

Chapter Five

DISEASES OF MUSHROOMS

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General Disease Control Measures for Mushrooms

Proper cultural practices and strict adherence to sanitation and hygiene are **essential** to an effective disease prevention program on the mushroom farm. Many of these practices are effective for the control of all mushroom diseases. To avoid repetition in the main text, these practices are listed here.

1. Practice strict sanitation:

- a) Remove stumps and trash from production surfaces and farm premises daily. Keep floors clean. Do not sweep **dry** floors and avoid excess splashing of water when cleaning production rooms after spawning, casing or harvesting.
 - b) Deal with disease when it first appears. Diseased mushrooms should be covered with salt (NaCl), lime (Ca(OH)₂) or lime and gypsum (CaSO₄) mix (see note on Cobweb). Cover disease areas, especially Trichoderma green mould, with sodium hypochlorite solution, salt, lime or lime-gypsum mix.
 - c) Do not allow workers to stand on side boards.
 - d) Compost or casing spilled on the floor should be considered contaminated and discarded along with spent substrate or stumps.
 - e) At the end of the crop, the compost temperature should be raised to 70°C for at least 12 hours before emptying. Remove spent substrate from the farm premises. After the substrate has been removed, first dry clean the room, remove netting and thoroughly high pressure wash all shelving, walls and floor. Clean netting with high pressure washer. Under high farm disease pressure, re-steam empty rooms with netting in place at 70°C for at least 6 hours prior to filling.
 - f) Equipment used in and around mushroom facility, such as picking boxes, trash boxes, shovels, spawning and casing machines, etc., must be cleaned and disinfested before each use. First remove excess material, then wash the equipment as much as possible with water, then disinfest with formaldehyde [(COM) SN 3.75 litres (ai)/1,000 litres of water], sodium hypochlorite [1000 - 2000 ml (ai)/1000 litres of water], Verticide [4 - 16 mL/litre of water] or other appropriate sanitisers.
2. Store casing material on concrete, under cover, protecting it from contamination by compost, soil, dust, spent substrate and ground water. Prepare casing material in a clean area, preferably a container such as a converted cement mixer that has been cleaned with water and/or formaldehyde solution. The preparation area should be free of dust, ingressing insects and personnel traffic.
 3. Formaldehyde may be incorporated into the casing material before placement. Normally, bagged peat moss is not treated. If considered necessary, add formaldehyde (COM) SN [3.6 to 4.2 litres of solution (74 - 92.5 litres (a.i)/1000 litres of water) for each dry cubic metre of casing material] to the casing make-up water. Mix thoroughly and keep casing covered for at least 24 hours after treating, keeping the air and casing material at least 18°C. All odour of Formaldehyde must be gone before casing is applied to compost.
 4. Install high efficiency (95% dust spot efficiency) air filters in mushroom facility ventilation systems.
 5. The spawning and casing crews should not have had contact with compost, spent substrate or diseased mushrooms prior to these operations. Clean work clothes, disposable coveralls or clean colour coded uniforms are necessary. Shoes and boots should be washed and/or dipped in disinfectant. These crews should be restricted in movement about the farm until the operations are complete.

6. Between crops, after washing the production rooms, the rooms may be disinfested with formaldehyde [(COM) SN 7.5 - 14.8 litres (ai)/1000 litres of water]. After heating the room to at least 18°C, wash down all surfaces with the solution. Keep room closed for at least 24 hours after treating.

or

Between crops, after washing the production rooms, the rooms may be disinfested with Verticide [4 to 16 mL/litre of water]. Treated surfaces should remain wet for at least 10 minutes and let air dry.

or

Between crops, clean wood and allow to dry.

Mix PQ-57 at 10 litres/100 litres in a plastic drum. Avoid high pressure mixing which causes foaming. Apply to all wood surfaces in room, starting at lowest shelves first. Use a low pressure sprayer. Allow to dry. Install nets, re-steam the room and fill with compost.

Precautions: Corrosive - Wear splash-proof goggles, rubber gloves and protective clothing. Avoid splashing and overflow of containers. Do not allow to run off to ground water, streams, ponds or lakes. Toxic to fish.

or

Gently mix Safetray P (propiconazole) at 600 mL in 100 L water. A few drops of an anti-foaming agent may be added to avoid excessive foaming. Apply the spray solution with a large droplet sprayer to the wood surfaces. To insure a thorough coverage use approximately 20 L of spray solution per 100 m² of wood surface. The applicator must wear a full respirator and protective clothing during all activities. The wood needs to dry before compost is added. Drying should take place in a sheltered, well-ventilated area. Propiconazole is fixed in wood substrates and is not subject to leaching. It is thermally stable at 320°C, enabling pasteurization and steam-off without thermal decomposition. There are no restrictions on compost or wood disposal from using Safetray P.

7. Store spawn in clean, cool area away from other mushrooms.
8. Minimize dusty conditions on roadways or premises.
9. Harvest for only three breaks.

Terminating a significantly infected diseased crop early using steam (see above) will significantly reduce build-up of disease organisms on the farm and the spread from a problem room to newer rooms.

10. Cover spawned compost with plastic or paper.
11. Maintain an effective fly control program.
12. Harvest significantly infested diseased rooms last. Or designate separate harvesting crews for each break, ie. a 1st-break crew, a 2nd-break crew, etc.
13. Under high disease pressure, minimize movement of personnel, especially harvesting crews, past younger, more vulnerable rooms.

Formaldehyde-Chlorine Danger

Any mixing of formaldehyde (Formalin) and chlorine (household bleach, sodium hypochlorite, etc.) can result in the formation of a very potent carcinogen (bis-chloro-methyl ether). To avoid any possible danger, these chemicals should not be allowed to mix in either the vapour or liquid forms. These materials should be disposed of in separate areas and not be allowed to mix.

MUSHROOM (*Agaricus bisporus*)

ABIOTIC DISORDERS

Note: During cultivation of the commercial mushroom, there frequently occur a number of abnormalities that are not caused by any living organism. These conditions are described by the following names: stroma, rose comb, hardgill, open veil, weepers, hollow case, purple stem, saggy socks. Although these conditions are rare, they can disturb growers. Refer to general references for more information on these disorders.

BACTERIAL BLOTCH

Pseudomonas fluorescens (biotype G)

Cultural: Air temperature should not be allowed to rise above bed temperature. If heating is required, provide only a small amount of heat at any one time. Maintenance of a **stable** difference between wet and dry bulb reading of 1 to 1.5°C will significantly reduce the occurrence of bacterial blotch. Do not water mushrooms less than two days before harvest. After watering, surface of mushrooms must be dried in 2-4 hours by ventilating and heating.

Resistant Cultivars: None.

Chemical: None.

Notes: Sodium hypochlorite at 160-320 mL ai/1,000 litres of water is used as a drench by growers to control this disease although it is not registered for use. Household bleaches generally contain 5.25-6% sodium hypochlorite. A slight acidification of the water-chlorine solution increases the effectiveness of chlorine.

Precaution: Hazards have been noted when sodium hypochlorite solutions combine with acids. Toxic chlorine gas is emitted. Both mixing tank and solutions should be in well ventilated areas.

Calcium chloride (food grade) at 0.3% (ai) is applied in the irrigation water from early pinning to the end of the crop to enhance drying and reduce the browning reactions.

MUMMY DISEASE

Pseudomonas spp.

Cultural: Where mummy disease is present, remove 20-cm wide section of compost across the beds and 1.5 m from either side of the infection. The exposed netting and shelving should be thoroughly treated with formalin solution and the surface of the infected area covered with plastic. Thoroughly clean up and disinfect the production room before refilling to prevent reinfection. If plastic is used to cover the compost during spawn-run, remove two days before casing to permit water on compost surface to dry.

Resistant Cultivars: None.

Chemical: None.

DRY BUBBLE*Verticillium fungicola*

Cultural: Follow strict sanitation practices (see page 2) to prevent introduction of the disease, including use of clean or pasteurized casing media and properly maintained air filtering system. Control fly populations. Dry bubble is effectively kept in check on many farms by cropping for only three breaks.

Resistant Cultivars: None.

Chemical: Water early infection centres with formaldehyde (COM) SN drench. For protective measure, use benomyl (COM) WP; zineb (COM) DU. Apply chlorothalonil (COM) SU at casing or mix into casing material at 254 mL formulation per 100 m² of production surface and pinning at 128 mL formulation per 100 m². A minimum of 100 L water per 100 m² is necessary to achieve good coverage of the casing. The applicator must wear a full respirator and protective clothing during all activities. No more than two applications are permitted per crop. The treated area is not to be re-entered for 48 hours. However, short-term tasks, not involving handling the treated casing, are permitted 4 hours after application. This individual must wear long-sleeved shirt, hat and chemical-resistant gloves.

Limitations: Preharvest interval - 2 days (benomyl); 1 day (zineb); 7 days (chlorothalonil).

Notes:

1. Careful use of the **Vineland Verticillium Medium** will aid the grower in detecting the weak link in the sanitation program or source of the infection (see references).
2. *Verticillium* is generally resistant to benomyl. Repeated use (greater than 2 times per crop) may increase *Verticillium's* tolerance to benomyl.
3. Although zineb is allowed for use on mushrooms in Canada for domestic consumption, it is not recommended for mushrooms that will be exported to the U.S.A.

WET BUBBLE*Mycogone perniciosa*

Cultural: Strict sanitation procedures must be followed (see page 2).

Resistant Cultivars: None.

Chemical: Eradicate early infection centres with formaldehyde (COM) SN drench. When bringing casing layer to full moisture capacity, apply benomyl (COM) WP through the irrigation water. Zineb (COM) DU, WP may be applied as a protective dust to the casing surface.

Limitations: Preharvest interval - 2 days before first pinning (benomyl); 1 day (zineb) - 2 days in Ontario.

GREEN MOULDS

Trichoderma koningii, *T. viride*, *T. harzianum*.

Cultural: *Trichoderma koningii* and *T. viride* flourish in compost as indicator moulds when excess carbohydrates are available or when the compost is not supplemented with sufficient nitrogen. Adequate compost formulation and schedules will prevent the problem. In addition, supplements added at spawning should be evenly mixed throughout the compost.

T. harzianum (biotype Th4) appearance is similar to the other green moulds. However, this species is able to aggressively attack and colonize mushroom compost and casing, devastating production. Manage the infection pressure through a thorough sanitation and hygiene programme, especially targeting post crop steamoff and its clean up, cooldown, spawning and early spawn run. Cover spots with sodium hypochlorite solution, salt, lime or gypsum and lime mix. Good insect and mite control and personnel traffic patterns further reduce the spread of the disease. Optimize the compost preparation and horticultural conditions for a healthy vigorous growth of the mushroom fungus.

Resistant Cultivars: Brown strains may be more tolerant against *Trichoderma harzianum* (biotype Th4).

Chemical: Benomyl (COM) WP may reduce growth in the casing soil. Neither benomyl nor chlorothalonil are effective against an established infection of *Trichoderma harzianum* (biotype Th4).

Benomyl (COM) WP may be applied to the spawn grains as a 'seed coat' at 0.25 g (a.i.) per 22 gypsum per 1 kg spawn as a preventative against *Trichoderma harzianum* (biotype Th4).

Limitations: Preharvest interval - 2 days (benomyl); 7 days (chlorothalonil).

COBWEB

Cladobotryum dendroides (= *Dactylium dendroides*)

Cultural: Good sanitation is essential. Disease is favoured above 18°C and R.H. > 90%. Pasteurize casing material. Spread a wet paper towel over the spot and then cover the towel with salt, lime or gypsum and lime mix, especially before crop irrigation. The spores are easily airborne.

Resistant Cultivars: None.

Chemical: Eradicate early infection centres with formaldehyde (COM) SN as a drench. Apply zineb (COM) DU between breaks as required.

Limitations: Preharvest interval - 1 day (zineb).

LA FRANCE DISEASE (X DISEASE)

Virus (several)

Cultural: Once the disease is established it is impossible to control without complete sterilization of the production facilities, tools, and all materials previously used in production. The following measures must be taken to prevent establishment of viruses: all rooms should have high efficiency filters in the fresh air system; discourage visits from other growers and do not visit other mushroom farms where virus is suspect or known to be present; do not employ workers who visit or do part-time work on a farm where virus is present; and immediately disinfest any shipping bins that are returned to the farm to avoid contamination. Mushrooms should be picked before the veil opens to prevent liberation of spores that carry the virus. Cover spawned compost with plastic so diseased spores cannot land on the surface. Routinely between crops, clean and steam all shelving material and nets, which can harbour diseased mycelium.

Resistant Cultivars: None.

Chemical: None.

Notes: A routine rotation of different mushroom strains in each production room will help in preventing the establishment of virus disease.

WEED MOULDS

Chaetomium olivaceum (olive-green mould); *Coprinus fimetarius* (ink cap); *Sporendonema purpurescens* (lipstick mould); *Chromelasporium* sp. (cinnamon brown mould); *Papulaspora byssina* (brown plaster mould); *Scopulariopsis fimicola* (white plaster mould); *Trichoderma viride* (green mould); *Doratomyces stermonites* (black whisker mould).

Cultural: Good pasteurization and sanitation practices are always essential. Lack of oxygen during the conditioning phase of indoor pasteurization promotes olive green mould. Ink cap mould appears when compost contains excess ammonia due to poor conditioning of compost during Phase II. Lipstick mould is reported to be associated with chicken manure in compost formula or wet compost, and occasionally where virus is present. Cinnamon brown mould is an opportunistic fungus growing on casing that has been overly pasteurized, where strong formalin solution has been used, or where virus has killed the mycelium in the casing. White and brown plaster moulds are stimulated by amines in the mushroom compost. Modifications of composting practices (Phase I and Phase II) to improve compost quality will reduce the occurrence. Both green mould and black whisker mould develop under conditions where compost has been under composted, the C:N ratio was too high, or where the compost has over heated during the spawn run period.

Resistant Cultivars: None.

Chemical: Eradicate early infection centres with formaldehyde (COM) SN as a drench. Apply zineb (COM) DU between breaks as required.

Limitations: Preharvest interval - 1 day (zineb).

OTHER DISEASES

Aphanocladium Cap Spotting (*Aphanocladium album*)

Gill Mildew (*Cephalosporium* spp.)

Hormiactis Cap Spot (*Hormiactis alba*).

Mat Or Confetti Disease (*Chrysosporium luteum* and *C. medarian*)

Shaggy Stipe (*Mortierella bainieri*)

Truffle Disease (*Diehliomyces microsporus*)

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APPENDIX I. Fungicides Registered for use against Diseases of Mushrooms in Canada.

Disease	Trade Name	Active Ingredient	Formulation	PCP#
Dry bubble	Benlate	benomyl	WP	11062, 24678
Dry bubble	Zineb 15 Dust	zineb	15% DU	8144
Dry bubble	Bravo 500	chlorothalonil	500 g/L	15723
Wet bubble	Benlate	benomyl	WP	11062, 24678
Wet bubble	Zineb 15 Dust	zineb	15% DU	8144
Green mould	Benlate	benomyl	WP	11062, 24678
Green mould	Zineb 15 Dust	zineb	15% DU	8144
Green mould	King Mushroom Dust	zineb	DU	11268
Cobweb	Zineb 15 Dust	zineb	15% DU	8144
Cobweb	King Mushroom Dust	zineb	DU	11268

EMPTY HOUSE FUMIGANTS & STERILANTS

Clean Crop Formalin Fungicide Solution	formaldehyde	6998
PQ-57	copper 8-quinolinolate	15314
Safetray P	propiconazole	24813
Verticide	dimethyl benzyl ammonium chloride 6.14% didecyl dimethyl ammonium chloride 9.22%	25276