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Biological management of competitor moulds and diseases of mushrooms

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Abstract
Generally production of mushroom is effected due to the occurrence of diseases that can be caused by both pathogens and competitor moulds. The main diseases that occur in mushroom are dry bubble, wet bubble, cow web, green mould, bacterial blotch, yellow blotch etc. mainly and the diseases caused by competitor moulds are false truffle, brown plaster mould, yellow mould, ink caps, pink moulds and white plaster mould etc. mainly and competitor moulds that attack edible mushrooms are *Diehliomyces microspores*, *Myceliophthora lutea*, *Coprinus* spp., *Cephalothecium roseum corda*, *Scopulariopsis fimicola*, *Aspergillus* spp., *Alternaria alternate*, *Drechslera bicolor*, *Sclerotium rolfsii*, *Trichoderma viride*, *Fusarium* spp., *Rhizopus* spp., *Oedocephalum* spp., *Mucor* sp., *Penicillium* sp., *Mycogone perniciosa*, *Chaetomium* spp., *Verticillium* spp., *Sordaria* sp., *Psathyrella* sp., *Podospora favrelli*, *Rhizoctonia solani* etc. mainly and to control these diseases and competitor moulds the various Biocontrol agents are used like bacterial strains of Pseudomonads and Bacillus strains include *B. licheniformis*, *B. subtilis*, *B. pumilus*, *B. amyloliquefaciens* and also by *Bacillus velezensis* QST 713, *Psuedomonas reactants*, *Pseudomonas putida* and *P. floroscencs* and by some essential oils produced by some aromatic plants like *Origanum vulgate*, clove, thyme, cinnamon, tea tree which secretes volatile substances like carvacrol, thymol, genariol, citronellol which have antiseptic, antifungal and antibacterial properties and also some plant extracts or botanicals which helps in control of competitor moulds are onion, garlic, neem, lantana, gauva, tulsi, tomato etc. mainly, where neem gives the best results when used to control many competitor moulds.

Keywords: Diseases, competitor moulds, biocontrol agents, essential oils, botanicals

Introduction
The different workers studied several features of diseases and fungal contaminants of *Pleurotus* spp. (Castle *et al*., 1998; Hermosa *et al*., 1999; Mamoun *et al*., 2000; Neelam *et al*., 2014) [12] and reported several major contaminants like *Penicillium* spp, *Aspergillus* spp, *Trichoderma* spp, *Coprinus* spp, *Stemonitis* spp, *Moniliasi tophila*. When the collected substrate is not pasteurized properly then the contaminants species become more active in *Pleurotus* cultures. The most damage caused among the contaminants species is *Trichoderma harzianum* and it reduces the production of *Pleurotus ostreatus* i.e., 30-50% by aggressively competing with it. (Shin, 1987) [52].

In mushroom beds of *P. florida* the competitor moulds found more attacking are *Sclerotium rolfsii*, *Penicillium* sp., *Coprinus* sp. and *Aspergillus niger* (Biswas and Kuiry, 2013) [10]. They observed that the contaminants found mainly on the production bed of oyster mushroom are *Rhizopus*, *Trichoderma*, *Aspergillus* and they occur more frequently in spring and summer season than winter and autumn season (Jaivel and Marimuthu, 2010) [25]. In India, the fungicides are widely used in control of competitor moulds in oyster mushroom cultivation. (Jain and Vyas, 2002; Singh and Kumar, 2011; Debata *et al.*, 2014) [53]. To reduce the pest resistance we use various plant extracts for controlling the growth of competitor moulds on mushroom beds (Patra *et al.*, 1998; Singh, 1999).

The samples of *Verticillium fungicola* is collected from the compost of mushroom farms of Haryana, Punjab, Himachal Pradesh (Sharma, 1992) [49]. The wet bubble disease in white button mushroom is caused by *Mycogone perniciosa* and this disease is first reported in India on mushroom farms in states of Jammu and Kashmir (Kaul *et al.*, 1978) [27]. Later this disease was observed in states of Maharashtra, Himachal Pradesh, Haryana (Sharma, 1974; Bhatt and Singh, 2000; Sharma and Kumar, 2000) [8, 37, 29].

The cow web disease is caused by *Cladobotryum dendroides* and this disease was first reported in India at Chail and Shimla (HP) and later observed in Solan and Kasauli with incidence of 18% - 26% (Seth and Dar, 1989) [42, 43]. The marketable losses caused by this disease is about 66% under artificial inoculation of pathogen (Sharma and Vijay, 1996) [46]. In white button mushroom a new pathogen is observed in Himachal Pradesh called *C. verticillium* (Sharma *et al*., 1992) [49]. False truffle disease is caused by *Diehliomyces microsporus* in white button mushroom, it is the most damaging competitor mould and It was first reported in India in states of Punjab, Uttar Pradesh, Himachal Pradesh, Haryana (Sharma and Vijay, 1996) [46]. When the temperature in compost of mushroom reaches above 22 -24 ºC, it is observed that losses caused by False truffle in mushroom increases at this temperature in India. In Himachal Pradesh, the incidence of this competitor moulds was reported up to 66-68% (Sharma and Jandaik, 1996) [46].

In India, this fungus is available on majority of mushroom farms appears at spawn run stage (Munjal and Seth, 1974; Kaul *et al*., 1978; Garcha *et al*., 1987; Sharma, 1992] [27, 15, 49]. Yellow mould or mat disease is caused by *Myceliophthora lutea*, *Chrysosporium luteum*, *Chrysosporium sulphureum* and it was first reported at Jammu and Kashmir (Kaul *et al*., 1987). Ink caps disease is caused by *Coprinus* spp. and it is observed mostly on mushroom beds in northern India at spawn run period (Kaul *et al*., 1978; Garcha, 1984; Sohi, 1986) [27, 54]. Cinnamon mould disease is caused by *Chromelosporium fulva* and it is observed in Mushroom beds of Jammu and Kashmir (Kaul *et al*., 1978) [27], Himachal Pradesh (Sohi, 1988) [55], Punjab (Garcha *et al*., 1987) [15].
Pink mould disease is caused by *Cephalothecium roseum Corda* and it is majorly observed in Chail and Solan in Himachal Pradesh (Seth, 1977; Sohi, 1986) [45, 54] and also reported in areas of Jammu and Kashmir (Kaul *et al*., 1970).

Diseases of mushroom

The main diseases that effect growth and development of mushroom are:

Dry bubble: It is caused by *Verticillium fungicola* and it causes losses in the mushroom by decreasing the weight and also number of fruiting bodies produced in mushroom and is about 47.2% (Sharma and Vijay, 1993) [48]. The main symptom of this disease is that the infected fruiting bodies gets malformed and also becomes onion shape, irregular size and the dry leathry tissue mass enlarges (Fig. 1) (Sharma, 1994).

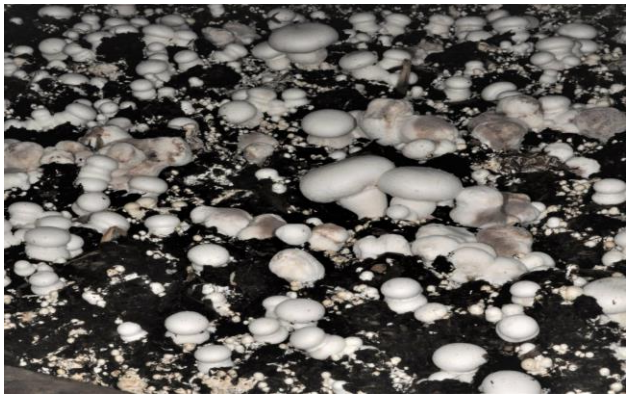

Fig 1: Infected fruiting bodies of white button mushroom with *Verticillium fungicola*

Wet bubble

It is caused by *Mycogone perniciosa* and it causes losses about 15.72 to 80. 13% yield of mushroom under artificial inoculation. (Bhatt and Singh, 2000) [50]. Mainly the symptoms include white mouldy growth which leads to giving of foul smell from the mushroom, generally infected sporophores form two main symptom i.e tumour forming on pinheads, and other is occurring of malformation at later stage (Fig. 2).

Fig 2: Infected sporophores of white button mushroom with *Mycogone perniciosa*

Cow web: It is caused by *Cladobotryum dendroides* and it causes losses about 66% to marketed mushroom and various temperature it causes losses about 21.95 – 48.95%, generally the symptoms include when mycelial felt is removed from infected mushroom, it exudate some drops of dark brown colour liquid which give foul smell (Seth and Dar, 1989) [42, 43]. and also other main symptoms are entire fruiting body gets decompose and in later stages as the development of infection occurs the mycelium gets pigmented and later turns to pink colour, and also brown to pinkish brown spots appears on the mushroom caps (Fig. 3) (Sharma, 1994).

Fig 3: Infected fruiting bodies of white button mushroom with *Cladobotryum dendroides*

False Truffle: It is caused by *Diehliomyces microsporous and* due to this competitor mould it causes about 58-80% yield losses in mushroom beds (Sharma and Jandaik, 1996) [46]. The symptoms include small wefts of creamy white colour mycelium appears on compost of mushroom, later the mycelial growth gets thick and causes round or irregular fungal masses which are solid and wrinkled shape appears in white colour and at maturity they turn to pink, reddish colour (Fig. 4) and gets disintegration into powdery mass exudate chlorine smell.

Fig 4: Infection occurs in compost of white button mushroom with *Diehliomyces microspores*

Bacterial blotch: It is caused by *Pseudomonas tolaasii* and it is the most destructive bacterial disease that occur in white button mushroom and the pathogen first observed in India (Guleria, 1976). It also causes yield losses is about 5 to 10%, and losses can mainly occur after harvest of mushroom and when stored night long at low temperature (Nair, 1969). The symptoms include appearance of brown spots on pilei and in severe cases also appears on stripes, on the margins of cap irregular yellow spots develop and which enlarge rapidly and combined to form suken chocolate brown blotches and in severe cases when blotch symptom appears the mushrooms may get distorted and the caps get split and also concave spots appears on surface of infected fruiting bodies (Fig. 5).

Fig 5: Infected fruiting bodies of white button mushroom with *Pseudomonas tolaasii*

Yellow blotch: It is caused by *Pseudomonas agarici* and it causes losses like total crop failure in mushroom beds was observed by (Jandaik *et al*., 1993) [26]. The symptoms include appearance of blotches of different sizes on pilei they appear as sunken, yellow to brown or orange in colour when the disease occur at pinhead formation or primordia development stage the early fruiting bodies get totally infected and under high humidity condition slimy appearance occurs on infected fruiting bodies (Fig. 6).

Fig 6: Infected fruiting bodies of white button mushroom with *Pseudomonas agarici*

Competitor moulds

The various competitor moulds of Oyster mushroom that suppress the growth of mushroom by uptaking the nutrients required for mushroom are: *Aspergillus* spp., *Coprinus* spp., *Alternaria alternate, Fusarium* spp., *Mucor* sp., *Penicillium* sp., *Rhizopus* spp., *Drechslera bicolor, Trichoderma viride, Sclerotium rolfsii, Oedocephalum* spp. and these competitor moulds causes losses in oyster mushroom spp. is about 70% (Sharma and Jandaik, 1980,1981; Singh and Sexena, 1987; Doshi and Singh, 1985; Vijay and Sohi, 1989; Das and Suharban, 1991) [42, 43].

The various competitor moulds of paddy straw mushroom that are destructive for its growth are: *Mycogone perniciosa, Chaetomium* spp., *Verticillium* spp., *Sordaria* sp., *Scopulariopsis fimicola (*Gupta *et al*., 1970). Also some other competitor moulds which are observed in the substrate of mushroom are: *Rhizopus* spp., *Psathyrella* sp., *Sclerotium* spp., *Coprinus* spp., *Aspergillus* spp., *Penicillium* spp. and these are the major pathogens or competitor moulds that causes severe damage to paddy straw mushrooms (Munjal, 1975; Bahl, 1984; Purkayastha and Das, 1991; Rangaswami, 1978). The competitor moulds like *Podospora favrelii* is a main competitor and it causes reduction in growth of mycelium was observed by (Bahl and Chowdhry, 1980). Also other competitor moulds like *Rhizoctonia solani* observed on the substrate of mushroom and it decreases the formation of sporophore and also causes disfigured fruiting bodies. (Bhavani Devi and Nair, 1986) [9]. Following moulds used to occur on mushroom crops:

Green mould: It is caused by *Trichoderma viride* and it causes losses about 12.5 ₹ 80.8% during artificial inoculation [Sharma and Vijay, 1996] [46] and it is also caused by *Trichoderma harzianum* and it also causes losses about 50% under artificial inoculation (Jandaik and Guleria, 1999). The symptoms include dense white mycelial growth occurs on compost and later turns into green colour mycelial growth due to heavy sporulation of pathogen (Fig. 7) and it mainly infects new parts and primordia development.

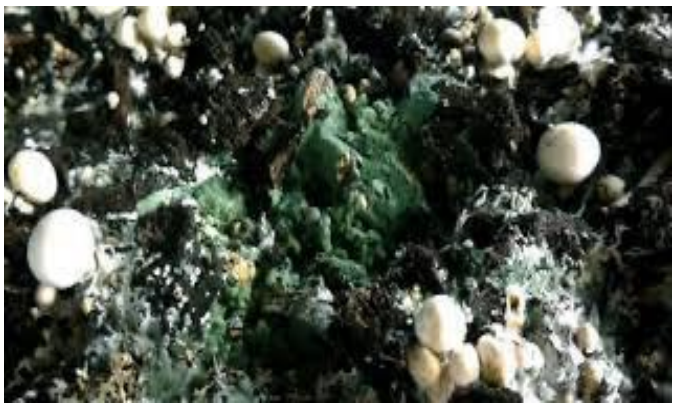

Fig 7: Infection occurs on compost of white button mushroom with *Trichoderma viride*

Brown plaster mould: It is caused by *Papulaspora byssina Hots.* and due to this competitor mould it causes about 90 ₹ 92% yield losses in mushroom beds in *Agaricus bisporus* (Munjal and Seth, 1974) and this competitor mould also causes crop failure in oyster mushroom (Dar and Seth, 1981). The symptoms include white mycelial growth on compost, trays, bags due to condensation of moisture and later it develops into dense large patches and the colour also changes

to light brown and later turns to cinnamon brown and finally turns to rust colour (Fig. 8).

Fig 8: Infection occurs on compost of white button mushroom with *Papulaspora byssina*

Yellow mould: It is caused by *Myceliophthora lutea* and it also causes yield losses in mushroom beds about 20% and this competitor mould at various stages causes losses about 27 to 89% in artificial inoculation in the yield of mushroom beds (Seth and Bhardwaj, 1989) [42, 43]. The symptoms include forming of circular colonies in compost by fungus, the yellow brown corky mycelial layer occurs on compost and stroma like morphology develops so that can't be detected when spawning occurs (Fig. 9) and finally it reduces mushroom production.

Fig 9: Infection occurs on compost of white button mushroom with *Myceliophthora lutea*

Ink caps: It is caused by *Coprinus* spp. *and* this competitor mould also causes losses when spawning occurs about 20 to 94% and also causes decrease in weight of fruiting bodies is about 15 to 95% (Sharma, 1992) [49]. The symptoms include slender bell shaped mushrooms first appears as cream colour and later turns to bluish black colour, this fungus appears on compost and mushroom beds in cluster form and due to autodigestion the ink caps gets decay and finally appears as bluish colour slimy mass (Fig. 10).

Fig 10: Infection occurs on compost, mushroom beds of white button mushroom with *Coprinus* spp.

Pink mould: It is caused by *Cephalothecium roseum* Corda and this competitor mould causes crop failures and yield losses about 90% (Seth, 1977; Sohi, 1986) [45, 54]. The symptoms include at first they appears white colour mycelial growth and later at maturity turns pink in colour, spawn run doesn't occur, compost turns into dull brown in colour and chlorine like smell occur when it gets disintegrated into powdery mass and it doesn't allow mycelial growth of mushroom (Fig. 11).

Fig 11: Infection occurs on compost of white button mushroom with *Cephalothecium roseum Corda*

White plaster mould: It is caused by *Scopulariopsis fimicola* (Fig. 12) *and* this disease is commonly observed in various parts of India and it causes losses to the yield about 37% (Garcha, 1978; Kaul *et al*., 1978; Sohi, 1986; Bhardwaj *et al*., 1989) [17, 27, 42, 43, 54]. The symptoms include the the fungus appears densely on casing,compost of mushrooms and changes from a white fluffy growth to a dense mat of mycelium as it develops the colour changes from white to pink and later turn red, later the spots becomes yellow colour and finally it reduces the production of mushroom

Fig 12: Infection occurs on casing, compost of white button mushroom with *Scopulariopsis fimicola*

Bio-control of Microbial pathogens in edible mushrooms: The control of microbial pathogens that causes major losses in mushroom crops or in mushroom beds is done by maintaining proper hygienic conditions (Fletcher and Gaze, 2008; Berendsen *et al*., 2010; Gea *et al*., 2010; Carrasco *et al*., 2016) [14, 4]. The bio control agents like *Bacillus velezensis* QST 713 is used in control of pathogen on mushroom beds (Pandin *et al*., 2018) [38]. The bio control agent which is commercially marketed as Mycostop which is obtained from *Streptomyces griseoviridis* was more efficient in controlling *L. fungicola* in mushroom cropping (Beyer *et al*., 2016) [6]. Generally now a days the bacterial strains of genera

Pseudomonads and Bacillus are more used as bio control agents and the bacillus strains like *B. licheniformis, B. subtilis, B. pumilus and B. amyloliquefaciens* can control the pathogens that inhibit the growth and development of mushroom in vitro stage (Berendsen *et al*., 2012; Liu *et al*., 2015; Stanojevic *et al*., 2016; Milijasevic- Marcic *et al*., 2017) [5, 31, 57, 34]. At *In-vitro* condition the mycelial growth and germination of spore in pathogens that attack the mushroom can be hindered by Bacillus spp. So for the purpose of making success of crop trails the proper selection of most effective strains are used at in vitro condition at a particular time interval application for commercial mushroom production cycle (Milijasevic-Marcic *et al*., 2017; Aslani *et al*., 2018) [34, 1].

To stop losses caused by green mould disease during mushroom growth the bio control agents that are introduced like *Bacillus subtilis* B-38, *Bacillus velezensis* QST 713 (Pandin *et al*., 2018; Milijasevic-Marcic *et al*., 2017) [38, 34]. To decrease the fungicides usage to control fungal pathogens some eco- friendly biomolecules are tested and also shown that they have the capability to reduce the occurrence of fungal diseases in mushroom crop growth and development (Gea *et al*., 2014; Mehrparvar *et al*., 2016; Dos Santos *et al*., 2017) [18, 33, 13, 19].

It is observed that some essential oils from particular aromatic plants is used due to their fungicidal, antiseptic and bactericidal effects on pathogens and for controlling them effectively (Bakkhali *et al*., 2008) [3]. Some essential oils also acts as fungicides and it stops the pathogen from germinating on mushroom beds (Sokovic *et al*., 2006; Glamoclijia *et al*., 2007, 2009) [56, 22, 21]. Among the essential oils from several aromatic plants the *Origanum vulgate* (wild marjoram) shows highly effective against many pathogens (Sokovic *et al*., 2006) [56].

The essential oils from the aromatic plants like clove, thyme, cinnamon, tea tree produces volatile secretions like carvacrol, thymol, genariol and citronellol shows the antifungal characters against cowweb and bubble diseases at in vitro condition (Mehrparvar *et al*., 2016; Dos Sontos *et al*., 2017; Tanavic *et al*., 2006, 2009; Potocnik *et al*., 2010) [33, 19, 60, 59, 40]. In some crop trails the essential oils produced from *Cymbopogon citratus, Thymus vulgaris and Lippa citriodora* are toxic against *M. perniciosa* so that it controls the pathogen from effecting the mushroom crop trails (Regnier and Combrinck 2010) [41].

The essential oils consist of phelonic compounds that have both antifungal and fungistatic affect on cell membrane both structure and function, these bioactive compounds are mainly volatile in nature which help in obtaining commercialized products and it decreases residues of chemicals (Sokovic *et al*., 2006) [56]. In white button mushroom it is observed that by usage of extracts of teas compost we can contol dry bubble diseases without inhibiting the growth and development of button mushrooms in case of both *in vivo* and in vitro conditions (Gea *et al*., 2012, 2014) [19, 18].

In some cases it is also observed that when treatment is given with tea compost which is obtained from the wastes produced from mushroom cultivation is an better treatment to control *L. fungicola* and bubble diseases at both in vitro and *in vivo* conditions and it also decrease fungitoxic effectivity on host crop (Gea *et al*., 2012; Dos Sontos *et al*., 2017) [19, 13]. Generally it is observed by some scientists that in bacterial diseases like brown blotch can be contolled by using bio control agents like antagonistic bacteria (Largeteau and Savoie, 2010; Kim *et al*., 2011; Tajalipour *et al*., 2014; Aslani *et al*., 2018) [30, 28, 58, 1].

Suppose for example we can take. P. rectans bacteria which produce a substance named lipopeptide which helps in reducing the toxic nature of lipopeptide toxin tolaasin so that *P. tolaasii* causes symptoms in white button mushroom, the bio control agent P. rectans is used to control bacterial blotch diseases of white button mushroom (Largeteau and Savoie, 2010) [30]. It is observed that some bacterial strains like *Bacillus thuringiensis* De 4 and *Pseudomonas taiwanensis* Bi 1 which are isolated from wild mushrooms helps in controlling the diseases caused by bacteria like *Ewingella americana* and *Psuedomonas tolaasii* and it causes diseases like brown blotch and internal stripe necrosis symptoms in mushroom crops and also helps in reducing these diseases (Aslani *et al*., 2018) [1].

Some other bacterial strains are also there like *Bacillus subtilis* A5, *Pseudomonas reactants* A2 and A6, *Pseudomonas putida* A1, *Pseudomonas fluorescens* A3 and A4 which are obtained by isolation from the fruiting bodies and casing compost and also these bacterial strains helps in reducing the symptoms and damage caused by brown blotch in mushroom culture (Tajalipour *et al*., 2014) [58]. Some botanicals are also used like plant extracts that are helpful in phytochemical control of some bacterial diseases much efficiently (Sokovic *et al*., 2006; Malapani *et al*., 2012) [56, 32].

To naturally preventing occurrence and spread of bacterial blotch disease by maintaining proper environmental conditions like water drying on surface and also to prevent occurrence of moisture on mushroom caps (Narvarro *et al*., 2018). Some botanicals or plant extracts are used in white button mushroom for control *V. fungicola* which causes dry bubble disease like onion, garlic, neem, lantana, guava, tulsi, tomato are mainly used (Nene and Thapliyal, 2000) [37]. It is observed that neem extract is used for controlling false truffle disease in white button mushroom and it also gives better results when treated with neem extract at in vitro conditions (Sharma and Jarail, 2000) [50].

It is also observed that when 10% neem leaf extract treatment is effective in controlling the pathogen *Sepedonium chrysospermum* that causes yellow mould disease in white button mushroom (Sharma and Rajesh, 2005). In white button mushroom the control of *Trichoderma harzianum* and *Trichoderma viride* is done when treated with 5 – 10% neem leaf extract or neem seed cake to get better results at in vitro condition (Mishra, 2009) [35].

Conclusion

In this article we will learn about various diseases caused in various edible mushrooms by pathogens and competitor moulds and also various competitor moulds that attack the mushroom beds and losses caused by them to mushroom production and finally how to control them in eco- friendly manner by using various Biological control methods like biocontrol agents, essential oils, plant extracts or botanicals so that to reduce the losses caused by the pathogens and competitor moulds to get more mushroom yield.

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