

## **Cultivation of White Button Mushroom**

### **(Agaricus bisporus)**

button mushroom cultivation has two major components, composting (preparation of substrate/compost), and the crop management, (raising of mushroom crop). The substrate preparation has undergone scores of innovations/improvements suiting environment protection laws in many developed countries. At the same time, casing medium has also been standardized with use of peat and its alternative materials (FYM, Spent Mushroom Compost and Coir Pith) with prime objective to improve productivity and quality of mushrooms. Similarly, the crop management techniques have also been improved upon to harvest highest possible mushroom yield over a shortest period of time. All the operations/applications done after completion of composting are handled under the head crop management. These include:

#### **A. Agronomic crop management**

#### **B. Environmental crop management**

##### **A. Agronomic Crop Management**

Agronomic crop management deals with the compost quantity to be filled per m<sup>2</sup> bed area, moisture content of compost, spawning method employed, compost thickness in a bed or bag, casing application and thickness, watering regimes employed, harvesting of crop and after care, pest management, hygiene maintenance and so on. However, more important among these are

##### **1. Spawning and spawn run**

##### **2. Casing materials, casing treatments, casing application, case run and pinhead formation**

##### **1. Spawning and spawn run**

The steps involved are (Fig. 9.1)

- Good quality compost with temperature of 25°C
- Mixing of grain based spawn (@ 0.5-0.7% of wet compost weight) of *A.bisporus* under clean conditions (i.e. with clean hands and pre-sterilized area)
- Filling of spawned compost into polythene bags (12-15" depth) or beds (6-8" depth)
- Little compressing and levelling of spawned compost



**Fig. 1. Process of spawning and filling in bags for white button mushroom**

**Loosely closing the mouth of polythene bags filled with spawned compost (Covering with a clean newspaper / plastic sheet if filled in trays/shelves)**

- **Shifting the compost filled bags in cropping rooms with a temperature of  $23 \pm 1^{\circ}\text{C}$  (air temp.), RH of 95% and high  $\text{CO}_2$  conc. (1.0-1.5% strain dependent), and keeping the bags under above conditions for 12-14 days**
- **Completion of spawn run (change of dark brown compost mass in to light brown colour)**

### **Precautions**

- **Use of fresh pure culture spawn**
- **Spawning under clean conditions (preferably under positive pressure created using bacterial filters before inlet fans and air curtains at doors)**
- **Proper treatment of spawning area and tools with formalin, and cleaning of hands with dettol**
- **Maintaining good hygienic conditions during spawning by keeping all the doors/windows closed**

## **2. Casing and case run**

**Casing is a 3-4 cm thick layer of soil applied on top of spawn run compost and is a pre-requisite for fructification in *A. bisporus*.**

### **a. Casing materials**

**Earlier sub-soil material or organic matter rich soils were used as casing in button mushroom cultivation. Presently peat is the most desirable casing material used world wide with excellent mushroom yields and superior fruit**

body quality. However, pest is not available in India. The other alternative recommended materials are,

- Well decomposed Farm Yard Manure (FYM) preferably two years old
- Well decomposed Spent Mushroom Compost (SMC) (two years old anaerobically decomposed)
- Composted coir pith (coir industry waste) (well decomposed & water leached)
- 1:1, 2:1 and 1:2, v/v of well decomposed FYM and SMC
- 1:1, v/v of decomposed FYM or SMC with composted coir pith
- Decomposed powdered bark of some forest trees
- Paper industry waste
- Burnt rice husk is also in use along with decomposed FYM (2:1, v/v) in seasonal

cultivation of button mushroom in Hayrana and Punjab with reasonable success

#### **b. Quality of casing materials**

- Soft texture
- Light weight
- High water holding capacity
- High porosity
- Deficient in available form of C and N
- Neutral pH (7.0 – 7.5)
- Low conductivity (400-600  $\mu$  moh)

#### **c. Casing treatment**

Casing material should be treated properly before its application on the spawn run compost and the steps involved are:

- Make a heap of casing material
- Wet it up to 50-60% water holding capacity

- Fill in trays and shift them to pasteurization chamber
- Steam pasteurization at 60-65°C for 6-8 hours
- Auto-Cooling

Alternatively,

- Make a heap of casing material on a cemented platform
- Wet it up to 50-60% water holding capacity
- Drench the wet casing with formalin @ 1 litre/m<sup>3</sup> (40% formaldehyde) by mixing with shovel
- Cover it with polythene sheet and seal the outer periphery thereafter by pouring sand/soil on outside margin
- Keep the material for 24-48 hours in sun for fumigation effect
- Remove the cover after 48 h and expose the material to open air and sunlight by spreading over with clean tools and permitting the formalin fumes to escape in to air for 2-3 days before it is used as casing (formalin treatment effect decreases at low temperature due to inadequate fumigation)

#### d. Casing application (Fig. 9.2)

- Unfold the fully spawn run bag and make the top surface even by gentle pressing with hands
- Light spray of water on spawn run compost
- Application of 4-5 cm thick layer of casing uniformly using iron rings of 4 cm height or wooden blocks
- Water spray in installments immediately after casing application



**Fig. 2. Process of casing soil application for button mushroom cultivation**

#### **Precautions**

- Casing material should not be sieved but used as such with clumps, which permits more air spaces in casing
- Top casing surface should have small mounts and valleys
- Care should be taken to prevent re-infection of the casing materials
- Store casing material in a sterilized /clean room before use in polythene bags or synthetic cloth bags
- Apply water to casing in a few installments so that water does not run into spawn run compost

#### e. Case run and pinhead formation

Case run is done at a temperature of  $24 \pm 1^{\circ}\text{C}$ , RH-95% and  $\text{CO}_2 > 7500$  ppm (strain dependent) for about one week. There is no requirement for fresh air introduction during case run. It is considered complete when mycelia come in the valleys of casing layer. After case run, the environmental conditions are changed by bringing down the temperature to  $15-17^{\circ}\text{C}$  (air), RH to 85% and  $\text{CO}_2$  to 800-1000 ppm (strain dependent) by opening of the fresh air ventilation and exhausting  $\text{CO}_2$ . This change in environmental parameters induces pinhead formation in 3-4 days (strain dependent) time. The pinheads develop into solid button sized mushrooms in another 3-4 days (Fig.3). At this stage, the air inside the cropping room is changed 4-6 times in an hour to maintain appropriate  $\text{CO}_2$  conc. as  $\text{CO}_2$  production is at its peak during first flush (actually peaks at case run).



**Fig. 3. Arrangement of bags in cropping room and mushroom at button stage of development**

### 3. Supplementation

Supplementation with protein rich supplements such as cotton seed meal, soybean meal, alfa-alfa meal, feather meal, etc. has been found to increase the mushroom yield. Supplementation can either be done at spawning or after



spawn run before casing. The later is more useful. Supplement is first grounded coarsely and denatured by treating with 5000 ppm formalin and before its mixing in compost. The practice normally increases the temperature of compost by 4-5°C and if done at the time of spawning or in poor quality compost, it results in killing of mushroom mycelium or increased incidence of moulds. If these problems are overcome supplementation can give 20-25% enhanced yield. Supplementation at casing in spawn run compost also helps in early and higher mushroom yield.

#### **4. Ruffling**

Ruffling of compost on completion of spawn run is done just before casing. This practice is particularly useful for round the year cropping when 5-6 crops are taken per year and cropping period is reduced to about 4 weeks, as this practice helps in exhaustion of compost earlier than normal. Ruffling of casing after a 3-4 days or so after casing is done by some growers to get uniform pinning.

#### **5. Watering**

Mushroom contains nearly 90% water and that gives us an idea how water is important for the crop. Mycelium gets water from compost during spawn run and compost + casing during case run and from casing during fruit body formation. Water level in casing is maintained in 2 ways. One way is by its regular spray when pinheads are pea sized and then by maintaining RH at 80-85% during cropping. If one of the factors, (water spraying and RH) during cropping is disturbed, it will affect crop productivity. Low RH during cropping will result in drying of beds, lightweight mushrooms, discoloration of mushrooms and crop losses. Drying of casing will seal the casing medium resulting in mat formation, which becomes impervious to water, and results in tremendous crop losses. Water has to be replenished in casing to accommodate the water losses from casing due to mushroom growth and evaporation. Lesser the water loss to room air, better it is. Bed moisture and RH are although two different factors, but are interdependent. Water spraying on mushroom beds at pin breaks should be avoided. The casing should be wet enough when fresh air is brought in and room temperature lowered. The wetness should be sustained till pin heads become pea sized, and that is the stage when bed will require additional watering to allow pea-sized pins to develop into button sized mushrooms. Watering to beds requires monitoring at each stage. RH in the cropping room is monitored by using dry & wet bulb thermometers. Two ordinary stem thermometers are put in the cropping room, placing one in the casing/compost bed and one hanging in the air nearby (few cm apart). Bed temperature is 1-2°C higher than air temperature. Computer control of AHU ensures application of cropping parameters with precision during spawn run, case run and cropping. The water used for irrigation (spraying) on mushroom beds should be clean, neutral in pH and free from salts, heavy metals and other impurities. Water good enough for drinking/watering for vegetables/field crops is also good for mushroom cultivation. It is desirable to test the quality of water before the mushroom growing is started at a particular site.

## **6. Harvesting and after care**

Mushrooms with 4-5 cm dia., with hard pileus and closed veil are ready for the harvest. Mushrooms are harvested by holding them between forefinger and thumb, and rotating in clockwise/anticlockwise direction. The soiled stem portion is cut with sharp edged knife and mushrooms are collected grade-wise in baskets. Dropping of the stem cuttings on the floor or the bed should be avoided, as these will promote the growth of undesirable microorganisms. Cleaning of mushroom beds and floor is recommended after each crop harvest. Fresh casing is applied at places from where mushrooms have been removed. Water is sprayed at the rate the mushrooms have been harvested, i.e. for every kg of mushroom harvested 1 litre of water is added after harvesting. Damaged pins/mushrooms, if any, are also to be removed from the bed manually. If bunching of mushrooms is observed, then there is a need to address the climate controls for creation of optimal environmental conditions during pinhead formation. Mushrooms after harvest are graded, packed in PP bags/card board boxes and preferably chilled at 4°C for 6-8 hours before sending to the market. The pre-market chilling enhances the shelf life of mushrooms. While harvesting care should be taken to keep the pileus free from casing soil, as it stains the mushrooms. Washing of mushrooms to make them extra white for increased acceptability in the market is undesirable, especially with Potassium metabisulphite solution. Unwashed mushrooms stay fresh for a longer period. Mushrooms should be handled carefully, and not bruised during the harvesting operation. Bruising will damage the mushroom tissue, which will turn the pileus dark/pink on exposure to air. While packaging mushrooms in PP bag one should not forget to make a small hole (0.2 mm), as it will prevent the development of aflatoxins in transit or storage.

Button mushroom can be stored at 4°C for a few days without any deterioration in its quality but it is desirable to consume/market fresh mushrooms. Since button mushroom has a very short shelf life and it cannot be stored for longer periods, hence it requires processing for long storage. Mushrooms are best preserved in brine solution after blanching, either in cans or jars. The properly processed mushrooms stay in good condition for over a period of 1 year. It is possible to transport canned mushrooms over longer distances without any deterioration in their quality. But fresh mushrooms can only be transported short distances in refrigerated vans/by air to reach up to a remunerative market.

## **B. Environmental Crop Management**

Mushroom is an indoor crop, raised in cropping rooms with simulated environmental conditions suiting to a particular mushroom. Hence management of crop environment becomes utmost important. It includes the temperature, RH, CO<sub>2</sub> concentration, air speed/evaporation rate over crop beds, air changes in the room/oxygen availability and other such factors, which directly influence crop productivity.

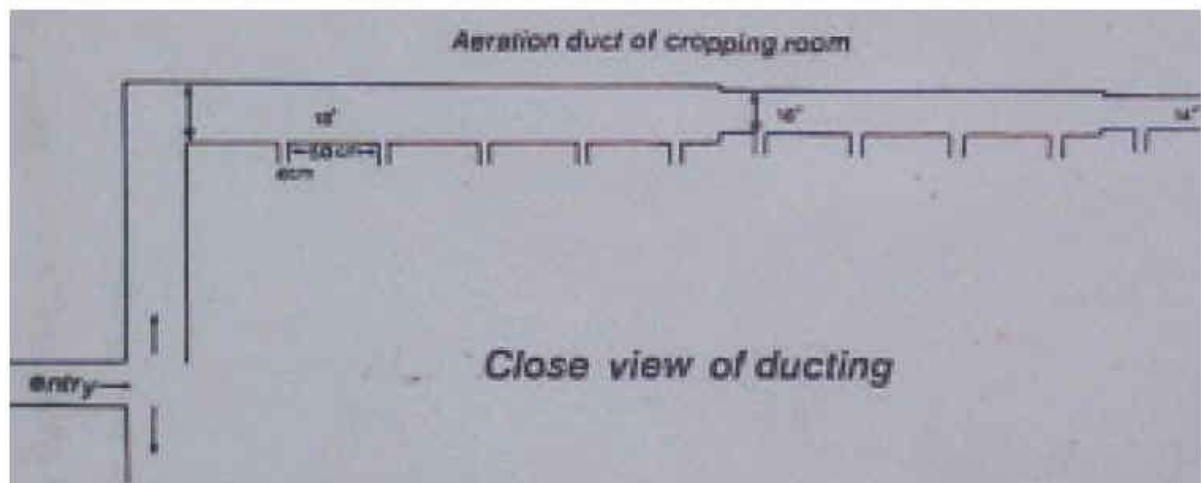
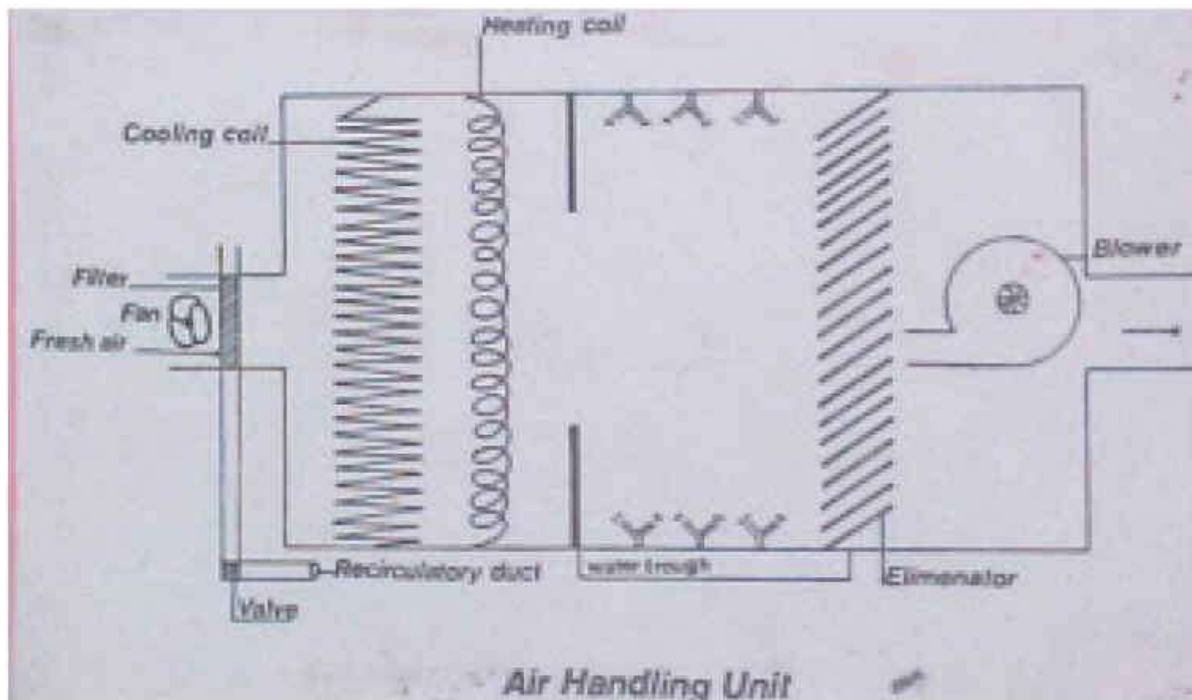
The environment management in the cropping room includes addressing of the

following factors:

1. Temperature
2. Relative humidity (RH)
3. CO<sub>2</sub> concentration

### 1. Temperature

Temperature in the room has two areas for monitoring i.e., air temperature and bed temperature. Temperature has direct bearing on crop productivity in synergy with other





## **Fig. 4. Schematic view of Air Handling Unit and aeration duct**

Factors like RH and CO<sub>2</sub> /O<sub>2</sub> conc. in the cropping room. The bed temperature in the cropping room is directly influenced by the air temperature, so it is the air temperature that has to be addressed. The air temperature inside the room can be manipulated with use of cooling/heating coils in an Air Handling Unit (AHU) installed inside or outside the cropping room for climate control. An independent AHU is desirable for each cropping room. The AHU inside contains a set of cooling coils, heating coils, RH fogging jets and a centrifugal blower fan for blowing the conditioned air into the cropping room (Fig. 4).

The AHU is generally installed on top of the entry door and is joined with a recirculating duct from inside the cropping room. The cooling coils are fed with chilled water from the chiller, while the heating coils are fed with steam from boiler and fogging jets get water from trough placed at the bottom of the AHU by a small pump. The cooling requirement will depend upon compost quantity fed inside the room, outside prevailing temperature, insulation on the walls, etc. The blower fan blows the conditioned air into the room (Fig. 3). The fresh air into the room goes in via AHU through a control valve, and during most of the crop raising period fresh air valve is placed at 20-30% and recirculating at 70-80%. During spawn run the entire air is recirculated (100%) and no fresh air entry is required.

### **a. Spawn run**

For spawn run air temperature of  $23 \pm 1^\circ\text{C}$  is maintained inside the cropping room, which corresponds to bed temperature of 24-25°C (1-2°C higher than air temperature). During this phase, the fresh air valve is closed and entire air is recirculated, allowing the carbon dioxide to accumulate to the level of 15000 ppm, desirable for quick spawn run.

Higher concentration of CO<sub>2</sub> accelerates the spawn run/vegetative growth of the mushroom. Any increase or decrease in temperature affects the CO<sub>2</sub> production of the compost and the RH of the room. With increase in temperature, RH will tend to fall, and just vice versa with decrease in temperature. The properly insulated room will ensure uniform temperature inside the cropping room at every stage of crop growth. The heat from the cropping room is removed via cooling coils fitted inside the AHU.

### **b. Case run**

The environmental conditions suitable for spawn run, are suitable for case run as well. The same conditions, as for spawn run will be continued for next 7 days for case run, i.e., temperature of  $23 \pm 1^\circ\text{C}$  in the air and 24-25°C in the bed. The RH/CO<sub>2</sub> will also be same as for spawn run. Under aforesaid conditions the case run will be completed within one week, and at the same time the mycelium is observed in the casing valleys. Valleys are the areas between the peaks as can be seen on top of casing. The CO<sub>2</sub> conc. and RH

should also be maintained within the optimum range for quick and effective case run.

### **c. Cropping**

After completion of case run, cooling inside the room is enhanced to bring the air temp. 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 recirculated (70%). This brings down the CO<sub>2</sub> conc. inside the room to 800 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. At this stage fresh air can be slightly reduced to achieve 1000-1500 ppm CO<sub>2</sub> concentration. The environment parameters are maintained as above during entire period of cropping. Since the temperature has influence on RH and CO<sub>2</sub> production from compost hence should be manipulated, keeping in mind its effect on other two factors. All the three parameters work in synergy with each other to induce pinning. The pinning will be affected adversely if any of these factors is not in its optimal range. High temperature for a long period of time during cropping will lead to sealing of casing, and will result in stopping of pinhead formation. The mycelium will continue growing in vegetative phase and will seal the casing, making it impervious to water, thus resulting in serious yield losses. The desired temperature in cropping room can be maintained with good precision by the use of sensors and controlling devices attached to cooling/heating coil inlets fitted inside the AHU. These devices are easily available and are effective in temperature control in the cropping room.

### **2. Relative humidity**

Relative Humidity (RH) is the ratio/proportion between absolute humidity (AH) and saturation point of humidity (SPH) at a given temperature, expressed in percentage. Absolute humidity is number of grams of water vapours contained in a cubic meter of air at a given temperature. Saturation point of humidity is the maximum number of grams of water vapours feasible in a cubic meter of air at a given temperature. Relative humidity (RH) of 85% is necessary for obtaining highest pin head formation in synergy with other factors like temperature and CO<sub>2</sub> concentration. RH of 85% permits slow evaporation of

water from the crop bed to air in the cropping room and thereby facilitating the upward movement of nutrients in the compost. This exchange of air facilitates loss of CO<sub>2</sub> + heat into the air, necessary for healthy pin head development and crop productivity.

In the event of RH falling below 85% inside the cropping room, more moisture from the crop bed will be withdrawn resulting in drying of the casing layer. This will seal the casing and result in crop losses. Lower RH in the room will be indicated by bed temperature falling below the air temperature, an undesirable situation to be avoided at any cost. Under normal circumstances the bed temperature is always higher by 1-2°C than air temperature for

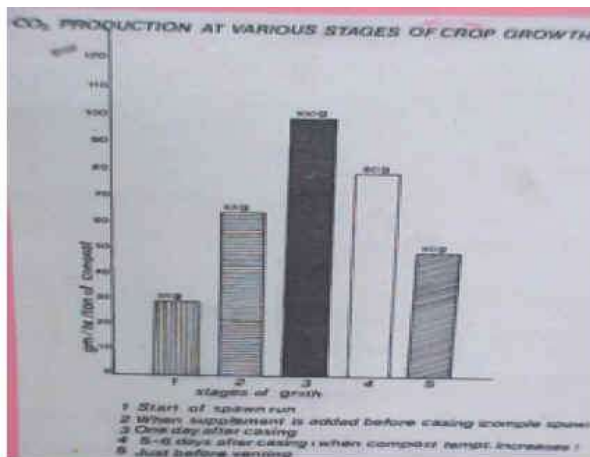
development of a healthy crop of mushrooms. For round the clock monitoring of RH, monitoring of the bed and air temperature inside the room is desirable.

The incoming air should be humidified enough to prevent loss of moisture from the crop beds. Evaporation of moisture from crop beds has to be taken into consideration for calculating the g of water vapours required per m<sup>3</sup> air in a room for maintaining the required RH for cropping. Air in a cropping room contains 9.6 g water vapours per m<sup>3</sup> of air at 14°C (A), the saturation point of humidity at 14°C is 12 g/m<sup>3</sup> (S). The RH of the room air will be  $A/S \times 100 = 9.6/12 \times 100 = 80\%$ . The ultimate expression is the quantity of water vapours contained per m<sup>3</sup> of the air space of the room at a given temperature. 31 g of water vapours gets evaporated from 1 m<sup>2</sup> bed area at 17°C/85% RH/hour. The change in room temperature will alter the RH in the room. Use of RH sensors with cut off/starting devices for recording and maintenance of RH in a cropping room is very useful. The sensors will control the fogging jets in the AHU as per the requirement in the room. For obtaining a temperature of 17°C and RH of 85% in the cropping room, air temperature is brought down to 14°C at exit point of AHU with 100% RH. The air on reaching the crop bed will receive some heat from crop bed and raise the air temperature to 17°C with RH automatically falling to 85%.

### 3. Carbon dioxide

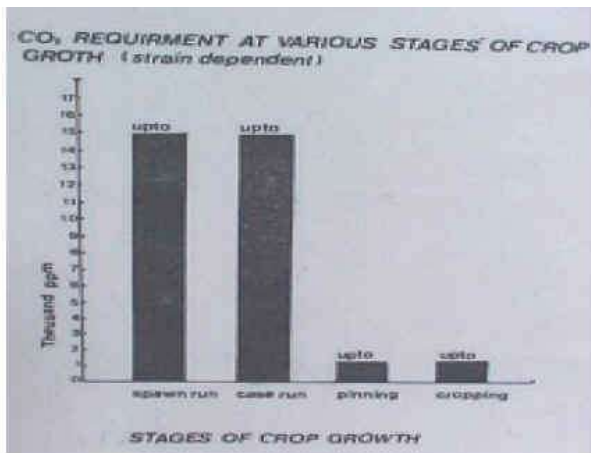
Carbon dioxide concentration is the third important factor in management of environment inside the cropping room. CO<sub>2</sub> is produced by actively growing microorganisms in compost during spawn run, case run and by mushroom mycelia and mushrooms during entire cropping cycle (Fig. 9.5).

During spawn run, higher concentration of CO<sub>2</sub> is desirable, which helps in quick and quality spawn run. For spawn run, CO<sub>2</sub> concentration between 10000-15000 ppm is desirable (strain dependent) and it helps in quick spawn run in compost. Higher concentration of CO<sub>2</sub> is also desirable during case run (Fig. 9.6). For pinning and cropping, the CO<sub>2</sub> concentration is lowered around ambient (800-1000 ppm). CO<sub>2</sub> concentration upto 1500 ppm is maintained during pinning & cropping, and this is done by venting/opening of fresh air duct to bring in oxygen and exhaust of CO<sub>2</sub> from exhaust vents under positive pressure. The opening of vent will bring in fresh air, which is conditioned in AHU (heated or cooled/humidified) and then blown into the cropping room via ducts. The CO<sub>2</sub> gets



**Fig. 5. CO<sub>2</sub> production during different**

**stages**



**Fig. 6. CO<sub>2</sub> requirement at different stages**

mixed up with the fresh air and is carried under positive pressure towards the exhaust vent and finally exhausted. This also facilitates the exhaust of heat alongwith the CO<sub>2</sub> from the room air. The heat is removed via cooling coils after the room air gets into the AHU via recirculating duct. During air circulation, recommended air speed over the crop beds is 15cm/sec. Ensure that the desired air movement is there in the central shelf in the middle row. This can be checked with the help of a burning incense stick, which will indicate the direction of air movement in the cropping room.

Higher concentration of CO<sub>2</sub> during pinning can seal the casing or produce onion shaped mushrooms with a bulbous base & a small cap. During development from pinhead to button sized mushroom, higher concentration of CO<sub>2</sub> will lead to long stiped mushrooms with a small cap (opened), which reduces the crop yields. By gentle movement of air over the crop beds, the CO<sub>2</sub> is carried away from the crop canopy, thus saving the bad effect of CO<sub>2</sub> trapped between the mushrooms in the crop canopy. To ensure healthy crop production, about 6 air changes per hour are recommended from the venting time to completion of first 2 flushes. During this period, CO<sub>2</sub> production is highest (10 g/h/m<sup>2</sup>) and it requires to be removed at a faster rate. Along with CO<sub>2</sub>, heat is also produced @ 10W per hour from one m<sup>2</sup> bed area at 17°C and 88% RH.

In subsequent flushes, 4 air changes per hour are sufficient to maintain right O<sub>2</sub> content in the cropping room (about 16%). During first two flushes fresh air vent is opened to 30% entry and 70% recirculation, and in subsequent flushes the fresh air vent is put at 20% and recirculation at 80%. Use 2 µm mesh filters on fresh air entry points into the cropping room to restrict the entry of diseases/competitor mould spores. The CO<sub>2</sub> after mixing with the room air, gets exhausted under positive pressure from exhaust vents, thereby helping in heat + CO<sub>2</sub> removal from the room. Maintenance of right combination of casing moisture (about 50 ± 2%), CO<sub>2</sub> concentration, RH and temperature at



**Fig. 7. High CO<sub>2</sub> symptoms in button mushroom**

pinning stage of crop growth helps in obtaining a heavy pin set, thus resulting in a luxurious crop growth and excellent yield of mushrooms.

If onion sized mushrooms/drum sticks (Fig. 9.7) are observed, correct air circulation for effective CO<sub>2</sub> removal from crop beds is required. Lack of air movement and accumulation of CO<sub>2</sub> creates this type of situation. Long stemmed mushrooms are again the outcome of CO<sub>2</sub> accumulation in the air around crop canopy due to faulty air movement/air circulation inside the cropping room.

### **C. Airing Procedure for Fruiting**

Venting or opening of fresh air for induction of fruiting after case run is a critical phase in mushroom growing. Whether to cool first or bring in fresh air first is a question bothering commercial mushroom growers. The airing is done suiting a particular situation, whether one wants to have a heavy first flush followed by moderate flushes later or equally spaced flushes. The airing accordingly is handled under 3 heads:

**1. Soft airing**

**2. Moderate airing**

**3. Severe airing**

**1. Soft airing**



**Soft airing means that we will have severe restriction on venting to get smaller flushes suiting to market demand and the air is opened slowly. The growing parameters to be manipulated for soft airing are listed below:**

Air temperature	19°C in 48 hours
Compost temperature	21°C in 96 hours
CO2 concentration	4000 ppm in 48 hours 2000 ppm next 24 hours 1000 ppm after 72 hours
RH	98% to 92% in 48 hours

## **2. Moderate airing**

**Moderate airing means that we will have some restriction on airing/venting to get well spaced flushes of moderate levels.**

**The growing parameters to be manipulated for moderate airing are listed as under:**

Air temperature	17°C in 24 hours
Compost temperature	20°C in 72 hours
CO2 concentration	2000-2500 ppm in 24 hours Less than 1000 ppm in 48 hours
RH	98% to 92% in 24 hours

## **3. Severe airing**

**Severe airing is done to obtain a heavy first flush and no restriction is put on airing. This results in heavy pin set and large first flush, followed by smaller subsequent flushes.**

**The growing parameters to be manipulated for severe airing are listed below:**

Air temperature	15°C as soon as possible
Compost temperature	20°C in 48 hours
CO2 concentration	Less than 1000 ppm in 12 hours
RH	98% to 90% in 12 hours

### **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 twelveth 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<sup>0</sup> 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 colour, sweet unobnoxious smell and free from ammonia, insects and nematodes. After the process is complete, the substrate is cooled down to 25<sup>0</sup> C.

## **Long Method of composting**

The long method of composting is usually practiced in areas where facilities 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 g.) 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.

## **Spawn Running**

After the spawning process is over, the compost is filled in polythene bags(90x90 cm., 150 gauge thick having a capacity of 20-25 kg. per bag)/ trays(mostly wooden trays 1x1/2 m. accommodating 20-30 kg. compost) / shelves which are either covered with a newspaper sheet or polythene. The fungal bodies grow out from the spawn and take about two weeks (12-14 days) to colonise. The temperature maintained in cropping room is  $23 \pm 2^{\circ}$  C. Higher temperature is detrimental for growth of the spawn and any temperature below than that specified for the purpose would result in slower spawn run. The relative humidity should be around 90% and a higher than normal CO<sub>2</sub> concentration would be beneficial.

## **Casing**

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 cowdung 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<sup>0</sup> 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<sup>0</sup> C and relative humidity of 85-90% for another 8-10 days. Low CO<sub>2</sub> concentration is favourable for reproductive growth at this stage.

## **Fruiting**

Under favourable environmental conditions viz. temperature (initially  $23 \pm 2^{\circ}\text{C}$  for about a week and then  $16 \pm 2^{\circ}\text{C}$ ), moisture (2-3 light sprays per day for moistening the casing layer), humidity (above 85%), proper ventilation and  $\text{CO}_2$  concentration (0.08-0.15 %) the fruit body initials which appear in the form of pin heads start growing and gradually develop into button stage.

### **Pest & Diseases**

The **insect pests** mostly observed are nematodes, mites and springtails.

The crop is suspect to **several diseases** like Dry Bubble (brown spot), Wet Bubble (White Mould), Cobweb, Green Mould, False truffle (Truffle disease), Olive green mould, Brown plaster mould and Bacterial blotch.

Professional help and extension advice will have to be sought by the entrepreneur to adopt appropriate and timely control measures against pests & diseases.

### **Harvesting and Yield**

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.

About 10-14 kg. fresh mushrooms per 100 kg. fresh compost can be obtained in two months crop. Short method used for preparation of compost under natural conditions gives more yield (15-20 kg. per 100 kg. compost).

## **6. POST HARVEST MANAGEMENT**

### **6.1 Packing and Storage**

#### **(A) 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 10L. 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 250-500 g. of mushrooms. They can be stored in polythene bags at  $4-5^{\circ}\text{C}$  for a short period of 3-4 days.

The mushrooms are usually packed in unlabelled 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.

#### **(B) 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.