Diseases of Mushroom

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Mushroom culture

- Mushroom culture is a remarkable system of biological manipulation whereby the organisms that are most likely to be harmful are minimized, and those that are beneficial are encouraged.

- A suitable medium, the compost, is the end product of a complex but controlled biological process involving fungi, bacteria, and actinomycetes.

- When well prepared, it is a living ecosystem that is suitable for the growth of mushrooms. Mushroom mycelium, once introduced into the compost, affects the system substantially and the development of other microorganisms may be minimized by competition and probably antagonism.

- However, mushroom compost is not a selective medium in the strict sense, and other fungi introduced at the completion of composting and before mushroom spawn may also grow well, often at the expense of mushroom mycelium.
<table>
<thead>
<tr>
<th>Phase 0</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Spawning</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–60°C/2–6 days</td>
<td>Up to 80°C/6–7 days</td>
<td>60°C/6 days</td>
<td>1 day</td>
<td>25°C/16–18 days</td>
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</table>

**Phase 0**
- Wetting and blending of raw materials. Apart from soil contamination not vulnerable to pest and pathogen entry.

**Phase I**
- Composting in windrows or bulk systems. High temperatures and ammonia levels make pest and pathogen entry and establishment unlikely.

**Phase II**
- Pasteurization at 60°C followed by conditioning at 48°C. Not vulnerable to pest and pathogen entry, until cool down.

**Spawning**
- Often an exposed process and vulnerable to the entry of pests, pathogens and competitors.

**Phase III**
- Vulnerable to flies in older systems. Emptying phase III and old crops generates mushroom mycelial fragments which may trigger virus disease.

**Fungal pathogens in soil and soil water**
- Virus, Sciarids
- Trichoderma, Virus, Sciarids
- Sciarids
- Phorids
- Virus
- Virus in mushroom mycelial fragments
<table>
<thead>
<tr>
<th>Casing</th>
<th>Case-running and cropping</th>
<th>Crop termination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>25–18°C/31–38 days</td>
<td>65–70°C for 12 hours</td>
</tr>
</tbody>
</table>

- **Casing**: An exposed process vulnerable to the entry of fungal pathogens and mushroom spores and mushroom mycelial fragments.
- **Case-running and cropping**: Vulnerable to fungal and viral pathogens during case running. By the end of cropping large populations of pests and pathogens are possible that may endanger other crops, concurrent and future.
- **Crop termination**: Major pest and pathogen elimination.
Biotic factors responsible for disorders

• Insect pests
• Mites
• Nematodes
• Parasitic fungi
• Antagonistic fungi
• Pathogenic bacteria
• Viruses
• Viroids, mycoplasmas, and rickettsias
Insect pests

• Many disorders are caused by species of Diptera (flies). Flies are attracted to the mushroom crop and their larvae may feed directly on the mycelium, swarm over the mushrooms, or tunnel into the developing, or developed, mushrooms.

• The symptoms resulting from fly attack vary from a reduction in yield, due to direct or indirect effects on mycelium, to discolouration and damage to the mushrooms resulting from direct attack.

• There may also be spoilage, as a result of flies being present in enclosed pre-packs. Tissues that have been physically damaged by fly larvae often become colonized by bacteria that cause soft rot, thereby accentuating the problem.
Mites

• Like fly larvae, some mites may feed on mushroom mycelium and on developed mushrooms, where they can cause surface discolouration and reduce yields.

• Others may live on fungi other than *Agaricus bisporus* (e.g. the antagonistic fungi, see below) found in mushroom culture, some feeding on decaying organic material, and some on nematodes.

• They can be symptomatic of poor compost preparation.

• When mites are numerous they can be a source of irritation to pickers, thus reducing harvesting efficiency.
Nematodes

• The most destructive nematodes (parasitic) are those that feed on mushroom mycelium, resulting in bare patches or sunken areas of bed which can reduce crop yield significantly.

• Those that live entirely on organic matter, such as mushroom casing (saprophytic), are frequently found in mushroom crops and can reduce yield, but only in very specific circumstances.

• Nematodes are very small and only visible when they aggregate into clusters on the casing surface.

• Large numbers of saprophytic nematodes are often symptomatic of problems in compost preparation.
Parasitic fungi

• Various fungi are known to be parasites of the cultivated mushroom.
• Mycological identification of these fungi is generally based on their spores or spore producing structures, but the diseases are recognized by the symptoms shown by affected crops.
• Most of the common fungal pathogens attack mushrooms and not the mushroom mycelium. Generally the earlier the attack the greater the yield loss and the more distorted the ultimate mushrooms; for example, very large distorted mushrooms result when mushroom initials are attacked by *Mycogone perniciosa*.
• Some fungi (for example *Diehliomyces microsporus* and *Trichoderma aggressivum*) attack mycelium of the crop. Symptoms of fungal attack can vary from decay (cap spotting and stalk rot), to severe distortion (malformed mushrooms), to complete loss of yield.
Antagonistic fungi

• The relationships between mushrooms and other fungi that can occur in mushroom crops are only imperfectly understood.

• Many of these fungi become established at or soon after spawning, because the physical and chemical environment of substandard compost is favourable for their growth.

• Some moulds are able to grow in well prepared compost and then compete with mushroom mycelium for nutrients; others are antagonistic, and once established, prevent the mushroom mycelium from growing into affected compost. In both cases, the end result is yield reduction.

• It is also likely that some moulds produce toxins and some of these may be volatile. Toxins can induce distortion in developing mushrooms.

• Moulds can sometimes be recognizable in the compost or on the casing surface, by the coloured spores or mycelium they produce, and for this reason they have frequently been given descriptive names such as Olive green mould, Plaster mould and Lipstick mould. In modern methods of production they are much less obvious, but in some ways, just as dangerous.
Pathogenic bacteria

• Some bacteria have a vital role in the successful production of mushrooms, but others can cause serious disorders.

• World-wide, the most common and most investigated bacterial disorder is Bacterial blotch (*Pseudomonas tolaasii*), which discolours and sometimes disfigures the developing or more frequently the mature mushrooms, even after marketing.

• There is some evidence that pathogenic bacteria can be present within apparently healthy mycelium with no obvious effect on mycelial growth. Symptoms may then develop when mushrooms are produced.

• For instance, bacteria (or similar organisms) that are present within the mycelium are the causes of such diseases as Drippy gill and Mummy disease.

• Bacteria are known to cause distortion, discolouration and decay; they may also be responsible for delayed mushroom production. After harvest, they are a major cause of mushroom browning.
Viruses

• Many fungi are known to contain particles which are very like those of plant viruses. There are relatively few instances where the presence of these is associated with disease symptoms, *Agaricus bisporus* being one of the few. There are no known vectors of mushroom viruses.

• Mushroom viruses are transmitted in mycelium and also in mushroom spores.

• Exhaustive work on the significance of the various types of virus particle found in mushrooms has yet to be completed.

• The precise effects of these, individually and in combination, is still not known, and there is therefore an element of uncertainty concerning the symptoms produced by specific viruses in mushrooms.

• There is increasing evidence that the traditional virus disease of the crop (La France virus disease) is caused by only one of the various viruses frequently found in apparently healthy crops. Whether the other viruses contribute to symptom production in any way is not known.

• A number of different dsRNAs (mushroom viruses are predominantly double-stranded ribo-nucleic acid), apparently not contained within a protein coat, have been associated with the new Mushroom virus X disease.
Viruses

• Mushroom virus diseases cause considerable reductions in yield.

• Symptoms that have been attributed to virus diseases include growth abnormalities of mycelium, discolouration and distortion of mushrooms such as browning of caps and elongation of the stalks. Early opening of caps, crop delay, delayed pinning development often in specific areas of the crop, and die-back of the mycelium, may also be symptoms of virus diseases.

• Most of these symptoms can also be caused by other factors.
Viroids, mycoplasmas, and rickettsias

• These three groups are known to cause diseases in plants and animals, but have not so far been found to cause diseases in mushrooms.

• They are all difficult to study and easy to overlook. It is possible that, individually, they may be playing an important role in some of the diseases at present attributed to other causes, e.g. viroids in virus diseases and rickettsias or mycoplasmas in bacterial diseases such as mummy disease.
Abiotic factors responsible for disorders

- Suboptimal environmental conditions in the atmosphere,
- Poorly produced compost,
- Poor casing,
- The presence of toxic substances particularly in casing, and
- Genetic abnormalities of spawn
Identification of disorders

• Are the symptoms like any described in the literature?
• When was the disorder first seen on the farm?
• What was the distribution of the disorder both on the farm and in affected crops?
• Did the disorder occur irrespective of compost or casing source or type, or was it related to a specific material?
• Have laboratory tests been done on affected mushrooms and/or compost?
• Was the disorder confined to one spawn type or were different spawns affected?
• Was the affected crop treated differently from the normal ones?
• Have the environmental settings been achieved for the affected crop?
• Have pesticides been used on the crop and was the rate of application correct?
Insects, mites, and nematodes

• All macroscopic organisms varying in size from 1 to 5 mm.

• When associated with a disorder, they are usually present in large numbers and are not difficult to see.

• Nematodes are the most difficult, although saprophytic nematodes sometimes swarm and can be seen in the compost or on the casing surface.
Fungi

• It is the spores that are most useful in making precise identifications.

• It is usual to culture samples of compost on agar so that moulds can be isolated and identified.

• Where quantification is required, a water extract is made (using a Stomacher) which is diluted sufficiently to allow the colonies of fungi that develop on the agar to be counted.

• The numbers, generally the higher the more significant, can be very important when identifying the cause and potential of a compost problem.

• When more than one species or strain of a fungus could be involved, it may be necessary to make very precise identifications. For instance, there are various species of *Trichoderma*, and strains of *T. aggressivum* (syn. *T. harzianum*), that cause different symptoms.
Bacteria

• There is some variation in their morphology but not enough to enable them to be identified using this factor alone. Bacterial identification is dependent upon a series of chemical tests in which materials are added to agar media, and the ability of the bacterium to utilize these and to grow on the media is measured.

• In the case of *Pseudomonas tolaasii*, the cause of Bacterial blotch, precise identification is achieved by the white line test. This is a very specific interaction with a related bacterium, which when together with *Ps. tolaasii* on the same agar plate, results in the production of a white line of precipitation between the two bacterial colonies.
The white line test for the identification of *Ps. tolaasii*. The organism *Ps. reactans* is in the centre of the plate and the isolates to be tested are streaked either side (10 in this case). A white line of precipitation forms in the agar between isolates of *Ps. tolaasii* and *Ps. reactans*. There are three positive identifications on this plate. We are grateful to Dr W.C. Wong for the use of this figure.
Viruses

• The first described virus disease, La France disease, was initially identified by comparing the growth rate of mushroom mycelium from an affected mushroom, with that of the parent spawn.

• When virus is present at high concentrations, the growth rate of the affected mycelium is less than a half of that of the healthy strain. Because all strains may not grow at the same speed, it is important to make comparisons with a known healthy culture of the same strain.

• The infectious nature of a La France virus affected culture can be readily demonstrated on agar by anastomosis (hyphal fusion) with a healthy culture. It can be shown that, within days of anastomosis occurring, the previously healthy culture grows much more slowly, and at a rate comparable to that of the diseased culture, demonstrating the presence of the virus and its transfer.
Transfer of mushroom virus by anastomosis. Virus-affected culture (round white block in centre left) has anastomosed with the healthy culture (white round block centre right), and the resultant growth on the right is tested from the leading edge (four agar plugs taken) and these show the same slow growth rate as the original virus culture if anastomosis has occurred and the virus been transferred.
Effective Pest and Disease Control

• It is important that modern commercial mushroom production is essentially pest- and disease-free. The means of achieving this has changed with production methods, and market requirements. In order to reach current high standards all available means of pest and disease control are used.

• The integration of these requires a sound knowledge of the biology of the pests and pathogens. The most important single factor in an integrated programme is the effective management of pest and pathogen populations. When populations are out of control, major crop losses soon follow.
Pest and pathogen management

• The maintenance of healthy crops is the aim of integrated pest and pathogen control and the programme often referred to as ‘farm hygiene’, although in mushroom farming the term hygiene is generally used in a more restricted sense to refer to all means of control other than the use of insecticides and fungicides.

• The programme has three very important aims. First the exclusion of harmful organisms, second the containment of those that have not been excluded, and finally the elimination of any that remain. It requires a continuous effort on the part of management and lapses will quickly result in increases in pest and pathogen populations.
Practices and operations

- Pest and disease recording
- Filtration
- Ventilation and air movement
- Dust management
- Disease removal
- Harvesting hygiene
- Foot-dips
- Disinfection of vehicle wheels
- Crop termination
- Emptying
- Empty trays
<table>
<thead>
<tr>
<th>Pathogen/disease</th>
<th>Spore type</th>
<th>Spore size (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verticillium fungicola var. fungicola</td>
<td>Conidia</td>
<td>3.8–7.2 × 1.2–2.4</td>
</tr>
<tr>
<td>Dry bubble</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verticillium fungicola var. aleophilum</td>
<td>Conidia</td>
<td>4.5–8.0 × 1.5–2.5</td>
</tr>
<tr>
<td>Verticillium psallioteae</td>
<td>Conidia</td>
<td>6.0–10.0 × 2.0–3.5</td>
</tr>
<tr>
<td>Mycogone perniciosa</td>
<td>Conidia</td>
<td>13.6–17.5 × 3.7–6.1</td>
</tr>
<tr>
<td>Wet bubble</td>
<td>Aleuriospore</td>
<td>18.3–23.7 × 19.9–26.1</td>
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<tr>
<td>Cladobotryum dendroides</td>
<td>Conidia</td>
<td>22–27 × 7.5–9.0</td>
</tr>
<tr>
<td>Cobweb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cladobotryum mycophilum</td>
<td>Conidia</td>
<td>15–32 × 7.5–12.0</td>
</tr>
<tr>
<td>Diehliomyces microsporum</td>
<td>Ascospores</td>
<td>5.0 × 7.0</td>
</tr>
<tr>
<td>False truffle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichoderma aggressivum</td>
<td>Conidia</td>
<td>2.4–3.2 × 2.2–2.8</td>
</tr>
<tr>
<td>Trichoderma compost mould</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichoderma viride</td>
<td>Conidia</td>
<td>2.8–5.0 × 2.8–4.5</td>
</tr>
<tr>
<td>Trichoderma koningii</td>
<td>Conidia</td>
<td>3.0–4.8 × 1.9–2.8</td>
</tr>
<tr>
<td>Cap spot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penicillium chermesinum</td>
<td>Conidia</td>
<td>2.0–2.5 × 1.5–2.0</td>
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<tr>
<td>Smoky mould</td>
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<td></td>
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<tr>
<td>Agaricus bisporus</td>
<td>Basidiospore</td>
<td>5.0 × 7.0</td>
</tr>
<tr>
<td>Mushroom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Disease removal

To ensure that disease teams operate efficiently the following points are essential:

- **Identification**: disease teams must be trained to recognize abnormalities and in particular the early stages of disease development.
- **Illumination**: must be adequate in order for disease teams to see the early stages.
- **Disinfectant**: disease teams must use a disinfectant foot-bath between crops.
- **Isolation**: disease teams must be trained in the use of appropriate isolation or removal techniques.
- **Authority**: their work must be given priority and they must have the time and authority to complete it. Management must recognize the importance of the work of the disease team.
- **Access**: the disease team should have priority to work in a crop before watering or harvesting begins.
- **Timing**: as part of the disease control hygiene strategy, judgement is required on when inspection should begin and at what frequency. For instance, inspection before the first pick is not usually necessary, but occasionally is essential if disease has been found. Teams should not be used where success is unlikely, for example, when searching for Cobweb disease with a flush of open mushrooms that are completely covering a bed.
- **Inspection**: the frequency of inspection is normally once a day, but in some instances, for example with rapidly developing Cobweb disease, twice a day may be needed.
Disease removal

- The following points are very important when treating disease on beds:
  - **Verticillium- or Mycogone-affected mushrooms** should be carefully and completely covered with salt. The cover should be extended to an area about twice the radius of patches of the visible disease. Free-flowing salt is usually considered easier to use than the large crystal type.
  - All areas of **Cobweb disease** should be very carefully covered with damp paper towelling, ensuring minimal disturbance of the surface. The towel is then covered with salt starting from the edge of the colony and working towards the centre in order to weigh down the paper and trap spores.
  - **Large mushrooms with Mycogone and Verticillium** (never Cobweb) are best physically removed because they are difficult to cover with salt.
  - Physical removal requires very particular attention, due to its potential for disease spread. The disease should never be handled directly but should be picked-off with disposable paper towelling or disposable gloves, used once only.
  - The removed mushrooms should be either bagged or, if the quantity is small enough, placed in a bucket with disinfectant. The area from which the disease has been removed should then be salted. Disposal of bags of diseased mushrooms should be done with great care.
Harvesting hygiene

- Picking teams should work from clean to dirty crops, which is usually from the youngest to the oldest.

- Disposable gloves are used and should be replaced between every crop.

- Overalls should be laundered every day.

- Everything moveable in the cropping house which is touched by the pickers, such as knives, stools, picking racks, steps, and crates should not be taken to other houses unless these items have first been thoroughly cleaned and disinfected.

- All surfaces touched by pickers, such as radios and door handles including those in canteens, rest rooms, and lavatories, can become contaminated. These should all be disinfected.

- Returnable plastic containers should not be taken into crops unless they have been adequately cleaned.
Farm design

- Mushroom farms often change over a period of time and may be far from ideal when factors affecting pest and disease control are considered, but new farms can be designed with effective control in mind.

- The principal aim of the design is to separate cropping areas from preparation areas both physically and also in terms of traffic flow. Compost must move on a pathway from phase I to phase II, to spawning, to spawn-running, to cropping in such a way that the risk of contamination by pathogens, pests, or mushroom mycelium and spores is minimized.

- Such an ideal is not always possible, even when starting with a new farm, as the topography of the site may dictate where some of the buildings are situated. However, the principle of keeping clean away from dirty should be followed if at all possible.
Chemical control

- The chemicals used by mushroom growers as part of the integrated control strategy of pests and pathogens include fungicides, insecticides, acaricides (collectively referred to as pesticides), and disinfectants.
<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Bacteria</th>
<th>Fungi</th>
<th>Factors influencing efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohols</td>
<td>S</td>
<td>S</td>
<td>pH independent</td>
</tr>
<tr>
<td>Ethyl</td>
<td></td>
<td></td>
<td>OM independent</td>
</tr>
<tr>
<td>Isopropyl</td>
<td></td>
<td>S</td>
<td>Skin irritant</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>S</td>
<td>S</td>
<td>Skin irritant</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td></td>
<td></td>
<td>Possible carcinogen</td>
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<tr>
<td>Glutaraldehyde</td>
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<td></td>
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</tr>
<tr>
<td>Chlorine</td>
<td>S</td>
<td>M</td>
<td>pH dependent</td>
</tr>
<tr>
<td>Sodium and calcium</td>
<td></td>
<td></td>
<td>OM inactivated</td>
</tr>
<tr>
<td>hypochlorite</td>
<td></td>
<td></td>
<td>Light inactivated</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td></td>
<td></td>
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<tr>
<td>Iodophors</td>
<td>S</td>
<td>S</td>
<td>pH dependent</td>
</tr>
<tr>
<td>Organic iodines</td>
<td></td>
<td></td>
<td>OM inactivation slow</td>
</tr>
<tr>
<td>Phenols</td>
<td>S</td>
<td>S</td>
<td>Best at neutral pH</td>
</tr>
<tr>
<td>Substituted phenols</td>
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<td>OM independent</td>
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<tr>
<td>including alkylphenols,</td>
<td></td>
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<td>Non-ionic soaps inactivate</td>
</tr>
<tr>
<td>cresols, xylenols</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Quaternary ammonium</td>
<td>M</td>
<td>S</td>
<td>pH best above 7</td>
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<tr>
<td>compounds (QACs)</td>
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<td>OM inactivated</td>
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<tr>
<td>Surfactants</td>
<td>S</td>
<td>S</td>
<td>Anionic soaps Inactivate</td>
</tr>
<tr>
<td>Types include anionic,</td>
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<td></td>
<td>pH independent</td>
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<tr>
<td>non-ionic, and amphoteric</td>
<td></td>
<td></td>
<td>OM inactivation slow</td>
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<tr>
<td>Peroxides</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Peracetic acid and</td>
<td>S</td>
<td>S</td>
<td>OM inactivated</td>
</tr>
<tr>
<td>hydrogen peroxide</td>
<td></td>
<td></td>
<td>Corrosive</td>
</tr>
</tbody>
</table>

S: sensitive; M: moderately sensitive; OM: organic matter.
Action points during compost production and cropping

**Phase I compost**

- Bulk organic components must be checked for freedom from soil.
- Straw and other bulk materials must not be stored on a soil surface.
- Straw or other bulky materials with plant roots attached should be avoided.
- Water from surrounding land must not drain onto the phase I area.
- The phase I area must have a well maintained concrete surface so that it can be effectively power washed.
- Drain water that is reused should be checked for high concentrations of nutrients and toxic chemicals.
- Materials stored for use in phase I should be in such a position that fragments from them will not contaminate phase II or growing room areas.
Action points during compost production and cropping

Phase II compost

- Fresh air used to ventilate tunnels should have absolute filtration.
- Filters and ducts must be checked regularly for efficacy and leaks respectively.
- Bulk phase II compost must be very evenly loaded into tunnels.
- The plenum of tunnels should have organic debris removed regularly.
- Tunnels, including nets, should be cooked-out regularly.
- Shelves and trays used for the preparation of phase II in situ must be effectively cleaned between crops.

- The accuracy of the temperature recording equipment used during phase II must be checked regularly.
- The concentration of ammonia 3 hours into ‘kill’ should be at least 450 ppm.
- Contamination of compost by dust and debris at cool-down must be avoided.
- Phase II compost must be removed from the tunnel without the risk of contamination with dust or debris.
Action points during compost production and cropping

**Phase III compost**

- Compost must be filled at one end of the tunnel and removed from the other.
- Compost must be filled as evenly as possible.
- Absolute filtration must be used for the air that controls the compost temperature.
- The oxygen content of the compost atmosphere must not drop to below 16%.
- Equipment used to fill phase III should be dedicated to this process.
- Phase II spawning areas should be slightly positively pressurized.
- Workers should have dedicated overalls and boots which are only worn in the phase III area.
- Protective clothing should be cleaned daily.
- Boots should be disinfected every time the phase III area is entered.
- Nets should be sterilized regularly.
- All equipment used to move spawned phase II into the tunnels must be disinfected before use and power washed afterwards.
- Similar procedures apply to equipment used to remove phase III compost from tunnels.

- Equipment used for blocking or bagging phase III should be regularly cleaned and disinfected.
- All transport equipment entering the loading area should pass through a disinfectant trough which disinfects the wheels.
- Tools and implements should be dedicated to phase III use only.
- Instruments recording the compost environment must be checked regularly and recalibrated if necessary.
Spawning and spawn-running for trays, shelves, bags, and blocks

- Air used in temperature control must be absolute-filtered.
- Spawn-running rooms must be cleaned, preferably by cook-out, between crops.
- Floors must be disinfected after cook-out and before spawn-running.
- Doors of spawn-runs must be kept closed at all times.
- Compost temperatures must be checked regularly.
- Spawn-running compost must be covered with paper.
Casing and casing run

- Casing ingredients must be stored in a clean area and kept free from contamination by air-borne spores and dust.
- Dust and debris must not contaminate the casing when it is being applied.
- Casing inoculum must be carefully and cleanly mixed into casing before application.
- Mushroom mycelium in compost, used as casing inoculum (cacing), must be carefully chosen from healthy spawn-run compost.
- Ruffling equipment used on casing must be disinfected before use and preferably at regular intervals during its use.
- Instruments recording the environment must be checked regularly.
- Excess casing should not be power washed from the floor of cropping rooms unless the floors are free from cracks.
Action points during compost production and cropping

### Cropping

- Pickers must use clean overalls every day.
- Knives and other equipment used for harvesting must be regularly disinfected during the working day.
- Disinfectant troughs or pads must be placed in the doorways of cropping houses.
- Doors of cropping houses must be opened as little as possible.
- Disease removal teams must have full authority to do the job.
- Disease removal teams must have adequate light to allow thorough bed inspection.
- Pest and disease levels must be recorded.
- Disease removal teams must be able to recognize crop abnormalities and know how to deal with them.

- Pesticide use must be decided after taking into account current pest and disease levels.
- Crops should be inspected for disease before watering.
- Crops should be inspected for disease before harvesting.
- Generally the youngest crops should be inspected first and the oldest last, but this order can be changed according to the disease status of the crops.
- Pickers must never handle disease.
- Debris must be removed from the bed surface and the house after harvesting.
- Power washing the floor of a cropping house must be done with care to avoid splash onto the beds.
- Temperature and humidity readings should be checked regularly and instruments recalibrated if needed.
Fungal Diseases

• General distribution of various competitor moulds and pathogenic fungi is as follows:

• Those occurring mainly in compost include: Olive green mould (Chaetomium olivaceum and other spp.), Ink caps (Coprinus spp.) Green moulds (Aspergillus spp. Penicillium spp. and Trichoderma spp.), Black moulds (Mucor spp., Rhizopus spp.) and other (Myriococcum praecox, Sporotrichum sp., Sepedonium sp., Fusarium spp., Cephalosporium spp., Gliocaldium spp., and Papulospora spp.).

• Fungi occurring in compost and in casing soil: White plaster mould (Scopulariopsis fimicola): Brown plaster mould (Papulospora byssina), Lipstick mould (Sporendonema purpurencens), False truffle (Diehliomyces microsporus) and green moulds.

• Fungi occurring on and in casing soil and/or on the growing mushrooms: Cinnamon mould (Peziza ostracoderma), wet bubble (Mycogone perniciosa), Dry bubble (Verticillium fungicola), Cobweb (Cladobotryum dendroides), Pink mould (Trichothecium roseum) and green moulds.

• Fungi attacking the fruit bodies only: Fusarial rot (Fusarium spp.)
WHITE BUTTON MUSHROOM
(Agaricus bisporus, A. bitorquis)

- **Diseases**
  - **DRY BUBBLE**
    Pathogen: *Verticillium fungicola*
    Common Name: Verticillium disease, brown spot, fungus spot, dry bubble, La mole
  - **WET BUBBLE**
    Pathogen: *Mycogone perniciosa*
    Common Name: Wet bubble, La mole, white mould, bubble, Mycogone disease
  - **COBWEB**
    Pathogen: *Cladobotryum dendroides*
    Common Name: Mildew, Soft decay, Hypomyces mildew disease, Dactylium disease.
  - **GREEN MOULD**
    Common names: Trichoderma spot, Trichoderma blotch, Trichoderma mildew, Green mould
WHITE BUTTON MUSHROOM  
(Agaricus bisporus, A.bitorquis)

• Competitor moulds
  – FALSE TRUFFLE  
    Pathogen : Diehliomyces microsporus  
    Common name : Truffle disease
  – OLIVE GREEN MOULD  
    Pathogen : Chaetomium olivaceum, C. globosum
  – BROWN PLASTER MOULD  
    Pathogen : Papulaspora byssina Hots
  – YELLOW MOULD : (Mat disease; Vert-de. gris)  
    Pathogen : Myceliophthora lutea, Chrysosporium luteum, C. sulphureum
  – SEPEDONIUM YELLOW MOULD  
    Pathogen : Sepedonium spp
WHITE BUTTON MUSHROOM  
(Agaricus bisporus, A.bitorquis)

– INK CAPS
  Pathogen : Coprinus spp.
  Common names : Ink weed, wild mushrooms

– CINNAMON MOULD
  Pathogen : Chromelosporium fulva, C. ollare
  Common name : Cinnamon brown mould, brown mould

– LIPSTICK MOULD
  Pathogen : Sporendonema purpureascens
  Common name : Lipstick, Red lipstick

– LILLIPUTIA MOULD
  Pathogen : Lilliputia rufula (Berk & Br.) Hughes

– PINK MOULD
  Pathogen : Cephalothecium roseum Cord
OYSTER MUSHROOM  
(Pleurotus spp.)

- Diseases

<table>
<thead>
<tr>
<th>SN</th>
<th>Casual organism</th>
<th>Symptoms</th>
<th>Control</th>
<th>References</th>
</tr>
</thead>
</table>
| 1  | *Cladobotrym apiculatum*  
   C. verticillatum  
   C. variospermum | White cottony growth on the substrate; small brown irregular sunken spots or fluffy growth on fruit bodies; soft rot and decay of sporophores emitting foul smell. | Spray bavistin  
   50ppm                | Upadhay *et al.* 1987; Sohi and Upadhay 1980; Goltapeh *et al.* 1989 |
| 2  | *Gliocladium virens*  
   G. deliguescens  | Fruit bodies covered by mycelium and green spots; young pin-heads become soft, brown, pale yellow and decay. Mature fruit bodies show brown spots enclosed by yellow halo. | Spray 100ppm  
   bavistin or benomyl | Bhardwaj *et al.* 1987; Sharma and Jandaik, 1983 |
| 3  | *Arthrobotrys pleuroti* | Fluffy growth on substrate and fruit bodies; infected tissues turn yellow, water logged and rot. | Spray 50ppm  
   bavistin            | Ganeshan, 1987       |
| 4  | *Sibirina fungicola* | Powdery white growth on stipe, gills and the primordia; primordia show brownish discoloration and soft rot and mature fruit bodies turn fragile. | Proper aeration and RH essential; spray benomyl twice | Sharma and Jandaik, 1983, Jandaik and Sharma, 1983. |
GENERAL GUIDELINES

• In order to decide the most effective measures for controlling a disease in mushroom, it is necessary to understand the size of the initial inoculum, density, the rate at which the disease develops and spreads and the time when the infection takes place.

  – Ecological-by manipulations of environmental factors such as temperature, humidity and ventilation.

  – Biological-by use of antagonistic organisms through incorporation of biocontrol agents and organic amendments.

  – Chemical-by use of safe and minimum doses of specific fungicides, antibiotic etc.
The location of mushroom unit should be in such an area where effluents of chemical industries do not pollute the water and also the air is free from toxic fumes or gases.

Floor for the preparation of compost should be cemented/tiled and covered with a roof.

Substrates used for compost preparation should be fresh, protected from rain and mixed in exact proportion.

Pasteurization and conditioning of the compost should be for optimum duration at right temperatures as over/under pasteurization may not produce quality compost and invite many disease problems.

Do not allow free access of persons working in composting yards to spawning and other cleaner areas without changing the dress and foot-dip. Similarly, all machinery including tractors and fork-lift trucks should not be moved to the cleaner areas. After filling, all equipment and machinery should be thoroughly cleaned.

Spawn should be fresh and free from all the contaminants.

All equipments used for spawning, floor and walls of spawning area must be washed and disinfected.

The fresh air should be filtered before it enters the growing rooms to exclude all particles of 2 micron and above.

Casing mixture should be properly pasteurized (60-65C for 5-6 hours).

Casing mixture should be stored in a clean and disinfected place.

All the containers, equipments and machinery used for casing should be thoroughly washed and disinfected. Keeping dust to a minimum and not to have dusty operations going on at the same time elsewhere on the farm is also very helpful.

The pickers should use clean overalls and gloves. Picking should start from new or cleaner crop towards older crops.

Waste from picking, chogs, trash, stems, unsaleable mushrooms should be carefully collected not allowing to fall on the floor, and be disposed off carefully.

Avoid surface condensation of water on developing mushrooms.

Add bleaching powder (150ppm) at every watering to manage bacterial disease.

Remove heavily infected bags from the cropping rooms or treat the patches by spot application of 2% formalin or 0.05% Bavistin.

Maintain optimum environmental conditions in the cropping rooms to avoid abiotic disorders.
## Viral Diseases

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Host/Disease</th>
<th>Shape</th>
<th>Size</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td><em>Agaricus bisporus</em>&lt;br&gt;La France, Watery stipe, X-Disease, Die-back, mushroom disease</td>
<td>Spherical</td>
<td>25nm, 29nm, 35nm, 40-50nm</td>
<td>Australia, England, Holland, America, France GDR, India</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bacilliform</td>
<td>18x50nm</td>
<td>U.K.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Club shaped</td>
<td>60-70nm dia or 120-170 long with a spherical body of 40-50 nm &amp; a cylindried tail 20-30nm in dia</td>
<td>France, W. Germany S. Africa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rods of varying length</td>
<td>19x9-90nm, 19x35nm, 20x130nm</td>
<td>Poland GDR China</td>
</tr>
<tr>
<td>II</td>
<td><em>Pleurotus spp.</em>&lt;br&gt;<em>P. colombinus</em>&lt;br&gt;<em>P. ostreatus</em>&lt;br&gt;<em>P. pulmonarius</em>&lt;br&gt;<em>P. sapidus</em>&lt;br&gt;<em>P. florida</em></td>
<td>Spherical</td>
<td>26+ 2nm</td>
<td>France India China China</td>
</tr>
<tr>
<td>III</td>
<td><em>Volvariella volvacea</em></td>
<td>Spherical</td>
<td>35nm</td>
<td>China</td>
</tr>
<tr>
<td>IV</td>
<td><em>L. edodes</em></td>
<td>Spherical</td>
<td>20nm, 23nm, 36nm, 45nm, 30nm</td>
<td>China, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stiff or</td>
<td>17x200x1200nm, 15x700-900nm, 18x1500nm, 15x16x200-300nm</td>
<td>Japan China</td>
</tr>
</tbody>
</table>


# BACTERIAL DISEASES

<table>
<thead>
<tr>
<th>Mushroom</th>
<th>Disease</th>
<th>Causal organism</th>
<th>Distribution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Agaricus bisporus</em></td>
<td>Bacterial blotch</td>
<td><em>Pseudomonas tolaasii</em>&lt;br&gt;<em>P. fluorescens</em></td>
<td>Worldwide</td>
<td>Fletcher et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Ginger blotch</td>
<td><em>P. gingeri</em>*</td>
<td>UK, Netherlands</td>
<td>Fletcher et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Drippy gill**</td>
<td><em>P. agarici</em></td>
<td>UK, Netherlands</td>
<td>Fletcher et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Mummy</td>
<td><em>P. aeruginosa</em></td>
<td>UK</td>
<td>Wuest and Zarkower (1991)</td>
</tr>
<tr>
<td><em>A. bitorquis</em></td>
<td>Bacterial blotch</td>
<td><em>P. tolaasii</em></td>
<td>Worldwide</td>
<td>Fletcher et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Soft rot</td>
<td><em>Bukholdria gladioli pv. agaricicola</em></td>
<td>Worldwide</td>
<td>Guleria et al. (1987)</td>
</tr>
<tr>
<td><em>Oyster mushroom</em></td>
<td>Bacterial rot</td>
<td><em>P alcaligenes</em>*</td>
<td>India</td>
<td>Biswas et al. (1983)</td>
</tr>
<tr>
<td>(Pleurotus spp.)</td>
<td>Brown blotch</td>
<td><em>P. tolaasii</em></td>
<td>Japan, Australia</td>
<td>Fermor (1986)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Netherlands</td>
<td>Ferri (1985)</td>
</tr>
<tr>
<td></td>
<td>Yellow blotch</td>
<td><em>P. agarici</em></td>
<td>India, USA</td>
<td>Jandaikh et al. (1993b)</td>
</tr>
<tr>
<td></td>
<td>Fist-shaped</td>
<td><em>P. fluorescens</em></td>
<td>Belgium, Italy</td>
<td>Bessette et al. (1985)</td>
</tr>
<tr>
<td>Fruit bodies*</td>
<td></td>
<td></td>
<td>and Europe</td>
<td>Poppe et al. (1985)</td>
</tr>
<tr>
<td><strong>Other mushrooms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Volvariella spp.</em></td>
<td>Bacterial rot</td>
<td><em>Pseudomonas</em> sp.</td>
<td>India</td>
<td>Kannaiyan (1974)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Indonesia</td>
<td>Fermor (1986)</td>
</tr>
<tr>
<td><em>Lentinus edodes</em></td>
<td>Browning*</td>
<td><em>P. fluorescens</em></td>
<td>Japan</td>
<td>Komatsu and Goto (1974)</td>
</tr>
<tr>
<td><em>Flammulina velutipes</em></td>
<td>Brown soft rot*</td>
<td><em>Erwinia</em> sp.</td>
<td>Japan</td>
<td>Phawicke (1985)</td>
</tr>
</tbody>
</table>
BACTERIAL DISEASES

91 Bacterial blotch with variation in colour of the spots from light brown to very dark brown.
References

• Mushroom Pest and Disease Control – A Colour Handbook, John T. Fletcher

• Diseases and Competitor Moulds of Mushrooms and their Management S.R. Sharma, Satish Kumar, V.P. Sharma