Cropping

Button mushroom cultivation has two major components, one composting i.e. preparation of substrate/compost, and another the crop management, meaning raising of mushroom crop from the substrate. 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

- Spawning and spawn run
- Casing and case run
- Supplementation
- Ruffling
- Watering
- Harvesting and after care

B. Environmental crop management

- Temperature
- Relative Humidity (RH)
- \( \text{CO}_2 \) concentration

A. Agronomic crop management

Agronomic crop management deals with the compost quantity to be filled per \( \text{m}^2 \) bed area, moisture content of compost, spawning method employed, compost thickness in a bed/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), mixing of seeds (spawn) with the compost (referred as spawning), allowing the spread of fungus in the compost (referred as spawn run), (2) covering of spawn run compost with specially made and treated materials (referred as casing).

Spawning and spawn run

- Take the fully prepared cooled compost and spread out in the pre-cleaned spawning area
- Thoroughly mix the spawn in compost @ 0.5-0.75% of fresh compost weight under hygienic conditions
- Fill the spawned compost in polythene bags (12-15” depth) or beds (6-8” depth)
- Little compressing and leveling of spawned compost is desirable
- Loosely close the mouth of polythene bag filled with spawned compost (Covering with a clean newspaper / plastic sheet if filled in trays/shelves)
Shift the compost filled bags in cropping rooms with a temperature of 23 ± 1°C (air temp.), RH of 95% and high CO₂ concentration (1.0-1.5% strain dependent), and keep the bags under above conditions for 12-14 days till complete spawn run.

Completion of spawn run is indicated by change of dark brown compost mass in to light brown colour.

**Precautions**

- Use fresh, good quality spawn of known strain.
- Do not mix spawn of different strains and therefore avoid mixing spawn from different sources.
- Spawning may be done 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 disinfectant is desirable.
- Maintain good hygienic conditions during spawning by keeping all the doors/windows closed.

2. **Casing and case run**

Casing layer is a layer of substrate material (3-4 cm thick) 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 commonly used casing material in the world with excellent mushroom yields. In our country, the commonly used casing materials are,
   - Well decomposed Farm Yard Manure (FYM) preferably two years old.
   - Well decomposed Spent Mushroom Compost (SMC; two years old anaerobically decomposed).
   - Coir pith.
   - 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 + decomposed FYM (1: 2, v/v) or burnt rice husk + coir pith (1:4).
b. **Quality parameters of casing materials**

- Medium texture
- Low bulk density
- High water holding capacity (> 150 %)
- High porosity
- Deficient in available nutrients
- Neutral pH (7.0 – 7.5)
- Low conductivity (400-600 µmoh)

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 properly (65-70 % moisture)
- Fill the materials in trays and shift to casing soil chamber
- Steam pasteurization at around 65°C for 6-8 hours
- Cool the casing material by auto-cooling

Alternatively,

- Make a heap of casing material on a cemented platform
- Wet it up to 50-60% moisture
- Drench the wet casing material with formalin @ 1 l/m³ (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 5-6 days for fumigation effect
- Remove the cover after above period and shake the casing material with shovel. Now the casing soil is ready.

d. **Casing application**

- Unfold the fully spawn run bags and make the top surface even by its gentle pressing with hands
- Spray water lightly on exposed compost surface
- Apply 4-5 cm thick layer of casing material uniformly using iron rings of 4 cm height or wooden blocks
- Spray 0.2% formalin immediately after casing application

![Fig.2: process of casing soil application for button mushroom cultivation](image-url)
**Precautions**

- Casing material should not be sieved and used as such with clumps, which permits more air spaces in casing
- Casing surface should not have plastered and smooth surface 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 such a way that water does not leach in to compost

**c. Case run and pinhead formation**

Case run is done at a temperature of $24 \pm 1^\circ C$, RH–95% and $CO_2 > 7500$ ppm (strain dependent) for about one week. There is no requirement of fresh air introduction during case run. It is considered complete when mycelium reaches to the valleys of casing layer. After case run, the environmental conditions are changed by bringing down the temperature to 15-17$^\circ C$ (air), RH to 85% and $CO_2$ to 800-1000 ppm (strain dependent) by opening the fresh air ventilation dampers. This change in environmental parameters induces pinhead formation in 3-4 days time. The pinheads develop into solid button sized mushrooms in another 3-4 days. At this stage, the air inside the cropping room is changed 4-6 times in an hour to maintain appropriate $CO_2$ concentration.

**3. Supplementation**

Supplementation with protein rich materials 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 at casing. The later is more useful. Supplement is first grounded coarsely and denatured by treating with 5000 ppm formalin before mixing in compost. This practice normally increases the temperature of compost by 4-5$^\circ C$ and if done at 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.

**4. Ruffling**

Ruffling of casing is done after 3-4 days when mycelium has travelled to half of the casing layer. This practice distributes the mycelium evenly in the entire casing medium thereby giving uniform and early 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 water spray when pinheads are pea sized and maintaining RH at 80-85% during cropping. If one of the factors, (water spray 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 into the room air. Lesser the loss to room air, better it is. Bed moisture and RH are although two different factors, but these are interdependent. Water spray 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. That 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. Drying of casing is not desirable, as it will result in sealing of casing and mat formation. 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.

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, CO₂ 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. CO₂ concentration

**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 factors like RH and CO₂/O₂ 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.3). The AHU is generally installed outside the cropping room 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. 1 and 2). 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 80-70%. During spawn run the entire air is recirculated (100%) and no fresh air entry is allowed.

a. **Spawn run**

For spawn run air temperature of 23 ± 1°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 CO₂ accelerates the spawn run/vegetative growth of the mushroom. Any increase or decrease in temperature effects the CO₂ 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 ± 1°C in the air and 24-25°C in the bed. The RH/CO₂ 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 CO₂ conc. and RH should also be maintained within the optimum range for effective/quick 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 CO₂ conc. in side 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 CO₂ concentration. The environment parameters are maintained as above during entire period of cropping. Temperature has influence on RH and CO₂ production from compost and 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 effected 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.

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 CO₂ concentration. RH of 85% permits slow evaporation of water from the crop bed, thereby facilitating the upward
movement of nutrients in the compost, and exchange between compost and air in the cropping room. This exchange of air facilitates loss of CO\(_2\) + 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\(^3\) air in a room for maintaining the required RH for cropping. That air in a cropping room contains 9.6 g water vapours per m\(^3\) of air at 14°C (A), the saturation point of humidity at 14°C is 12 g/m\(^3\) (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 m\(^3\) of air in the air space of the room at a given temperature. 31 g of water vapours gets evaporated from 1 m\(^2\) 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%.

**Carbon dioxide**

Carbon dioxide concentration is the third important factor in management of environment inside the cropping room. CO\(_2\) is produced by actively growing microorganisms in compost during spawn run, case run and by mushroom mycelia and mushrooms during entire cropping cycle (Fig. 4).

During spawn run, higher concentration of CO\(_2\) is desirable, which helps in quick and quality spawn run. For spawn run, CO\(_2\) concentration between 10000-15000 ppm is desirable (strain dependent) and it helps in quick spawn run in compost. Higher concentration of CO\(_2\) is also desirable during case run (Fig. 5).

For pinning and cropping, the CO\(_2\) concentration is lowered around ambient (800-1000 ppm). CO\(_2\) 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\(_2\) 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 CO₂ gets 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 along with the CO₂ 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 CO₂ 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 CO₂ 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 CO₂ is carried away from the crop canopy, thus saving the bad effect of CO₂ 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, CO₂ production is highest (10 g/hr/m²) and it requires to be removed at a faster rate. Along with CO₂, heat is also produced @ 10W per hour from one m² bed area at 17°C and 88% RH.

![CO₂ production during different stages](image1)

Fig. 4. CO₂ production during different stages

![CO₂ requirement at different stages](image2)

Fig. 5. CO₂ requirement at different stages

About 4W is eliminated through and 6W (21.6kg/hour) requires to be eliminated. In subsequent flushes, 4 air changes per hour are sufficient to maintain right O₂ 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% & 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 CO₂ after mixing with the room air, gets exhausted under positive pressure from exhaust vents, thereby helping in heat + CO₂ removal from the room.

![Chart](image3)

Maintenance of right combination of casing moisture (about 50 ± 2%), CO₂ concentration, RH and temperature at 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.6) are observed, correct air circulation for effective CO₂ removal from crop beds is required. Lack of air movement and accumulation of CO₂ creates this type of situation. Long stemmed mushrooms are again the outcome of CO₂ accumulation in the air around crop canopy due to faulty air movement/air circulation inside the cropping room.

![Fig.6: High CO₂ symptoms in button mushroom](image)

**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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>19°C in 48 hours</td>
</tr>
<tr>
<td></td>
<td>17°C in 72 hours</td>
</tr>
<tr>
<td>Compost temperature</td>
<td>21°C in 96 hours</td>
</tr>
<tr>
<td>CO₂ concentration</td>
<td>4000 ppm in 48 hours</td>
</tr>
<tr>
<td></td>
<td>2000 ppm next 24 hours</td>
</tr>
<tr>
<td></td>
<td>1000 ppm after 72 hours</td>
</tr>
<tr>
<td>RH</td>
<td>98% to 92% in 48 hours</td>
</tr>
</tbody>
</table>

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
20°C in 72 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