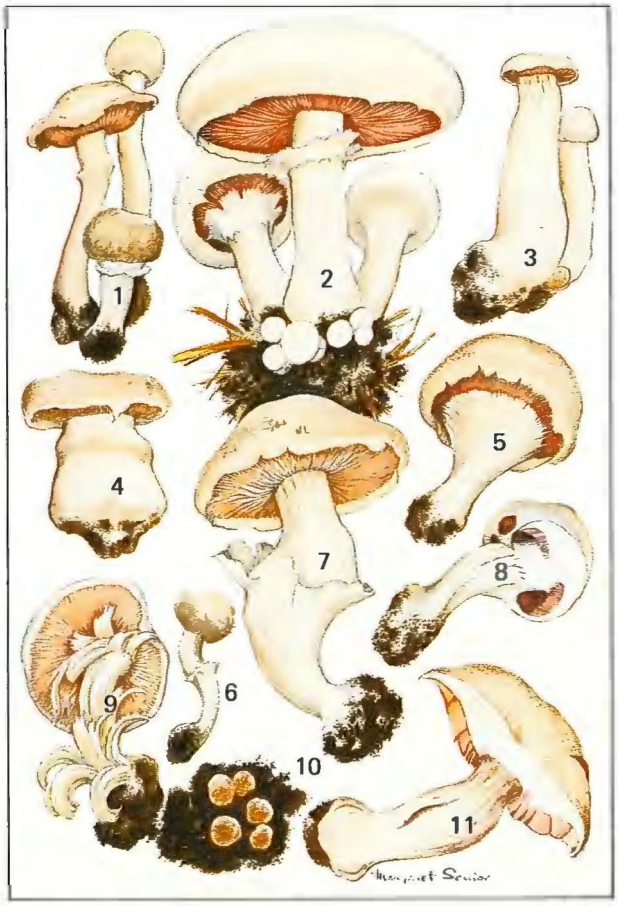
Virus infection causes one of the most serious diseases of cultivated mushrooms.

Cause: Six virus-like particles have been observed in Australia. Five of these are spherical virus particles 19, 25, 29, 35 and 50 nm diameter and one is a sausage-shaped particle 19 x 50 nm. Particles 19 x 50, 25, and 35 nm are the most commonly observed viruses in diseased mushrooms. They may occur singly or, more commonly, in combination.

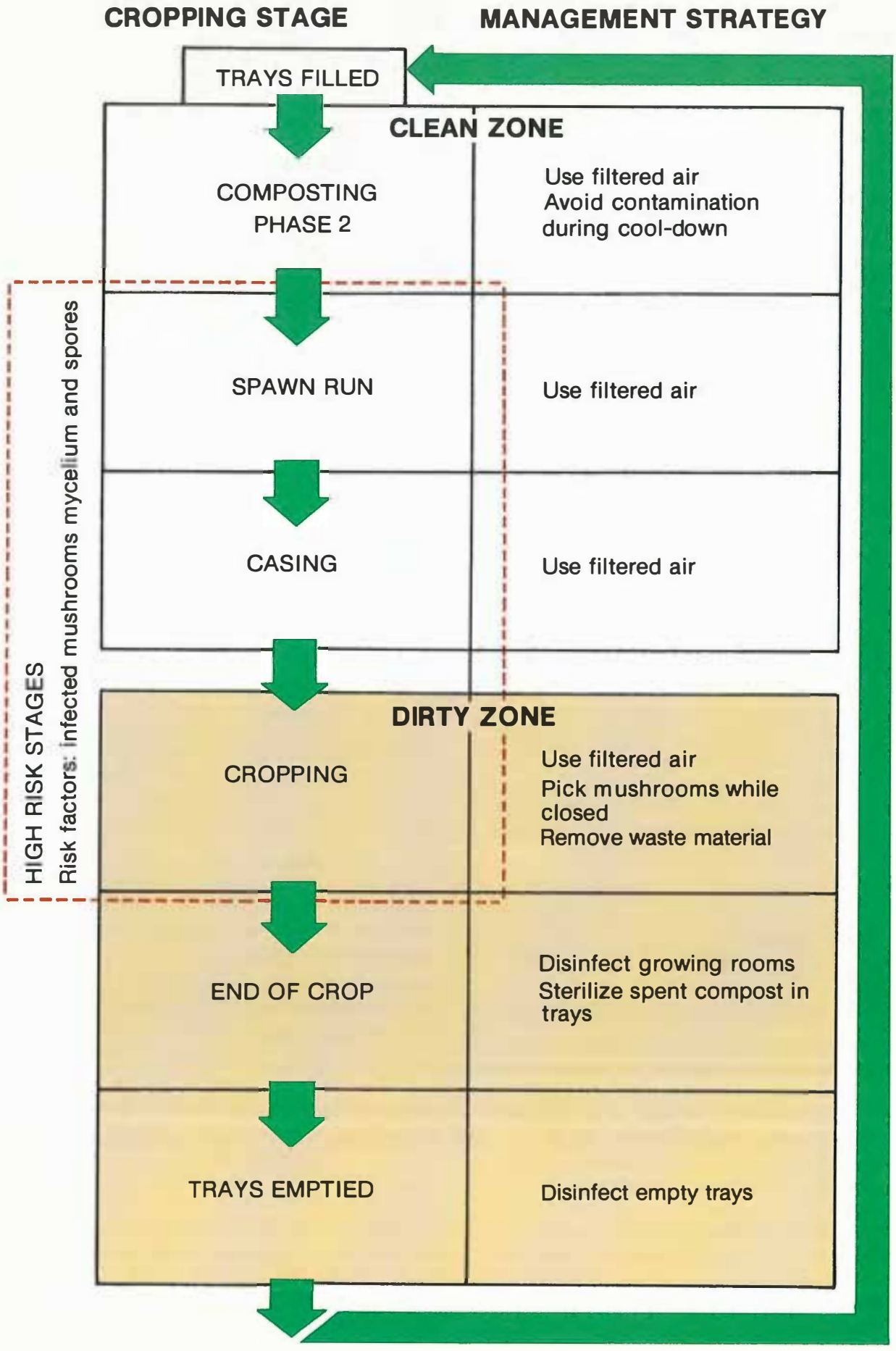
Symptoms: Varied. "Drum-stick"-formation (long stalks and small caps) and premature opening of the veil are indications of virus infection, but these symptoms are also caused by certain environmental and cultural factors. Other symptoms of virus infection are bending, splitting and swelling of the stalk. Severe infection can lead to bare patches on the mushroom beds.

It has not been possible to associate any particular type of virus particle with any specific symptom: in fact, virus-infected mushrooms may show no symptoms. Virus particles have been detected in apparently healthy mushrooms from relatively high yielding crops. Infected mycelium grows slowly in the mushroom beds and in these areas fruit bodies are not produced. Thus bare patches can be seen on mushroom beds infected with viruses. As a general rule, infection of the crop at spawning can lead to a high level of disease. Infection entering at casing and cropping is likely to result in moderate and low levels of disease respectively.

Symptoms of virus infection—1: drumstick formation; 2: healthy mushrooms; 3: premature opening of veil; 4: swollen stalk; 5: tapering stalk; 6, 7, 8: bent and twisted stalks; 9: split stalk; 10: dying pinheads; 11: swollen stalk.—Illustration: Margaret Senior.



VIRUS CONTROL/PREVENTION PROGRAMME



Sources of infection: Viruses carried in spores from infected mushrooms are the most common means of spreading the disease. Virus-infected mushroom mycelium can also survive in mushroom trays and transmit the disease to fresh mushroom mycelium of succeeding crops.

Effects of the disease: Severe infection significantly reduces yields and can even lead to complete crop failure.

Varietal reaction: All commercially grown strains of *Agaricus bisporus* are susceptible to the disease, but the strains of *A. bitorquis* are known to be resistant.

Preliminary diagnosis is based on symptoms of diseased mushrooms, but the presence of virus diseases can only be confirmed by examination of diseased specimens under an electron microscope. The Department's Biological and Chemical Research Institute, Rydalmere, will test specimens for commercial growers.

Control: Strict farm hygiene is the best means of prevention and spread. As a routine measure, disinfect all machines used for filling, spawning and casing after each operation, as well as the work areas and growing rooms.

Sterilize mushroom trays after cropping by steaming for 12 hours at 70°C. After steaming, remove trays from the growing room, dispose of spend compost and disinfect the emptied trays. To prevent the virus from spreading, pick mushrooms while the veils are still closed.

A well-designed and built farm can greatly reduce the risk of infection. Plan farm layout so that there is one-way movement from the "clean" to the "dirty" area during normal operations; and install filters to treat air entering spawn-running rooms, growing rooms, and work areas used for spawning and casing (see diagram p. 3).

FUNGUS DISEASES

DRY BUBBLE

Cause: The fungus *Verticillium* (*V. fungicola*).

Symptoms: Initially, brown spots appear on mushroom caps. At this stage, the disease can be confused with bacterial brown blotch. But if mushrooms are incubated in a humid chamber, the brown spots of those affected with dry bubble will give rise to a greyish-white growth: the mycelium of the *Verticillium* fungus. Infected mushrooms can be deformed with swollen and curved stalks, sometimes with strips of tissue peeling and then curling upwards. The infection commonly spreads up one side of the mushroom so the stalk and cap do not develop on that side of the fruit-body. This results in an unbalanced and tilted cap.

Blemishes on cap and greyish-white growth on gills are caused by dry bubble disease. Note that infection has spread up one side, creating an unbalanced and tilted cap.

The name "dry bubble" refers to the appearance of affected mushrooms. When deformed by this disease, mushrooms are rarely solid and there are spheres ("bubbles") of undifferentiated tissue on the caps. These spheres have a dry surface covered by a greyish-white powdery layer—the conidia, or spores, of the pathogen. The disease does not usually occur on the gills of mushroom fruit-bodies.

Sources of infection: Soil dust, casing soil, infested trash and spent compost. The pathogen is transmitted by air currents, splashing water, mushroom flies and farm workers. Growing-room temperatures of 15 to 18°C combined with 90 to 95 per cent relative humidity are ideal for the growth and spread of the pathogen.

Effects of the disease: Recontamination within the mushroom production units leads to repeated outbreaks of the disease in the farm. Spread of the disease throughout a growing room can seriously reduce yields.

Varietal reaction: All commercially grown strains of *A. bisporus* are susceptible. However, strains of *A. bitorquis* appear to be less sensitive to infection, as they are not susceptible to attack by the same variety of *Verticillium fungicola*.

Control: Incidence of the disease can be reduced by decreasing humidity in the growing room to 80–85 per cent, and by lowering the growing temperature to 14°C. A short picking cycle can further reduce the likelihood of infection. Control of the disease depends also on farm hygiene: prompt disposal of spent compost and debris and disinfection of mushroom beds. If soil is to be used as a casing material, pasteurize it at 60°C for half an hour with aerated steam before spreading it over the beds.

WET BUBBLE

Cause: The fungus *Mycogone perniciosa.*

Symptoms: Infected mushrooms have malformed stalks and caps, and the surface is covered by a white "felt"—the mycelium of the pathogen. The undifferentiated tissues of the cap and stalk are destroyed by a wet, soft rot that drips a brown liquid. The name "wet bubble" is derived from the foul-smelling, misshapen wet mushroom tissues.

Sources of infection: Contaminated casing material and soil are the main sources of infection. Infection spreads within the growing room by means of the conidia (normal spores) of the pathogen. These may be airborne, but can also be spread by water splash and by workers during cultural operations. Primary infection can be caused by the thick-walled spores (chlamydospores) of the pathogen which are produced under certain conditions and can survive for a long time in soil.

Effects of the disease: Wet bubble reduces yields and also downgrades quality of mushrooms for the fresh market. The disease has been seen mainly on small farms that use soil as a casing material. Outbreaks of the disease in bigger farms have often been related to earth moving work close to the farm.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Disinfection of casing material (or steam-air pasteurization if soil is used as the casing material), can control the disease. Developing mushroom fruit-bodies must be protected throughout the cropping period by good hygiene. This means giving full attention to disinfecting the work area, removing all spent materials, disinfecting all harvesting tools and carrying out after-crop sterilization using steam at 70° C for 12 hours.

Mushrooms infected with wet bubble disease are misshapen and foul-smelling. Tissues of cap and stalk are undifferentiated.

Aphanocladium disease: symptoms of infection on gill tissues.

APHANOCLADIUM DISEASE

Cause: The fungus *Aphanocladium album.*

Symptoms: Infected mushrooms develop brown spots which, under conditions of high relative humidity, show the greyish-white mycelium of the fungus. The gill tissues of the mushroom fruit-body are a common target for infection by the pathogen.

Sources of infection: Contaminated casing material and soil appear to be the main sources of infection. Spread within a mushroom growing room can occur under conditions similar to those favouring dry and wet bubble diseases.
Effects of the disease: Reduction in the yield and quality of mushrooms.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Disinfection of the casing material appears to control the disease. Management of the crop environment, similar to that recommended for dry and wet bubble diseases, is also effective.

MILDEW

Cause: The fungus *Cladobotryum* sp.
(= *Dactylium* sp.).

Symptoms: A "cotton wool" type of growth on the mushroom fruit-body which spreads over the casing layer to neighbouring mushrooms. This growth, the greyish-white mycelium of the pathogen, can envelop the mushroom fruit-body completely. Infected mushrooms die with a soft wet rot.

Sources of infection: Contaminated casing material. The conidia (spores) of the pathogen spread through the air, and are also carried by insects, tools and workers.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Mildew appears as a "cotton wool" type growth, which spreads over casing peat, stalks and caps.

Control: Disinfection of the casing material and strict hygiene.

BACTERIAL DISEASES

BROWN BLOTCH

Cause: The bacterium *Pseudomonas tolaasii.*

Symptoms: Brown (occasionally dark yellowish to pale brown), slightly sunken blotches appear on the developing mushroom fruit-body. The disease affects only the surface layers of the mushroom and, in severe cases, brown streaks also develop on the stalk.

Sources of infection: Mushroom compost (before and after pasteurization), soil, water supplies, casing soil and (sometimes) casing peat moss. The disease is often associated with high humidity and fluctuating temperature in the growing area. When humidity is high, temperature fluctuations lead to water condensation on mushroom caps. Consequently, the bacterial pathogen multiplies and infects the mushrooms. It is thought that water splashed onto the mushrooms may spread the disease, or the bacteria may reach the mushroom from the casing and compost.

Symptoms of brown blotch on mushroom caps.

Effects of the disease: The disease can occur at any stage in the development of the mushroom during the entire cropping period. It is endemic, potentially serious and can appear suddenly in epidemic proportions. The pathogen can spoil harvested mushrooms in transit and storage. There have been instances where mushrooms have been cropped unblemished, but have turned brown in storage at low temperatures. As the fresh market demands unblemished mushrooms, the disease is of economic importance to wholesale agents and retailers in the fresh market as well as to growers.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Disinfectants applied during cropping give temporary relief, but the disease is best controlled by manipulating the crop environment. To avoid spread of the disease by splashing water, keep the surfaces of the mushrooms as dry as possible between waterings. If mushroom surfaces dry within an hour or two of watering, no infection occurs. Mushroom surfaces will dry out even if the humidity is high, as long as the temperature remains constant and there is free circulation of air over the mushroom beds. The temperature of the air coming into the growing room must therefore be closely controlled.

DRIPPY GILL

Cause: The bacterium *Pseudomonas agarici.*

Symptoms: Dark brown, round spots appear on the side and bottom edges of the gills. At the centre of each spot, a creamy grey droplet may show on the gill surface. If the infection is severe, bacterial droplets join to form long streaks of slime which may lead to distortion and collapse of the gills. Damage is restricted to the gill tissue of mature mushrooms.

The name "drippy gill" refers to the bacterial droplets which develop on the gills.

Sources of infection: Mainly compost and casing soil, but mushroom flies can also transmit the disease.

Effects of the disease: This disease has not had serious effects on mushroom crops. If infected mushrooms are picked and sold before the veil breaks, the disease may go unnoticed, but shelf life of harvested mushrooms is likely to be reduced.

Drippy gill infection causes creamy-grey droplets to form on gills (top) and brown fluid to drip from cap (lower).

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Disinfection of casing soil.

MUMMY DISEASE

Cause: As species of the bacterium *Pseudomonas.*

Symptoms: In diseased mushrooms the stalk is bent and the cap tilted. Often there is a dense growth of mycelium around the base of the stalk on the surface of the casing layer. Infected mushrooms remain intact for several days (depending on the degree of infection), after which they are invaded by secondary bacteria.

Bent stalks, tilted caps and fungal growth on casing caused by mummy disease.—Photo courtesy P. J. C. Vedder.

Mushrooms often fail to mature and remain in the "button" stage with unopened veil.

Sources of infection: Infected mushroom mycelium and soil.

Effects of the disease: Mushroom yields may be considerably reduced. The disease spreads within growing rooms where mushroom mycelium production (spawn-run) is continuous, such as with the shelf-bed system. Although it is not regarded as a common disease, it has been seen on many farms in New South Wales.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Strict hygiene on the farm is the best means of controlling the disease. Disinfecting the casing layer can help to reduce risk of infection.

PARASITIC NEMATODE DISEASES

Two parasitic nematodes, *Aphelenchoides composticola* and *Ditylenchus myceliophagus,* infest cultivated mushroom crops.

Symptoms: Infested patches of compost during spawn-run become dark, wet and foul-smelling. Mushroom mycelium disappears from the infested areas. Infestation through the casing results in large numbers of nematodes swarming over the mushroom beds. Mushrooms may turn brown and die at the "button" stage of growth.

Effects of the disease: Infestation of compost at spawning time reduces mushroom yields from the first or second flush. Infestation occurring at casing time will lead to a reduction in yield of mushrooms during later flushes.

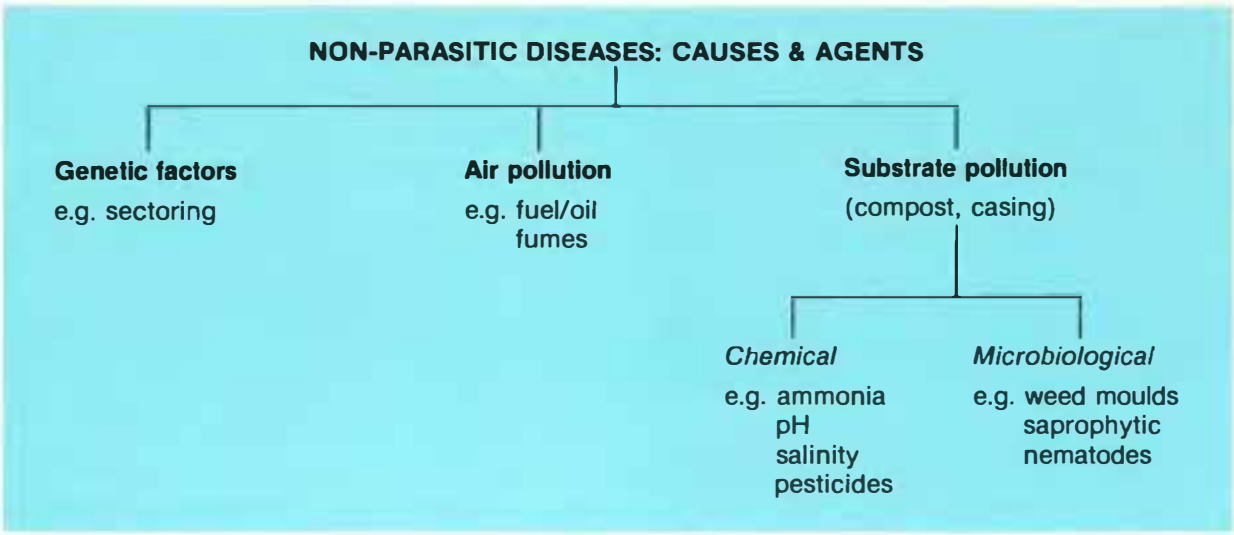
Sources of infestation: Mainly casing soil and water supplies.

Varietal reaction: All commercially grown strains of the cultivated mushroom are susceptible.

Control: Efficient pasteurization of compost and disinfection of casing soil.

Further information on mushroom nematodes is available in Agfact H8.AB.32.

Nematode feeding on mushroom mycelium, viewed under a microscope.



NON PARASITIC DISEASES

SAPROPHYTIC NEMATODES

Several species of saprophytic nematode, which feed on bacteria and small particles of organic matter, are found in mushroom beds.

Symptoms: Patches of mushroom bed surface become dark and soggy and the mushroom mycelium deteriorate in these areas.

Effects of the disease: Some saprophytic nematode populations reduce the yield of mushrooms, others do not.

Source of infestation: Casing soil appears to be a main source of infestation.

Varietal reaction: Off-white strains of the cultivated mushroom appear to be more susceptible than white strains.

Control: Disinfection of the casing layer should help to reduce the level of infestation.

WEED MOULDS

Mushrooms are grown in specially prepared compost which favours the selective growth of the mushroom mycelium. However, if the composting is not carried out properly, weed moulds develop, some of which can reduce the mushroom crop by as much as 40 per cent.

Since the presence of weed moulds in compost indicates that composting has not been done properly, these moulds are referred to as **indicator moulds.** Weed moulds compete with mushrooms for compost nutrients and are, therefore, also called **competitor moulds.**

Control: There is no effective chemical control for weed moulds. Follow correct composting procedures to prevent weed moulds infesting mushroom crops. After-crop sterilization, in which mushroom trays are treated with steam at 70°C for 12 hours after harvest, eradicates these moulds and prevents spread of their spores to new crops.

Brown mould.

White plaster mould.

Olive green mould.

Green mould.

Lipstick mould.

Yellow mould.

False truffle.

***Schizophyllum* sp.—Photos: M. Hill.**

WEED MOULDS IN MUSHROOM CROPS

Common name	Fungus	Symptom	Effect on mushroom mycelium	Comments
Olive green mould	*Chaetomium olivaceum*	Unrestricted growth in compost	Inhibitory	Indicates insufficient air during Phase II of composting
Ink cap	*Coprinus fimetarius*	Unrestricted growth in compost	Initially inhibitory	Indicates under composting and ammonia in compost
Brown mould	*Oedocephalum* sp.	Unrestricted growth on casing	Not inhibitory	Indicates residues of ammonia in compost
Brown mould	*Peziza ostracoderma*	Unrestricted growth on casing	Not inhibitory	High humidity and low ventilation in growing room appear to encourage its growth
Brown plaster mould	*Papulospora byssina*	Unrestricted growth on casing	Inhibitory	Indicates over composting
White plaster mould	*Scopulariopsis fimicola*	White colonies spread on casing	Inhibitory	Indicates over composting and alkaline (high pH) compost
Green mould	*Trichoderma viride*	Green colonies with white border on casing	Very inhibitory	Indicates uncomposted organic matter in the compost and excess carbohydrates
Lipstick mould	*Geotrichum* sp.	Small red colonies with white border in compost or casing	Inhibitory	Usually air-borne contamination from soil
Yellow mould	*Sepedonium* sp.	Small yellow colonies in compost	Slightly inhibitory	Occurs in compost after establishment of mushroom mycelium
Black whisker mould	*Doratomyces* sp.	Unrestricted greyish growth in compost	Inhibitory	Indicates under-composted straw and excess carbohydrates
Mat disease	*Chrysosporium luteum*	Small white colonies becoming yellow underneath casing	Very inhibitory	Contamination from soil
False truffle	*Diehliomyces microsporus*	Irregularly-shaped fruit-bodies in compost or casing	Very inhibitory	Prefers high temperature and is a soil contaminant
None	*Pythium* sp.	Dark areas in compost	Inhibitory	Contamination occurs during spawning
None	*Schizophyllum* sp.	Light brown fruit-bodies	Inhibitory	This mould grows in compost and also on wooden trays
None	*Aspergillus* sp.	Green to yellowish to orange colonies	Inhibitory	Indicates excess carbohydrates
None	*Mucor* sp.	Fluffy grey-black colonies	Slightly inhibitory	Indicates excess carbohydrates
None	*Penicillium* sp.	Green to blue-green colonies	Not inhibitory	Indicates excess carbohydrates

ROSE COMB

Rose comb is a term commonly used to describe a malformation of mushrooms in which the caps produce gills on the upper surface or in which the tissues of the cap are seamed and patterned. It can also result in such restriction of gill formation that the mushroom appear to be almost devoid of gills. In most cases the condition is caused by the presence of kerosene or other oils in the mushroom beds.

WHITE GILL

White gill (also known as pale gill), is a disorder or defect that causes mushrooms to be small, with pale or white gills. The gills are also abnormally short with extra tissue at their base. White gill might appear on the first flush, but usually appears in second or later flushes. Its occurrence is unpredictable: one flush may produce many pale-gilled mushrooms, yet mushrooms in the next flush may be normal. The cause of this condition is not known, although it is possibly genetic, associated with certain strains of mushroom. Under local conditions, however, there is no constant association with any particular strain of spawn.

FURTHER INFORMATION

Further information on mushroom diseases is available from the Biology Branch, Biological and Chemical Research Institute, P.M.B. 10, Rydalmere 2116 (telephone (02) 630 0251).

Splitting and distortion are the result of pesticide damage.

Related Agfacts: H8.AB.32, *Nematodes in mushroom crops.*
H8.AE.3, *Insect and mite pests of mushrooms.*

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ISSN 0725–7759