12

Commercial Mushroom Production and Marketing

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Ministry of Education, Science and Technology
Curriculum Development Centre
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Technical and Vocational Stream

Learning Resource Materials

Commercial Mushroom Production and Marketing

(Grade 12)

Plant Science

Secondary Level

Government of Nepal

Ministry of Education, Science and Technology

Curriculum Development Centre

Sanothimi, Bhaktapur

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. It is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizenswith applied technical and vocational knowledge and skills. This Learning Resource Material for Plant Science has been developed in line with the Secondary Level Plant Science Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Prof. Khemraj Dahal, Dr. Resham Bahadur Thapa, Lal Prasad Amagain, Arjun Prakash Poudel, Nabin Rawal, Kapil Poudel, Mahesh Poudel, Samir Sharma and Dinesh Timalsina is highly acknowledged. The book is written by Sujan Karki and the subject matter of the book was edited by Badrinath Timsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.by Badrinath Timsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

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Unit-1

Introduction to Mushroom Production

A. Content Elaboration:

Mushroom is the fleshy, spore bearing fruiting body of a fungus which is produced above ground on soil or on its food sourceand characterized by heterotrophic mode of nutrition. It belongs to the kingdom fungi and phyum Basidiomycota. They are also called as "meat vegetables". Mushroom provides necessary amino acid (Lysine, Trytophan) which are not found in cereal and vegetable protein. In Nepal, mushroom cultivation started in 1970/71 AD. Generally three types of mushroom are cultivated in Nepal.

- Button Mushroom: *Agaricus bisporus*: at Kathmandu valley
- Oyster Mushroom: *Pleurotus sajor-caju*: temperate and sub-tropical
- Paddy Straw Mushroom: *Volvoriella volvacea*: sub-tropical and tropical

1. Importance and Scope of Mushroom Production

1.1. Importance of mushroom cultivation in Nepal

Mushroom farming in Nepal is being popular between Nepali farmers. It is a new farming concept in the context of Nepal. Now there are many commercial mushroom farms in Nepal that produce different variety of mushrooms. Mushrooms are edible fungus which are grown in indoor and supplied in the market. Most of the part of Nepal is suitable for mushroom cultivation. Farmers can cultivate mushroom year round in natural environment different variety like shiitake, oyster, red mushroom in Nepal.

Mushroom cultivation is a relatively new concept in Nepal. It was introduced in 1974 by Nepal Agriculture Research Council (NARC), which initially introduced the 'White Button Mushroom' in 1977. After which the Plant Pathology division of NARC started distributing spawn. Then after, Oyster mushroom was introduced to farmers in 1984, which were farmed by only a handful of farmers in Bhaktapur and Kathmandu district. Currently, there are over 5000-6000 mushroom farmers in Kathmandu only, who at an

average produce over 10000 kg of mushroom per day. Pokhara and Chitwan are other major mushroom producers. Currently, there are 5 species of mushroom cultivated commercially.

1. White Button Mushroom
2. Oyster Mushroom
3. Shiitake
4. Straw Mushroom
5. Ganoderma

Mushrooms are known for their nutritive and medicinal values. Now-a-days commercial cultivation of mushroom in Nepal is increasing rapidly. Currently about five species of mushroom are cultivated in commercial scale. Among them white button mushroom and oyster mushrooms are produced and consumed more. Straw mushroom is also being cultivated in terai region. However, interestingly now-a-days there is a growing trend of consumption of mushroom because of its health related benefits

Nutritional importance of mushroom

Mushroom is considered to be a complete, healthy food and suitablefor all age groups viz., child to aged people. The nutritional value of mushroom is affected by numerous factors such as species, stage of development and environmental conditions. Mushrooms are rich in protein, dietary fiber, vitamins and minerals. The digestible carbohydrate profile of mushroom includes starches, pentoses, hexoses, disaccharides, amino sugars, sugar alcohols and sugar acids. The total carbohydrate content in mushroom varied from 26-82% on dry weight basis in different mushrooms. The crude fibre composition of the mushroom consists of partially digestible *polysaccharides* and *chitin*. Mushroom protein contains essential amino acid. It also contains Vit B_2 which is useful for diabetic patient. Minerals such as calcium, phosphorous, iron and potassium are also obtained in great quantity from mushroom.The greatest difficulty in feeding man is to supply a sufficient quality of the body building material.

Table 1: Nutritive values of different mushrooms (dry weight basis g/100g)

Mushroom	Carbohydrate	Fibre	Protein	Fat	Ash	Energy k cal
Agaricus bisporous	46.17	20.90	33.48	3.10	5.70	499
Pleurotus sajor-caju	63.40	48.60	19.23	2.70	6.32	412
Lentinula edodes	47.60	28.80	32.93	3.73	5.20	387
Pleurotus ostreatus	57.60	8.70	30.40	2.20	9.80	265
Vovarella volvaceae	54.80	5.50	37.50	2.60	1.10	305
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	378
Auriculariaauricula	82.80	19.80	4.20	.30	4.70	351

Courtesy: Stamets, 2005 (*A. bisporous, P. sajor-caju, Lentinula edodes*), FAO, 1972 (*Pleurotus ostreatus, V. volvaceae*), Doshi and Sharma, 1995 (*Calocybe indica*), Crison and Sand, 1978 (*Flammulina velutipes* and *Auricularia spp*).

Protein

Digestibility of protein is 72-83%, so less amount of consumed protein is wasted. In dried mushroom protein content range from 19-35%. In terms of crude protein, mushroom rank below animal meat (9-20%) but well above other foods including milk (2.9-3.5%). Mushroom protein contains all essential amino acids; Glycine- 1.2%, Histidine- 0.68%, Isoleucine- 1.28%, Leucine-2.16%, Tryptophan- 3.94% (Not found in vegetables).

Energy

In 454 gm fresh mushroom 120 kcal energy is obtained, 0.95% mannitol, 0.28% reducing sugar, 0.59% glycogen, 0.91% glucose

Vitamins

Vit-B_2 is found higher in fresh mushroom andare useful for diabetic patients. Ascorbic acid, Pantothenic acid, folic acid and Niacin are also found in good amount.

Minerals

Minerals such as calcium, phosphorus, iron, sodium and potassium are obtained in good quantity.

Medicinal importance of mushroom

Since thousands of years, edible fungi have been reversed for their immense health benefits and extensively used in folk medicine. Specific biochemical compounds in mushrooms are responsible for improving human health in many ways. These bioactive compounds include polysaccharides, tri-terpenoids, low molecular weight proteins, glycoproteins and immuno modulating compounds. Hence mushrooms have been shown to promote immune function; boost health; lower the risk of cancer; inhibit tumor growth; help balancing blood sugar; ward off viruses, bacteria, and fungi; reduce inflammation; and support the body's detoxification mechanisms. Increasing recognition of mushrooms in complementing conventional medicines is also well known for fighting many diseases. Medicinal values of the some important mushroom are given below:

Table 2: Medicinal values of some important mushrooms

Name of mushroom	Medicinal values
Morchella	To cure fever and diarrhea
Pleurotus officinalis	Help to stop bleeding, use against T.B, Jaundice and worms
Fistulina hepatica	Used for the healing of wounds
Ganoderma lucidum	Fight against any disease
Lycoperdon giganteum	Use for comfort surgical dressing
Agaricus bisporus	Lower blood cholesterol level

Good for heart

The edible mushrooms have little fat with higher proportion of unsaturated fatty acids and absence of cholesterol and consequently it is the relevant choice for heart patients and treating cardiovascular diseases. Minimal sodium with rich potassium in mushroom enhances salt balance and maintaining blood circulation in human. Hence, mushrooms are suitable for people suffering from high blood pressure. Regular consumption of mushrooms like *Lentinula, Pleurotus spp.* helps to decrease cholesterol levels.

Low calorie food

The diabetic patients choose mushroom as anideal food due to its low calorific value, no starch, and little fat and sugars. The lean proteins present in mushrooms help to burn cholesterol in the body. Thus, it is most preferable food for people striving to shed their extra weight.

Prevents cancer

Compounds restricting tumor activity are found in some mushrooms but only a limited numbers have under gone clinical trials. All forms of edible mushrooms, and white button mushrooms in particular, can prevent prostate and breast cancer. Fresh mushrooms are capable of arrestingthe action of 5-alpha-reductase and aromatase, chemicals responsible for growth of cancerous tumors. The drug known as Polysaccharide-K (Kresin), is isolated from *Trametes versicolor* (*Coriolus versicolor*), which is used as a leading cancer drug. Some mushroom-derived polysaccharides have ability to reduce the side effects of radiotherapy and chemotherapy too. Such effects have been clinically validated in mushrooms like *Lentinula edodes, Tramtes versicolor, Agaricus bisporous* and others.

Anti-aging property

The polysaccharides from mushrooms are potent scavengers of super oxide free radicals. These antioxidants prevent the action of free radicals in the body, consequently reducing the aging process. Ergo-thioneine is a specific antioxidant found in *Flammulina velutipes* and *Agaricus bisporus* which is necessary for healthy eyes, kidney, bone marrow, liver and skin.

Regulates digestive system

The fermentable fiber as well as oligosaccharide from mushrooms acts as a pre-biotics in intestine and therefore they anchor useful bacteria in the colon. This dietary fiber assists the digestion process and healthy functioning of bowel system.

Strengthens immunity

Mushrooms are capable of strengthening the immune system. A diverse collection of polysaccharides (beta-glucans) and minerals, isolated from mushroom is responsible for up-regulating the immune system. These compounds potentiate the host's innate (non-specific) and acquired (specific) immune responses and activate all kinds of immune cells.

Economic importance

Mushroom cultivation activities can play an important role in supporting the local economy by contributing to subsistence food security, nutrition, and medicine; generating additional employment and income through local, regional and national trade; and offering opportunities for processing enterprises (such as pickling and drying). Income from mushrooms can supplement cash flow, providing either:

- **a safety net** during critical times, preventing people falling into greater poverty;
- **a gap-filling** activity which can help spread income and generally make poverty more bearable through improved nutrition and higher income; or
- **a stepping stone** activity to help make people less poor, or even permanently lift them out of poverty.

1.2 Scope of mushroom cultivation in Nepal

The term "importance" means values and the usability, while scope indicates one or more conditions suitable for production. While coming to the scope of mushroom cultivation, it is having a huge demand in public. Nowadays all types of people prefermushrooms for eating. Mushrooms are good in giving energy and increase the health. They are having a huge scope of medicine. Mushrooms are having a huge

demand in pharma and cosmetic companies. Mushrooms are the fruiting body of the microorganisms like Fungi.

These mushrooms are good in taste so it is having more demand than other foods. These mushrooms are serving as food in many countries. Some of the mushrooms are harmful and highly poisonous. Apart from those some are very delicious to eat. While there are various benefits to eat mushrooms. Economic Importance of Mushroom Cultivation is also high. Some aspect that are pertinent to the scope of mushroom cultivation are mentioned as under,

Climate:

The series of climate condition that prevail through a season or a year depends on the locality in this country. A variety of climates permit us to grow different variety of mushroom cultivation within the country.

Topography:

Nepal is a mountainous country where lands are undulated and fragmented. So that by utilizing such land structure, we can grow a mushroom in any parts of the country. Mushroom cultivation can be practiced in small area of land or more over large area in commercial farming.

Demand and supply:

The consumption of mushroom in a required quantity is good for human health. These produce either in fresh or in processed form have high demand. The net per capita consumption of mushroom has increased as people demand for more and better food in hygienic condition. According to the demand for preferential mushroom supplies are less than limited. Therefore, there is a large scope for production of mushroom.

Marketing facilities:

Mushrooms are perishable in nature. These must be disposed quickly to get good price. In Nepal cold storage facilities are almost nonexistent and proper channel in price fixation and marketing system are yet to be developed. Since agriculture roads are under construction in different parts of the country so that the produce of one locality can be mobilized and made available to other locality upon completion of these roads.

Employment opportunities:

Trade in cultivated mushrooms can provide a readily available and important source of cash income for men and women and the old, infirm and disabled alike. The role played by women in rural mushroom production can be very significant. Certain parts of the mushroom cultivation process, such as filling substrates in containers and harvesting, are ideally suited for women's participation. Several programs have enhanced women's empowerment through mushroom production by giving them the opportunity to gain farming skills, financial independence and self-respect.

1.3 Advantage of mushroom cultivation

Mushroom farming is increasingly becoming attractive to small farmers around urban centers. Mushroom farming done around Kathmandu valley is also dominated by small farmers. The farmers in rural areas are yet to be convinced about the profits of mushroom farming. In these remote areas, mushroom consumed are mostly wild mushroom brought from forest. Since there is lack of scientific technique to test the poisonous nature of wild mushroom, every year many people die due to its consumption. The reasons behind popularity of mushroom farming among small farmers are:

- Raw materials can be actively used for the cultivation of mushroom. This kind of bio- conversion can greatly reduce environmental pollution.
- Mushroom cultivation is labor intensive activity, therefore will serve as means of generating employment, particularly for rural women and youths in order to raise their social status.
- The extractable bioactive compounds from medicinal mushroom will enhance human's immune systems and improve their quality of life.
- Mushroom cultivation is a cash crop; harvested fruiting bodies can be sold in local markets for additional family income or export outside.
- Some warm mushroom eg: *Volvoriella volvacea* and *Pleurotus sajor- caju* are relatively fast growing and can be harvested in 3 to 4 weeks after spawning. It is short return agricultural business and can be of immediate benefit to the community.
- Mushroom farming is both science and art. The science developed through research and art is perfected through curiosity and practical experience.

1.4 Potentiality of mushroom production in relation to local as well as international markets

Mushroom farming has good potential for income generation to farmers. Due to the geographical and biological diversity, wide variety of mushroom can be produced. But we have to explore different kinds of mushroom, their nutritional and medicinal values to create demand of mushroom. Also the farmers need to have easier access to loan at reasonable rate of interest. With subsidies, farmers may be encouraged to take risks too. Also with Nepal's successful community forestry, user groups can utilize the forest resource and take forestry and mushroom farming together, for the species of wild mushroom which cannot be cultivated, this can be a way. The most feasible areas for mushroom farming would be in hills surrounding the Kathmandu valley or any other areas near urban centers. Since the market is concentrated in urbanareas, farming would be most appropriate in the surrounding areas.

Important factor to be considered are:

- Since these areas are near to cities, market access will not be a problem. Most areas also have motorable roads, which makes transportation easier.
- Though these areas are near cities, they are agriculture dominated. The farmers too, due to vicinity to cities, are more open to new technology for farming which is essential for introduction of any new crop.
- The poverty level of these areas also needs to be addressed. Though they are near to cities, they have been constantly overlooked by any form of development.
- Areas around all part of the country have good climatic condition for mushroom farming.

The marketing channels of mushroom are delineated in figure. Usually, three intermediaries are involved in the channel for mushroom - producers, wholesalers and retailers. Producers of mushroom sell their product to nearby mushroom wholesalers and retailers.

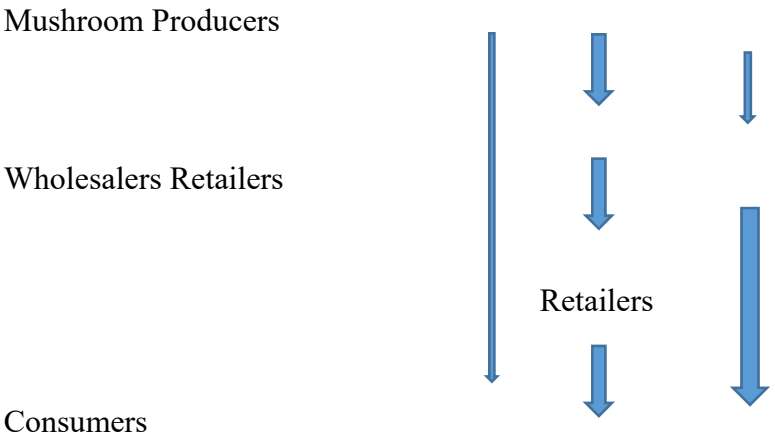


Fig: Marketing channels of mushroom production

The wholesalers buy mushroom directly from producers and sell it to retailers or sometimes directly to consumers. The retailers buy mushroom from wholesalers or directly from producers and sell it to consumers. Similarly sometimes producer directly sell the product to the consumer in the local market or big market.

1.5 Classification of mushroom

Classification of mushroom is made according to the standard procedure in taxonomic identification. Mushrooms are generally classified under Phylum Basidiomycota, Division Eumycota, Subdivision Basidiomycotina, and Class Hymenomycetes. Mushrooms under this class are separated into different orders: Order Agaricales, Order Polyporales, Order Sclerodermatales, Order Aphyllophorales, Order Lycoperdales, Order Auriculariales and Order Tremellales. Mushrooms or toadstools are noted widely in edibility. A relatively few species are delicious, many are edible but tough or of an unremarkable flavor, some are inedible and produce varying degrees of illnesses, some commonly known toadstool are violently deadly poisonous.

The scientific classification of an oyster mushroom:

Kingdom: Plantae
Division: Mycota
Sub-division: Basidiomycota
Class: Basidiomycetes

Order: Agaricales
Family: Agaricaceae
Genus: *Agaricus*
Species: *bisporus*

Order Agaricales has 8 families having pale colored spores

1. *Amanitaceae*: Spore- white, Gill- free, Veil- universal+partialeg. *Amanita*
2. *Lepiotaceae*: Spore- white (greenish), Gill- free, Partial veil eg. *Lepiota*
3. *Tricholomataceae*: Largest and most diverse family. Spore- whitish yellow, Gill- attached, Partial veil. Eg *Tricholoma, Mycena, Armillaria, Laccaria, Cystoderma*
4. *Pleurotaceae*: eg. *Pleurotus*: on hard wood, shelf fungi, spore round
5. *Pleurocybella*: On conifer
6. *Hygroporaceae*: waxy cap, waxy gills, often brightly colored, gills attached to decurrent, white spore, long basidia
7. *Eg. Hygrophorus:* waxy gills, gills decurrent, white to bright colored
8. *Hygrocybe:* waxy caps, brightly colored

Families with dark colored spores

1. Cortinariaceae
2. Strophariaceae
3. Agaricaceae
4. Coprinaceae
5. Pleuteaceae
6. Entolomataceae

1.6 Important cultivation and wild mushroom of Nepal

Due to the geographic diversity many varieties of mushroom are found in Nepal. Though only few are domesticated, there are large numbers of wild mushrooms which are edible and has high nutritional and medicinal value. Very lessstudy has been done regarding this. Many parts of Nepal still remain unexplored for mushroom. All the cultivated species are not indigenous. Table 1 gives utility value of mushroom species in Nepal.

Table 3: Number of mushroom species with different utility values

Edible	Medicinal	Toxic	Others
110	13	45	6

The types of mushroom in Nepal can be broadly classified as: a) Cultivated mushroom, b) Wild mushroom.

Types of cultivated mushroom

Table 4: Types of cultivated mushroom

Types	Name	Geographical Distribution
White button mushroom	Gobrechyau (*Agaricus bisporus*)	Hilly region
Oyster Mushroom	Kanye chyau (*Pleurotus ostreatus*)	Hilly regions, Terai region in winter
Shiitake	Mirgechyau (*Lentinus edodes*)	Midhills
Straw mushroom	Paralechyau (*Volvorielle volvacea*)	Terai region
Ganoderma	Ratochyua (*Ganoderma lucidum*)	Hilly Region

b. Wild mushroom:

There are many species of wild mushrooms found in various areas of Nepal. Villagers consume wild mushroom, but the harvest of wild mushroom is in very less amount. Many species have been placed under medicinal plant by department of forest. Some important wild mushrooms of very high commercial value are:

i) *Lycoperdon* (Fushfuse chyau in Nepali)

In Nepal, up to now two sp of *Lycoperdon*, *L. pusillium*, *L.pyriforme* are found. These types of mushrooms are more preferred by the people of terai. These are found in Khumbu himal region. Due to rough texture people do not prefer this.

ii) Morels (Gucchi Chyau)

It is also known as Morchella. 3 species are found in Nepal. *M. esculenta*, *M. conica*, *M. smithiana*. These types of mushrooms are found in mid-western hills of Jumla, Humla. White and black color mushroom, white color type found in found in sunny

area after rainfall and black color type found in moisture area. After Chitra/Baisakh they can be seen in the forest. In India after identification and development of *Morchella*s train, commercial cultivation of *Morchella* has been started.

For cultivation, 2.6% sugar substance, Inorganic nitrogen, pH 5-7, temperature 25ºC is essential. *Morchella* are seen in high organic manure soil, high moisture and also in Pinus, Alnus, and Apple orchard. *Morchella* fungus exists in mycorrhizal association with higher plants.

iii) Cordyceps sinensis (Yarchagumba)

In Nepal 2 species are recorded. They are found in Himalayan region of India, China, Tibet, Bhutan and Nepal. After the onset of spring season to the mid spring season, this mushroom is found in Himalaya grassy belt. In the soil, black fungus is seen. Mycelium of the fungus grows inside the soil and attacks the larva of Lepidoptera and gives fruiting structure in next generation. There is also saying that it is 6 months insect and 6 months plant. But scientist says it is the fungus that is foe to lepidopteron insect larvae.

Fungus enters inside the body of larvae and colonize inside the body at last larvae becomes unmoved and becomes dead. Fungus derives nutrients from larvae and fungus develops from the head portion of larvae. Upper portion is swollen and stalk with varying length and width is seen. It can be consumed with milk or honey which acts as aphrodisiac.

iv) *Cantherellus* (Budi chyau)

Found in Kathmandu valley jungle in Shrawan – Bhadra.

v) Fistulina hepatica

Found at 500-2500 m altitude. Used as curative of wounds.

vi) Grifolia frondosa

Found at 1500-3000 m hight. Tamang called Nagrum. It controls tumor.

vii) Coriolus spp

Found at 1500-3000m altitude from east to west. It controls tumor.

Among these, *Cordyceps sinensis* has become important source of income for many people in the mid-western region. Most of morels collected in the forest of Nepal are exported abroad. It is not yet cultivated artificially. Recognizing the medicinal importance of *Ganoderma lucidum*, it has been tried to cultivate. This is yet to be transferred to farmers.

1.7 Characteristics and identification of edible and poisons mushroom

Mushrooms can be found extensively in a variety of natural environments and visual identification of mushroom species is well established. Some mushrooms are known because of their nutritional and therapeutical properties. Some species are known all over the world because of their toxicity that causes fatal accidents every year mainly due to misidentification. Some of the edible mushrooms are *Ganoderma* spp, *Cantharellus* spp, *Agaricus* spp, *Pleurotus* spp, *Russula* spp, *Auricularia* spp and *Termitomyces* spp; but the ornamentals are the beautifully ringed *Microporous spp*., *Amanita spp*, *Lepiota cristata*, *Lepiota brunneoincarnata* and *Inocybeasterospora*, are among the most important species responsible for mushroom poisoning.

Edible Mushrooms

Edible mushrooms are the fungi which bear fruiting structures that are large enough to be seen with the naked eye. They may be hypogenous or epigeous and can be picked by hand. What underscores edibility of mushrooms is the absence of poisonous effects on humans and desirable taste and aroma.

The nutritional composition of edible mushrooms is high and that is why they are consumed for their nutritional value and supposed medicinal value. Medicinal mushrooms are consumed by those practicing folk medicine for their nutraceutical composition. The hallucinogenic mushrooms like psilocybin mushrooms are consumed for recreational or religious purposes and they can produce severe nausea and disorientation – a reason why they are not commonly considered edible mushrooms.

Poisonous Mushrooms

Since there is no known test to tell if a mushroom is edible or not, a mushroom should never be eaten unless it has been accurately identified and the edibility of the species is known. Poisonous mushrooms represent less than 1% of the world's known mushrooms; hence constitute the dangerous and sometimes fatal species. For this reason, mushrooms must be identified by a competent mycological authority before consumption. Therefore, one must be absolutely sure whether a given mushroom is edible or not before consumption.

The toxins contained in various species are very different in chemical composition, thus the effects of poisoning differ considerably according to the species involved. In any case, suspected mushroom poisoning should never be regarded lightly and medical assistance should be sought at once. The following summary of mushroom poisoning is taken from the account.

Amanita-type poisoning

Unquestionably, the *Amanita phalloides* group causes the most dangerous type of mushroom poisoning. The toxins involved belong to the phallotoxin and amatoxin complexes. The phallotoxin phalloidin binds specifically to act in. The phallotoxins are not active following ingestion, but they are potent when injected intravenously and have proved useful in experimental studies. In such studies phalloidin, binding to actin, is coupled with fluorescent groups. By this means actin can be localized in the cells. It is the amatoxin such as amatine that is involved in amanita poisoning. Amatine is a specific inhibitor of RNA polymerase present in all eukaryotes. This blocking of the enzymes associated with the replication of RNA inhibits the formation of new cells. These toxins tend to accumulate in the liver and damage that organ severely. The RNA polymerase of the fungus is not affected. This group has caused the majority of recorded deaths from mushroom poisoning, especially in Europe. Generally the symptoms of this type of poisoning are said to be severe abdominal pains, nausea, violent vomiting, diarrhea, cold sweats, and excessive thirst. These may last for 48 hours, with dehydration, cramps, and anuria.

Muscarine-type poisoning

Two toxins, muscarine and ibotenic acid, are involved. They occur in *Amanita muscaria*, A. *pantherina*, and also in a number of Inocybe and Clitocybe species. Muscarine is known to be responsible for "pupil contraction, blurred vision, lachrymation, salivation, perspiration, reduced heart rate, lowering of blood pressure, and asthmatic-like breathing". Ibotenic acid is responsible for the insecticidal properties of *A. muscaria*, the fly agaric. Both muscarine and ibotenic acids are intoxicants, and there is a long history of different cultures using these compounds from A. *muscaria* for this purpose and in religious rites. The symptoms usually appear soon after eating the mushrooms, with vomiting, diarrhea, and salivation. The most characteristic symptoms are nervous excitement, difficulties in breathing, shivering, and a tendency to collapse.

Psychotropic or hallucinogenic poisoning

Several different toxins are involved, including psilocin and psilocybin, which are found in species of *Psilocybe, Conocybe,* and *Stropharia.* These compounds are similar in their reaction to d-lysergic acid diethylamide. They act on the central nervous system, producing distortions in vision and of tactile sensations as well as mixed emotional feelings of happiness or depression. Other symptoms are varied, including vomiting, increased rate of heartbeat, and hallucinations, which may last for various lengths of time.

Coprinus poisoning

Several Coprinus species, such as *C. micaceus* and *C. atramentarius*, when consumed with an alcoholic drink, produce unpleasant but not dangerous symptoms. The symptoms include reddening of the face, increased rate of heartbeat, and, in some cases, vomiting and diarrhea. The mode of action of the chemical in *C. atramentarius* mushrooms is similar to Antabuse, which is a drug used to induce nausea and vomiting in individuals who are trying to overcome an addiction to alcohol.

Poisoning from external sources

The poisoning is not caused by mushrooms themselves but by toxic substances that have accumulated in the mushrooms. The principal causes are:

(1) heavy metals due to polluting environmental conditions where the mushrooms are harvested that are far in excess of permissible levels, and

(2) Radioactive contaminants due to the pollution by contaminating radioactive materials in mushroomhunting areas and subsequent consumption of the collected mushrooms.

Traditional methods of distinguishing poisonous from edible mushrooms

Traditionally, the ethno-mycological knowledge of edible mushrooms is limited to their visible fruit bodies. Morphological identification is based on features such as cap color, cap shape, stipe color and shape, gills size and color of fruiting bodies which within a species can vary greatly depending on the environmental conditions, which often lead to errors in the determination of their species. Dimensional characteristics such as cap size and stipe length, the substratum they are attached to and spore growth are often used as distinguishing features. Other differences between poisonous and edible mushroom are presented in Table 5.

Table 5: Traditional methods of distinguishing poisonous from edible mushrooms

Poisonous mushroom	Edible mushrom
When you cut the mushroom it turns either green or purple.	When you cut the mushroom it does not stain green or purple.
When you taste a piece of the mushroom, it burns or stings the tongue.	When you taste a piece of the mushroom, it does not burn or sting the tongue.
Poisonous mushrooms have bad odour.	Edible mushrooms have pleasant odour.
It tastes bitter.	It has sweet taste.
There is no presence of worms.	There is presence of worms.
There is presence of scales on the cap.	There is no scale on the cap.

1.8 Type of mushroom

The climate and topography of Nepal provides incredible opportunities for availability of different species of mushroom. Some of the Cultivated, Wild and Poisonous Mushroom Species Found in Nepal are given as:

Table 6: Cultivated, wild and poisonous mushroom apecies found in Nepal

Cultivated Mushroom Species	
1. Button or Paris Mushroom The white colored Button or Paris mushroom is most commonly found in the produce section of the grocery store. It remains the most highly cultivated mushroom throughout the world even though the actual culture is extremely complex. It requires the fabrication of very specific compost and a layer of casings.	
2. King Oyster Mushroom The King Oyster is a mushroom greyish in color and is easily recognized by its particular long form. It has a medium pronounced, aromatic flavor and it can be conserved longer than the majority of mushrooms. In nature, it often grows in association with plants of the Umbelliferes family- notably the carrot.	
3. Almond or Himematsutake Mushroom The Himematsutake or Almond mushroom is whitish in color and has an almond taste when cooked. It grows very well in association with many garden veggies- to name a few: kale, gordes, zucchini, potatoes and melon. The culture of this mushroom can grow on swaths of organic matter outside.	

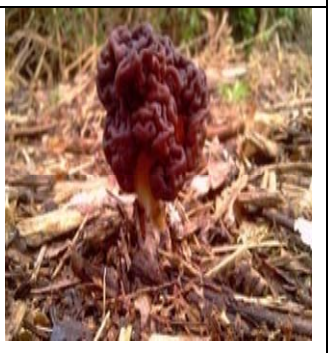
4. Reishi (*Ganoderma lucidum*) The reishi is a red to dark brown colored mushroom. Its peculiarity is that it is as hard as wood and it is recognized for its medicinal properties. It grows on buried logs and will produce over several years. The block of mycelium on sawdust can be directly buried in the ground. It is necessary to assure good drainage in the place where the logs are buried. This mushroom can be consumed in herbal tea (5 grams of mushroom by liter of water).	
5. Paddy Straw Mushroom (*Volvariella volvacea*) The Paddy Straw mushroom is a whitish/beige color. It grows on almost all the organic residues. It is a mushroom that needs heat and that flourishes in temperatures around 35°C. It can, thus, grow at the top of a compost heap or in a tunnel made from a transparent plastic. The mushroom and its mycelium must not be preserved in the refrigerator like all other mushrooms; it will degrade and the mycelium will die.	
6. Yellow Oyster Mushroom (*Pleurotus citrinopileatus*) The Yellow Oyster is a very beautiful mushroom due to its lemon yellow color. Its taste is gently less pronounced than other types of oysters though it gives off an interesting aroma. It's a tropical species so it requires a lot of warmth; its biological effectiveness is less impressive than other Oyster mushrooms.	

7. Pleurotus sajor caju It is widely practiced in commercial level. Temperature requirement of pleurotus is higher then nagaricus and lower than volvariella. So, it is gaining popularity among the farmers of different agroecological zones. This mushroom is white under hot climate weather and grayish in cold weather. The stipe is usually very short and is of same color of the pileus. Pileus is fan like when young and gradually becomes deeply lobbed to form branch like making the mushroom appear as they are growing in cluster. On the underside of the pileus numerous gills are present which are of various lengths. Four basidiospores are formed at the tip of asidia.	
Wild Mushroom Species	
1. Shitake (*Lentinula edodes*) The shiitake mushroom is beige and brown in color. It is recognized for its multiple medicinal properties. This mushroom is cultivated at the altitude of 1700-2500 masl where *Alnus nepalensis* and *Castanopsis cuspidate* are found. 5 sps. of lentinus are found in Nepal. L. edodes is successfully grown in lab also. They are used for curing tumor, high blood pressure and diabetes.	
2. Morel (*Morchella esculenta/angusticeps*) The Morel is beige to dark brown mushroom that has a very characteristic conical shape. It usually grows in forested areas just following a forest fire. It is also possible to find it growing in association with cultures like the Jerusalem artichoke or asparagus.	

	
3. Lycoperdon (*Lycoperdon pyriforme*) Pyriforme (pear-shaped puffball) are edible provided they are picked when young and the contents of the head are still white and firm. In Nepal upto now 2 species *Leycoperdon pusillium* and *Lycoperdon pyriformae* are found .this type of mushroom are more preferred by people living in terai region. They are found in khumbu himal region of Nepal have rough texture.	
4. *Cordyceps sinensis* In Nepal 2 species are recorded. They are found in the himalayan region of Nepal. After the commencement of spring and upto the rainy season they are found in Himalayan region grassy belt. In the soil black fungus are seen at autumn and rainy season. The lower portion of the fungus is inside soil or remains attached with the larvae of lepidopteron. This fungus attacks the larva and in next generation it gives fruiting structure. There is saying that it is 6 months insect and 6 months plant but scientist say it is the fungus that is foe to insect larva.	

5. *Amanita jacksonii* and *Amanita caesarea* (Caesar's Mushroom) Caesar's mushroom is so named because it was a favorite of the emperor Claudius and led to his demise when he ate some that had been mixed with poison (Benjamin 1995). It is found throughout eastern North America and the warmer parts of southern Europe in summer and autumn associated with oaks and other deciduous trees. Although the American and European forms of this mushroom are listed under *Amanita caesarea* in many texts, the former is now considered to represent a different species: *A. jacksonii*.	
6. *Laccaria laccata* (The Deceiver) This edible, highly variable, deceptive mushroom (hence the common name) is often found in clusters under deciduous and coniferous trees in late summer and autumn throughout temperate regions of the Northern Hemisphere. The caps, which are 1.5–6 cm in diameter and have widely spaced gills, are usually reddish brown with peach tones when moist, yellowish brown when dry. The caps are dome-shaped and shiny when young but become flattened with a depression in the center, or funnel-shaped with a wavy edge, as they mature. With age the caps may become dry and dull. The stalks and gills are a similar color to the caps.	

7. *Coprinus atramentarius* (Common Ink Cap) The light brown caps of the common ink cap are larger than those of the non-inky coprinus (*Coprinus disseminatus*); they are typically 3–7 cm high and 4–7 cm in diameter. The caps are borne on a white stalk 7–17 cm high, which can have the remains of a ring close to the base. This species is often found growing in unlikely places such as along roadsides and in waste areas where there is rotting wood in the soil. It also occurs in lawns. The caps are edible but must be cooked within a few hours of picking as they rapidly turn black and release the spores in a black liquid (which, incidentally, was used in the past as a substitute for ink).	
8. *Coprinus comatus* (Shaggy Ink Cap) The shaggy ink cap is much larger than the common ink cap, occasionally reaching as much as 40 cm in height. The caps are cylindrical at first but eventually become bell-shaped. The gills are initially white, soon turning pink and then black. Once the gills are black, the bottom edge of the cap begins to drip a black liquid that contains the spores. Shaggy ink caps are usually found in waste areas and along roadsides during late summer to late autumn. Old caps do not look very appetizing but do have a good flavor, though they must be cooked within a few hours of picking. This mushroom is very widely distributed throughout the world, in part because it has been introduced into regions where it is not indigenous.	
Poisonous Mushroom Species	

1. Deadly *Conocybe* Deadly *Conocybe* is the name for a type of mushrooms that have conical caps and rusty brown gills. Also known as *Pholiotina filaris*, these are widely distributed in America's Pacific Northwest. Often mistaken for the similar looking *Psilocybe*, these common lawn mushrooms contain deadly mycotoxins which could lead to death when eaten.	
2. Death Cap The death cap is a medium-large, beautiful mushroom, widely distributed across Europe and Asia. Often mistaken for the popular, edible paddy straw mushroom, the death cap is considered highly toxic, and its toxicity can't be reduced by freezing, drying or boiling. This deadly mushroom is responsible for the majority of mushroom poisonings worldwide.	
3. Deadly *Galerina* This gorgeous saprobic mushroom is actually a poisonous mushroom that contains the toxin, α-amanitin. It damages the liver cells most, along with the kidneys and the central nervous system. So, do not mess around with this truly toxic mushroom.	
4. False Morel Sometimes collectively called sponge mushrooms, false morels are the members of the genus *Gyromitra*. They can easily be recognized by the distinctive, complexly infolded caps that resemble the surface of a brain. Often mistaken for the true morel, some of the species contain MMH (Mono-Methyl Hydrazine), which is suspected to be carcinogenicand can cause vomiting, dizziness, diarrhea and sometimes death.	

5. Destroying Angel A white-gilled and almost oval mushroom, the destroying angel is the most common toxic mushroom around the world. It contains amatoxins, responsible for fatal mushroom poisoning, as death caps do. The damage starts with the destruction of the liver and kidney tissue within a couple of hours after consumption, leading to death. Mushrooming is considered a healthy hobby as one gets out into nature. Eating mushrooms adds flavor and richness to our food. But to enjoy the meal, you must remember to "never eat a mushroom unless you are 100% certain of the identification."	
6. *Amanita muscaria* (Fly Agaric) No introduction should be required for the fly agaric, which can be found illustrated in a host of children's books and is probably the most photographed of all mushrooms. The orange to red cap with white scales and white gills, stalk, and volva make it almost impossible to mistake.	
7. *Hebeloma* and *Inocybe* Species Mushrooms belonging to the genera *Hebeloma* and *Inocybe* have ochre to brown spores, and most have no ring on the stalk. *Hebeloma crustuliniforme* (poison pie) and *H. sinapizans* have tan caps, light brown gills, whitish stalks, and are found associated with hardwoods and conifers in late summer and autumn. Both species smell strongly of radish and have a bitter taste. Many species of *Inocybe* have a small brown cap with a raised center and a variety of strange smells, including that of semen. The gills are grayish beige when young, turning darker brown with age. Although most are associated with hardwoods and conifers, some can be found in the grassy margins of paths and trails.	

C. Assessment

Very short (Answer question)

1. Define mushroom.
2. Give any two examples of edible mushroom species in Nepal.

Short (Answer question)

1. Write any three common cultivated mushroom species in Nepal.
2. List out the scope of mushroom cultivation in Nepal.

Long (Answer question)

1. Write down the importance of mushroom cultivation in Nepal.
2. Discuss about the potentiality of mushroom production in relation to local as well as international markets.
3. Define wild mushroom. Write down the traditional methods of distinguishing poisonous from edible mushrooms.

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Unit-2

Cultivation Practices of Button Mushroom

A. Content Elaboration

Mushroom farming is a complex business, which requires precision. Indeed, it is not as simple as what some people often loosely stipulate. It calls for adherence to precise procedures. The major practical steps/segments of mushroom cultivation are: (a) selection of an acceptable mushroom species; (b) secreting a good quality fruiting culture; (c) development of robust spawn; (d) preparation of selective substrate/compost; (e) care of mycelial (spawn) running; (f) management of fruiting/ mushroom development; and (g) harvesting mushrooms carefully. If we ignore one critical step/segment, we are inviting trouble, which could lead to a substantially reduced mushroom crop yield and mushroom marketing value.

Agaricus also called white button mushroom including 4 species of *Agaricus* i.e., *A. bisporus*, *A. campestries, A. rodmani*, *A. silvicola*, are found in Nepalese forest. But recently two species *Agaricus bisporus* and exotic *Agaricus bitorquis* have been grown successfully in Kathmandu and hilly region for 2 seasons and for 1 season in terai belt. Its shape looks like an orange and the color is bright white. These mushrooms also have medicinal value. It works as an antioxidant. It also has a lot of proteins. It helps to reduce cholesterol and protect from tumor. Gobre mushroom cultivation can be done in plastic tunnel, thatched roof house etc. In hilly areas, compost can be made in Asadh/Shrawan and harvesting can be done in Ashoj- Mangshir. In terai, compost can be made in Kartik and harvesting can be done in Poush/Magh.

2.1 Selection of strains

The first stage in any mushroom cultivation process is to obtain a pure mycelial culture of the specific mushroom strain. Such cultures are now readily purchased from mushroom specialists, mushroom enterprises or mushroom institutes.Such cultures have originally been derived from single or multispore cultures or by tissue culture from a mushroom of a high yielding and vigorous strain.

2.2 Maintenance of strains

Many strains have been developed by considerable genetic breeding programs. Each type of mushroom culture generally requires unique substrate formulation for propagation and maintenance of purity.

2.3 Spawn and spawn production

Mushroom spawn is simply any substance that has been inoculated with mycelium, the vegetative growth of a fungus. Spawn is produced from fruiting culture / stocks of selected strains of mushrooms under sterile conditions. Stock culture may be produced in the lab or may be obtained from other reputed sources. Fruiting culture is mainly imported from various places including foreign sources which give higher yield than Indian strains and the spawn is produced in the lab. The spawn should be of good quality in terms of flavour, texture and size apart from having potential for high yield and longer shelf life.

2.4 Compost preparation

The compost should be prepared on well cleaned concrete or pucca floor, which should beat a higher level so that the runoff water does not collect near the heap. Composting is usually done in the open, but it has to be protected from rain by covering it with polythene sheet. It can also be done in a shed with open sides or a large room to shelter it from rain.

Method of compost preparation

The substrate on which button mushroom grows is mainly prepared from a mixture of plant wastes (cereal straw/ sugarcane bagasse etc.), salts (urea, superphosphate/ gypsum etc), supplements (rice bran/ wheat bran) and water. In order to produce 1 kg of mushroom, 220 g. of dry substrate materials are required. It is recommended that each ton of compost should contain 6.6 kg Nitrogen, 2.0 kg Phosphate and 5.0 kg of Potassium (N:P:K- 33:10:25) which would get converted into 1.98% N, 0.62% P and 1.5% K on a dry weight basis. The ratio of C: N in a good substrate should be 25-30: 1 at the time of staking and 16-17: 1 in the case of final compost.

Short method of composting

During the first phase of compost preparation, paddy straw is placed in layers and sufficient water is added to the stack along with fertilizers, wheat bran, molasses etc. The whole thing is mixed thoroughly with the straw and made into a stack (almost 5feet high,5 feet wide and of any length can be made with the help of wooden boards). The stack is turned and again watered on the second day. On the fourth day the stack is again turned for the second time by adding gypsum and watered. The third and final turning is given on the twelfth day when the colour of the compost changes into dark brown and it starts emitting a strong smell of ammonia.

The second phase is the pasteurization phase .The compost prepared as a result of microbe mediated fermentation process needs to be pasteurized in order to kill undesirable microbes and competitors and to convert ammonia into microbial protein. The whole process is carried out inside a steaming room where an air temperature of 60°C is maintained for 4 hours. The compost finally obtained should be granular in structure with 70% moisture content and pH 7.5. It should have a dark brown color, sweet pleasant smell and free from ammonia, insects and nematodes. After the process is complete, the substrate is cooled down to 25°C.

Long method of composting

The long method of composting is usually practiced in areas where a facility for steam pasteurization is not available. In this method, the first turning is given about six days after preparation of the substrate for composting. The second turning is given on the tenth day followed by third one on the thirteenth day when gypsum is added. The fourth, fifth and sixth turnings are given on the sixteenth, nineteenth and twenty-second day. On the twenty-fifth day the seventh turning is given by adding 10% BHC (125 gm) and the eighth turning is given on the twenty-eighth day after which it is checked whether there is any smell of ammonia present in the compost. The compost is ready for spawning only if it doesn't have any smell of ammonia; otherwise a few more turnings are given at an interval of three days till there is no smell of ammonia.

2.5 Preparation beds

For preparing the compost bed it is necessary to maintain optimum moisture content, which could be judged by squeezing a handful of compost, few drops of water should ooze out from the fingers.

Self-system:

The mushroom house is constructed with built-in shelves. The shelves are half a meter apart and the lowest one is 20cm from the floor. The shelves may be made out of wooden or steel framework. The compost should be filled out 14-15cm thick in each self.

Tray system:

Individual trays of wooden measuring 100cm x 50cm x 15cm are made. Legs of 1-1.5cm are provided for each tray so that while stacking there will be small gap for proper ventilation. The trays are filled with compost. These trays can be put in one room for spawning and can be easily shifted to another room for cropping

Growing in bags:

Polythene bags of thick gauge can be used instead of trays to hold about 25kg of compost per bag. They are used in the areas having cooler climates or where the temperature can be controlled.

2.6 Spawning method

The process of mixing spawn with compost is called spawning. The different methods followed for spawning are given below:

1. **Spot Spawning**
   Lumps of spawn are planted in 5 cm. deep holes made in the compost at a distance of 20-25 cm. The holes are later covered with compost.

2. **Surface Spawning**
   The spawn is evenly spread in the top layer of the compost and then mixed to a depth of 3-5 cm. The top portion is covered with a thin layer of compost.

3. **Layer Spawning**

About 3-4 layers of spawn mixed with compost are prepared which is again covered with a thin layer of compost like in surface spawning.

2.7 Casing method

The compost beds after complete spawn run should be covered with a layer of soil (casing) about 3-4 cm. thick to induce fruiting. The casing material should be having high porosity, water holding capacity and the pH should range between 7-7.5. Peat moss which is considered to be the best casing material is not available in India, as such the mixtures like garden loam soil and sand (4:1); decomposed cow-dung and loam soil (1:1) and spent compost (2-3 years old); sand and lime are commonly used.

The casing soil before application should be either pasteurized (at 66-70°C for 7-8 hours), treated with Formaldehyde (2%), Formaldehyde (2%) and Bavistin (75 ppm) or steam sterilized. The treatment needs to be done at least 15 days before the material is used for casing. After casing is done the temperature of the room is again maintained at 23-28°C and relative humidity of 85-90% for another 8-10 days. Low CO2 concentration is favorable for reproductive growth at this stage.

2.8 Handling the crop

After completion of case run, the cooling of the room is enhanced to bring the air temperature down to 15-17°C in the room within 2-3 days' time. Simultaneously, the fresh air vent is opened to 30% and rest of the air is re-circulated (70%). This brings down the CO2 conc. in the room to 300 ppm to 1000 ppm, desired for pinhead formation. Likewise, the RH is also reduced to 85% from 95%. This facilitates pinhead formation on the casing within a week's time. The pinheads grow into full button sized mushrooms in another 3-4 days. The environment parameters are maintained as above during entire period of cropping. Temperature has influence on RH and CO2 concentration and hence should be maintained/manipulated, keeping in mind its effect on other two factors. All the three parameters work in synergy with each other to induce pinning on casing surface.

2.9 Harvesting method

Harvesting is done at button stage and caps measuring 2.5 to 4 cm. across and closed are ideal for the purpose. The first crop appears about three weeks after casing. Mushrooms need to be harvested by light twisting without disturbing the casing soil. Once the harvesting is complete, the gaps in the beds should be filled with fresh sterilized casing material and then watered.

2.10 Grading, packaging and storage

Grading

Soon after harvest, mushrooms have to be cleaned and graded before sending to the market or storage in a cool atmosphere. The grading and sorting is done according to their colour (pure white, slightly brown, damaged), size, stage of the cap or partial veil (Intact, slightly open, open), length of the stem etc. Grading is generally done on the basis of size of the button, shape of pileus and opening of gills, also known as buttons, cups and umbrellas, respectively.

Packaging

The mushrooms for fresh market are packed in plastic containers, perforated polythene bags of 100 gauge thickness or loose bags at varying packages.

Storage

Short Term Storage

Button mushrooms are highly perishable. Harvested mushrooms are cut at the soil line and washed in a solution of 5g. KMS in 10 lit of water for removing the soil particles as well as to induce whiteness. After removing excess water these are packed in perforated poly bags each containing around 250-500g of mushrooms. They can be stored in polythene bags at 4-5°C for a short period of 3-4 days.

The mushrooms are usually packed in unlabeled simple polythene or polypropylene for retail sale. Bulk packaging does not exist. In developed countries, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) are in vogue.

Long Term Storage

White button mushrooms are not usually dried by common procedures used in case of Oyster, Paddy and Shitake mushrooms. Canning is the most popular method of preserving the white button mushrooms and sizeable quantity of canned produce are exported to international markets. Besides that, freeze drying, IQF and pickling are also practiced by some units.

2.11 Marketing of mushroom

Mushrooms are highly proteinaceous and are used as food. The White Button mushroom is sold as fresh mushroom or is canned and made into soups, sauces and other food products. Protein in mushrooms have 60-70 % digestibility and contains all the essential amino acids. It has medicinal properties also. A high amount of retene is present in the button mushroom which is supposed to have an antagonistic effect on some forms of tumors.

Marketing of mushrooms in Nepal is not yet organized. It is the simple system of producers selling directly to retailer or even to the consumer. Wholesale distributor is mostly missing. However, trade in the processed (canned and dried) is sizeable and organized.

2.12 Processing of mushroom

Sun-drying of mushrooms is one of the simplest and oldest methods followed by the growers from the time immemorial. Due to the difficulties in drying of some of the mushrooms, new preservation technologies like cabinet drying, canning, pickling, freeze-drying and irradiation treatment of mushrooms have developed to improve the shelf life and consumption of mushrooms. A variety of products are being prepared from mushrooms. These are mushroom pickle, mushroom powder for preparing mushroom soup, mushroom sauce, mushroom candy etc. Farmers can prepare these products when there is surplus.

C. Assessment:

Very Short (Answer question)

1. Write down the scientific name and family of Button Mushroom.

2. List out the four species of Button mushroom found in Nepal.
3. List the method of spawning on Button mushroom.

Short (Answer question)

1. Define spawn and spawning.
2. Write down the spawning method in Button mushroom.
3. What do you mean by strain selection?

Long (Answer question)

1. What is compost? Write down the method of compost preparation in Button mushroom production.
2. What do you mean by strain and its maintenance? Write down the harvesting method, grading, packaging and storage of Button mushroom.

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Unit-3

Cultivation practices of paddy straw mushroom

A. Content Elaboration

Paddy straw mushroom (*Volvariella volvacea*) also known as Chinese mushroom ranks sixth among the cultivated mushrooms of the world. This mushroom has several advantages like requirement of the tropical or sub-tropical climate, fast growth rate, easy cultivation technology and good acceptability at consumers' level. The raw materials required for its cultivation are also available in abundance in country at very nominal rates. The high temperature requirement for its cultivation also makes it a good choice for adoption in round the year cultivation of mushrooms. Paddy straw mushroom contains good amount of protein, crude fibers and ash, all make it a healthy diet along with superior composition of various elements and essential amino acids.

3.1 Spawn production

Spawn is the mycelium of mushrooms growing in its substratum and prepared for the purpose of propagating mushroom production. In a more simple language, it is defined as a medium impregnated with mushroom mycelium that serves as the "seed" for mushroom cultivation. The different stages of spawn production are as follows:

1. Starting culture
   The starting culture can be obtained from any authorized agency or can be raised by any of the following three methods:-
   - Single spore culture technique
   - Multi spore culture technique
   - Tissue culture technique

2. Culture media
   There are several media on which the mushroom cultures can grow, the compositions of which are given below:
   - PDA (Potato Dextrose Agar) medium
   - Malt Extract Agar

3.2 Substrate selection

A number of materials, alone or in different combinations are popular as spawn substrates. The most common substrates are rice straw cuttings, sorghum, wheat and rye grains, cotton waste, used tea leaves etc.

3.3 Time of growing

Paddy straw mushroom can be cultivated year round if the climate can be maintained as per the requirement and available of raw materials. However, winter season is more preferred for general cultivation.

3.4 Cultivation methods

A variety of waste materials have been used for cultivation of the paddy straw mushroom, which include: paddy straw, water hyacinth, oil palm bunch, oil palm pericarp waste, banana leaves and saw dust, cotton waste. Paddy straw mushroom prefers high cellulose, low lignin containing substrate and produces a family of cellulolytic enzymes. The cultivation of *Volvariella* is less sophisticated, less extensive and can be rewarding in tropical and subtropical climates.The common methods employed for paddy straw mushroom cultivation are given below:

1. **Conventional method**
   The different steps involved in this method are as follows:

- Preparation of paddy straw bundles of 0.75 – 1.0 kg (80-95cm long and 12.16cm wide) preferably from hand threshed paddy.
- Immersing of bundles in clean water for 12-18 hours in a cemented water tank.
- Draining out of excess water by placing bundles on raised bamboo platform.
- Making bed by placing 4 bundles side by side and another four bundles similarly but from the opposite side, forming one layer of eight bundles. The open ends of bundles from opposite sides should overlap in the middle.
- Forming of second, third and fourth layer by intermittent spawning between first and second, second and third and third and fourth layers.
- Spawning on entire surface of the layers of the beds at a space of 5cm apart leaving margin of 12-15cm from edges.

- Sprinkling of red gram powder over the spawned surface.
- Using 500 gm spawn and 150 gm of red gram powder for a bed of 30-40 kg of dried paddy straw.
- Pressing of bed from the top and covering with clean plastic sheet for maintaining required humidity (80-85%) and temperature (30-35°C).
- Removing of plastic sheet after 7-8 days of spawning and maintaining temperature of 28-32°C and relative humidity about 80%.
- Appearing mushroom after 4-5 days of sheet removal and will continue for next 20 days.
- Using the substrate after crop harvest for manuring the field.

2. Improved cage cultivation

a. Material required

- Paddy straw bundles 60/Cage
- Spawn bottle 2/Cage
- Wooden cage 1 No. (1 m x 50 cm x 25 cm)
- Drum 1 No. (100 liters cap.)
- Polythene sheet 4 meters
- Binding threads 3 meters
- Sprayer/Rose cans 1 No.
- Dithane Z-78/Bavistin 1 Pkt.
- Malathion 1 bottle (250 ml)
- Dettol/Formalin 1 bottle (1/2 liter)
- Dao (Hand chopper) 1 No.
- Thermometer 1 No.

b. Methodology

- Select dry, fresh and hand-threshed paddy straw free from moulds and leafy portion. Make 25 cm long and 10 cm thick bundles @ 60 bundles for each cage (Bed).
- Soak the bundles in boiling water for 20-30 minutes followed by cooling and draining off excess water.

- Disinfect the cage and polythene sheet with 2% Formaline or Dettol solution.
- Arrange ten straw bundles uniformly in the cage as the bottom layer and put some spawn grains over and inside the bundles. Put up a second layer of ten bundles over the first and spawn as before. Repeat this till six layers of bundles are achieved or till the entire cage is filled.
- Spray 0.1% Malathion and 0.2% Dithane Z-78 solutions all over the bed. Cover with polythene sheet and bind securely with a binding thread.
- Keep the spawned cages in a room or under a shed for spawn run. A warm place with temperature around 30□C is helpful for better spawn run.
- Remove the polythene sheet after the spawn run is complete. Maintain high humidity in the bed and room till pinheads appear.
- Pinheads appear within 10-15 days after spawning. Harvest mushrooms at the egg stage.
- Continue water spray for the next flush of mushrooms to appear within a week or so.

3. Outdoor method

The best place to cultivate paddy straw mushroom outdoor is under shade created by trees or creepers. The steps involved are as follows:

- Prepare a raised platform either from sand or bamboo poles or wooden planks or bricks.
- Prepare bundles of 45 cm length and 10 cm width.
- Soak the bundles in running water or in 2% CaCO3 solution.
- Prepare a layer of bundles (5 bundles of four layers) followed by spot spawning and covering spawn with gram dal powder.
- Lay 4 layers of bundles during summer months and 7 layers during rainy season.
- Make top of bed with 20 cm deep layer of rice straw followed by covering with polythene sheet.
- Remove polythene sheet after 4 days and sprinkle water carefully on 6th day. Water spray can be avoided during rainy season.

- Don’t spray water after appearance of mushroom pinheads.

4. Indoor method

The indoor method can be divided into following 5 steps:

a. Substrate

Cotton waste is the preferred substrate for cultivation of paddy straw mushroom by this method. However, paddy straw can also be used. Cotton waste is preferred over paddy straw as it contains more cellulose and hemi-cellulose and the fine texture of cotton waste helps in retention of moisture, which minimize the water requirement at later stages of cropping and thus helps in avoiding damage to fruiting primordia.

b. Compost preparation

Substrate (cotton ginning mill waste or paddy straw + cotton ginning mill waste in 1:1, w/w ratio) is wetted for first 2 days with sufficient treading of the cotton waste so that it absorbs sufficient water. After 2 days of substrate wetting, poultry manure is added @ 5.0% to the wetted substrate and pile (1.5 m high x 1.5 m wide) is raised. However, nothing is added in cotton waste substrate. First 2 turnings are given at an interval of one day each and calcium carbonate @ 1.5% (dry wt. basis) is added at third turning and the substrate is left for fermentation for next 2 days.

c. Bedding and pasteurization

After 4 days of outdoor composting, the compost is spread on shelves and the thickness of the substrate varies in different season from 5 cm to 10 cm. During summer months lesser thickness is needed, while higher in winter to preserve moisture and heat. The compost surface is made even by pressing it lightly. After 8-12 hours of compost filling live steam is introduced in the room. A temperature of 60-62°C is maintained for 4-5 hours for cotton waste compost and 65°C for 6 hrs.for paddy straw compost. After pasteurization, the compost is kept at a temperature of 50°C for next 24-36 hrs. and followed by its natural cooling. The compost is spawned when substrate temperature reaches 35°C.

d. Spawning

The compost is spawned with fresh spawn @ 1.5% (dry weight) or 0.4% (wet weight) basis of the compost. The pieces of broken spawn are inserted at a depth of 2 to 2.5 cm at a distance of 12 to 15 cm apart. The spawn is covered with displaced compost and the bed is covered with thin plastic sheet. The room temperature is maintained at 32 to 34°C during spawn run and at this temperature the compost will be colonized with in next 4-5 days in cotton waste based compost and 5- 6 days in paddy straw compost.

e. Fructification and crop management

During spawn running water and light are not needed but a little ventilation is required. By the end of 3-4 days fluorescent light along with little more ventilation is provided in the rooms. The plastic sheets are removed on 4-5th day, followed by little water spray on the beds. The pinhead will start appearing on 5^{th} - 6th day of spawning. After another 4 to 5 days, the first flush of mushroom is ready for harvest. The desired conditions needed for better fructification are temperature 30°C, relative humidity 80%, fluorescent light and intermittent fresh air. The quick growth rate of this mushroom demands ample supply of water and oxygen. However, watering of the compost is not quite recommended as it lowers the temperature and suffocates the tiny primordia, which reduces the yield. Crop management to achieve the best possible combination of light, temperature, ventilation, relative humidity and compost moisture is in fact an art of judgement, experience and effort.

3.5 Method of harvesting

The straw mushroom is harvested before the volva breaks or just after its rupture. These stages are called as the button and egg stages. This mushroom grows very fast at high temperature with high moisture hence it has to be harvested twice or thrice in a day (morning, noon and evening). This mushroom usually takes 9-10 days from spawning to harvest of first crop and the first flush normally keeps on for 3 days, which constitutes about 70 to 90% of the expected mushroom yield. The intervening period

of 3 to 5 days require thorough watering and maintenance of optimum conditions inside the rooms. The next flush again remains for 2-3 days and yields less mushroom than the first flush. The second flush adds only 10 to 30% of the total crop.

Fruit bodies, ready to harvest should be carefully separated from the beds/substrate base by lifting and shaking slightly left or right and then twisting them off. The mushrooms should not be cut off by knives or scissors from the base of the stalk as the stalks left behind on the bed/substrate will rot and may be attacked by pests and moulds leading to decrease in yield in subsequent flushes.

3.6 Grading, packaging, storage of mushroom

Grading

Soon after harvest, mushrooms have to be cleaned and graded before sending to the market or storage in a cool atmosphere. The grading and sorting is done according to their colour (pure white, slightly brown, damaged), size, stage of the cap or partial veil (Intact, slightly open, open), length of the stem etc. Grading is generally done on the basis of size of the button, shape of pileus and opening of gills, also known as buttons, cups and umbrellas, respectively.

Packaging

The mushrooms for fresh market are packed in plastic containers, perforated polythene bags of 100 gauge thickness or loose bags at varying packages.

Storage

Straw mushroom is more perishable than other edible mushrooms and cannot be stored at 4°C as it undergoes autolysis at this temperature. This mushroom can be stored at a temperature of 10 to 15°C for 3 days and little more at 20°C or under controlled atmosphere storage. The loss of moisture in 4 days stored mushroom could be as high as 40-50% in unpacked mushroom, while it can be reduced to 10% on packaging in perforated polythene begs.

3.7 Marketing of mushroom

Mushrooms are highly proteinaceous and are used as food. The straw mushroom is sold as fresh mushroom or is canned and made into soups, sauces and other food products. Protein in mushrooms have 60-70 % digestibility and contains all the essential amino acids. Marketing of mushrooms in Nepal is not yet organized. It is the simple system of producers selling directly to retailer or even to the consumer. Wholesale distributor is mostly missing. However, trade in the processed (canned and dried) is sizeable and organized.

3.8 Processing the mushroom

Straw mushroom can be processed by canning, pickling and drying. Sun-drying of mushrooms is one of the simplest and oldest methods followed by the growers from the time immemorial. Due to the difficulties in drying of some of the mushrooms, new preservation technologies like cabinet drying, canning, pickling, freeze-drying and irradiation treatment of mushrooms have developed to improve the shelf life and consumption of mushrooms. A variety of products are being prepared from mushrooms. These are mushroom pickle, mushroom powder for preparing mushroom soup, mushroom sauce, mushroom candy etc. Farmers can prepare these products when there is surplus.

C. Assessment:

Very Short (Answer question)

1. Write down the scientific name and family of paddy straw mushroom.
2. List out the cultivation method of paddy straw mushroom production.

Short (Answer question)

1. Define grading and its uses in mushroom.
2. What do you mean by substrate selection?

Long (Answer question)

1. What is spawn? Write down the method of spawn production in paddy straw mushroom.

2. What do you mean by mushroom cultivation? Write down the improved cage cultivation method of paddy straw mushroom.
3. Define fructification. Write down the indoor method of paddy straw mushroom production.

Reference:

Chang, S-T.and Miles, P.G. 1989. *Edible mushrooms and their Cultivations*.CRC Press Inc., Boca Raton, Florida.

Kapoor, J.N.1999.*Mushroom Cultivation. Publication and information division*, Indian council of Agricultural Research, Pusa, New Delhi, India.

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Unit-4

Cultivation practices of Oyster mushroom

Objectives:

After the completion of this course, the students will be able to:

- describe about the cultivation practices of oyster mushroom in various aspects.
- explain about the different technic used oyster mushroom cultivation.

A. Content elaboration

Oyster mushroom (*Pleurotus* sp.) belonging to Class Basidiomycetes and Family Agaricaceae and grows naturally in the temperate and tropical forests on dead and decaying wooden logs or sometimes on dying trunks of deciduous or coniferous woods. It may also grow on decaying organic matter. The fruit bodies of this mushroom are distinctly shell or spatula shaped with different shades of white, cream, grey, yellow, pink or light brown depending upon the species.It is one of the most suitable fungal organisms for producing protein rich food from various agro-wastes or forest wastes without composting.

4.1 Spawn production

A pure culture of *Pleurotus* sp. is needed for inoculation on sterilized substrate. It takes 10-15 days for mycelial growth on cereal grains. It has been reported that jowar and bajra grains are superior over wheat grains.

4.2 Substrate selection

Oyster mushroom can be cultivated on a large number of agro-wastes having cellulose and lignin which helps in more enzyme production of cellulose that is correlated with more yield. These include straw of paddy, wheat and ragi, stalk and leaves of maize, millets and cotton, used citronella leaf, sugarcane bagasse, saw dust, jute and cotton waste, de-hulled corncobs, pea nut shells, dried grasses, sunflower stalks, used tea leaf waste, discarded waste paper and synthetic compost of button mushrooms etc. It can also be cultivated by using industrial wastes like paper mill sludge, coffee byproducts, tobacco waste, apple pomace etc.

The popular methods of substrate preparation are:

- Steam Pasteurization
- Hot Water Treatment
- Sterile Technique (Till method)
- Fermentation or Composting and
- Chemical Sterilization.

4.3 Selection of growing site

Oyster mushroom can be cultivated under local conditions using simple production techniques. It does well in a wide range of substrate, has a unique taste and high nutritive value. The incubation room must be dark, cool and dry with temperatures of between 25 to 28°C. During fruiting the room should be kept humid with temperatures of between 18 and 23°C and humidity between 65 and 95%. We can achieve this by spraying clean water on the floor at least three times a day or by placing water filled pots in the growing room.

The size of the house depends on the number of bags we want to handle. Place your windows on the upper side of the room. The windows should not be very large. E.g. it is recommended that for a 10 ft. x 10 ft. house, the windows be 1 x 1" in opposite directions. This is to allow fresh air and light in to the growing room. Construct wooden shelves for placing the bags or racks for hanging tubes. Remember, 45 cm from the ground, 45 cm between shelves and 45 cm from the roof.

4.4 Spawning

Freshly prepared (20-30 days old) grain spawn is best for spawning. Old spawn (3-6 months) stored at room temperature (at 20-30°C) forms a very thick mat like structure due to mycelium aggregation and sometimes young pinheads and fruit bodies start developing in the spawn bottle itself. The spawning should be done in a pre-fumigated room (48 hrs with 2% formaldehyde).

4.5 Filling

Cultivation of *Pleurotus* is usually carried out in transparent polythene bags. It is also possible to grow it in trays, which can be stacked vertically. A wooden mould (50cm x30cm x15cm) having no top or bottom is usually used. The spawned substrate is packed in bags or filled in mould. It should not exceed 6 kg (1.5 kg dry straw) per bag or mould. The bags should be perforated by cutting holes to permit ventilation and to cool down any increase in temperature. If blocks are made, they are wrapped loosely in a transparent sheet.

4.6 Handling of crop

Handling of crop requires the maintenance of good climatic condition for crop growth. The following aspect should be maintained properly:

Light

Oyster mushrooms require light to grow. Place your Oyster kit in a well-lit area to grow, but not in direct sun light. Regular strong reading light is sufficient. Constant light is not necessary. It is fine to leave your kit in the dark overnight.

Temperature

Mushrooms grows best at temperatures between 65 - 68º F.We can also produce mushrooms between 55 - 74ºF, but it will do better if kept in the 65-68 degree range.

Water

Water the kit by sprinkling or spray misting water on to the kit's surface once a day. In this case watering the black plastic bag with the ¼ inch holes in it should be done. Increase watering to 2-3 times a day when the small Oyster mushrooms begin to force themselves out of the bag holes in 3-7 days. Leave the top of the box liner pulled up and open to allow air circulation. Air circulation is necessary for normal mushroom growth. The lack of fresh air will prevent mushrooms from growing and produce long stringy mushrooms. The liner will help keep some humidity around the fruiting mushrooms. Over watering the kit before the baby

mushrooms are formed should be avoided. Standing water in the bottom of kit will encourage rot and contaminants to grow.

4.7 Harvesting methods

The right shape for picking can be judged by the shape and size of the fruit body. The fruit bodies should be harvested before spore release, by twisting so that the stubs are not left on the beds (straw). It is advisable to pick all the mushrooms at one time from a cube and the next flush will appear at one time. More than 500 kg of fresh mushrooms per ton of dry wheat or straw can be obtained in case of crop produced in 45-60 days.

4.8 Grading, packaging, storage and marketing

Grading

Soon after harvest, mushrooms have to be cleaned and graded before sending to the market or storage in a cool atmosphere. The grading and sorting is done according to their colour (pure white, slightly brown, damaged), size, stage of the cap or partial veil (intact, slightly open, open), length of the stem etc. Grading is generally done on the basis of size of the button, shape of pileus and opening of gills, also known as buttons, cups and umbrellas, respectively.

Packing and transportation

Fresh mushrooms are packed in perforated polythene bags. Poly pouches containing crushed ice and overwrapped in paper are put in trays/baskets which are then covered with thin polythene sheet with sufficient perforation for proper aeration. The pre-packed pouches (250 or 500 g) can be transported by roadways in trucks, buses depending upon the quantity to be transported.

Storage

Short-term storage

Fresh mushrooms are packed in perforated polythene bags which are directly sent to the local market situated nearby. Freshly harvested mushrooms can be stored at low

temperature (0-5°C) for 1-2 weeks without loss in quality in case it is to be sent to the distant markets.

Long-term storage

Dried mushroom with 2-4% moisture can be stored for 3-4 months in sealed pouches without any change in taste. The dried produce can be rehydrated in Luke warm water (40-50°C) within 20-30 minutes giving 80-90% of original weight.

Marketing

Domestic marketing does not pose a problem at present because only small quantities are being traded. As production develops, marketing promotion measures will need to be undertaken to bolster the demand. Export potential exists and needs to be taken advantage of by organizing cooperatives of producers linked to commercial units for processing fresh mushroom into dehydrated powder for export.

4.9 Processing

Straw mushroom can be processed by canning, pickling and drying. Sun-drying of mushrooms is one of the simplest and oldest methods followed by the growers from the time immemorial. Due to the difficulties in drying of some of the mushrooms, new preservation technologies like cabinet drying, canning, pickling, freeze-drying and irradiation treatment of mushrooms have developed to improve the shelf life and consumption of mushrooms. A variety of products are being prepared from mushrooms. These are mushroom pickle, mushroom powder for preparing mushroom soup, mushroom sauce, mushroom candy etc. Farmers can prepare these products when there is surplus.

C. Assessment

Very Short (Answer question)

1. Write down the scientific name and family of Oyster Mushroom.
2. List out the popular method of substrate selection.

Short (Answer question)

1. Define storage and its uses in mushroom.

2. What do you mean by spawn production?

Long (Answer question)

1. Define Oyster Mushroom? Write down the procedure of site selection for Oyster Mushroom production.
2. What do you mean by substrate selection? Enlist the popular method of substrate selection in Oyster Mushroom.

Reference:

Chang, S-T.and Miles, P.G. 1989. *Edible mushrooms and their Cultivations*.CRC Press Inc., Boca Raton, Florida.

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Unit-5

Cultivation practices of Gyanoderma and Shiitake Mushroom

A. Content Elaboration

Lentinus edodes also called black forest/ oak mushroom. Shitake is the Japanese name. Edibility of this mushroom is valued for its production for a long time for its unique taste and flavor and as medicinal tonic.

It can be cultivated either on wood log or on synthetic substrate logs. This type of mushroom are successfully cultivated in 4 to 20 years old Utis (*Alnus nepalensis*), Katus (*Castanopsis cuspidate*). Wood log should be disease free, uniform in size, matured bark which are tightly packed and are not injured. The wood logs which are used for mushroom cultivation should be cut between Kartik to Magh before new flush comes. After the woods are cut, to reduce the excess moisture log should be placed in shade and warm place for 7-15 days.

5.1 Spawn production

The Shiitake fungus is introduced into logs by inserting the mycelium in the form of spawn, a process known as inoculation.

5.2 Substrate selection

In their natural environment, shiitake mushrooms grow on dead hardwood tree logs in a warm, moist environment. The combination of warm temperatures and high rainfall promotes rapid growth of the Shiitake mycelium, the mass of thread-like structures from which the mushroom grows. A sudden change in temperature or moisture triggers the fruiting response, resulting in mushroom production.

Because Shiitake mushrooms grow on logs, many growers make mushroom production part of their woodlot management plan. If logs must be purchased, care should be taken that the proper tree species are selected, only healthy trees are cut, and the logs are handled properly. Shiitake mushrooms will grow on a wide range of tree species, with varying degrees of success. In North Carolina, oaks (red, white, and

chestnut) and sweet gum are excellent mushroom producers. Shiitake mushrooms grow best on logs with a high wood density, a high ratio of sapwood to heartwood, and bark that is strong but not too thick. Growers are advised to experiment with the logs available to them. Log from different tree species requires different management strategies. For example, thin-barked logs must be handled carefully to prevent damage to the bark. Logs with thin bark also lose moisture faster than logs with thick bark; therefore, log moisture content must be monitored closely.

Trees should be cut while they are dormant, preferably in the late winter or early spring before bud break, for two important reasons. First, the Shiitake mycelium requires carbohydrates for growth, and carbohydrates in the wood are at their highest levels when the tree is dormant. Second, the bark of the logs must be intact and must adhere to the logs well. If the trees are cut after the sap begins to flow in the spring, the bark will have a tendency to "slip" and can be damaged easily. Some growers have reported success with trees cut in late fall.

Once the trees have been cut, it is important to keep the moisture content of the wood high and the bark dry until the logs are inoculated with the Shiitake fungus. Trees cut in late winter (November to January) should lie for 10 days with branches intact before being cut into logs; logs should be inoculated within 90 days of cutting. Trees cut in early spring (February to March) should also be allowed to lie for 10 days with branches intact before being cut into logs, but they should be inoculated within one month, to prevent the establishment of contaminating fungi. If the trees must be cut into logs at the time of felling, they should be inoculated within two weeks. Growers should also take measures to prevent moisture loss. If the weather is dry and windy, store the logs in a bulk pile and cover them loosely with burlap, muslin, or other porous material. If the weather is rainy, stack the logs loosely to permit good air circulation, and cover them loosely with plastic sheeting

5.3 Selection of growing site

Lentinus edodes is a kind of wood rot fungus. In nature, it grows on dead tree trunks or stumps. In general the wood for the mushroom growth consists of crude protein 0.38%, fat 4.5%, soluble sugar 0.50%, total nitrogen 0.148%, cellulose 52.7%, lignin

18.09% and ash 0.56%. C: N ratio in the substrate should be in the range of 25 to 40:1 in the vegetative growth stage and from 40 to 73:1 in reproductive stage. If nitrogen source is too rich in the form reproductive phase fruiting bodies of the mushroom are not formed.

The optimum temperature of spore germination is 22-26^{o}c. the temperature for mycelia growth range from 5-35^{o}c, but optimum temperature is 23-25^{o}c. *Lentinus edodes* belong to low temperature mushroom, the initial and fruiting body formation is the range of 10-20^{o}c and optimum temperature of fructification for most varieties of the mushroom is about 15^{0}c. The optimum pH of the substrate used in making the mushroom is about 5-5.5.

5.4 Spawning

Spawning is carried out by removing the cotton plugs. Grain spawn is introduced @ 3% (dry wt basis) under aseptic conditions. After inoculation bags are placed in cropping rooms where these are incubated in a 4 hrs/20 hrs, light/dark cycles at 22-26°C. Spawn run may take 60-80 days or more depending upon the strain and environmental conditions. During the period it goes through mycelial growth, mycelial coat, mycelial bump, pigmentation/browning and coat hardening phase.

5.5 Filling

A 2.5cm deep hole is made by drilling in log with 1-1.5 cm diameter driller. 5 cm in each side of the log is left and the spacing of 10 cm holes is made. Distance between two lines should be 5cm and holes made in first line should be in between the second line. Spawn are made small balls and are inoculated in the holes. After gentle pressing, holes are sealed with wax.

5.6 Handling of crop

For induction of fruiting suitable temperature, high RH, good ventilation and cold water/ shock treatment are required. After 5-8 days of cold-water (4-6°C) treatment for 10-20 minutes, initiation of primordia begin. The fruit bodies further develop and became ready to harvest in next 5-7 days.

5.7 Harvesting methods

Daily harvesting is required during fruiting periods. Mushrooms should be picked while there is still a small curl at the edge of the cap, usually five to seven days after the mushroom first appears. Mushrooms should be cut or twisted off at the base of the stem. Then they should be gently placed into smooth-sided, clean, vented containers. We should not stack the mushrooms more than six inches high, to prevent bruising.

5.8 Grading, packaging, storage and marketing

Grading

Soon after harvest, mushrooms have to be cleaned and graded before sending to the market or storage in a cool atmosphere. The grading and sorting is done according to their colour (pure white, slightly brown, damaged), size, stage of the cap or partial veil (Intact, slightly open, open), length of the stem etc. Grading is generally done on the basis of size of the button, shape of pileus and opening of gills, also known as buttons, cups and umbrellas, respectively.

Packaging

Bulk Shiitake mushrooms are commonly sold in vented, waxed cardboard boxes in amounts of 3 to 5 pounds. They are also sold in small 2 to 4ounce retail packages consisting of trays wrapped in a gas-permeable plastic film.

Storages

Cool the mushrooms to a temperature between 32°F and 36°F after harvest as soon as possible, and maintain the relative humidity at about 85%. Under these conditions, the mushrooms will store well for at least two weeks. They can also be dried very successfully. The simplest way to dry them is to place them in a forced-air drier at about 120°F.

Marketing

Many people can grow Shiitake mushrooms. The successful producers, however, are those who can also market them. If production is small and seasonal, marketing efforts should be concentrated in the local area. Marketing opportunities include high-quality restaurants, health-food stores, local supermarkets, farmers' markets, tailgate markets, newspaper ads, and direct

sales. Before large-scale production is initiated, start negotiations with food service and produce brokers, or negotiate directly with large-scale buyers of fresh produce.

5.9 Processing

Drying can preserve mushrooms for 6 months to a year. Shiitake are usually air dried to a moisture content of about 13 percent and have a 7 to 1 reduction in weight. This means that 7 pounds of Shiitake mushrooms dried to 13 percent moisture will yield 1 pound of dried mushrooms. Before drying, separate mushrooms by size and grade. Remove stems completely, as they harden when they dry. Place mushrooms on trays with gills down. Avoid allowing the mushrooms to touch each other. Mushrooms can be dried in the sun but the quality is usually lower than it is for those dried in a controlled-air dryer. Convection or forced-air dryers can be used for air-drying. Forced-air dryers use fans to move the air. The high temperatures reached during air-drying denature enzymes and kill bacteria. Home food dryers can be used to dry 2 to 3 pounds of fresh mushrooms at a time.

C. Assessment

Very Short (Answer question)

1. Write down the scientific name and family of Shitake Mushroom.
2. List out the tree species used for Shitake Mushroom production.

Short (Answer question)

1. Define spawning and filling of Shiitake Mushroom.
2. Write the method of harvesting in Shiitake Mushroom.

Long (Answer question)

1. Describe about the Grading, packaging, storage and marketing of Shiitake Mushroom.
2. What do you mean by substrate selection? Describe about the substrate selection of Shiitake Mushroom.

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Unit-6

Diseases and pest of mushroom and their management

A. Content Elaboration

Mushroom cultivation, one commonly comes across certain undesirable micro organisms which appear in spawn bags, spawned composts and cropping beds resulting into spoilage of spawn, hindrance in spread of mycelium during spawn- run period as well as the fruit body formation during cropping period causing reduction in yield and sometimes crop failures. These are also known as contaminants because they are undesirable ones. The contaminants can be divided into three well defined groups:

- **Insects, mites, nematodes and animal pests**: Majority of these contaminants are big enough to be seen with naked eyes, whereas some like nematodes are microscopic also.
- **Pathogens**: These are the microscopic contaminants that directly attack mushroom fruit bodies and cause economic damage like viruses, bacteria (*Pseudomonas tolassii*, *Pseudomonas*. spp.), and fungi (*Verticillium fungicola* , *Mycogone perniciosa*, *Dactylium dendroides*, *Trichoderma viride*).
- **Competitor or indicator moulds**: Those contaminants, mostly fungi, which compete for food in the substratum along with the mushrooms.

Following are some of the established vectors or the sources of contamination:

- Air
- The mycelium or spawn
- The substrate or the compost
- Casing materials
- Grower or workers.
- Equipment, containers and tools.
- Water
- Insects and animals.

6.1 Fungal diseases

1. Green Mould:

It is the most common mould and found in beds of every type of mushroom cultivated. Mainly three types of fungi *Trichoderma*, *Penicillium* and *Aspergillus* have been found to be associated.

Symptomatology

Green patches appear in compost, spawn, on casing surface and also sometime on the mushroom surface, engulfing the fruit bodies with its white and greenish mycelium causing Trichoderma blotch disease. The pathogenic species of Trichoderma like *Trichoderma harzianum*, infect the fruit body, otherwise green moulds try to spread rapidly and cover entire compost structure depending upon the quality of compost and environmental conditions. The appearance of green mould indicates poor quality compost, unhygienic cropping conditions and low compost pH.

Causal organism

The most common species of *Trichoderma* appearing in mushroom beds are *Trichoderma viride*, *T. koningi*, *T. harzianum*, *T. hamatum* and several species of *Aspergillus* and *Penicillium*. Rifai in 1969 has revised andproposed nine different species of *Trichoderma*. *Trichoderma viride* is the most commonly occurring weed

mould whereas, *T. koningi* and *T. harzianum* have been reported to be competitors as well as pathogenic to button mushroom producing blotch symptoms on fruit

Epidemiology

The fungus mainly enters spawn laboratory or the cropping room through air, dust particles, contaminated overall or hands, infected spawn, contaminated equipment and machinery; vectors like mites, mushroom flies etc. The compost quality mainly determines the establishment and growth of this mould. Poor quality compost prepared under unhygienic conditions, high moisture content, use of straw having short texture for composting, highly pressed compost heap during composting, low pH of compost, high humidity etc., are the predisposing factors for the growth and development of the fungus.

Control measures

There should be complete hygiene inside and around the mushroom farm, compost ingredients should never come in contact with the soil particles; proper turnings, conditioning and pasteurization of compost is a must, use of foot dips at the doors of cropping rooms, lesser use of formalin sprays, proper cleaning of equipment and tools, use of clean and washed clothes, early removal of infected bags etc., are some of the recommended methods of control.Spray of some fungicides like 0.1 % Carbendazim, Thiabendazole, Mancozeb (0.2 %) etc. on cropping beds have been found effective in controlling the mould.

2. Olive green mould:

During spawn run stage, small military green coloured cockle burrs appear sometimes in the compost which is easily recognizable and that affect the yield.

Symptoms:

The initial signs of fungus consist of appearance of greyish - white aerial mycelial growth in the compost just after spawning confused with the growth of mushroom mycelium. These mycelial structures later on give rise to small, round, military green or grey green cockle burr (1/16 inch diameter) structure in the compost strictly adhering to the straw.

Causal Organism:

Mainly two fungi *Chaetomium olivaceum* and *C. globosum* have been observed occurring in mushroom beds.

Epidemiology:

The spores of *Chaetomium* are already present in the compost or they may come through air and casing materials. It has been found that during compost pasteurization process, mainly at peak heat or kill stage (59-60ºC), it should never be processed in the absence of fresh air or Oxygen. Absence of aeration during peak heat or kill may lead to compost damage which favors the appearance and development of these fungi.

Control Measures:

In case of pasteurization process, the peak heat or kill should be done at 58 – 59 ºC for 3-4 hours in the presence of fresh air or aerated steam. Carbendazim (0.05%) and Diathane Z-78 (0.2%) have been found to be effective in controlling the mould only in case of minor damage of the compost.

3. BROWN PLASTER MOULD:

The mould appears as white mycelial growth on the surface of compost during spawn run stage and also on the casing surface slowly changing colour from white to light brown to cinnamon brown and finally changed to rusty in appearance.

Causal Organism:

Papulospora byssina is the fungus responsible for causing brown plaster mould. The mycelium is initially white which later turn'sbrownish, septate, producing clusters of brown coloured, spherical bulbils.

Epidemiology:

The fungus mainly enters through air, spent compost, casing material or the containers as well as the workers' hands. But wet, soggy and improperly pasteurized, bad quality compost favour its rapid growth. It commonly occurs on compost prepared by long method of composting.Greasy and wet compost is vulnerable to infection.

Control measures:

Good hygiene and preparation of good quality compost removes the chances of its appearance and further development. Addition of good quality gypsum is recommended and proper turning of compost with attentive pasteurization procedures help in preventing this mould. Sometimes spray of some fungicides like Carbendazim (0.05%) and Dithane Z-78 or Dithane M-45 (0.025%) has been recommended for its control.

4. White Plaster Mould

The mould appears as white patches in between or on the compost surface during spawn run stage or also in the casing layer. It inhibits the growth of mushroom mycelium causing yield loss to the extent of 5 to 30 percent.

Causal Organism:

Scopulariopsis fimicola is the fungus responsible for the contamination.

Favourable factors:

Under or over -composted conditions having high pH (above 8.0) favours the growth of this mould.

Control measure:

Mixing of compost ingredients in recommended quantities, proper wetting and turning of compost under hygienic conditions have been highly recommended. Removal of mould from the compost layer and spray of Benomyl or Carbendazim (0.05%) are recommended for its control . In case of high pH and moisture content of compost, delayed turning or conditioning and addition of gypsum is recommended.

5. Yellow Mould (Confetti, Vert-de-gris, Mat Disease)

Since a number of fungi produce yellow mycelial growth in the compost (yellow mould) or beneath the compost in the form of yellow layer (mat) or in the form of circular colonies (confetti) or distributed all over the compost (Vert-de-gris) , these are known by different names.

Causal Organism:

The mycelium of *Chrysosporium luteum* is white at the initial stage that turns yellow to dark tan with dull white sporulation.

Epidemiology:

The sources of inoculum are mainly the compost ingredients, chicken manure, air, spent compost and wooden trays. It further spreads through workers' hands or clothes, mushroom flies, mites, faulty technique of water spray (splash) and the picking tools.

Control measures:

Proper hygiene, removal and burial of mould affected spent compost at a distant place, proper turning and pasteurization of the compost and casing mixture, use of light and misty water spray technique, covering the windows and ventilators with fine wiremesh, use of filtered air and spray of Benomyl (400- 500 ppm) and Blitox (0.25 %) have been found effective in controlling the disease.

6. Sepedonium Yellow Mould

This mould is found growing in between the compost layer or at the bottom layer. The fungus is initially white but turns yellow or tan coloured at maturity.

Causal Organism:

Sepedonium chrysospermum, Bull (Fries) and *S. maheshwarianum* (Muker) have been found mainly responsible for the occurrence of the mould.

Epidemiology:

Spent compost, soil, air, improperly pasteurized compost / casing soil, wooden trays etc., are the primary sources of inoculum as the thick walled chlamydospores are resistant to peak heat temperature, if not pasteurized properly. The compost prepared by long method of composting have more chances to have this mould.

Control measures:

Strict hygiene followed by proper pasteurization of compost at 59-60ºC for minimum four hours is recommended. Uses of filtered air with high efficiency filters in the cropping rooms and cook out of compost at the end of the crop with steam at 70ºC for 10-12 hours are recommended. Sterilization of chicken manure

with 2 % Formalin and 0.5 % Carbendazim prior to composting has been found to give good result.

7. False Truffle

It is the most serious competitor mould found during *A. bisporus* cultivation apart from its appearance in *A. bitorquis beds*. It is commonly found occurring in compost prepared by long method of composting, especially during summer months.

Symptoms:

The mycelia colour is initially white at the start and hence difficult to differentiate with the growth of the mushroom mycelium, but soon turns creamy yellow at later stage. It appears as small, wefts of white cream coloured mycelium in compost and casing soil, mainly below the casing. The mycelium becomes thick and develops into whitish, solid, round to irregular, wrinkled fungal masses resembling calves' brain which are the ascocarps of the fungus.

Causal Organism:

The ascocarps of *Diehliomyces microsporus* are fleshy white initially which turn brown and reddish brown at a later stage.

Epidemiology:

The fungus enters the cropping room through spent compost, chicken manure, casing material, old infected wooden trays and already infected rooms as the ascocarps can survive for a period of five years in soil and spent compost and for six months in the form of mycelium.

Control measures:

The compost should never come in contact with the soil; hence it is always better to have a cemented composting yard, covered with a roof with slight gradient. Proper pasteurization of compost (59ºC for 3-4 hours), systematic turning and conditioning is very much essential for complete elimination of the fungus. The casing soil should be sterilized at 65±1ºC for 6-8 hours. The bed temperature during spawn run and cropping should be maintained below 18 ºC as it is a very critical situation. Cook out at 70 º C for 10-12 hours will eradicate the fungus as

the thermal death point of the fungus has been reported to be 70 º C for 1 hour (ascospore) and 45ºC for 30 minutes (mycelium)

6.2 Bacterial diseases

1. Bacterial blotch and bacterial pit diseases of white button mushroom

Symptoms:

Circular but irregular, yellowish spots appear superficially on or near margin of the cap of a wet mushroom which enlarge rapidly under high humidity conditions and coalesce to form bigger rich chocolate brown spots that are slightly depressed and slimy.

Causal organism:

The pathogen *Pseudomonas tolaasii* can devastate the crop of button mushroom and *Psilocybe sp*. The bacterium has cylindrical (Bacilli) and spherical forms (Cocci) with its cells measuring 0.4-0.5 x 1.0-1.7µm in size, with either one or more flagella (motile hairs) attached at one or both the ends for locomotion. The bacterium is gram negative in character.

Epidemiology:

The casing ingredients and air borne dust particles are the primary sources of infection. Under high humidity and damp conditions, bacterial population increases on cap surfaces and cause the disease. The bacterium remains suppressed in the compost, casing, tools and debris under dry conditions, but it becomes active under high humidity conditions and further spreads through worker's hands, tools, mushroom spores, debris, water splash, flies, mites etc.

Control measures:

Avoid heavy water sprays during rainy season, introduce fresh air immediately for about one hour after water spray and ensure that water droplets do not remain on the cap surface, remove all the diseased fruit bodies and spray bleaching powder (0.015%) on the cropping beds at 7 days interval.

2. Yellow Blotch

The yellow blotch disease of *Pleurotus spp.* is caused by *Pseudomonas agarici*.

Symptoms:

Disease appears as blotches of various sizes in pilei, yellow hazel brown or organic in colour. The infected fruit bodies turn yellow and remain stunted, turn slimy and start giving foul smell.

Control measures:

Same as suggested for controlling bacterial blotch disease of button mushroom.

6.3 Viral diseases

Diseases due to mushroom viruses are also known as La France, Die back disease and Mummy disease.

Symptoms:

The viral diseases are not detectable during spawn – run stage; the initiation of pinheads is inhibited and vigour of mycelium severely reduced; yield is drastically reduced, mushrooms appear with distorted shape, delay occurs in appearance of first flush, sporophores with elongated stem and small caps giving drum stick like appearance and tilted towards one side, mushrooms appear in patches, pre-mature opening of veils, watery stipe and streaking in the stipe. In case of *Oyster* Mushroom, dwarfing or elongation of stem has been observed whereas; no detectable symptoms appear in infected *Volvariella sp.*

Sources of Infection:

Infected mycelium and spores released from infected mushrooms are the primary sources of infection. These viruses further disseminate through worker's hands, equipment, infected spawn / mycelium present in the trays/bags and spent compost etc.

Control methods:

Complete hygiene, use of disease free spawn, frequent disinfection with Formaldehyde, aeration strictly through high efficiency filters, cook out of exhausted compost at the end of the crop with live steam at 70-71 º C for 10-12 hours, regular disinfection of equipment, wearing clean and changed clothes everytime while entering a mushroom house, harvesting of mushrooms before opening when the veil is intact, visitors to be discouraged, wooden trays and shelves to be washed regularly with 4% sodium pentachlorophenate solution, growing of resistant strains like *A. arvensis* and *A. bitorquis* have been recommended.

6.4 Insect pest

1. Mushroom flies

Mushroom flies and midges are present in nature wherever fungi are found. Attracted by the odour of the decomposing manure and vegetable matter as well as smell of the growing mycelium, the adult female enters the composting yard or the mushroom farm and lay eggs on the compost, near the mycelium or fruiting bodies. Mainly three types of flies are known to infest mushroom beds:

1. Phorid flies or dung flies (*Megaselia nigra, M. halterata*)
2. Sciarid flies or big flies (*Lycoriella solani, L. mali, L. auripila*)
3. Cecids or gall midges (*Heteropezapygmiae, Mycophilaspeyeri*)

Nature of damage:

The larvae of flies that emerge from the eggs laid in the mushroom beds mainly causes the damage as they directly feed on the white mycelium spread in the compost and casing layer and also feed on the mushroom fruit bodies making tunnels through the stems. Mushrooms from the infested mushroom beds are found blackened from inside and infested with white larvae. Mushrooms infested at the pinhead stage become brown and remain stunted. Infested oyster mushrooms remain stunted, wrinkled and bent downwards with a large number of larvae and pupae lying embedded inside the

tissues. Adult flies are the carriers of mites and mushroom pathogens such as spores of *Verticillium, Trichoderma, Mycogone* etc. attached to their hairy body parts.

Lifecycle:

The adult female fly lay about 150-170 eggs in the compost or mushroom beds which hatch into larvae. After feeding for some time, each larva secretes from the mouth and forms a pupa. As a result of the metamorphological changes inside, larva turns into an adult fly and comes out of the pupal cell for causing further damage and breeding. In case of cecid flies, the reproduction takes place paedogenetically. Here a larva becomes mother larva and instead of forming a pupa, a mother larva carries about 14 – 16 larvae in its body which hatch out after few days. Thus they multiply in a very rapid manner and so the damage also increases.

Control measures:

- Strict hygiene in the mushroom house.
- Proper turnings during composting process.
- All the doors, windows, exhaust vents and fresh air intake openings should be fitted with fine wire mesh / mosquito netting.
- All the implements and tools should be cleaned and disinfected.
- Proper pasteurization of the compost at Phase-II with aerated steam at 58-59 ºC for 3-4 hours and the conditioning at 50-55º C till ammonia is eliminated.
- Dry mixing of the casing materials, proper pre wetting and its sterilization with steam at 65± 1ºC for 3-4 hours or with 5 % formalin solution.
- Use of light traps and sticking bands.
- Storage of raw materials in dry and ventilated rooms.
- The spent compost, after the end of the crop, should always be thrown away at a distant place.
- Growing rooms, all containers and equipment / implements should be cleaned with water and disinfected every time before and after the crop is over.
- Spraying beds with safe insecticides like Malathion (0.05%) one week before harvest.

Mushroom mites

Mites are very small, spider like in appearance that live and breed in decomposing vegetable matter feeding on moulds present therein. They differ from the insects in that the mites have four pair of legs instead of three pairs. The environmental factors like moist and warm atmosphere (20-30ºC) and closed area support their exponential growth and a rapid succession of generation. Under adverse conditions, certain mites have the ability to change into an intermediate stage called a "Hypopus" which have flattened body, short stubby legs and a sucker plate with which they become attached to moving objects and thus are dispersed or carried away to distant places, mainly through the mushroom flies and human beings.

Nature of damage

Mites have the chewing type of mouth part with which they eat mycelia and the mushrooms. They devalue the crop causing certain spots on the surface and crawl into the pickers' body causing discomfort.

Life cycle:

The mites complete their life cycle within 13 days at 75ºF and 36 days at 60ºF as the high temperature facilitates rapid reproduction. They lay eggs which hatch into larva, proto-nymph and triro-nymph stages before reaching the adult reproductive stage

Control measures:

- Complete hygiene and sanitation.
- Proper pasteurization of compost and casing materials.
- Drenching mushroom houses and premises.
- Use of fresh polythene bags and chemical sterilization of empty trays and trolleys.
- Burning sulphur in the empty rooms @ 3.5-5 kg /100 cubic meters.
- Cook out of the exhausted compost with live steam at 71ºC for 8–10 hours.
- Disposal of spent compost at a distant place.
- Spraying beds with safe insecticides like Chlorfenvinphos, fenitrothion (1g a.i / m^2 bed area) or malathion (0.05 %).

2. Springtails

Adults are silver grey to ground colour with light violet band along the sides of the body and black cellular fields present on the head. Body length is 0.7 to 2.25 mm and abdomen 4-6 segmented. Antennae are 3-6 segmented. *Lepidocyrtus sp., L. cyaneus, Seira iricolor, Achorutes armatus* etc., are the main species damaging mushrooms.

Nature of damage:

Springtails cause damage to the oyster, button and shiitake mushrooms. Staying in groups in the dark, they feed on mycelium in the compost resulting in disappearance of mycelium from spawn – run compost. Fruiting bodies of button mushrooms are also attacked causing slight pitting or browning at feeding sites. In oyster and shiitake, they feed on gills destroying the linings and also eat out the mycelial strands at base of the stipes.

Life cycle:

Springtails enter the mushroom house mainly through organic matter. A female lays about 10-40 eggs which are smooth, spherical, white and measure 0.19 mm. The eggs hatch in 30 days at 30ºC. Life cycle ranges from 70 – 78 days at 26ºC.

Control methods:

- Preventive measures like clean cultivation, proper pasteurization of compost and casing materials, proper disposal of spent compost, raising the crop above floor level etc; should be followed.
- Use of 0.05 % malathion as spray for disinfection, mixing diazinon 30 ppm in compost at the time of filling and spray of insecticides like malathion at 0.025 – 0.05% conc. during spawn run and cropping have been recommended for their control.

3. Beetles

Some beetles (Staphylinus sp, Scaphisomanigro fasciatum) have also been found to cause serious damage to the oyster mushroom crop. These tiny insects are dark brown in colour with short elytra and large membranous hindwing and tip of the back culled over its body. The beetle *Scaphisomanigro fasciatum* is deep amber coloured, with its head hypognatus and top of the abdomen not fully covered with elytra.

Nature of damage:

The grubs are found to feed voraciously on the mycelium and spawn, making tunnels in the stipe, pileus and gills of mushrooms. The infested fruiting bodies turn into abnormal shape and rotten masses. Grubs are seen hiding in between the gills of oyster mushrooms. The insect has been found to complete its life cycle within three weeks.

Control methods:

- Strict hygiene
- Proper pasteurization of straw.
- Application of chlorinated water or bleaching powder on cropping beds.

6.5 Nematodes

1. Mushroom nematodes

Nematodes, especially the myceliophagous nematodes are the most numerous and harmful creatures. Also known as eelworms, these are microscopic, thread like roundworms which live in soil, decomposing organic matter, fresh or salt water, also living on host plants, fungi, insects and animals.

Sources of infestation

Compost ingredients like wheat straw, chicken manure, horse manure, saw dust, pig manure, cotton cake; farm soil, air, water; casing materials like FYM, spent compost, moss pea , forest soil; wooden trays, shelves and other containers etc; can be the primary source of infestation.

Spread

Once these nematodes get entry into the mushroom house, they further spread through air, faulty spray of water, workers' hands, implements, mushroom flies, mites etc.

Types of nematodes

The mushroom nematodes are of following two types:

1. Mycophagous or myceliophagous naematodes
2. Saprophagous nematodes

Symptoms of nematode infestation

- The compost surface sinks
- Mycelium grows sparsely in patches and turns stingy
- The white mycelium starts disappearing from the infected mushroom compost leaving only the coarse strands showing black compost mass.
- Because of the build -up of high population of bacteria, compost becomes soggy and foul smelling.
- The pinheads turn brown, watery and remain stunted.
- The fruit bodies appear in patches in the beds
- Due to reduction in flush pattern and crop duration, the yield is drastically reduced.

Nature of damage

With their tube like mouthparts, they are structurally incapable of causing any direct damage to mushroom mycelium. Due to their faecal materials, the Rhabditids not only spoil the structure and quality of composts in cropping beds emitting foul smell, but also cause inhibition of mycelial growth, reduction in yield due to disturbed flush pattern, reduction in crop duration and quantitative loss of the sporophores etc.

Life cycle:

The female generally lays eggs which hatch into small larvae. These larvae feed on the substratum and change into L-1, L-2, L-3 stages until they become adults and enter the reproductive stage. These have a life span of 7-12 days or more which again depends on the prevailing temperature.

Control measures:

- Complete hygiene
- Proper pasteurization of compost and casing materials
- Drenching mushroom houses and premises with some disinfectants
- Use of fresh polythene bags and sterilization of empty trays or trolleys with formalin or other disinfectants
- Use of nematode free spray water
- Workers should wear clean overalls, including hand gloves and first harvest the healthy sporophores carefully and only then the older infected ones
- Cook out of the exhausted compost at 71± 1 º C for 8 – 10 hours
- Disposal of spent compost at a distant place
- Growing resistant mushroom varieties like *Agaricus bitorquis*, *Pleurotus sajor-caju*, *Strophariarugoso-annulata* etc.
- Nematode trapping fungi like *Arthrobotrys oligospora*, *A. superba*, *A. robusta* and several species of Pleurotus can be used as bio- control agents against mushroom nematodes.
- Mixing of plant extracts of neem, castor, groundnut, karanj etc. in compost at the time of spawning or cropping.

C. Assessment:

Very Short (Answer question)

1. Write down the two fungal disease of Mushroom.
2. List out the major insect pest of mushroom production.

Short (Answer question)

1. Define disease and pest of mushroom.
2. Write the nematode disease of mushroom?

Long (Answer question)

1. Define fungal disease. Describe about the fungal disease of mushroom production.
2. What do you mean by viral disease? Describe about the management aspect of viral disease in mushroom production.
3. Describe about the disease and pest management process in mushroom production.

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Glossary of Commonly Used Terms for Mushroom Cultivation

***Agaricus bisporus*:** Common cultivated mushrooms, in a variety of lines.

Ammonia: Necessary by-product of phase i produced during the fermentation and decomposition processes. Should be converted to microbial protein and eliminated during phase ii composting. Free ammonia at the end of phase ii composting is toxic to the mushroom mycelium.

Anaerobic fermentation: The reverse of aerobic or otherwise the lack of oxygen during fermentation - undesirable.

Biological efficiency (B.E): one way to express the productivity of a substrate.

$$\mathbf{BE} = \frac{\textbf{kg of fresh weight of mushrooms}}{\textbf{kg of dry weight of substrate at spawning time}}$$

The range of BE for a commercial farm varies between 60-120%.

Blended compost: A mixture of wheat straw bedded horse manure (HM) and other materials such as hay, wheat straw, corncobs, cotton seed hulls, etc. in several formulations, i.e., 80% HM, 20% hay and cobs, etc

Brewers grain: Grain hulls, residue from breweries, having a nitrogen content of 4.0 to 4.3%.

Buttons: Marketable mushrooms, but not mature.

Carbon dioxide (CO_2): A by-product of the microorganisms during fermentation in both phase I and II. it is also a very important by-product of spawn run, casing and later in production.

Casing: The casing operation is the fourth step in mushroom farming and is a top-dressing placed directly on spawn- run compost from 14 to 21 days after the spawning operation.

Casing layer: The top-dressing is required to induce the fruiting of the mushroom mycelium. Peat moss with limestone is main casing material used worldwide. Spent mushroom substrate and loam top-soil can also be used.

Casing inoculums (CI): Low nutrient materials like vermiculite, peat or spent mushroom substrate that is sterilized and then it is fully colonized with mushroom mycelium. This material is then added to the casing layer to speed up the colonization of the casing layer and shorten the time to harvesting. Fully colonized spawn run compost may also be used but must be free of all molds or potential pathogens. Adding this compost at casing (CAC) is not as commonly used as CI.

Colonize: The process of the thread-like strands of growth, called mycelium, that develop in the compost after having grain spawn applied.

Competitor molds: Any of a variety of molds, when present in the compost or casing, which compete for nutrients, inhibits or destroys mushroom mycelium.

Composted substrate (compost): A mixture of organic and inorganic substances, managed specifically to produce nutrients (food) selectively, favorable to the growing of the common cultivated mushroom.

Compost turner: a machine specially designed to manipulate the raw materials (compost) in phase I into a homogenous rick or pile.

Cropping, cropping cycle: the sixth step in mushroom fanning begins 16-20 days following casing when the first mushrooms are harvested. Mushrooms are generally harvested (picked) for 3 to 5 days, followed by several days when no mature mushrooms are present. The period between harvesting is used for watering the casing layer. This cycle is repeated in a rhythmic fashion for the duration of the crop and is also called a break or flush.

Dry -matter (expressed in percent): pertains to the amount of compost sample remaining after having been dried in an oven at 100°C for a 24-hour period. Precise weighing and handling is required to assure accurate data.

Filling: the moving of compost from phase i into containers or a structure to undergo phase II composting

First break: the time when the first mushrooms of each crop are harvested, usually 16-20 days following casing.

Flushing: another important step required to promote the development of mushroom initials. Fresh air is introduced to reduce the level of carbon dioxide produced by mushroom mycelium. Temperature and relative humidity is also adjusted to move or hold back pin development.

Friable: the physical structure and condition of loam top-soil, i.e., crumbly.

Fungi: plant life lacking chlorophyll and therefore lacking the capacity to produce or convert chemicals into complex life substances.

Gypsum, agricultural: a naturally occurring mineral consisting of Calcium Sulfate. It is used in phase i.e., composting to prevent greasiness.

Homogenous mix: the thorough and complete mixing of all materials used.

Hyphae: single strands of mushroom mycelium.

Isolate: a product of a tissue, multi-spore or single spore culture maintained on a nutrient medium.

Line: a mushroom isolate maintained over time.

Mesophilic: the first microorganisms to become active in phase i compost and as they grow and multiply causing temperatures to increase rapidly. These initial mesophilic organisms are incapable of growth at temperatures exceeding 45°C (112°F).

Microorganisms: the smallest form of living organisms (or animal life) found in most raw materials and can only be seen by use of a microscope.

Moisture: in mushroom growing, refers to a certain amount of water diffused in the compost, casing layer, etc. moisture is one of the most important, measurable elements to be monitored during the entire mushroom growing process.

Mushroom: fruit body of the mycelium at the surface of the casing layer. Sporophore is another term for mushroom fruiting body.

Mushroom cap: the very top portion of the mushroom, sitting (attached) on top of the stipe (stem). The cap is the only part of the mushroom that may have a different color as related to the 'line' being grown.

Mushroom mycelium: the white or grayish white, thread-like growth that develops after spawning. It is the conduit through which the mushroom gets its nourishment from the compost.

Nitrogen: an important and measurable element of substrate. Results on a dry weight basis are used by growers to monitor supplementation during phase I substrate preparation and at spawning for efficiency of phase ii composting.

Nutrients: those ingredients added at the beginning of phase I composting that are directed at feeding the microbial population. Nutrients added at spawning are directed toward actual consumption by the mushroom itself.

Pasteurization: the act of freeing the compost of undesirable microbes, like fecal coli forms, nematodes, and insects, during phase II composting. This step in composting is performed under controlled environmental conditions at lower temperatures than phase I composting.

Peat, sphagnum: a decomposed material fanned from sphagnum moss, considered a superior casing material.

Pests mushroom: all unwanted organisms which interfere with mushroom production, that by infestations, compete for nutrients needed by the mushroom, or directly attack the mycelia strands or the mushroom itself. Example pests are nematodes, mushroom flies, virus diseases, mummy, fungal pathogens, competitor molds.

Phase I composting: the first step of six steps involved in mushroom farming. This first step is to create compost with sufficient nutrients to grow mushrooms and at the same time, provide little or no nutrition for other fungi or competitor organisms. This process involves much higher temperatures than those required in phase ii composting.

Phase II composting: the second step in mushroom farming, after phase I composting is complete and the compost has been filled into containers or into a structure. Phase

II composting has two main purposes: formal conditioning of compost so it becomes mushroom specific (absence of ammonia and readily available carbohydrates) and pasteurization. This step is performed under controlled environmental conditions and at much lower temperatures than phase II composting.

Pinning: the fifth step in mushroom farming and is initiated when rhizomorphs form in the casing and then emerge at the surface of the casing. There are two important steps involved in causing the mycelium to go from the vegetative stage to the fruiting stage. The two steps are to lower the air temperature approximately 10°F and introduction of outside fresh air to purge the CO_2 from the surface of the casing. At the time of pinning, a final watering is sometimes added to protect against drying out of the casing layer due to the introduction of fresh air.

Poultry manure: phase I compost supplement used in two forms, i.e., mechanically dried and pulverized or raw, uncured. In either form it is used as a source of nitrogen at the beginning of Phase I composting. Nitrogen content varies but should be approximately 4%.

Pre-wet turner: A machine specially designed to manipulate the raw materials (compost) in phase i into a homogenous material, usually in a windrow not rick

Production cycle: The total time of mushroom growing beginning with build through to steam-off and clean-out

Recipe, compost: Proven-formulations for the use of various raw materials used to produce compost favorable to the growing of the common cultivated mushroom.

Relative humidity (RH): The ratio of the amount of water vapor actually present in the air to the greatest amount possible at the same temperature. Various methods of measuring RH is available but the sling type apparatus or wet-bulb, dry-bulb is the most used.

Rhizomorphs: The visibly thick strands or cord of compacted mycelia which is the stage between the mycelium and mushrooms. Mushrooms actually form from rhizomorphs.

Rick (windrow, pile): Phase I composting term for the windrow of homogenous mix of raw materials used to produce mushroom compost. The rick has straight and tight sides and looks like a loaf of bread.

Rhythm: refers to the cycles that develop after the first mushrooms are harvested.

Rose face: A specially hand crafted and drilled device used for applying water to the casing layer from the day of casing and throughout the cropping period. Rose faces come in various sizes, hole sizes, that are selected by each mushroom farmer according to his needs or experience with his particular casing material.

Scratching: Not a recommended practice, however, it is performed by loosening the casing layer by home-made devices, usually a narrow board with nails driven through it. Scratching is normally done to a depth just short of where the growth of mycelium is observed. The reasons mushroom farmers perform this extra step varies, however, sealing is the normal cause.

Sealed: An undesirable condition of the casing layer produced by too much water applied at one time to a particular area, or with too much force. This condition exists when particles of the casing soil re-align themselves in a pattern that drastically reduces the surface pore space. Very few, if any, mushrooms are found on a sealed casing layer.

Spawn: Rye, wheat, millet, or sorghum grain cooked with water and chalk, then sterilized. Mycelium is added and allowed to grow for 10-17 days. At this time the mycelium will have completely colonized the grain and is called spawn.

Spawning operation: Another step in mushroom farming, which is the placement of a spawn into compost prepared in phase I and phase II composting. By whatever method chosen or available, the importance of cleanliness, applying and mixing thoroughly cannot be over emphasized.

Spawning rate: Amount of spawn per square foot or, by weight, placed into the compost immediately after phase II composting. Rates vary among mushroom farmers and can be as low as 1 unit (less than a quarter) per 10 ft^2 of surface area, to as great a

rate as 1 unit per 5 ft^2. The actual rate used will be determined by experimentation with the system each mushroom farmer has in his care.

Spawn run: The time between spawning and casing, during which the mycelium fully colonizes (grows through) the mushroom compost.

Spent mushroom substrate: Substrate is removed from each house after it has been steamed off (sometimes called 'cooked-out' or 'post crop steaming'). It is usually 'aged' by spreading it on vacant fields, allowing it to be weathered for about $2\frac{1}{2}$ years before being reused as compost casing.

Spores: Mushroom spores are produced on the gills of the cap of the mushroom. They are microscopic spheres roughly comparable to seeds of higher plant life. Spores are used to spawn mushroom compost.

Sterilize: In mushroom farming, all equipment, such as utensils, knives, etc. that will come in contact with the mushroom or substrate after phase II must be sterilized to clean and free it from harmful pathogens.

Synthetic compost: Compost made with bulk ingredients other than horse manure. various recipes are used where straw, hay, are supplemented with supplements like crushed corn cobs, cottonseed hulls, poultry manure and sometimes are inorganic forms of nitrogen (e.g. urea, ammonium nitrate) are used.

Thermocouple: A special temperature sensing device, consisting of two dissimilar metals, manufactured in a stainless steel sheath. These devices require special electronic equipment to accurately read whatever medium they are placed in. Thermocouples are normally used in phase I, phase II or phase III as well as any place where remote reading of temperatures are necessary or advantageous throughout the cropping cycle.

Thermophiles: These are heat loving organisms that survive and multiply in temperatures up to 150ºF.

Turning: Occurs during phase i composting and after building a rick or in a bunker. It means to tear apart the rick, mixing the colder outside with the hotter inside compost, while adding supplements or water or neither, depending on each composter's regimen.

Vegetative: The growth of mycelium from spawning through to pinning. In order to cause fruiting (form mushroom initials), all vegetative growth must cease.

Ventilate: Introduction of outside fresh air during phase II composting, the fruiting or pinning process and throughout the cropping cycle.

Yield: The pounds of mushrooms harvested per square foot. Mushroom growers manage and make economic and cultural decisions based on variations yield.