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CASING IN MUSHROOM BEDS - A REVIEW

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ABSTRACT

During mushroom cultivation, compost colonized with mushroom mycelium is covered with a 3-5 cm thick casing layer which is nutritionally deficient medium to initiate the development of sporophores. Casing acts as a platform for initiation of uniform fruitification and also provides anchorage and essential reserves for developing sporophores of mushrooms. Peat moss is mainly used as casing in most of the countries but, in India, FYM + loam soil is used as casing for the production of *Agaricus bisporus*. Physical and chemical properties of casing like water holding capacity, porosity, bulk density, pH and electrical conductivity play very important role during mushroom production. In addition to physical and chemical parameters, microbiological parameters of the casing are also important for the proper fruiting of mushroom. Additionally, if already spawn run compost is added to casing, it increases the yield.

In the commercial cultivation of mushrooms, compost colonized with mushroom mycelium is covered with a 3-5 cm thick casing layer to initiate the development of sporophores (Eicker and Van Greuning, 1989). The history of edible mushroom cultivation dates back to many centuries and the use of casing to induce the development of sporophores has been practised since 17th century (Caron, 1987). The main function of casing layer is the production of mushrooms in quantity (Flegg, 1956). Casing layer, which is nutritionally deficient medium brings about important morphological changes from transition of vegetative growth to fruiting stage i.e. sporophore formation. Casing is generally done to make a surface where uniform fruitification can take place and also to provide anchorage and essential reserves for developing sporophores of mushrooms (Shandilya, 2002). In most of the mushroom growing countries, peat/moss alone or in combinations with other materials is used for casing. But, in India, moss/peat moss is not available or restricted to some reserves in Kashmir valley and cannot be used on a commercial scale (Gupta, 1997). Therefore, the need was felt to work out a suitable substitute to peat moss. Different workers in India have studied the suitability of various materials as a casing substrate for the production of *Agaricus bisporus* (Mantel, 1973; Nair, 1977; Shandilya *et al.*, 1976; Hayes and Shandilya, 1977; Sehgal, 1979; Shandilya and Agarwala, 1983; Jain *et al.*, 1983; Vijay *et al.*, 1987; Tripathi *et al.*, 1993; Singh *et al.*, 1993; Khanna *et al.*, 1995; Shandilya, 2000a). However, the combination of farmyard manure (FYM) + loam soil (1:1, v/v) is being used as a standard casing material in India for the cultivation of *A. bisporus*. Processed municipal waste has also been tested as a casing substrate for *A. bisporus* by Jarial and Shandilya (2002a). Though, there are no reports available in the literature regarding the use of municipal wastes as a casing substrate before it, but Delmas and Laborde (1972) have used municipal compost for growing mushrooms. The information available regarding the various aspects of different materials as casing substrate is being reviewed here.

Casing materials

In the ancient times, the selection of casing materials used to depend upon the availability of different materials in a particular locality. Earlier, loam soil was used in England (Robinson, 1870) while, the lime stone from core wall was used by French growers (La Chaumbe, 1882). Lambert and Humfeld

Table 1. Commonly used casing materials in different countries

Country	Type of casing used
Denmark	Peat/chalk
France	Local sub-soil mixture
Holland	Black peat/moss peat/moss/sand
India	Farmyard manure + loam soil/$CaCO_3$; Farmyard manure + 3 years old spent compost/$CaCO_3$
Polland	Peat/Chalk
Korea	Clay loam sub soil/hydrated lime
Russia	Peat/chalk
Taiwan	Clay loam sub soil/chalk
U.K.	Moss peat/chalk
U.S.A.	Local sub soil, peat/chalk

Chang and Hayes (1978), Vedder (1978), Shandilya and Agarwala (1983).

(1939) reported that clay soil rich in humus was better for casing than sandy soil. However, for the last fifty years, the mushroom growers in U.K. are using sphagnum peat/Irish peat for casing. In India, top soil from cultivated field was tried initially as casing material while, later on clay, loam, sand and mixture of ash, stone, gravel and spent compost were tried at Solan (HP) (Seth, 1978). In other countries different materials are being used for casing (Table 1).

Various materials have been tested as a casing substrate throughout the world by different workers. Bewley compared the suitability of variety of materials as casing and found an increased yield of mushrooms by the addition of peat to the soil (Bewley, 1938). However, the use of moss and mixture of garden soil (loam soil) and peat has been reported by Bels-Koning (1950). Stoller (1952) found that non-fibrous peat gave better yield. Edwards and Flegg (1954) used vermiculite, sand, peat and local soil successfully and as a result, the sphagnum peat became a standard casing substrate in England. Rao and Block (1962) reported that a mixture of sand and peat in equal volumes produced better and good quality fruit bodies. However, Visscher (1973) compared the hygromull, styromull and polyethers as replacement for peat dust and found hygromull (urea formaldehyde foam) at 25 per cent concentration to enhance the mushroom yield. Aaron (1975) compared pine bark and peat (1:1) and obtained comparable yield in these media, but also proposed the chances of phytotoxicity of soil with bark. Vijay *et al.* (1987) studied the suitability of sphagnum moss growing abundantly in hill areas and found that a mixture of sphagnum moss + loam soil (2:1, v/v) gave best results. Eicker and Van-Greuning (1989) reported the best yields of mushrooms by using the topogenous peat as a casing material. However, Ivanovic (1993) obtained best results with regards to mushroom yield with mixture of peat + river mud (2:1, v/v). Szudyga *et al.* (1999) reported greater mushroom weight with the strongly decomposed peat as casing as compared to weakly decomposed peat.

Sinden (1972) and Mantel (1973) have recommended the use of spent compost for the purpose of casing. Mantel (1973) developed a casing material based on one year old spent compost, sand and soil in the ratio of 4:1:1 (v/v/v) after treating it with steam, nemagon or formalin. However, Hayes *et al.* (1976) and Shandilya (1978) reported a number of irregularities during the crop production leading to poor yield and appearance of crop in patches with the use of one year old spent compost. Nair (1977) and Stoller (1979) also proposed the reuse of spent compost as a casing material. Garcha and Sekhon (1981) recommended use of paper mulch and two years old spent compost, giving highest yield in Punjab conditions. Shandilya and Agarwala (1983) suggested an increase in the mushroom yield with the ageing of spent compost. Grabbe (1987) has also emphasized the utilization of spent compost for casing soil mixtures. Tripathi *et al.* (1993) obtained the highest mushroom yield with the combination of spent compost + 8 per cent calcium carbonate. Szmidt and Conway (1995) also proposed that spent mushroom substrate could be recomposted after cropping of mushrooms to produce peat like material and could be modified by leaching to be used as casing material provided it was free of potentially harmful organisms and met the required physical and chemical attributes of casing. Sharma *et al.* (1999) assessed the chelated spent mushroom substrate as casing material for the production of *A. bisporus* and found that casing prepared from spent mushroom substrates treated with EDTA and blended with peat was most productive and had the potential to be used as a casing material for mushroom production. Brosius (1981) recommended that use of weathered spent compost for casing was a practically economical material if handled properly.

Hayes and Shandilya (1977) recommended the use of one and a half year old cowdung (farmyard manure) + loam soil (1:1, v/v) as standard casing for the mushroom cultivation to improve the yield of *A. bisporus*. Singh (1978) also found old cattle manure to give good results. Sehgal (1979) found farmyard manure as basic substrate for casing to increase mushroom yield. Shandilya (1982) observed that a mixture of farmyard manure and fermented tree bark was more suitable for obtaining maximum number of pin heads and mushroom yield. Shandilya and Agarwala (1983) recommended the use of combination of farmyard manure + three years old spent compost (1:1, v/v) as casing substrate. However, Singh *et al.* (1985) have recommended the use of farmyard manure + apple garden soil for casing the *A. bisporus* beds. Saini and Prashar (1992) reported the higher yield of mushrooms in a casing medium consisting of farmyard manure + waste compost + soil (2:1:1 v/v/v). Gupta and Dhar (1993) found that old cattle manure, farmyard manure and a combination of farmyard manure + spent compost + loam soil (1:1:1, v/v/v) were at par so far as yield was concerned. Singh *et al.* (1993) obtained highest yield of white button mushroom in the casing combination of rice husk + farmyard manure + soil (2:1:1, v/v/v). Singh *et al.* (2000) obtained the maximum mushroom yield in the casing combination of farmyard manure + spent compost (2:1, v/v) followed by casing mixture of farmyard manure + garden soil (3:1, v/v). However, Shandilya (2002) reported maximum yield of *A. bisporus* in a casing combination of farmyard manure + vermicompost leached + three years old spent compost in the already spawn run compost. Jarial and Shandilya (2002a and b) obtained better yield of *A. bisporus* with a casing combination of municipal waste fed to earthworms – leached + vermicompost – leached + farmyard manure (1:2:2 v/v/v) in terms of quality and quantity as compared to conventionally used casing i.e. FYM + loam soil (1:1 v/v).

Yields comparable to peat were obtained with paper and pulp mill by-product (PPMB) (Hayes *et al.*, 1978; Yeo and Hayes, 1979 and Cresswell and Hayes, 1979). Paper pulp product left to weather for two years (Eicker and Van-Greuning, 1989), another paper product called ORFA fibre® (Wuest and Muthersbaugh, 1990), crumbled recycled paper + 20 per cent peat moss and calcium carbonate named as "Champyros"® stored up to four months (Lelley *et al.*, 1995) and recycled paper commercially available as RPC+® (Morris and Wuest, 1995) have been reported to yield comparable to peat moss and result in the mushrooms of better quality. Wuest and Bayer (1996) reported that RPC + and Copogro resulted in good quality mushrooms suitable for fresh market. A defirated pine wood and bark showed good potential for being developed as a casing material (Nair and Bradley, 1981). Dergham *et al.* (1991) recommended the use of waste paper for casing due to its beneficial water holding capacity, neutral pH and good gaseous exchange as well as yielding mushroom fruit bodies free of surface particles and contamination.

Many other materials like sisal waste and groundnut husk (Hayes (1978), coir pith by-product of coconut industry (Border, 1993), decomposed coir pith either alone or in combination with farmyard manure and spent compost (Gupta, 1996 and 1997), forty per cent earthworms casting + 80 per cent inert material (Grappelli *et al.*, 1987), organic soils (Seker and Karakaplan, 1994), fresh fargo silty clay soil (Kurtzman Jr. and Elliot, 1995) and black soil + yellow soil + sand (Fiore and Albarracin, 1998) have also been tested by various workers to be used as casing substrate for mushrooms.

Khanna *et al.* (1995) reported better mushroom yield with burnt rice husks or biogas slurry when mixed with clay or loam soil or farmyard manure. Kurtzman Jr. (1995) suggested ground lime to be good casing material which supported mushroom yield approximately equal to yields obtained with peat moss lime stone casing. Noble and Gaze (1995) found best results in terms of yield with recycled granulated rock wool, a waste product from glasshouse industry. However, Nobel and Dobrovin-Pennington (2001) suggested the testing of composted bark fines as casing on commercial mushroom farms.

Physical and chemical properties of casing soil

It is a well established fact that physical and chemical properties of casing like water holding capacity, porosity, bulk density, pH and electrical conductivity play very important role during mushroom production (Bels Koning, 1950; Kleermaeker, 1953; Allison and Kneebone, 1963; Flegg, 1965; Edwards, 1973; Ganney and Richardson, 1974; Rainey *et al.*, 1986). Around 71.79 per cent variation in the mushroom yield has been reported due to water holding capacity, porosity, particle density, bulk density, pH and electrical conductivity (Jarial and Shandilya, 2004).

i) Water holding capacity: Heavy soils have been reported to perform better compared to light sandy soils when used as casing, as far as the yield of button mushroom is concerned (Lambert, 1939 and Lambert and Humfeld, 1939). Chapius and Courtieu (1950) demonstrated that a fine soil caused anaerobic conditions in the compost and reduced the yield. Bels-Koning (1950) concluded that the yield of mushrooms was better with higher water holding capacity of casing. Edwards and Flegg (1952) expressed the water requirement of casing in terms of soil moisture tension and obtained better yields when the casing mixture was kept between the range of PF 2.7-3.9. When the moisture tension was above PF 4.0 the mushroom yield was practically nil. They suggested that in case of mushroom also there was a point analogous to plant wilting point above which the sporophore formation did not occur. Flegg (1953) and Atkins (1974) stated that a good casing medium should have high water holding capacity and adequate moisture, as the mushroom contains more than ninety per cent water which is supplied by casing layer. Casing soil contributes water to the fruit bodies and with the increase in water content of casing, the size and yield of fruit bodies increase significantly (Flegg, 1965 and 1975). Delay in the watering at the time of casing alters the mushroom size which in turn influences the mushroom quality (Murphy, 1976). Tschierpe (1976) reported that imbalance of moisture availability between the compost and casing layer resulted in premature opening of fruit bodies and reduction in fruit body size, clearly indicating the significance of watering during crop production. The amount of water extracted from the casing soil during the fruit body growth was proportional to the weight of fruit bodies and the fruit bodies harvested from watered culture had less dry matter content as compared to unwatered cultures (Kalberer, 1990). However, an entirely different view was adopted by Gerrits (1968) who stated that the casing water content had nothing to do with the increase in the water content of mushrooms and the water needed by fruit body was supplied by the substrate-compost.

High water holding capacity has been reported to be an important character of a good casing material during mushroom production (Gierszynski, 1974; Hayes, 1981 and Kalberer, 1983). Flegg (1959) mentioned that in order to counteract the loss of moisture flow in casing due to drying out quickly, a higher water holding capacity was necessary. Singh *et al.* (1992) suggested the increase in mushroom yield in a combination of spent compost and garden soil over the other casing media tested due to the high water holding capacity of this casing combination. A better mushroom yield has been reported in the casing materials having high water holding capacity ranging between 95-191 per cent (Singh *et al.* (2000). A positive correlation between water holding capacity and mushroom yield indicating an increase of 1.93 units of mushroom yield with every unit increase in water holding capacity has been reported by Jarial and Shandilya (2004).

ii) Pore space: The importance of pore space in casing layer was emphasized by Edwards and Flegg (1953) for the first time. An adverse effect on the yield was observed, when the soil disintegrated upon watering forming a crust over the surface of beds (Lambert and Humfeld, 1939) and it was postulated that the casing must remain porous so that aerobic respiration could be maintained in the compost (Bels-Koning, 1950). It has been observed that a casing soil made up of small aggregates (<1/4 inch) resulted in a much lower yield than the same soil when used on the beds as larger (1/4 inch to 3/4 inch) aggregates (Edwards, 1952). With fewer pore spaces occupied by the mycelium, water holding capacity might increase resulting in a tendency for larger mushroom (Reeve *et al.*, 1959 and Schroeder and Schisler, 1981)). Porosity is necessary to maintain the gas exchange between the compost surface and the growing room air (Visscher, 1975) and casing materials retain water primarily within their micropores (Rainey *et al.*, 1986). Porosity has been reported to be more important than water holding capacity (Kurtzman Jr., 1995 & 1996). Singh *et al.* (2000) while studying the impact of physico-chemical properties of casing on yield of *A. bisporus* suggested that with higher percentage of porosity there was increase in mushroom yield. A positive correlation between porosity and mushroom yield has also been suggested by Jarial and Shandilya (2004) who found that a unit increase in porosity of various casing media caused 9.09 units increase in mushroom yield.

iii) Bulk density and particle density: It has been found that casing soil with an apparent density of 0.75-0.81 g ml^{-1} and true density between 1.5-1.6 g ml^{-1} can hold sufficient water and also have enough porosity for good growth of mushroom (Sharma, 1997). Good mushroom yields have been recorded in the casing materials having bulk densities ranging between 0.64-0.78 g ml^{-1} (Singh *et al.*, 2000). Particle and bulk densities of various casing materials have been found to be positively correlated with mushroom yield indicating 331.28 and 468.76 units increase in mushroom yield with every unit increase in particle and bulk densities of different casing media, respectively (Jarial and Shandilya, 2004).

iv) pH: Various workers have suggested different ranges of casing pH for good mushroom yield. These include 5.5-8.0 with a optimum of 7.6 (Lambert, 1933), 7.2-8.2 (Courtieu, 1949), 8.0-9.0 (Bels-Koning, 1950), 8.0 to 8.2 (Kleermaeker, 1953), 7.5 (Park *et al.*, 1971), 6.4 to 7.4 (Jain *et al.*, 1983) and 8.0 (Ivanovic, 1993). Pizer (1950) while investigating casing soils found that cropping was improved with the addition of $CaCO_3$. whereas, decrease in yields due to low pH was reported by Allison and Kneebone (1963). Singh *et al.* (2000) obtained good yields of mushrooms in the casing media having pH ranging between 6.8-7.16. A pH range between 7.0-8.0 has also been reported by several workers (Hawker, 1966; Atkins, 1972; Edwards, 1978; Shandilya, 1982). pH has been reported to be correlated negatively with the mushroom yield by Jarial and Shandilya (2004). They fitted regression line to these variables which indicated that every unit increase in pH resulted in decrease of 367.82 units in yield of mushrooms.

v) Electrical conductivity: Besides the pH of the casing, salt concentration of casing layer is another important factor which affects the mushroom yield. Cation exchange capacity of a material may determine its suitability as a casing medium (Stoller, 1952). Addition of soluble salts to the casing layer affects the mushroom fruiting and these effects are related to the electrical conductivity irrespective of the salt used. Also the high levels of soluble salts in the casing are detrimental to fruit body formation (Flegg, 1961). With the progression of crop ions/soluble salts accumulate in the casing layer which ultimately affect the electrical conductivity of the casing soil (Yeo and Hayes, 1979; Shandilya and Hayes, 1987 and Shandilya, 1989). However, according to Hayes (1981) a good casing should have low availability of soluble inorganic ions. Shandilya and Agarwala (1983) obtained higher yields of *A. bisporus* with the ageing of casing and salt concentration was one of the important chemical factors responsible for increased mushroom yield. According to Shandilya (1989) calcium, potassium, sodium, chloride and sulphate ions show increase in their levels in casing layer with the crop progression and are the main ions responsible for increase in the salinity of casing media. A delay in the initiation of fruit bodies and decrease in the yield has been reported by addition of cobalt chloride to casing (Kurtzman Jr., 1995). However, according to Singh *et al.* (2000) electrical conductivity plays an important role in the production of *A. bisporus*, but it is not the sole controlling factor. Shandilya and Hayes (1987) reported a decrease in the number of pin heads with an increase in the conductivity. De Gier (2000) also suggested that addition of salts led to increase in the electrical conductivity value of the casing soil making it more difficult for mushroom to extract water from the soil. He also stated that this resulted in a firm mushroom with a high dry matter content and whiter colour. He reported that an electrical conductivity value of more than 7 to 9 mho had a negative influence on the quality and especially quantity of mushrooms. Jarial and Shandilya (2004) also reported a negative correlation between electrical conductivity and mushroom yield indicating a decrease of 0.02 units in mushroom yield with every unit increase in electrical conductivity.

Microbiological properties

In addition to physical and chemical parameters of casing, bacterial microflora is also essential for the commercial fruiting of mushroom. No fruitification can develop if sterile casing is used (Eger, 1961). Urayama (1961) obtained increased mycelial density and fruit body production by spraying the casing material with a suspension of *Bacillus psilocybe*. Since Eger's work in the early 1960's, the "key" to basidiome initiation is now widely accepted to see the presence of bacteria normally found in soil (Eger, 1963). She found that sporophores were not initiated when casing was sterilized, suggesting that the stimulus was associated with the presence of microorganisms. Hayes *et al.* (1969) isolated bacteria from casing soils which when returned to sterile casing layer over axenically grown cultures of *A. bisporus* in compost, induced fruiting. In addition, these bacteria were identified as being a range of strains related to *Pseudomonas putida*. Park and Agnihotri (1969) also found that bacteria could trigger sporophore formation. An increase in mycelial density, earlier initiation of fruiting and higher total yield was recorded by Curto and Favelli (1972) after spraying the spores of range of bacteria and yeasts on spawned compost before casing and after one week of casing.

The number of actinomycetes found in the casing soils infested with *Diehliomyces microsporus* was less than 0.5 per cent of that found in healthy soils indicating that the species of actinomycetes in the healthy soil were antagonistic to the pathogen (Lin, 1974). Similarly, Shandilya (1982) suggested that actinomycetes isolated from casing material had an inhibitory effect on the bacterial population. However, Jarial (2002) suggested that the population of actinomycetes species *viz.*, *Brevibacterium membrellneri*, *Exiguobacterium acetylicum.*, *Dienococcus erythromyxa*, *Gordona rubropertinctus*, *Micrococcus lylae* GC sub group A and *M. luteus* GC subgroup C isolated from different casing media (Jarial and Shandilya, 2002 c) was positively and significantly correlated with number of pin heads on +14 and +21 days after casing coinciding with the pinning of *A. bisporus*.

According to Wood (1976) the mushroom mycelium produces self inhibitory compounds which are removed by the bacteria (*Pseudomonas putida*) to below a threshold level, permitting the fruit body initiation. The microorganisms in the casing layer play an important role in triggering the fruit body initiation and influencing its development (Visscher, 1978 and Hayes, 1981). According to Shandilya and Agarwala (1983), the bacterial isolates found in farmyard manure used for casing in India are beneficial for pinning. Higher bacterial population was found between 14 to 21 days after casing by Shandilya (1987), which coincided with the pinning of *A. bisporus*. Addition of spawned compost to the casing layer results in significant increase in the bacterial population in the casing, the number of basidiocarps formed and the number of fruit bodies harvested as compared to un-amended casing suggesting that higher the bacterial population in the casing, higher is the yield (Reddy and Patrick, 1990). The microflora present in the casing soils play an important role in the mushroom fruit body initiation and development (Vijay and Gupta, 1992 and Fermor *et al.*, 2000). Due to large increases in the total bacterial count during the first 14 days of culture (until the first crop flush) which further tends to stabilize or fall off, it has been proposed that fluorescent *Pseudomonas* isolated from the peat based casing material and found to adhere to hyphal wall of *A. bisporus* could remove the fungal deposits of crystalline calcium oxalate from the hyphal walls of *A. bisporus* which is a pre-requisite for fruitification (Miller *et al.*, 1995).

Colauto and Eira (1998) evaluated the quantity of bacterial community in the *A. bisporus* and reported that during the production phase, the populations of total bacteria and *Pseudomonas* spp. exceed 10^7 and 10^6 cfu/g dried casing, respectively. Various bacterial species including species of *Pseudomonas, Flavobacterium, Acaligenes, Serratia* and *Bacillus* have been isolated from casing (Shandilya, 2000b and Jarial and Shandilya, 2002c). Jarial (2002) found a positive and significant correlation between the population of *Bacillus megaterium* and *Pseudomonas* sp. isolated from various casing media (Jarial and Shandilya, 2002 c) and number of pin heads on +14 and +21 days after casing which are the peak days of mushroom production.

Species of *Corethropsis, Geotrichum, Haplotrichum* (Williams *et al.*, 1940), *Aspergillus, Penicillium, Trichoderma, Geotrichum, Fusarium* and *Chrysonilia* (Labuschagne *et al.*, 1995) have been isolated from the casing soil. But the role of these fungi on production of mushrooms is yet to be studied. Jarial and Shandilya (2002c) also isolated seven species of fungi *viz.*, *Aspergillus flavus, A. fumigatus, A. wentii, Penicillium brevicompactum, Cladosporium cladosporoides, Pythium* sp. and *Mycelia sterilia* from different casing materials. Jarial (2002) found that the population of above mentioned fungal species was maximum on the day of casing which declined upto +21 days after casing and completely vanished after +28 days of casing. He indicated a possibility of an inhibitory effect of bacteria and actinomycetes on fungal population.

Spawned casing

MacCanna and Flanagan in late 1960's discovered the spawned casing technique (MacCanna and Flanagan, 1972). Already spawn run compost when added to casing has been reported to reduce the time taken for pin head formation and increase the yield (Shandilya *et al.*, 1976). Casing added with already spawn run compost is an improved agronomic practice which has been reported to give increased mycelial growth (Visscher, 1989) and mushroom yield (MacCanna, 1983; Hermans and Visscher, 1989; Vedder, 1989; Visscher, 1989; Gupta *et al.*, 1989 and Gupta and Dhar, 1993). It is a simple technique for improving the quality and crop management in mushroom production (Mac Canna, 1983; Romanenes *et al.*, 1989 and Gupta and Dhar, 1993). This technique has been reported to advance the harvest by 5 days (Hermans and Visscher, 1989). De Gier (2000) also stated that casing added with already spawn run compost had the specific influence on the quality and quantity of mushrooms. Addition of increased quantity (30 g/3 kg compost bag) of grain spawn as well as spawn run compost has been reported to take minimum time for pin-head formation and exhibit maximum number as well as yield of white button mushroom as compared to lesser quantity (10 and 20 g/3 kg compost bag) of grain spawn and spawn run compost added to casing (Jarial, 2002 and Jarial and Shandilya, 2002d).

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