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# Diseases of Mushroom and their Managements Trategies

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***Abstract:*** Mushrooms are high in nutrients, including proteins, minerals, vitamins, and bioactive components like phenolic compounds, terpenes, steroids and polysaccharides. The demand for cultivating mushrooms is growing day by day, as people become more aware of its palatability and high nutritional worth. But diseases cause heavy losses in commercial mushroom farms worldwide. The output and productivity of commercial mushroom farming can be severely harmed by disease outbreaks. Intensive cultivation of edible mushrooms is commonly afflicted by fungal, bacterial, and viral infections which frequently result in significant production losses. Beside these, a number of non-infectious physiological disorders are found to occur frequently that reduce the yield of the crop. Warm temperatures, high humidity, and a low aeration rate, which are typical circumstances for mushroom growth, encourage the spread of these illnesses. Due to a short term crops, chemicals management of mushroom diseases are not recommended owing to residual dangers. Mushroom cultivation is a young developing sector that is flourishing all over the world today. There is utmost necessary to pay greater attention to healthy mushroom production and proper disease management. In this article we described fungal, bacterial and viral diseases, several actinomycetes moulds and contaminants and non-infectious physiologic disorders that frequently occur in mushroom production farms. General and specific management practices of these diseases and disorders during mushroom production are also described.

***Keywords:*** Mushroom, Diseases, Fungal, Bacterial, Abiotic, Biotic, Management

## INTRODUCTION

The organisms of the fungal lineage include mushrooms, rusts, smuts, puffballs, truffles, morels and yeasts, as well as many less well known organisms (Abulude and Ndamitso, 2013). The word Mushroom is derived from the French word for Fungi and Mold (Chatterjee and Patel, 2016). Mushroom is a macro fungus which has distinctive fruiting bodies that can either be epigeous or hypogenous (Nongthombam*et al*., 2021). Mushroom lacks chlorophyll. So, it cannot synthesize its own food so it depends on dead and decay materials to utilize food materials as ectomycorrhizal relationship. It has the potential to solve many growing global problems like food demand, unemployment, environmental pollution etc. (Nongthombam*et al*., 2021). Around 2,000 species are existing in nature but around 25 are widely accepted as food (Chatterjee and Patel, 2016). Mushroom culture is the remarkable system of biological manipulation whereby the organism that are most likely to be harmful are minimized, and those that are beneficial are encouraged (Fletcher *et al*., 1989). A suitable medium, the compost is the end product of complex but controlled biological process involving bacteria, fungi and actinomycetes, when well prepared; it is living ecosystem that suitable for the growth of mushrooms. Mushroom mycelium once introduces into the compost, affect the system substantially and

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development of other microorganisms may be minimized by competition and probably antagonism. However, mushroom compost is not a selective medium in 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. Apparently, Mushroom are a rich source of nutrients, particularly proteins, minerals vitamins as well as bioactive constituents, such phenolic compounds, terpenes, steroids and polysaccharides (Okhuoya*et al*., 2010). Mushroom is an excellent source for anemic plant. Mushroom cultivation can be done at cottage and small-scale level besides large scale farming. Mushroom growing is one of the fastest growing and most technologically sophisticated horticultural industries in the world. They are cholesterol free and virtually no fat or sodium. Mushroom supply dietary fiberis good source of several important B group vitamins, especially niacin and riboflavin. Mushrooms have their own medical properties and edible both. Mushroom species have therapeutic properties (Chatterjee and Patel, 2016). It helps in fighting for diabetes and cancer. Due to its high potassium to sodium ratio, it is ideal for people suffering from heart disease and hypertension. Mushroom species are known to have wide range of metabolites such as antitumor, antioxidant, antigen toxic, anti-platelet aggregating, anti-hyperglycemic, antimicrobial and antiviral activities (Nongthombam*et al*., 2021). Today's mushroom are grown commercially in enclosed atmosphere controlled environment, production is therefore largely independent of environment. The most industrialized countries viz. USA, Great Britain, China, Holland and France are producing mushroom more technologically. On the contrary, mushroom is being cultivated under semi scientific causing condition (use of partially sterilized media and soil, use of implements, container etc., seldom treated with formalin etc.) with limited input in developing countries. Other biotic stress such as insects, bacteria, fungi, virus and nematodes cause heavy loss. Mushroom survival and multiplication are associated to a number of factors, which may act individually or have interactive effect among them. Intense cultivations of edible mushroom can often be affected by some fungal and bacterial diseases that rather frequently cause dramatic production loss. These infections are facilitated by the particular conditions under which mushroom cultivation is commonly carried out, such as warm temperatures, humidity, carbon dioxide ($CO_2$) levels and presence of pests. Due to these reasons, mushroom growers are frequently challenged by mushroom disease of bacterial and fungal origin. While an increasing number of commercial farms cultivate mushrooms, growers have faced serious challenges caused by various viral infections. Fungal viruses, namely mycoviruses, persistently infect fungal taxonomic groups, including plant pathogenic fungi and mushrooms. The infection has been known to cause few significant phenotypic effects on mushrooms. Although careful farm management and extreme hygiene may prevent major attacks, some diseases are very difficult to control. Moreover, shelf life quality is severely affected by diseases that are still asymptomatic at the time of harvest. Epidemiological studies conducted by mushroom experts all over the world will be useful in determining the best methods for spreading and transmitting certain infections across a farm. To prevent a build-up of pathogen propagules around the farm, strong hygiene standards (disinfection, cook-out, foot-dips, door-seals, filters, flies-control) will be necessary across the board, every day, every crop. Given the high costs and restrictions for licensing new chemicals, as well as growing consumer and merchant requests for reduced pesticide use, new compounds will be few and far between. Because there are fewer pesticides available to manage disease outbreaks in the mushroom industry, and new and changing pathogens are emerging, farmers will become increasingly reliant on quick detection and containment of disease outbreaks as a first line of defense. Although biological control products are more likely to be accepted, they may not be as effective as traditional chemicals. Collaborative research studies across the major mushroom-producing countries could pave the way for identifying and registering any products that show to be beneficial. The newly

founded Worldwide Mushroom Diagnostic Group wants to share expertise on mushroom disease diagnostics, and it's a great place to work on international collaborative projects and spread information. Moreover, Indigenous plants are being tested for this purpose in Brazil, China, India, and the United States. To have enough raw materials to use for plant-based insecticides, it will almost certainly be essential to expand the planted area of beneficial crops. Furthermore, many indigenous plants can be found in abundance in villages, but farmers lack information on suitable collecting and storage procedures. To reduce application costs, growers frequently combine chemicals and plant products. Standardization of allelochemicals and complicated extracts is problematic in such circumstances. Similarly, extracting, isolating, synthesizing, and formulating plant material is a time-consuming and costly operation (Gahukar, 2012). New approaches for precise and speedy quantification of allelochemicals or maintaining quality norms can help alleviate this problem. High performance thin-layer chromatography, for example, is a method that uses less solvent and is more efficient than other procedures (Verma*et al*., 2011). Different dominant contaminants were reported during mushroom cultivation. *Trichoderma harzianum*, *Coprinus* spp., *Aspergillus niger* and *Penicillium* spp. were obtained during the incubation and cultivation period of the spawn of oyster mushroom, *Pleurotus ostreatus* (Akhter *et al*., 2017). The use of disinfectants such as chlorine (household bleach) and the application of selected fungicides are generally practiced in the cultivation of mushrooms, which involve significant costs. Furthermore, the use of chemicals is cultivation leaves undesired residues, several of which have been banned from use. Most chemicals that are still allowed have failed to adequately control major mushroom diseases as resistance us easily induced. Therefore, good alternatives have to be found.

## TYPES OF MUSHROOM AND DISEASES

Mushrooms are the fleshy fruiting bodies of fungi and include edibles species in the genus Agaricus (button mushrooms, portabellas and criminis), Pleurotus (oyster mushrooms) and Volvariella, (straw mushrooms). Mushrooms are highly variable in appearance depending on their stage of development and variety. Agaricus mushrooms have a cap and stem, the cap is a pale grey or brown in color and is rounder while immature, but flattens out as it reaches maturity and can reach a diameter of 5-10cm (2-4in). Pleurotus mushrooms may not have a stem and instead may be laterally attached to a growing substrate such as the bark of a tree. Pleurotus mushrooms are smooth and elongated and can reach 4-5cm (1.5-6.0in) in diameter. Volvariella mushroom are small, with pink gills and characteristic sac-like covering (volva) at the base of the stem. The cap can reach 5-15cm (2-6in) in diameter. There are two kind of mushroom diseases that occur; biotic or infectious diseases caused by fungi, bacteria, virus etc. and abiotic or noninfectious diseases or disorder caused by environmental factors.

## FUNGAL DISEASES

Microorganisms cause enormous losses in commercial mushroom farm worldwide. There are various competitor moulds and pathogenic fungi found to either grow on or infect different mushroom species. Those occurring mainly in compost include olive green mould (*Chaetomium olivaceum* and other spp.), inky caps (*Coprinus* spp.), green moulds (*Aspergillus* spp., *Penicillium* spp. and *Trichoderma* spp.), black moulds (*Mucor* spp., *Rhizopus* spp., *Fusarium* spp., *Cephalosporium* spp., *Gliocladium* spp., and *Papulospora* spp.). Fungi occurring in compost and casing soil are white plaster mould (*Scopulariopsis fimicola*), brown plaster mould (*Papulospora byssina*), lipstick mould (*Sporendonema purpurascens*), false truffle (*Diehliomyces microsporus*) and green moulds. Fungi occurring on and in casing soil and/or on the growing mushrooms are cinnamon mould (*Peziza ostracoderma*), wet bubble (*Mycogone perniciosa*), dry bubble (*Lecanicillium fungicola*), cobweb (*Cladobotryum dendroides*), pink mould (*Trichothecium roseum*) and green moulds. The disease, where, fungi attacking the fruits.

Some fungal diseases, causal organism's symptoms and their management are suggested below:

**Soft mildew or cobweb**

**Causal organism**- *Cladobotryum dendroides*

**Symptoms: -** A fluffy, white, cobweb like mould grows over the surface of the casing soil. Initially it is white but later changes to pink with age. The chief sources of infection are soil, air, wet surface and high humidity.

**Control: -** Good ventilation and prevent excess humidity. PCNB (Pentachloro Nitro Benzene) @0.1% and dithaneZ-78@0.2%.

**Brown plaster mould**

**Causal organism**- *Papulospora byssina*.

**Symptom: -** Occurs on the cropping tress, initially cloudy white appearance later changes to brown. Originally fungus rises in compost. Too wet compost, high temperature (28-32$^{o}$C) during spawn run and cropping at more than 18$^{o}$C encourages infection.

**Control: -** Maintain suitable temperature during the spawn run and cropping 2% of formalin.

**White plaster mould**

**Causal organism**- *Scopulariopsis fumaroles*.

**Symptoms: -** Closely resembles brow plaster mould initially but later changes to pink shade. Too much water in the composting anaerobic peak heat leads to the growth of fungus.

**Control:-**Formalin2% anddithaneZ78@0.2%.

**Olive green mould**

**Causal organism** - *Chaetomiumolivaceum*.

**Symptoms: -** Appear in compost or spawn before casting. Initially white and change to olive green afterwards. Improper pasteurization and inadequate ventilation leads to it.

**Control: -** Temperature maintained below 60$^{0}$Cduring pasteurization. Spray 0.2% thiram and captan @0.05% at trays.

**Inky cap**

**Causal organism** - *Coprinuslagopus* and *Coprinuscomatus*.

**Symptoms: -** Appearance of long cylindrical stalk with small thin cap and turns into black inky liquid its presence indicates the presence of ammonia in compost. **Control: -** Trays of compost should be freed from ammonia Re-pasteurization of spawn trays at 60$^{o}$C for 2hrs and respawned and recused.

**Green mould**

**Causal organism** -*Trichodermaaggressivum*.

**Symptom: -** Appear as green patches on spawn and cased trays. Checks pin formation and hence reduces yield. Fungus grows on dead decomposed matter and dead mushroom tissue. Improper pasteurization and high humidity also responsible.

**Control: -** Spray 0.05% benlate.

**Truffle disease**

**Causal organism–***Pseudobalsamiamicrospora*.

**Symptoms: -** Appearance of round, cream coloured, and wrinkled convoluted surface giving it a brain like appearance. On maturity turn reddish brown and released spores. Lack of ventilation and high humidity leads to it.

**Control: -** Spawn run and cropping bed temperature

**Wet bubble diseases**

**Causal organism** - *Mycogoneperniciosa*.

**Symptom: -** Dense white mat of mycelium leading too reduction in yield. Swollen stalk and smaller cap at early stage. Unpasteurized compost also leads to it.

**Control: -** Beds sterilized@2% formalin. Spray dithane Z-78 @0.2% and benlate@0.05%.

**Dry bubble or brown spot disease**

**Causal organism** - *Lecanicilliumfungicola* or *Verticilliumpsialliste*.

**Symptom: -** Brown spot on cap, resulting in irregular patches in severe infection mushroom become distorted. Affected mushrooms become leathery.

**Control: -**Dithane Z78@0.2% 3 times at casing. Control of high temperature at casing and proper ventilation.

**Mat**

**Causal organism** - *Chrysosporium luteum*.

**Symptoms: -** Primordia (pins) do not form in the casing and, consequently, mushrooms do not develop. The cottony, white mycelium of *C. luteum* may aggregate in a distinctive

matted layer located between the compost and the casing. Small oval conidia, 3.0 to 4.5 µm, are borne irregularly on swollen cells, and short chains of two or three conidia may be produced on a pedicel. The species is more serious when mineral soil is used as casing rather than peat moss (Carmichael, 1962).

**Confetti**

**Causal organism** - *Chrysosporiummerdarium*.

**Symptoms: -** Confetti-like mycelial mats interspersed throughout the compost are caused by *C. merdarium*. These small mats yellow as they age and may be difficult to see by naked eye. The species is more severe when mineral soil is used as casing rather than peat moss. Formation of mats, within the compost for confetti disease, and on the surface of the compost for mat disease, reflects the growth stage of the pathogen and its interaction with the mushroom mycelium. It is thought that secondary metabolites interfere with the formation of the mushroom primordia. Initial infestation of compost likely occurs from sources outside of mushroom operations, like surrounding fields are plowed or eroded by wind. Infested compost can also be a source of large amounts of inoculum. Compost exposed to inoculum of Chrysosporium, when it is spawned will be thoroughly infested and crop losses will result (Carmichael, 1962).

**Cultural management of mat and confetti**

Mat and confetti inocula, when present in compost, can only be managed through pasteurization (12 hours at 70 °C) before the compost is removed from the growing rooms. *Chrysosporium* species are more difficult to control than other molds, hencethe need to use a higher-than-normal temperature and a longer time for pasteurization. Otherwise, disease management is based on reducing the number of spores released into the air in the vicinity of the spawning operation. High efficiency particle (HEPA) filters and positive air pressure should be used in the spawning area to minimize infestation of the compost.

**Sepedonium yellow mold**

**Causal organism** - *Sepedoniumniveum*.

**Symptoms: -** The white mold produced by Sepedonium turns dull yellow to tan with the maturity that competes with the mushroom mycelium. It has been found at the bottom layers of the tunnels in bulk pasteurization and conditioning methods. In culture, the thallus is white when young, then turns golden yellow both in and on the substrate (Botha and Eicker 1986). Conidia are large (13 to 17 µm), globose, thick- and rough-walled, light yellow and borne singly at the apex of short conidiophore. The spores of Sepedonium are survive peak heat as they are resistant to high temperature and can spread easily to the compost by air currents during the filling and spawning operations, or during spawn-run. Unpasteurized or spent compost sticking to beds or trays can spread this mold to the crop.

**Cultural management practices of Sepedonium yellow mold:**Yellow mold can be prevented through careful attention to maintain hygieniccondition and by proper air filtration. Careful monitoring in every stage of production and post crop pasteurization temperatures are also necessary (Sinden 1971).

**Nematode-trapping fungi:** The infectious agents are *Arthrobotrys* spp.

**Symptoms: -** When nematode populations are high, a superficial, sparse, thin, white growth, pink or brown colonies of the fungus is frequently observed on the casing surface depending on the species present on the casing surface. The affected area can be greater than 1 m in diameter. This fungus traps and feeds on free-living, saprophytic nematodes (*Rhabditis* spp.). Conidiophores are erect, arising from the substrate or from fasciculate aerial hyphae, and are simple or branched. They produce apical clusters of two-celled, hyaline conidia successively on broad denticles on sympodial branches. As the fungus needs nematodes to survive, it will appear only in association with peak infestations and usually near the end of the mushroom crop.

**Cultural management practices of Nematode-trapping fungi**: Sanitation and other practices that reduce the build-up of saprophytic nematodes in casing can help to prevent the growth of *Arthrobotrys* spp.

**Other fungal diseases:** Other minor and uncommon fungal diseases including Aphanocladium cap spot caused by *Aphanocladium album*, Gill mildew caused by *Cephalosporium* spp., Hormiactis cap spot caused by *Hormiactis alba* and Shaggy stipe caused by *Mortierellabainieri*. These less common fungal diseases occasionally have been reported to cause significant yield loss to commercial mushroom production (Flegg*et al*., 1985; Fletcher *et al*., 1989).

**General management practices of fungal diseases**: The best and common approaches to combat the diseases and environmental control measures of mushrooms are as follows (Gea and Navarro, 2017):

1. Any mushroom crop-related action should always be performed onthe newer crops before the older ones.
2. Store casing materials in areas where they won't get contaminated.
3. Before watering or harvesting, remove all affected mushrooms. Onthe mushroom farm, pay great attention to irrigation and toolsmanagement.
4. Do not move nozzles or hoses from old to new mushroom-growingcrops unless they have been disinfected first.
5. Use only new or disinfected collector boxes that have not beenpolluted by contaminated crops.
6. Don't make the crop cycle any longer than it needs to be.
7. Once the crop cycle is finished, thoroughly clean and disinfects themushroom farm.

**Bacterial diseases**

A world-wide survey has shown that representatives of all the major commercially important genera of edible mushrooms, Agaricus, Pleurotus, Lentinus, Flammulina, Volvariella and Auricularia, are affected by bacterial diseases. *Pseudomonas* are the causal agents in most cases and crop losses increase as more intensive cultivation methods are used. The cultivated mushroom *Agaricusbisporus* is the most valuable protected crop grown in the UK. Losses due to spoilage by bacterial blotch (*Pseudomonas tolaasii*) are estimated at 5-10% of the total mushroom grown, with some further 10% downgraded in market value (Fermor, 1986).

**Brown blotch**

**Causal organism** - The disease is caused by *Pseudomonas tolaasii*. Brown blotch is the most common bacterial disease of commercial mushrooms, and it causes considerable economic losses each year through quality reduction.

**Symptoms: -** The symptoms most often observed include pale yellow areas or blotches on the cap that later turn golden yellow, yellow-brown or chocolate brown. The stem (stipe) also may be affected. Occasionally, the caps will have an overall dingy off-color with rapid deterioration and discoloration after harvest. Symptoms occur more frequently on mushrooms that remain wet for a long time and in places where they touch one another. The symptoms can be confused with those of other diseases, such as *Verticillium* spot. Main source of infection is infection in soil and separate through flies, mites should be there.

**Cultural management of Brown blotch:** The best practice to manage brown blotch is manipulating the growing environment. High relative humidity and surface wetness encourage the expression of disease symptoms. Blotch can easily develop when the mushrooms stay wet longer than two to three hours. Watering followed by additional ventilation will assist in drying. Maintaining a stable difference of 1 to 1.5 °C between wet and dry bulb readings will lessen the chance of condensation and significantly reduce the incidence of blotch. The crop should not be watered on consecutive days and growers should avoid watering mushrooms that are within one or two days of being harvested.

**Chemical control of Brown blotch:** Using chlorinated water may lower the bacterial population on the mushroom surface and thereby reduce the amount of blotch though chlorine alone is not sufficient to cure of this disease. The use of chlorine may negate the effectiveness of fungicides previously applied to the casing surface through a process of chemical inactivation. Recommended watering practices

and proper humidity management is important to reduce bacterial blotch severity.

**Wet Spot/Sour rot**

**Causal organism**- *Bacillus*spp. Heat resistant endospores.

**Symptom: -** A dull gray to mucus-like brownish slime characterized by a strong but foul odor variously described as smelling like rotting apples, dirty socks or burnt bacon.

**Management:** Soaking the grain at room temperature for 12-24 hours prior to sterilization.

**Mummy**

The pathogen is suspected to be a fluorescent pseudomonad, proximate to *Pseudomonas tolaasii*. Mummy disease is frequently encountered in mushroom crops; however, the data of annual economic loss is not available through the loss is typically only in a portion of any mushroom production chamber.

**Symptoms-**There is no known effect of this disease on spawn or case run, but, once fruiting has begun the symptoms appear. The first symptom may be a delayed first break. Mushrooms affected by mummy disease are characterized by curved stems with tilted caps. At the base of the stem, the rhizomorphs are stringy and cling to the casing. The base is frequently swollen and covered with a fluffy growth of mycelium. When harvested, a large amount of casing adheres to the base. Affected mushrooms die, become dry and are tough and leathery. Harvesters can often detect the disease by the tough feel of the stems when cut. Internal stem tissue will often have longitudinal brown streaks or be discolored, and when cut across; minute brown spots can be seen.

**Management of mummy disease**: Monitoring: Compost should be examined for wetness after the pasteurization of phase II compost. Wet areas on the compost surface at casing time or areas where the casing dries rapidly should be carefully examined for the disease.

**Cultural management of mummy disease:** Once mummy has been identified, diseased areas should be isolated from uninfected ones by completely removing the compost at least 1.5 m on either side of the affected area to a width of 20 cm and covering them with plastic. At the end of the crop, the compost should be thoroughly pasteurized. Netting and shelving should be carefully cleaned and disinfested before re-use.

**Chemical control of mummy disease:** Infested netting and shelving should be treated with a formalin solution or hydrated lime.

**Actinomycetes mould**

Composts have long been known as important sources of actinomycetes (Miehe, 1907; Miquel 1888; Tsiklinsky, 1899) and it was also soon discovered that many of the species in these materials are thermophilic and able to grow at temperatures up to 65-70 °C. Such high temperatures result from the strong microbial activity, possible when there is adequate water, nutrient and oxygen, releasing energy through their respiration faster than it can be dissipated. Mushroom compost is generally prepared by a specialized two phase process, involving artificial heating during the second phase. However, the microbiology of this process has been studied more thoroughly than composting of other materials and it will be used as the basis for a discussion of the occurrence and role of actinomycetes in composts in this paper. General Actinomycetes found in compost are *Thermoactinomyces* (White, yellow colony), Micromonospora (Orangeblack colony), *Promicromonospora* (Yellow colony), T*hermomonospora* sp. and *T. chromogena* (White colony), *Saccharomonospora* (Blue, green, violet colony), *Saccharopolyspora* (White, pink, brownish grey colony), *Microtetraspora* (Blue-grey, cream, grey, pink, violet, yellow, white colony), *Actinomadura* (White, yellow, pink, blue, green, grey colony), *Nocardiopsis* (White to yellowish grey colony), *Saccharothrix* (Yellowish - white, yellowish-grey colony), *Nocardia* (White, pink colony), *Pseudonocardia* (White colony), T*hermocrispum* (White colony), *Amycolatopsis* (White colony) and *Streptomyces* (White, yellow, green, grey, blue, pink, red, purple colony) (Korn-Wendisch et al., 1995; Lacey, 1997). Sewage composts contain several isolates including *Nocardia*, *Saccharopolyspora* and *Saccharomonospora* spp., *Streptomyces* spp., and the ***thermophilic*** Stm. megaspores, Stm.

Macrosporus, Stm. Thermolineatus (Goodfellow et al., 1987), *Promicromonosporacitrea* and *Thermoactinomyces vulgaris* (Lacey, 1997).

**Control of actinomycetes:** Sanitation practices and dust control measures or enclosure of composting facilities may therefore be necessary. Workers should be fully protected against inhalation and contaminate of actinomycetes at all times.

**General management of bacterial diseases**: The best and common approaches to combat the diseases and environmental control measures of mushrooms are as follows: The best approaches to combat the disease are to adhere to stringent cleanliness and environmental control measures (Gea and Navarro, 2017): Wipe the culture surface clean of all carpophores.

1. Increase evaporation from the culture surface and the carpophores' surface.
2. When composting, stay away from low temperatures.
3. Remove any remaining water on the fruiting bodies' surface.
4. After irrigation, run a 2-hour drying cycle.
5. Maintain a precise temperature control so that the dew point is notreached. Temperature swings should be avoided.
6. Prevent casing material flooding during the crop cycle.
7. Keep all tools in a clean environment.

**Viral diseases**

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, *Agaricusbisporus* being one the few. There is no known vector of mushroom viruses. Various diseases like La France (Sindenhauser, 1950) Brown disease and watery stripe (Gandy, 1950) X disease (Kneebone et al., 1962) Dieback disease (Gandy and Hollings, 1962).

**Symptom:** Mushrooms get shriveled, leathery and brown colored. Under humid condition stripe become watery and grey. Cream and off colored mushrooms suffer less than pure while variety. La France virus disease X disease of mushroom.

**Management of viral diseases**: It's necessary to reduce or remove the virus's ability to enter fresh crop cycles at any stage, whether through spores or fragments of contaminated mycelium. Surfaces, machines and workers' clothing should all be cleaned and disinfected as part of the hygiene program (Gea and Navarro, 2017). Following steps should be taken to manage viral diseases.

1. A strict hygiene or sanitation program is necessary.
2. Increase the amount of pressure in the spawning area.
3. Worker movement in the spawning region should be restricted.
4. Diseased mushrooms must not be allowed to open and release their spores because spores are a major vector of viruses.
5. Ventilation systems must be tight and not create a negative pressureand sucking spores in beyond the filter to capture the 5 by 7 pmspores in the mushroom farm.
6. Before the spores are released, collect the immature carpophores.
7. Prior to usage, every equipment in the composting industry must be cleansed and disinfected.
8. Breaking up the mycelium and relocating it within the casing layer by using ruffling technique of the casing.
9. Casing materials must be kept in a clean environment.
10. Give the crops a thorough cooking out (steam treatment).
11. During the incubation stage, place sheets of paper or plastic on thesurface of the substrate to keep spores from dropping on thecompost.
12. Before using reusable plastic containers, make sure they are clean.
13. Changing spawn strains or alternate variety that does not anastomose minimize virus inoculums levels.
14. Agaricusbitorquis is reported to be tolerant to viral diseases.

15. Shipment and storage of spawn and mushrooms in the same cooler should be avoided.
16. Shared equipment between the farms or shipping/picking containersshould be disinfested before use.
17. Heating the growing room + tray and compost at 70 °C for 12 hrs is effective.
18. Treating tray with 4% sodium pentachlorophenate, 0.5-1% soda solution.
19. Disinfection doors, floors and walls with 4% formaldehyde.

**Non-infectious disorders**

Deviations in environmental parameters from the optimum requirement can cause many abnormalities in mushrooms. Large number of abiotic factors create unfavorable environment for the proper growth of mushrooms resulting in the quantitative as well as qualitative loss. These abiotic factors include low or high moisture in the substrate, pH and temperature, $CO_2$ concentration in the room, wind velocity, fumes and relative humidity. Many of these factors make the substrate nonselective for mushroom mycelium and encourage other moulds and pests while some interfere with normal mushroom production (Sharma and Kumar, 2007). The following abiotic disorders are quite frequently observed in worldwide mushroom production.

**Cracked mushroom:** It is also known as malformed mushroom. Fluctuation in humidity and temperature leads to cracked mushroom.

**Hard cap/Hard gill:** Flock is a physiologically induce malformation of the mushroom's cap and gill tissue. The cap opens pre-maturely and gills of the affected mushrooms are rudimentary, poorly developed and have little pigmentation (Sharma and Kumar, 2007). Affected mushrooms appear normal when viewed from above. From below, however, they are open and lack a veil. The gills are pink or frequently white. Sometimes, the gills are distorted, resembling those of a polypore. The cap is hard and brittle. The mycelium grows well through the compost and casing. First break is delayed and the time between breaks lengthened. The condition occurs throughout the crop. Mushroom production can be reduced to as little as 20% of a normal harvest.

**Cultural management:** Growers should follow practices recommended for the maintenance of spawn cultures and the growth of mushroom crops.

**Open veil:** Watering nearing to harvest can cause the mushrooms to open prematurely. This often occurs when the mushrooms have been under a water stress and a generous watering follows. Temperature fluctuation can also trigger opening of the veil, as can excessive carbon dioxide levels during cropping. Symptoms-The cap opens prematurely and the gills are fully developed and brown pigmented. Sometimes, the cap is disproportionally smaller than the stem. Open veil sometimes can be a symptom of a viral disease.

**Cultural management:** Generally, open veil can be avoided by maintaining suitable growing conditions and by not putting the crop under stress.

**Stroma:** Stroma are noticeable aggregations of mushroom mycelium on the surface of spawned compost of the casing. These are related to the genetic characteristics of the fungal strain. This can occur due to use of old or repeatedly spawn multiplied spawn. This is characteristically more common in some strains than others. Changes in moisture and humidity may also cause these symptoms. Excessive CO2, with high water content in the compost and prolonged spawn run period may also result in stroma (Sharma and Kumar, 2007). A few sectors will not affect yield adversely but the presence of excessive stroma may reduce yield. However, stroma may be accentuated through mishandling of the spawn in transit, storage or during preparation. Non-uniform casing moisture, especially wet areas, often is associated with the occurrence of stroma (Rinker, 1993). Symptoms the mycelium on the compost or casing surface aggregates into discrete, white patches, which later develop into a dense layer that can be peeled from the surface of the substrate. The formation of stroma occurs in advance of pinning.

**Cultural management: -** Spawn should be carefully handled and stored to minimize the risk of this disorder.

**Weepers/Strinkers/Leakers**: Mushroom typically exude considerable amount of water from mushroom cap. When small water droplets exude from stem or cap, the mushrooms are called leakers. The distinction between a leakers and weeper is that the water droplets remain as droplets on the leaker mushrooms while it actually falls or flows from a weeper. Weepers are usually noticed since they are quite unusual (Sharma and Kumar, 2007). A smooth white mushroom seems to have some sort of protection against leakers and weepers. Other major types-off-white, cream, golden white is susceptible to this malady.

**Mass pinning:** Mass pinning or pinning below the casing are common, especially during seasonal cultivation. Sudden fall in temperature, excessive aeration or early lowering of $CO_2$ concentration than recommended can lead to such symptoms. Many of the abiotic disorders are strain specific and some high yielding strains may be more sensitive.

**Hollow core and Brown pith:** These two disorders seem to afflict cream strain much more than other strains, although off while strains can have hollow core (Fig. 10). When the bottoms of the stems are trimmed after harvesting, a circular gap is seen in the centre of the stem. This hole may extend the length of the stipe or it may be shorter. When the hollow cut end portion is brown in color the sale price is considerably reduced (Sharma and Kumar, 2007).

**Rose comb**: Sometimes we may observe pinkish gills on the cap in an abnormal manner giving the appearance of the comb (Fig. 11). Such mushrooms are not marketable. The abnormality is associated with hydrocarbons, phenols and other compounds contaminating the casing or contacting the mushroom surface. Diesel oil, kerosene oil, petrol, exhaust from engines, and petroleum-based pesticides or oil products are thought to be the principal source of these chemicals. The mushrooms can even burst or split and then turn brown. The mushrooms are grotesque and unsaleable.

**Cultural management:** Growers should avoid exposing mushroom crops to the harmful chemicals that have been associated with this disorder. To assess their possible toxicity, paints, caulking compounds and other products that are to be used in the growing rooms should be applied to a board and placed next to developing mushrooms. If no symptomatic mushrooms develop, the material is likely safe to use.

**Browning discolouration:** Browning of small pin heads or half-grown mushrooms is very common on seasonal mushroom farms. This may be caused by high temperature, sprinkling at high water pressure (maximum pressure is 0.4atm), chlorinating with too high a chlorine rate (maximum rate is 500ml (10%) per 100 litre of water per 100 $m^2$) or incorrect use of formalin, e.g.by spraying the mushrooms with a formalin solution (Sharma and Kumar, 2007).

**Scales or crocodiles:** Scales arise through the surface tissue failing to grow while the cap develops further. The main reason for scale formation is poor climate control, in particular too much drying out or too great air velocities. Strong formaldehyde vapours or excess pesticide can also cause the outer layer of the skin of half-grow mushrooms to tear off. As the mushroom continues to grown, the skin bursts and so-called "crocodile" skin is formed. The off-white and cream mushroom strains are more sensitive to scariness than white mushrooms.

**Long stem:** The presence of long stems in combination with a number of other symptoms can indicate virus diseases but it is often the result of too high $CO_2$ concentration so that the stems extend more (drumsticks). Such conditions can be avoided with the improvement of aeration.

**Other abnormalities:** There are a number of other abiotic conditions that result in the formation of abnormal fruiting bodies, such as hollow cores, shaggy stipe, purple stem and saggy socks. Although these conditions are rare, they often concern growers.

## General management practices of non-infectious diseases

Non-infectious disease is caused due to unsuitable growing environment for the mushroom. Controlling and providing suitable environment for the mushroom help to avoid most of the non-infectious diseases. Few management practices of non-infectious diseases are as follows:

1. Use fresh substrate for preparation of compost. Floor for thepreparation of compost should be cemented or tiled and coveredwith a roof.
2. Spawn should be fresh and free from all contaminants. Spawningarea must be fresh and disinfected with 2% formalin.
3. The fresh air should be filtered before it enters the growing roomsto exclude all the particles of 2 microns and above.
4. Rooms should always be clean and it is important to regularlyclean/ whitewash/spray/repair these so that areas where spores canpersist or enter the room are taken care of. There is lot of debrisafter rooms are filled and bags are cased. Remove the debriscarefully. Don't sweep or use water jets to clean. Maintain optimum environmental conditions of temperature andhumidity in the cropping rooms.

## CONCLUSION

Intensive cultivation of edible mushrooms can often be affected by some bacterial, fungal and viral diseases that, rather frequently, cause dramatic production loss. These infections are facilitated by the particular conditions under which the mushroom is commonly carried out, such as warm temperatures, high humidity and low aeration rate. The unhygienic conditions of mushroom cultivation provide a congenial atmosphere for many diseases and pests. Therefore, a clean environment is also lately essential to mushroom production. The important considerations include previously cleaned implements and maintaining overall hygiene. This article argues that an understanding of the symptoms and treatment controls are needed for suitable and efficient production of mushrooms. In the future, food industries, export houses, and governments should pay greater attention to mushroom production and proper disease management, forming groups/associations (private, public, and nongovernmental organizations) for value addition. To encourage producers to employ plant-based goods, government subsidies and initiatives should be enhanced wherever they are available.

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