Plant Pathology

Mushroom Cultivation

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Mushroom is a saprophytic fungus that grows on dead and decaying organic matter. Due to the absence of chlorophyll, it is unable to synthesize its own food and hence is dependent upon the organic matter/substrate for food. The first record of cultivation of mushroom dates back to the reign of Louis XIV (1637-1715). French scientists were the first to detail record the mushroom cultivation techniques which is valid even now. In the same context, an article was published in Paris in 1707, following that mushrooms were cultivated in the foothills of France in 1800. In these regions horse dung was used (which itself got pasteurized due to high temperatures), as the substrate for spawn inoculation and mushroom production.

Subsequetly, this technique spread to neighbouring areas and local inhabitants started mushroom cultivation in cases, mines and other moist areas. In 1810, mushroom cultivation began in specially designed crop rooms which got further cultivation in many parts of the world.

In India, commercial cultivation of mushrooms had been with the joint effort of scientists and farmers. Annual mushroom production has increased to 80,000 ton in 2006 from a mere 1,000 ton in 1981. Fifty percent of this is produced by marginal and small production units and the rest by industrial establishments. Mushroom husbandary is now one of the major sources of income for farmers of many states like Haryana, Uttar Pradesh, Punjab, Uttarakhand and Himanchal Pradesh. The major producers of mushrooms are Punjab (35,000 MT) Tamilnadu (15,000MT), and Andhra Pradesh (5000MT). Mushroom production of Uttarakhand alone increased from 2,640MT in 2000 to 5340MT in 2006, with Dehradun, Nainital, Haridwar and Udham Singh Nagar the major production centres. Button mushroom (*Agaricus bisporus*) constitutes about 90% of total production in India where that of other cultivated mushrooms viz. *Pleurotus, Lentinula, Auricularia* and *Calocybe* are very marginal.

History

The consumption of mushroom by man probably predates recorded history, and the historical record is an indeed ancient one. The historical records of the intentional cultivation of several important edible mushrooms are shown in Table 1. It is estimated that the first mushroom was cultivated around 600 A.D. This was *Auricularia auricula*. Later, around 800-900A.D. *Flammulina velutipes* was also cultivated in China. *Lentinula edodes* is estimated by us to have been cultivated for the first time between 1000-1100A.D. Of the leading mushrooms of today that were cultivated before 1900, *Agaricus* is the only one that was not first cultivated in China. *Volvariella volvacea* is estimated to have been first cultivated around 1700 and *Tremella fuciformis* around 1800 in China.

Table 1: Historical record of edible mushrooms cultivation

Sl. No.	Species	Date first cultivated	Earliest record	Source
1	*Auricularia auricula*	600 AD	659	So Jing (= So Gung) 659
2	*Flammulina velutipes*	800-900AD	Late T'ang Dynasty (618-907)	Han O (as interpreted by Zhang Shou-Cheng 1981)
3	*Lentinula edodes*	1000-1100 AD	1313	Wang Cheng (as interpreted by Zhang Shou-Cheng 1981)
4	*Agaricus bisporus*	1600 AD	1650	DeBonnefons (cited by Atkins 1979)
5	*Volvariella volvacea*	1700 AD	1822	Yuen Yuen 1822
6	*Tremella fuciformis*	1800 AD	1866	Hupei Fung Hsien Chih 1983)
7	*Pleurotus. sajor-caju*	1974 AD	1974	Jandaik 1974
8	*Pleurotus ostreatus*	1900 AD 1930's AD	1910	Falck (cited by Zadrazil)
9	*Calocybe indica*	1972	1974	Purkasyatha & Chandra (1974)

History of Mushroom Cultivation in India

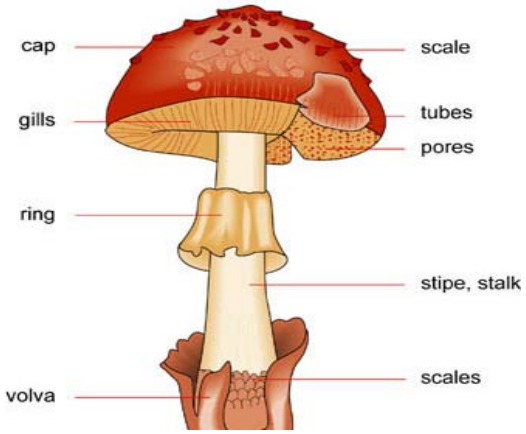
Cultivation of edible mushrooms in India is recent origin, though methods of cultivation for some were known for many years. The important developments in the cultivation of edible mushrooms are as below:

1886	**:**	Some specimens of mushrooms were grown by N.W. Newton and exhibited at the annual show of Agriculture, Horticulture Society of India.
1886-87	**:**	Dr. B.C. Roy of the Calcutta Medical College carried out chemical analysis of the local mushrooms prevalent in caves or mines.
1908	**:**	A thorough search of edibles mushrooms was Instituted by Sir David Rain.
1921	**:**	Bose was successful in culturing two *Agaricus* on a sterilized dung media. Details of which were published in the Indian Science Congress held at Nagpur during 1926.
1939-45	**:**	Attempts on experimental cultivation of paddy straw mushroom (*Volvariella*) were first undertaken by the Deptt. of Agriculture, Madras.

1941	**:**	Padwick reported successful cultivation of *Agaricus bisporus* from various countries but without much success in India.
1947	**:**	Thomas *et.al*. gave the details of cultivation of paddy straw mushroom (*V. diplasia*) in Madras. Asthana reported better yield of paddy straw mushroom by adding red powdered dal to the beds. He suggested April-June as the most suitable period for culturing this mushroom in central provinces and also carried out the chemical analysis of this mushroom.
1961	**:**	A scheme entitled "Development of mushroom cultivation in "Himachal Pradesh" was started at Solan by the H.P. Govt. in collaboration with ICAR. This was the first serious attempt on cultivation of *A. bisporus* in the country.
1962	**:**	Bano *et.al.* obtained increased yield of *Pleurotus* species on paddy straw.
1964	**:**	Cultivation of *A. bisporus* on experimental basis was started by CSIR and state Govt. at Srinagar in J. & K.
1965	**:**	Dr. EFK Mantel, F.A.O., Mushroom Expert, guided and assisted Deptt. of Agriculture for construction of a modern spawn laboratory and a fully air-conditioned mushroom house. Research on evaluation of different strains and use of various agriculture wastes and organic manures and fertilizers for preparing synthetic compost were undertaken. Dr. Mantel's consultancy concluded after a period of 7 years.
1974	**:**	Dr. WA Hayes F.A.O., Mushroom Expert guided in further improving the method of compost preparation. Pasteurization and management of important parameters in the mushroom house. New Compost formulations, casing materials and important parameters like nitrogen content in the compost, moisture in the casing soil, air movement and maintenance of proper environmental factors were also standardized which raised the mushroom yields from 7 to 14 kg/m^2.
1977	**:**	A 1.27 crore, Mushroom Development Project was lunched under the U.N.D.P. by the Deptt. of Horticulture (H.P.) wherein the services of Mr. James Tunney were made available. He got a bulk pasteurization chamber constructed and made available ready compost and casing soil to the growers of H.P. the UNDP Project was concluded during 1982 and since then Deptt. of Horticulture (H.P.) is running the project.
1982	**:**	The Indian Council of Agriculture Research (ICAR) sanctioned the creation of National Centre for Mushroom research and Training (NCMRT) during VI Plan on Oct. 23, 1982 with the objectives of conducting research on problems of mushroom production, preservation and utilization and to impart training to scientists, teachers, extension workers and interested growers. NCMRT started functioning w.e.f. 1983.
1983	**:**	The All India Co-ordinated Mushroom Improvement Project (AICMIP) was sanctioned by Indian Council of Agriculture Research (ICAR) during the VI Plan w.e.f. 1st April, 1983. The six centre initially sanctioned are located at G.B. Pant University of Agric. & Tech., Pantnagar

(Uttarakhand); P.A.U. Ludhiana (Pb.); TNAU, Coimbatore (TN); B.C.K.V.V.; Kalyani (W.B.); MPAU, College of Agriculture, Pune (MS) and C.S. Azad Univ. of Agric. & Tech., Kanpur (U.P.). In subsequent years Kanpur and Kalyani centres have been deleted and IGKVV, Raipur (MP) and NDUA&T, Faizabad (U.P.) has been added.

Morphology:



Mushrooms can be defined as "a macro-fungus with distinctive fruiting bodies, epigeous or hypogeous, large enough to be seen with naked eyes and picked up by the hands". The mushroom fruiting body may be umbrella like or of various other shapes, size and colour. Commonly it consists of a cap or pileus and a stalk or stipe but others have additional structures like veil or annulus, a cup or volva. Cap or pileus is the expanded portion of the carpophore (fruit body) which may be thick, fleshy, membranous or corky. On the underside of the pileus, gills are situated. These gills bear spores on their surface and exhibit a change in colour corresponding to that of the spores. The attachment of the gills to the stipe helps in the identification of the mushroom. On the basis of the attachment, gills are of following types:

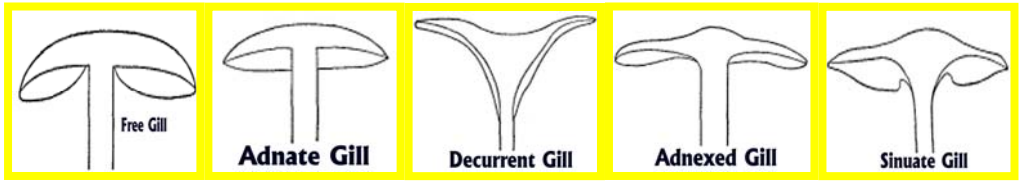
Free gill: when the gills do not touch the stipe or only do so by a fine line.

Adnate gill: when gills are attached directly to the stem forming nearly a right angle with the stem/stipe.

Decurrent gill: when the gills extend down the stem to a greater or lesser degree.

Adnexed gill: if the attachment of the gills is only by a part of the stem to a greater or lesser degree.

Sinuate gill: when gills are near the stalk in a deep notch.



Nutritional and Medicinal Values

Today, the popularity of mushrooms is due not only to their culinary value but also to their potential as a source of protein that can enrich human diets especially in some developing countries where meat may be rare and expensive. Mushrooms contain more protein than either fruits or vegetables. They can be eaten, as they are cooked or raw, unlike other protein sources such as soya. Mushrooms are also low in cholesterol. Besides their protein content, mushrooms are also high in certain vitamins such as B, C, D, riboflavin, thiamine, and

nicotinic acid. Mushrooms are also a good source of iron, potassium and phosphorus in addition to folic acid, an ingredient known for enriching the bloodstream and prevention deficiencies.

Table 2: Proximate protein content (dry weight) of edible mushrooms as reported by different authors.

Species	Protein content (%)
Volvariella volvacea	21.32
Agaricus bisporus	27.8
Pleurotus ostreatus	27.4
Pleurotus florida	37.19
Pleurotus sajor-caju	36.94
Lentinula edodes	17.5
Auricularia auricular-judae	8.1
Flammulina velutipes	21.9

Table 3: Vitamin content of some edible mushrooms.

Mushroom	Thiamine	Riboflavin	Niacin
	Content (mg/100g air-dried)		
Agaricus bisporus	1.1	5.0	55.7
Lentinula edodes	7.8	4.9	54.9
Pleurotus florida	0.35	2.97	64.88
Volvariella volvacea	0.32	1.63	47.55
Pleurotus sajor-caju	1.16 - 4.8	-	46.108

Medicinal Importance of Mushrooms

The invention of the so called "wonder drug" penicillin was a landmark in the field of medicinal uses of fungi. Since then several fungi have been well recognized for their antifungal, antibacterial, antiviral, antitumour and many others such properties of pharmacological values. In the recent past a variety of medicinal preparations in form of tablets, capsules and extracts from mushrooms have been produced and marketed. Mushrooms are perhaps the only fungi deliberately and knowingly consumed by human beings and they complement and supplement the human diet with various ingredients not encountered in or deficient in food items of plant and animal origin. Besides, chemical composition makes them suitable for specific group suffering with certain physiological disorders or ailments. Mushrooms are regarded as an ultimate health food, low in calories due to presence of good amount of quality protein, iron, zinc, vitamins, minerals and dietary fibres which protects from digestive ailments and strengthening of the human immune system.

Recent investigations have proved the empirical observations of the oriental herbalists that certain mushroom possesses very useful medicinal attributes. In the 1991, the value of world medicinal crops was estimated at 8.5 billion dollars and in the same year 1.2 billion dollars are estimated to have been generated from medicinal products from mushrooms. This was based on the sale value of products from *Coriolus, Ganoderma, Lentinula, Schizophyllum* and other mushrooms.

Although the biggest use of mushroom has traditionally been for reasons of their gastronomic and nutritional appeal. There has always been interest in certain mushroom for their medicinal attributes. Production of medicinal mushroom is now a days increasing over world wide. In the present era a variety of proprietary product based on mushroom nutriceuticals and pharmaceutical have already been produced and marketed. Various mushrooms and their metabolic extract have been reported to protect against cancer, tumor and pathogenic microorganisms. It is suggested that regular consumption of different mushroom varieties not only protects humans from heart trouble but also had medicinal potential for certain ailments.

Important Medicinal Mushrooms

Mushroom have a long history of use in traditional Chinese medicine . In fact it is estimated that in China more than 270 species of mushrooms are believed to have medicinal properties with 25% of them thoughts to have antitumour capability. Few of the edible mushrooms have also gained importance in modern medicine for their various pharmacological values. The details of medicinally important mushrooms are summarized as follows.

Ganoderma lucidum (Reishi mushroom):

Ganoderma lucidum (Ling Zhi or Reishi in Chinese ,Saruno ,Koshikake or Mannendake in Japanese), belonging to higher Basidiomycetes has been used extensively as "mushroom of immortality" in China and other Asian countries for 2000 years. It is full of medicinal compounds and is said to promote a healthy heart as well liver .Reishi is also believed to be a powerful anticancer agent. It is used in Chinese medicine for its immunogenic, antibacterial and anti-inflammatory properties. It demonstrates its antitumor and immunomodulatory activity by increasing bodily resistance against the growth of tumors. It can also act as a metabolic regulator.

Two main classes of compounds present in *Ganoderma* have been found to have pharmacological activities : Triterpenes and Polysaccharides. Anti-tumor property of *G. lucidum* is due to polysaccharide (referred as GP, *Ganoderma* polysaccharide).These polysaccharide especially the β- glucans fraction have been found to have broad stimulatory effects on white blood cells. These effects may ultimately lead to the

release of cytokines and lymphokines which produce antitumor and other effects. The triterpines have been tested and found to lower blood pressure to be beneficial as anti-inflammatory and as antiviral. Nature health practitioner in the west are beginning to use Reishi for its sleep promoting effects .Compound called tri-terpenes are thought to be responsible for producing a calming effect on the nervous system. In recent years this mushroom has got immense fame due to its wide medicinal use. It is cultivated in China, Japan and also found throughout India as stem parasite of several trees.

***Coriolus versicolour*:**

This fungus is called "turkey tail" in English. Probably because it has multi-colored fruiting bodies which grow in overlapping clusters on rotten wood of broad leaf trees and occasionally on trunks of pine. It is known in Chinese as Yun-zhi. Traditionally it is used as a tea or a dried powder to treat infection or inflammation of the respiratory, urinary and digestive tracts, liver diseases, general weakness and tumors. *Coriolus versicolour* also known as *Trametes versicolour* , is a common non edible polypore which has been found to produce polysaccharides commercially known as Krestin or PSK as anti tumor agent .It is a protein bound polysaccharide that is obtained as a hot water extract from the mycelium of *Coriolus versicolour.* This protein bound polysaccharide (PSK or PSP) is a biological response modifiers (BRM), which is capable of modifying the host's biological response by stimulating the immune system and thus exhibiting diverse therapeutic effects, particularly antitumor activity.

***Grifola frondosa* (Maitake):**

This species is found in the part of the Eastern U.S, Europe and Asia. In Japan it is called as Maitake, which means "dancing mushroom". *G. frondosa* is another mushroom which is highly effective in controlling blood pressure, diabetes and constipation. Maitake prevents the destruction of HIV-T-Helper cells. A patients T-helper cells count is measured to trace the progression of HIV to AIDS.

***Lentinula edodes* (Shiitake):**

L. edodes can be considered as leader of mushroom which can be used both for edible and medicinal purposes. It is known as Xiang gu in China, which means fragrant mushroom probably due to its characteristics flavour and shiitake in Japan, which derives its association with the shiia tree. The shiitake (*Lentinula*) is the most popular edible mushroom in Japan. The Asians have used it for thousands of year as a tonic and stimulant to increase vitality, prevent cerebral hemorrhage strokes, as well as improve circulation.
L. edodes is source of the well known antitumor polysaccharides lentinan from the fruiting body or mycelia. Lentinan is highly purified, high molecular weight polysaccharide which does not attack cancer cells directly but produces its antitumor effect by activating different immune response in host. In *Lentinula edodes,* an active hypo-lipidemic substance identified as eritadenine is found to exhibit a general response affecting

cholesterol, triglyceride and phospholipid level. Lentinan is being studied not only for its antitumor properties but also for its ability to lower cholesterol and blood pressure.

***Cordyceps* species (Keera ghas):**

Cordyceps an extremely rare mushroom is a native of high Himalayan Mountain. It can be found for a short time each summer, growing on its natural host, a caterpillar. Recent evidence has shown that the extract of *C. sinensis* has immunoregulatory activity. One of the most valued traditional Chinese medicine is used commonly for the replenishment of body health consists of the dried fungus *C. sinensis* growing on Lepidopteran (caterpillar) larvae. For medication the fruiting body (fungus) and the worm (caterpiller) are used together.

The fruiting body and its caterpillar host shows close resemblance in main constituents and antioxidation activity and the result suggest that the function of the worm in *Cordyceps* is to provide a growth medium for the fruit body.

***Tremella fuciformis*:**

It is believed to be sweet in taste, mild and non-toxic. It is used as a cough syrup for treating chronic tracheitis and other cough related conditions. It is able to help strengthen the vital internal organs such as sex organs, kidney, lungs and stomach and treat ulcers. It is also used as antipyretic agent and immune tonic. It is said to enhance beauty and gonadal activity. It is useful for weakness after child birth, constipation, abnormal menstruation, dysentery and gastritis. *T. fuciformis* contains acidic polysaccharides which show anti-tumor activity and enhance immune functions. It has cholesterol lowering effect attributable to the suppression of absorption of cholesterol from the digestive tract.

Poria cocos:

It is considered as mild sweet and bland. It is used to cure edema and clear febrile illness. The cortex of sclerotium of this mushroom is used as a diuretic and a decoction for cough whereas the internal white portion is used to relieve uneasiness arising from pregnancy and the heart discomfort. The polysaccharides of this fungus such as spachyman and pachymaran exhibit strong antitumor and immuno-modulatory activities. The low molecular weight tetracyclic triterpenes have immuno-stimulating and antiviral activities.

***Pleurotus* species (Oyster or Dhingri):**

Oyster mushroom is the third most popularly grown mushroom in the world and ranks second in India. In India *Pleurotus sajor-caju* is one of the commonly growing species. *Pleurotus sajor-caju* has been shown to exhibit hypotensive activity, reduce the rate of nephron deterioration which may be useful for chronic renal failure patient. Oyster mushroom (*Pleurotus ostreatus)* has also been found to have hypocholesterolemic effects in rats. *Pleurotus tuberregium* also shows some antimicrobial activity.

LEVEL OF GROWING SYSTEM / Mushroom houses

A. Marginal Scale:

- **Crop Rooms (Huts) :** Made up of Sarkanda, Bamboo, Straw and Grasses
- **Crop Room/Hut size :** 30'x17'x9'
- **Containers:** Shelves or racks of bamboo and Sarkanda
- **Composting :** Long method
- **Yield :** 14-18kg/100kg compost in 8-10 weeks of harvesting

B. Small Scale:

- **Crop Rooms :** Conversion of old buildings into crop rooms or insulated crop room
- **Rooms size :** 40'x18'x12-14' or 50'x21'x12'
- **Containers :** 3-5 tires bamboo shelves or metallic racks for 10-12kg compost
- **Composting :** Long method/Short method
- **Yield :** 15-20kg/100kg compost in 8-10 weeks of harvesting

C. Industrial Scale:

- **Crop Rooms :** Insulated and controlled
- **Room size :** 48'-100x18-27'x12'-18'
- **Containers :** Metallic racks for bags/shelves
- **Composting :** Short method
- **Yield :** 18-22kg/100kg compost in 4-6 weeks of harvesting

Edible and Poisonous Mushrooms

Some fungi are edible while others are poisonous. Poisonous mushrooms are known as toadstools though this is not a scientific term. In ancient time, people could not differentiate between edible and poisonous mushrooms, many lives were perhaps lost by the consumption of poisonous mushrooms. Classical writings give many references in which the harmful effects of mushrooms were mentioned. There is no general rule for the identification of edible and poisonous mushrooms.

There are many traditional methods for testing these fungi but they are unreliable. It was believed that mushrooms, which grew in the meadows are edible and those which grew among rusty nails, rotten eggs, near serpent holes or termite mounts or on trees producing poisonous fruits are not edible.

The belief was prevalent that edible fungus peeled off easily and did not change a silver spoon black while cooking. This belief is incorrect .It was also held that brightly coloured mushrooms were poisonous, whereas white or creamy ones were edible (This is wrong as "Chanterelle" (*Cantharelius cibarius*) and "Wood Blewits" (*Tricholoma nuduns*), even though bright coloured, are quite safe to eat, where as the "Death cap", (*Amanita phalloides*) "Fool's

mushroom" (*Amanita verna*) and "Destroying angel" (*Amanita verosa*) are completely white and deadly poisonous.

Two mushrooms may possess a morphologically close resemblance but one may be edible and the other may not be edible.Only by knowing the distinguishing characters one can separate the two. *Lepiota margani*, for instance, is a poisonous mushroom and if eaten causes a fatal illness, whereas *Lepiota rachodes* is edible and delicious. These two species are so closely related to each other and look so strikingly similar that only an expert can separate and distinguish them.

Spawn And Its Production

- Spawn is the planting material for the cultivated mushroom.
- It is merely the vegetative mycelium from a selected mushroom strain grown in a convenient medium.
- The particular strain of mushroom selected decides the type of mushroom the spawn would produce.

Mother Spawn/ Master spawn

The commonly followed method in India is as given below:

Ten kg of wheat or sorghum grains are boiled in 15 litres water. Water is drained off over a wire netting to dry slightly. 120 g gypsum and 30 g lime ($CaCO_3$) are mixed with 10 kg of boiled grains. The gypsum prevents the sticking of grains together as clump and lime adjusts the pH. The grains are then filled into a half litre milk or glucose bottle container upto three-fourth the capacity. Bottles are plugged with non-absorbent cotton plug and are to be sterilized at 20-22 lb. psi (126^0 C) for 1 ½ to 2 hours. Sterilized bottles are taken out from the autoclave while still hot and are shaken to avoid clump formation. The bottles are immediately transferred to inoculating room or chamber and allowed to cool down overnight. On the following day, bottles are inoculated with two bits of agar medium colonized with the mycelium of pure cultures raised either by tissue or spore by putting the culture bits just opposite to each other in the inner side of glass surface in the middle of the bottle. About 7-10 days after inoculation, bottles are to be shaken vigorously so that mycelial threads are broken and mixed with grains evenly. Three weeks after incubation, the stock culture becomes ready for further multiplication of spawn. One bottle of stock culture is sufficient to multiply in 30-40 polypropylene bags or bottles. Inoculated bottles are incubated at ambient temperature.

Commercial Spawn

The technique for raising commercial spawn is essentially the same as for master spawn except that instead of glass bottles, polypropylene bags can be used as the containers for filling grains. Inoculated bottles or polypropylene bags are incubated at ambient temperature. In two to three weeks after inoculation, spawn becomes ready for seeding the compost.

SPAWN PREPARATION

Wheat grains

↓

Boiled with water (1:1.5 w/v)

↓

Drain off excess water

↓

12g/kg grains $CaSO_4$ and 3g/kg grains $CaCO_3$

↓

Filled in bottle

↓

Sterilized at 22psi for 90 minutes

↓

Inoculation with pure culture

↓

Master spawn

↓

Commercial spawn

Qualities of a good spawn

- The spawn should be fast growing in the compost
- It should give early cropping after casing
- It should be high yielding
- It should produce better quality of mushroom

White Button Mushroom (*Agaricus bisporus*)

Favourable season : Oct. to March (for plains of India)
Required temp. and humidity:14-22^{0}C and 80-85%

Cultivation process involves four major steps

a. Preparation of compost
b. Spawning of compost
c. Casing (Covering the spawned compost)
d. Cropping and crop management

Preparation of compost:

Unlike other traditional crops soil is not the appropriate substrate for mushroom cultivation. Rather, the substrate for mushroom called compost, is prepared from agro wastes like straw, stem, shoot, apices etc. with organic manure. Mushroom substrate may be simply defined as a lingo-cellulosic material that supports the growth, development and fruiting of mushroom mycelium. This compost is pasteurized by various micro-organisms and at appropriate temperature range. Essential supplement are also added/ supplemented to the compost. The whole process is termed as

composting. Generally composting refers to the piling of substrates for a certain period of time and the changes due to the activities of various micro-organisms, which result in a composted substrate that is chemically and physically different from the starting material. The compost provides nutrients, minerals, vitamins and ions required for proper growth of mushroom. This compost supports the growth of only the mycelium of button mushroom and prevents that of other competitive moulds.

Methodology for compost preparation

Compost is an artificially prepared growth medium from which mushroom is able to derive important nutrients required for growth and fructification. Cemented floors are required for making good quality compost. There are two main methods for compost preparation:

1. **Long method of composting**
   This is an outdoor process and takes around 28 days in its completion with a total of seven turnings. The following materials are required for long method of compost:

Wheat straw	300 Kg
Wheat bran	15 kg
Ammonium sulphate or calcium ammonium nitrate	9 kg
Super phosphate	3 kg
Muriate of Potash	3 kg
Urea	3 kg
Gypsum	30 kg
Furadan	150 g
B.H.C.	150 g

Before making compost, wheat straw is spread on cemented floor and is turned many times with water being spread at regular intervals.

Day 0: At the stage, there should be around 75% humidity content in the wheat straw, to which wheat bran, calcium ammonium nitrate, urea, murate of potash, and super phosphate are mixed thoroughly and evenly. The material is then piled 1.5m thick x1.25m high with the help of wooden rectangular block. The blocks are removed. Once the entire material has been stacked up or piled up. Water is sprayed twice or thrice to keep the substrate moist. Temperature should be in the range of 70-75^{0}C.

1st turning Day 6: On the sixth day first turning is given to the stack. The purpose of turning is that every portion of the pile should get equal amount of aeration and water. If the turnings are not given, then anaerobic condition may prevail which may lead to the formation of non-selective compost. In the stack, the central zone is fermenting at its peak and has maximum temperature rest of the portion is either not at all fermented or ferments improperly. The correct method of turning is as: Removing about 15cm of compost from the top and spread it on one side of the floor, the rest part of compost on the other side of the floor. Now turning is

done by shaking the outer (top most) part and the inner part of the compost, first separately and then missing them altogether thoroughly with the help of wooden buckets.

2nd turning (Day 10): On the tenth day, again the top most part and the inner part of the compost is separated, water is sprayed on the top part. Again the two parts are piled up together in such a way that now the top part is inside and the inner part is on the top of the stack.

3rd turning (day 13)**:** it is also done in the same way as described earlier. Gypsum and furadan are mixed at this stage.

4th turning (day 16)**:** The same process of turning is followed.

5th turning (day 19)**:** The compost is turned in the same manner and B.H.C. is added.

6th turning (day 22)**:** The same process of turning is followed.

7th turning (day 25)**:** if no ammonia persists in the compost, spawning is done

2. Short method of composting

Compost prepared by short method composting is superior in production quality and the chances of infection and disease is quite low.

Ingredient:

Wheat straw	1000 kg
Chicken manure	600 kg
Urea	15 kg
Wheat bran	60 kg
Gypsum	50 kg

This method is accomplished in two phases:

Phase I- Outdoor composting

Wheat straw mixed with chicken manure is sprayed with water and a 45cm high pile is made on the fourth day and first turning is made. On 7th day, wheat bran, gypsum and urea is mixed thoroughly and piled up to 1.25-1.50 m height with a width ranging from 1.25 -1.5 m. The internal temperature of the compost should be maintained at 70-75^{0}C within 24hr. Second turning is done on this day where as third turning is done on 8th day with subsequent mixing of gypsum. On the 10th day, the compost is transferred to the pasteurization tunnel. Compost is filled in the pasteurization tunnel to a height of 7'. Filling height depends upon the size of the tunnel.

Phase II- Indoor composting

This is the pasteurization procedure which is done in a closed environment. Pasteurization has got many purposes.

i) If the temperature during composting has been low and the compost is heterogeneous, many parasites (nematodes, pathogens, flies and mites etc.) will

survive in the compost mass, therefore, pasteurization is the best means with which these parasites can be destroyed.

ii) To end fermentation and to convert compost into a chemical and biological state favourable to the development of the mycelium and unfavourable to moulds.

iii) Conversion of ammonia into microbial protein.

Compost is filled in the pasteurization tunnel and as soon as the compost in the tunnel is completely filled the doors and fresh air damper are properly closed and blower is put on for recirculation of air @ 150-250 cubic metre/ 1000 kg compost/ hour. The phase II process is completed in three stages:

i) **Pre-peak heat stage:** After about 12-15 hours of compost filling, the temperature of compost starts rising and once 48-50^{0}C is obtained, it should be maintained for 36-40 hours with ventilation system. Normally such temperature is achieved by self generation of heat by the compost mass without steam injection.

ii) **Peak heat stage:** raise the temperature of compost to 57-58^{0}C by self generation of heat from microbial activity if it is not obtained.injecting the live steam in the bulk chamber and maintain for 8 hours in order to ensure effective pasteurization. Fresh air introduced by opening of the fresh air damper to 1/6 or 1/4 of its capacity and air outlet too is opened to the same extent.

iii) **Post- peak heat stage:** lower down the temperature gradually to 48-52^{0}C and maintain till no traces of ammonia are detected in compost. This may take 3-4 days in a balanced formulation. When the compost is free from ammonia, full fresh air is introduced by opening the damper to its maximum capacity and cool down the compost to around 25^{0}C which is considered as the favourable temperature for spawning. Compost when ready for spawning should possess the following characteristics:

Moisture	About 68%
Ammonia	Below 0.006%
pH	7.2-7.5
Nitrogen	Around 2.5%
Fire fangs (Actinomycetes)	Excellent growth

Spawning

The process of mixing of the spawn in the compost is known as spawning. Spawn is thoroughly mixed in the compost at the rate of 600-750 gm per 100 kg of compost (0.6 - 0.75%). The spawned compost is filled in tray or polypropylene bags covered with formalin treated news papers. In case of bags, they should be folded at the top and covered up. After spawning, temperature and humidity of crop room should be maintained at 18-22^{0}C and 85-90%, respectively. Water should be sprayed over the covered news papers, walls and floors of the crop room. After 12-14 days of spawning white mycelial growth is seen running the entire length of the tray/bag. This is then covered with casing soil on the surface.

Casing soil

The significance of casing soil is to maintain the moisture content and exchange of gases within the surface of the compost which helps in the proper growth of the mycelium. The pH of the casing soil should be 7.5-7.8 and must be free from any infection or disease. In our country casing soil is prepared from the following ingredients.

Two years old manure + garden soil	3:1
Two year old manure + garden soil	2:1
Two year old manure + spent compost	1:1
Two year old manure + spent compost	2:1
Two year old manure + spent compost	1:2

Pasteurization of casing soil

The casing soil is piled on cemented floor and is treated with 4% formalin solution. Thorough turning of the soil is done and it is covered with polythene sheet for the next 3-4 days. Pasteurization of casing soil at 65^0C for 6-8 hours is found to be much more effective.

Using the casing soil

3-4cm thick layer of casing soil is being spread uniformly on the compost when the surface has been covered by white mycelium of the fungus. Formalin solution (0.5%) is then being sprayed. Temperature and humidity of the crop room should be maintained at 14-18^0C and 80-85%, respectively. Proper ventilation should be arranged with water being sprayed once or twice a day.

Harvesting of crop

Pin head initiation takes place after 10-12 days of casing and the fruiting bodies of the mushroom can be harvested for around 50-60 days. The crops should be harvested before the gills open as this may decrease its quality and market value.

Productivity

From 100 kg compost prepared by long method of composting 14-18 kg of mushroom can be obtained. Similarly, 18-20 kg mushroom can be obtained from pasteurized compost (Short Method Compost).

ECONOMIC ANALYSIS OF BUTTON MUSHROOM

I.	**Non-recurring**		**Total (Rs.)**
1.	Crop Room (30 x 17 x 9 ft) 3 tier	20,000/-	
2.	Instruments		
	a. Spray pump (1 No.)	1,400/-	
	b. Thermo-hygrometer (1 No.)	300/-	
	c. Bucket (1 No.)	100/-	
	d. Doormat (1 No.)	100/-	
	e. Balance (1 No.)	200/-	**22,100.00**
II	**Recurring (for two crops)**		
.	a. Spawn, compost (10 Ton), casing soil @ Rs. 2000/- per ton (LMC)	20,000/-	
	b. Pesticides insecticides & formalin	1,000/-	
	c. Polythene sheet (2000 sq.ft.)	2,000/-	
	d. Electricity, fuel, water charges	500/-	
	e. Miscellaneous (packaging, marketing)	1,000/-	**24,500.00**
		Total Rs.	**46,600.00**

Return

Total mushroom production	: 1800 kg
Market rate @ Rs. 45 per kg.	: Rs. 81,000.00
Depreciation @33.33% on Rs. 22,100.00	: Rs. 7,366.00
Interest on Rs. 46,600.00 @10%	: Rs.4660.00
Net profit	: Rs. 44,474.00

Oyster mushroom (*Pleurotus sajor-caju*)

This mushroom gained importance during the last decade and now several species of Pleurotus are available for commercial production such as: *P.sajor-caju, P.florida, P.sapidus, P.eryngii, P.columbinus, P. cornucopiae, P. flabellatus. P. platypus, P. opuntiae, P. citrinopileatus*

It is now being cultivated in many countries in the subtropical and temperate zones. In China, it is known as abalone mushroom (*P. abalonus or P.cystidiosus*).

Pleurotus spp. can be grown using various agricultural waste materials. The different species of *Pleurotus* grow within a temperature range of 20^0 to 30^0 C. *P. sajor-caju* can tolerate temperature up to 30^0 C although it fruits faster and produces larger mushroom at 25^0 C. *P. fossulatus* is the so-called low temperature *Pleurotus*, fruiting mostly at 12-20^0C. The tropical wastes like rice straw, wheat straw, corncobs, dried water hyacinth, sugarcane bagasse, banana leaves, cotton waste or sawdust are used for cultivation. The materials are usually soaked in water chemically sterilized with bavistin (7-10g) and formalin (120-150 ml)/ 100 litre of water for 16-18 hours. Extra water is drained off.

The process of spawn making is the same as for *Agaricus* species. *Pleurotus* spawn should be about 15 days old when mycelium has formed complete coating around the grain. The normal rate of spawning in a pasteurized substrate is 2.0-2.5% of the wet substrate. The spawning is usually done thoroughly. Before filling the substrate in polythene bags, holes of about 1 cm diameter are made at 10-15 cm distance all over the surface for free diffusion of gases and heat generated inside. The optimum temperature for growth of *Pleurotus* spp. is 23 $\pm 2^0$ C. Relative humidity in growing room should range between 85-90% during spawn-run. Usually 3 to 4 days after opening the bags, mushroom primordia begin to form. Mature mushrooms become ready for harvesting in another 2 to 3 days. An average biological efficiency (fresh weight of mushrooms harvested divided by dry substrate weight x 100) can range between 70-80% and sometimes even more. To harvest the mushrooms, they are grasped by the stalk and gently twisted and pulled. A knife should not be used. The mushrooms remain fresh for up to 3 to 6 days in a refrigerator/cool place.

Cost and Return for Oyster Mushroom (Two Crops)

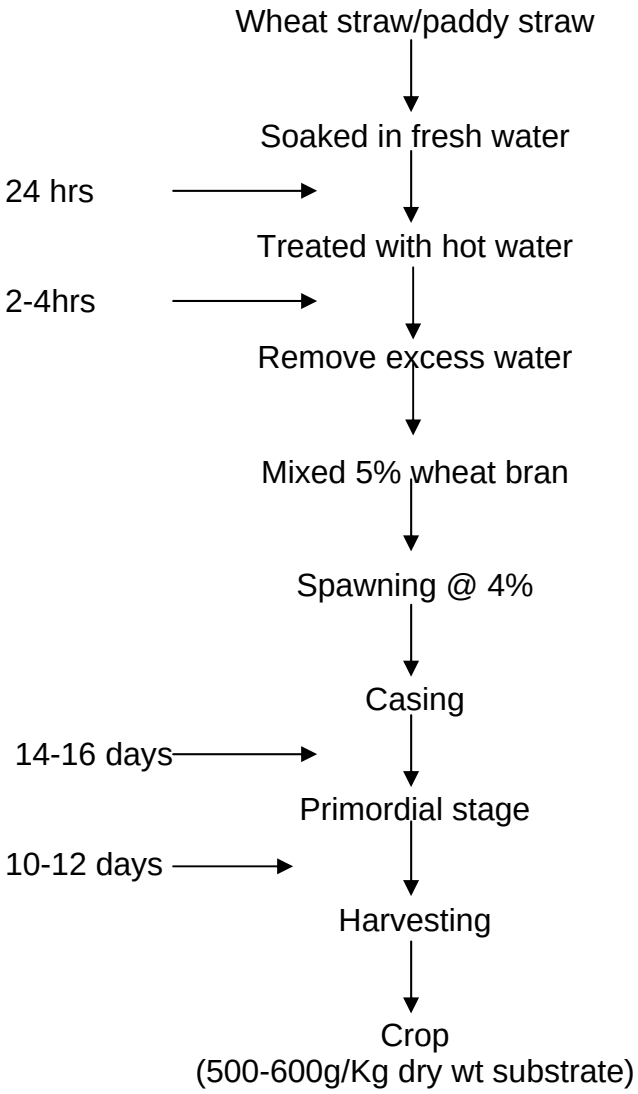
Sl. No.	Particulars	Approx. cost (Rs.)	Total (Rs.)
	Recurring (for two crops)		
1.	Wheat Straw 20 Qtl. @ Rs. 200/-	4,000.00	
2.	Spawn 120 Kg @ Rs. 50/-	6,000.00	
3.	Chemical treatment	1,500.00	
4.	Polythene bags @ Rs. 1.50/- each (2400 bags)	3,600.00	
5.	Electricity, water & labour	2,000.00	
6.	Miscellaneous (packaging &marketing)	2,000.00	**19,100.00**

Return:

Total Mushroom Production	: 14.00 Qtl
Market rate @ Rs.30/- per kg	: Rs. 42,000.00
Interest @ 10%	: Rs. 1,910.00
Net profit	**: Rs. 10,990.00**

Milky Mushroom (*Calocybe indica*):

Calocybe indica is an edible white summer mushroom also known as milky mushroom. It can be easily grown in the temperature range of 25-35^{0}C. It has moderate protein content and has a good biological efficiency (60-70%) under optimum conditions. Its sporophores have long shelf life. The major advantage is that it can be best fitted in relay cropping when no other mushroom can be grown at higher temperature. *Calocybe indica* has a very good scope for further cultivation and it can replace the other tropical mushrooms like *Pleurotus* spp. and *Volvariella* spp.



Cost and Return for Milky Mushroom (One Crop)

Sl. No.	Particulars	Approx. cost (Rs.)	Total (Rs.)
I.	**Recurring (for two crops)**		
1.	Wheat Straw 16 Qtl. @ Rs. 200/-	3,200.00	
2.	Spawn @ 4% 192 Kg @ Rs. 50/-	9,600.00	
3.	Chemical treatment	500.00	
4.	Electricity, water & labour	500.00	
5.	Miscellaneous (packaging &marketing)	1,000.00	**14,800.00**

Return:

Total Mushroom Production	: 960 kg.
Market rate @ Rs.30/- per kg	: Rs. 28,800.00
Interest @ 10%	: Rs. 1,480.00
Net profit	**: Rs. 12,520.00**

Paddy-straw mushroom (*Volvariella volvacea*)

Volvariella volvacea Sing., the paddy straw mushroom, or straw mushroom is the most popular mushroom in Southeast Asia. *V.diplasia* is white while *V. volvacea* is blackish. *V. bombycina* differs from the cultivated *V. volvacea* in terms of habitat as well as colour.

Cultivation of this mushroom started in China almost three hundred years ago. Several species of Volvariella have been grown for food. *V. bombycina Sing. and V.diplasia (Berk & Br.) Sing*, have been cultivated in India. *Volvariella volvacea* thrives in a temperature range of 28 to 38^0 C and relative humidity of 75-85% is required. In a modified method of cultivation, bundled substrates (rice straw, banana leaves or water hyacinth), prepared in the same way as those used for beds, are soaked in water, drained, then packed (layered) in the wooden frames. Spawn is mixed in with each layer as the frame is packed or filled. The spawned substrate in the boxes may be placed in a specially built incubation room with a high temperature (35 to 38^0 C) and high relative humidity (at least 75%), or it may be covered with plastic sheets and placed under shade outdoors. For spawning, the air temperature is cooled to 35^{0}C and the bed temperature to about 28 to 32^0 C The amount of spawn to be used is calculated at 1.5% of wet weight basis.

Economy

Production Cost	:	Rs. 15-20/- per kg
Market rate	:	Rs. 35-40/- per kg
Net profit	:	Rs. 20/- per kg

Cost-benefit status of different mushrooms:

Sl. No.	Mushroom sp.	Temp. (^{0}C)	Substrate	Produ-ction	Cost (Rs./Kg)	Market rate (Rs./Kg)	Net gain (Rs./Kg)
1.	*Agaricus bisporus* (Button mushroom)	14-22	compost (LMC/SMC)	14-18 kg by LMC 18-22 kg by SMC	25-30	45-60	20-30
2.	*Pleurotus* sp. (oyster mushroom)	18-28	wheat straw/ paddy straw	60-70kg/Qtl. dry wt. basis	12-15	30-35	18-20
3.	*Calocybe indica* (Milky mushroom)	25-35	wheat /paddy straw	50-60 Kg / Qtl dry wt. basis	15-18	30-35	15-20
4.	*Volvariella* spp. (Paddy straw mushroom)	28-38	Paddy straw	10-15kg/Qtl.	15-20	30-35	15-20

Major Diseases of Mushroom and their Management

Green mould (*Trichoderma* spp.)

Symptoms: Small blue green cushions are seen on spawned and cased trays/bags. It also grows on dead buds of mushrooms and cut stumps. Mushroom caps may turn brown o then top side. Green moulds generally appear in compost, rich in carbohydrates and deficient in nitrogen. High humidity with low pH of casing promotes its development.

Green mould Symptoms

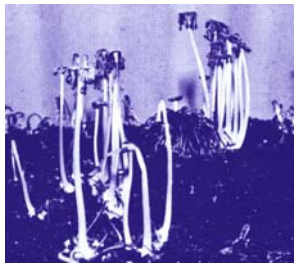
Brown plaster mould (*Papulospora byssina*)

Symptoms: whitish patches on the compost or casing ultimately turning to rusty brown in colour observed on the exposed surface of compost and casing as well as on the side in bags due to moisture condensation.

White plaster moulds (*Scopulariopsis fumicola*)

Symptoms: Dense white patches of mycelium on compost and casing soil can be seen, giving flour like appearance. If the compost retains smell of ammonia and has pH more than 8.0, white plaster moulds become common.

Inky caps (*Coprinus* spp.)



Symptoms: It appears with long slender stalks and thin caps, which disintegrate into black slimy mass of spores. It is common in the compost which contains excess nitrogen in ammonical form and insufficient gypsum.

Yellow mould (*Myceliophthora lutea, Chryosporium luteum* and *Sepedonium* spp.)

Symptoms: Brownish yellow corky layer of mycelium (stroma) with a white fluffy edge generally observed at the junction of compost and casing. Yellow moulds generally observed where the compost has more than 70% moisture and more than 20°C temperature in the crop room.

False truffle (*Diehiliomyces microsporus***)**

Symptoms: Initially white fluffy mycelium later turning creamy yellow, prominent between compost and casing layers. The mycelium becomes thicker, solid, wrinkled mass resembling peeled walnut or brain like structure. False truffle is very common where mushroom is grown under natural condition at more than 20°C.

Management:

- **i.** Proper hygienic conditions should be observed.
- **ii.** Compost and casing soil must be pasteurized/ sterilized.
- **iii.** Compost should be ammonia (NH_3) free (not more than 8-10 ppm) and pH should be in between 7.2-7.5 at spawning.
- **iv.** Use spore filters to prevent the entry of spores of these moulds.
- **v.** During spawn run the beds are covered with papers, should be moistened twice a week with 0.5% formalin.
- **vi.** Temperature and relative humidity in the crop room should be maintained as per requirement of the crop.
- **vii.** Stumps and dead mushrooms must be removed regularly from the beds.
- **viii.** Spray with Dithane M-45 (0.15%), bavastin (0.05%) at 8-10 days intervals
- **ix.** Cook-out at the end of crop.

Dry bubble disease (*Verticillium fungicola*)

Symptoms: Whitish mycelial growth initially appears on the casing surface which has the tendency to turn grayish yellow with age. If the pinhead infected at early stage, typical onion shaped mushrooms are produced and a small pimples are develop on their cap. When mushrooms are affected at later stage, the deformed mushrooms can be seen because of restricted growth of infected tissue on one side and normal growth on the other side of stipe. The strips of surface tissue of stipe may also peels away from the curved side.

The casing soil harbors the primary inoculum of the fungus. The secondary spread of the pathogen within the crop and in other crop rooms takes place by spores (conidia) through air, flies water splashes and pickers etc. High humidity, poor aeration, delayed picking of diseased mushroom and temperature above 18^0C favours diseases development and spread.

Management:

(a.) Adopt strict hygienic measures at the farm.

(b.) Use only sterilized casing soil and spent compost should be properly disposed off to avoid primary infection.

(c.) After spawning, spray dichlorovos @ 30 ml/100 lit. water /100m^3 area to check the flies.

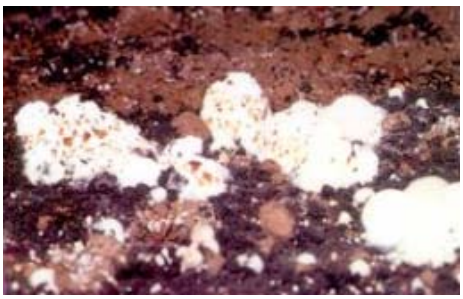
(d.) Remove all affected mushroom before picking and watering and take them away in plastic bags. Spray the affected patch with 2% formalin.

(e.) Spraying with Indofil Z-78 (0.15%) at weekly interval or one spraying of sporgon (0.15%) 7-9 days after casing.

(f.) Cook out at the end of cropping

Wet bubble disease (*Mycogone perniciosa*)

Symptoms



Wet bubble Symptoms

When young pin heads are infected, they develop into distorted masses of mushroom tissues, which look like a “cauliflower”. Small amber to dark brown drop of liquid develops (due to putrifying bacteria) on the surface of the undifferentiated tissue in very high humid conditions. At this stage an unpleasant odour comes out from the infected beds. Small, white fluffy mycelial growth can easily been on and around the infected mushrooms which becomes creamy brown after few days.

The infection mostly comes through casing soil, air and spent compost. Pathogens survive for long time in casing soil and spent compost. In the crop room, secondary spread of the pathogen is by air, water splashes, flies and pickers.

Management

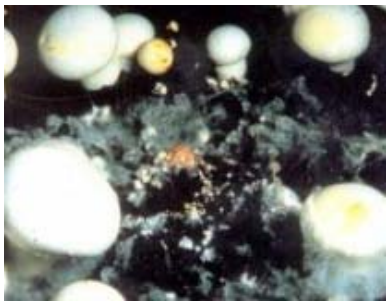
a. Strict hygienic conditions should be maintained.

b. Use only sterilized casing soil.

c. One spraying with prochloraz manganese (sporgon) (0.3%) at 7-9 days after casing, or Indofil Z-78 (0.15%) at weekly interval.

d. Cook out (70^0C for 12 hrs.) the crop room at the end of cropping.

<u>Cobweb disease</u> (*Hypomyces rosellus*)



Symptoms: The disease is first appearing as small circular patches of grayish white mycelium on the casing surface. As the disease progress, a fluffy white mycelium grows over the mushrooms which look like a cotton balls. Eventually they turn brown, begin to rot and die-off.

High relative humidity and temperature favours the disease. It normally introduced into the crop room by contaminated casing soil or spores through air. Secondary spread is by air movement, pickers, water splashes etc.

Management:

a. Use sterilized casing soil only.

b. Temperature and R.H. should not go beyond 18^0C and 85%, respectively.

c. Use spore filters at the ventilations.

d. Spraying with sporgon (0.3%), Indofil Z-78 (0.25%), Benlate or Bavastin (0.2%) between the flushes.

e. Cook out at the end of cropping.

<u>Mushroom Flies</u>

Sciarid flies: (*Bradysia paupera, B. Tritici*)

The adults are found to be grayish black, 2.2-3.2 mm long. In the female flies the abdomen is swollen with pointed ovipositor. Larvae are with dirty white transparent with visible alimentary canal and 6.0 to 8.0 mm long.

Phorid flies: (*Megaselia sandhui*)

The adult flies are observed to be hump-backed, light to dark brown, 1.9-2.0 mm long. The fully grown larvae are dirty-white, 3.0-3.5 mm long with visible blackish month hooks.

The larvae of these flies feed on thickened mycelium and restricted the spawn run. The damage to button mushroom was found to be more serious when larvae entered the root portion and move towards the cap in groups forming tunnels. The infested mushrooms turn brown and leathery with rotting tissues.

Management:

1. After the crop is over, spent compost along with casing material should be thrown in the compost pit and covered with at least 10 cm thick layer of soil.
2. Nylon or wire net (not less than 35mesh) should be placed at windows and ventilators for checking the entry of flies into the crop rooms.
3. During composting, mix thoroughly lindane @ 50g/qtl wheat straw at 7th turning.
4. If the flies present in the crop room before casing, mix thoroughly 35g lindane in 100kg ready casing soil.
5. When these flies are noticed moving on mushroom beds, spray Nuvan (Dichlorovos) @ 30 ml /100 cu. m. size crop room on the walls and floor only.

Springtails: (*Seira iricolor*)

Adults are observed to be of ground colour with light violet coloured band along the side of the body without forming a definite pattern. The adults measured 2.9 mm longs. Adults & nymphs feed on mycelium by scraping from the spawn grains and cutting the mycelial strands.

Management:

1. The surroundings and inside of crop room should be kept neat & clean.
2. Crop beds should be raised-off from the floor.
3. Compost & casing soil should be properly sterilized / pasteurized.
4. Surrounding areas should be sprayed with 0.05% Malathion.
5. In the infested compost, mix Diazinan @20ml/qtl at time of spawning.

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