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Physico-chemical characterization of different casing soil combinations for button mushroom and their evaluation for crop production

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ABSTRACT

Casing soil is one of the pre-requisites for the cultivation of button mushroom (*Agaricus bisporus*). Covering spawn run compost with casing soil helps to get primordia, transportation of nutrition from compost to fruit body, acts as water reservoir, prevents mushroom mycelium from water loss and physically support growing fruit bodies. Thus, a good casing soil helps to get a good crop of button mushroom by the farmers. In western countries, normally sphagnum peat is in common use as casing soil in button mushroom farming. In the present investigation, we have analyzed a total of six casing soil raw materials i.e. 2-year-old farm yard manure (FYM), 2-year-old spent mushroom substrate (SMS), loam soil, burnt rice husk (BRH), paddy straw digest and decomposed coir pith (CP) along with a control (casing used by ICAR-DMR, Solan). A total of 25 combinations of the raw material were developed based on the physico-chemical properties of different casing soil raw materials to reach to the near perfect physico-chemical properties of the peat-based casing soil. After the initial yield trials, a total of eight combinations were selected for further evaluation. The eight casing soil combinations were evaluated for yield and quality of button mushroom on a larger scale. The results indicated that coir pith is one of the most suitable material for casing soil. Although coir pith having very good water holding capacity but very low bulk density, allows frequent water drainage in to the substrate which is not desirable for the casing soil. Thus, combining coir pith along with some other material, which can increase the bulk density and not affecting the water holding capacity can be a better casing soil. In the present study also, coir pith along with Lime powder, FYM, loam soil and SMS proved to be better casing material than other tested combinations.

Keywords: Mushrooms, *Agaricus bisporus*, casing soil, physico-chemical properties, yield evaluation

White button mushroom (*Agaricus bisporus*) is one of the most cultivated and consumed mushroom species throughout the world. At present world production is increased to 43 million tons in 2018-19 (Singh *et al.*, 2020) and may surpass 50 MT by 2025. In early days of mushroom cultivation, button mushroom was the most dominant variety but over time, contribution of other mushrooms species is increased in the world mushroom production (Singh *et al.,* 2018). Mainly five mushroom genera viz., *Lentinula* (26%), *Pleurotus* (21%), *Auricularia* (21%), *Agaricus* (11%), and *Flammulina* (7%) accounted for 90% of the global mushroom production (Royse, 2018, Bijla and Sharma, 2023). Still in European, Australian and American continents, white button mushroom is the majorly grown variety (~90-95%) on commercial level. The decline in button mushroom contribution in world mushroom production is due to increase in cultivation of other mushroom species in Asian countries like in China, Japan, Korea, etc.

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In the cultivation of button mushrooms (*Agaricus bisporus*), applying a layer of specially prepared 'soil' known as casing over the spawn run compost is crucial for the initiation and development of pin heads (Flegg and Wood, 1985; Visscher, 1988). The casing layer serves to protect the mushroom mycelium from drying out, provides moisture to the growing fruit bodies, aids in the transfer of nutrients from the compost to the developing fruit bodies, and maintains an appropriate microbiome conducive to mushroom growth.

Earlier, a 1-inch (2.5 cm) layer of clay or clay-loam was utilized as casing soil (Flegg and Wood, 1985; Visscher 1988), but later, peat moss became widely adopted due to its ability to produce higher and more consistent mushroom yields (Edwards and Flegg, 1953, Bels-Koning, 1950), due to its greater water retention and improved physical structure (Puustjarvi and Robertson, 1976; Gallagher, 1976). In most European countries, a mix of sphagnum peat and lime with a thickness of 5 cm has been the standard for casing (Visscher, 1988; Noble and Gaze, 1995). Various combinations have been utilized for casing materials, including black wet-dug peat (Vedder, 1978), dried milled blond sphagnum peat, milled brown peats, and acadian moss peat, among others (Noble and Gaze, 1995; Nair and Bradley, 1981; Huerta *et al.*, 2001).

Peat supply is decreasing and prices are rising as environmental issues make it more difficult to get peat for horticultural use (Pryce, 1991). Much research has been conducted in an effort to find sustainable and renewable alternative casing materials such as Bark (Allen, 1976; Rainey *et al.*, 1987), spent mushroom substrate (SMS) (Nair and Bradley, 1981; Szmidt and Conway, 1995; Barry *et al.*, 2008), coconut fiber (Labuschagne *et al.*, 1995; van Jaarsveld and Korsten, 2008), paper by-products (Hayes *et al.*, 1978; Dergham *et al.*, 1991), green waste compost (GWC) (Sturgeon, 2007; Goldwater, 2021), processed corn stalks (Peters, 2021), and fermented grass fibers (van Boekel and van der Horst, 2020; Taparia *et al.*, 2021). None of these materials have yielded comparable mushroom yields and quality when used as full wet-dug peat replacements, despite the fact that some have shown encouraging mushroom cropping results when used as partial peat substitutes (Peters, 2021; Taparia *et al.*, 2021).

In India due to unavailability of peat, different raw material has been tried as casing material with sporadic success such as decomposed farmyard manure, loam soil, decomposed old spent compost, forest soil, burnt rice husk, loam soil, coconut coir pith, leached vermicompost, press mud, etc. in different combinations (Mantel, 1973; Shandilya and Agarwal, 1983; Saini and Prashar, 1993; Raina *et al.*, 2002; Suman and Paliyal, 2004; Jariyal and Shandilya, 2005; Bhatt *et al.*, 2006; Singh *et al.*, 2007; Ram and Holker, 2009; Ratnoo and Doshi, 2012; Sharma *et al.*, 2013). In India, still the standard casing material formulae is lacking and a standard casing formula needs to be studied for consistent mushroom yields.

It is well known that some physical and chemical properties, such as pH (7.4-7.6), buffering capacity (~0.2), water holding capacity (75-80%), water release capacity (70-80%), electrical conductivity (<500μS/cm), total dissolved solids (<1000 ppm), bulk density (0.35g/cm3), pore space (80-85%), physical texture (light and open textured), C:N Ratio (50:1 to 70:1), nitrogen (<1.20%), etc can affect both the vegetative and reproductive growth of mushrooms. In fact, for an adequate profitability in commercial cultivation, the casing material must fulfill the above conditions (Hayes, 1981; Stamets and Chilton, 1983a; Flegg and Wood, 1985; Rainey *et al.*, 1987; Visscher, 1988).

In order to search for a standard casing soil formula with near to standard physico-chemical parameters, we studied parameters of different casing soil raw material and prepared combinations of different raw materials so that parameters can be adjusted to near standard casing soil for button mushroom. Casing soil formulations with near to standard parameters were selected for yield trials.

MATERIALS AND METHODS

Casing material

A total of six raw materials were used as casing material i.e. 2-year-old farm yard manure (FYM), 2-year-old spent mushroom substrate (SMS), loam soil, burnt rice husk (BRH), paddy straw digest and decomposed coir pith (CP) with casing soil mixture used by ICAR-DMR, Solan (80% coco-peat + 20% FYM) as control. All the raw materials were analyzed for their physical and chemical properties i.e pH, electrical conductivity (EC), water holding capacity, bulk density (BD), particle density (PD), porosity, nitrogen, total organic carbon (TOC) and C:N ratio. On the basis of the analysis, a total of 25 combinations were developed, which showed the nearest parameters of sphagnum peat-based casing soil. Calcium carbonate was used to balance the pH and physical structure of the casing soil. All the casing soil raw material were leached properly to bring down the electrical conductivity to less than 500 µS/cm. The combinations were used in button mushroom cultivation trials for yield and quality evaluation. A total of eight selected combinations were further evaluated at a larger scale.

Mushroom cropping experiments

Button mushroom cropping experiments were conducted at ICAR-Directorate of Mushroom Research farm. Cultivation experiment was conducted on wheat straw-based compost in bag system of cultivation. In the first experiment, all the 25 treatments were replicated 5 times with 3 bags per replications. In the second experiment, 8 selected treatments were replicated 5 times with 10 bags of 10 kg compost per bag per replication. Growing room air and compost temperatures, air flow, relative humidity and carbon dioxide concentration were continuously monitored and regulated. The strain used for experiment was NBS-5 strain of button mushroom (developed by ICAR-Directorate of Mushroom Research).

Wetted and steam pasteurized casing materials was applied on the spawn run bags at a height of 1.5 inches and were watered at 250 ml/bag twice daily till pin head formation. Watering is reduced to minimum to keep casing wet after pinhead formation. Further watering was applied after the first and second flushes of mushrooms were harvested. Cropping room temperature, relative humidity and carbon dioxide concentration were maintained as per the standard procedure. Mushrooms were picked and weighed with the veils closed.

Analysis of casing raw materials

A. Physical Properties

Physical properties such as pH, electrical conductivity (EC), total dissolved solids (TDS), water holding capacity, bulk density (BD), particle density (PD), and porosity was analyzed for each casing soil raw material. EC, pH and TDS were analyzed using Eutech (Singapore) pH/conductivity/TDS meter. An amount of 10 g of dried casing material was taken and 20 ml distilled water was added to it. The suspension was kept stirring for 30 minutes and EC and pH was read using respective electrode (Rhoades, 1996).

To estimate water holding capacity of casing material modified funnel method provided by Bernard (1963) was used. The soil samples were taken in a funnel with a filter paper placed at the bottom and mounted on a graduated cylinder. Exactly 100 ml of water was added to each sample and left to drain for 72 hours. The amount of water collected in the measuring cylinder was recorded to determine WHC.

WHC = (a-b) (a is the amount of water added and b is the amount of water collected in the flask after 72 hrs)

Bulk density of the casing soil raw materials was estimated using direct method given by Han *et al.* (2016). The method included measurements of the mass and volume of oven-dried casing soil samples. The dry casing soil bulk density was calculated using the formula:

Bulk density (ρb) = Ms/Vs (ρb is in g cm^{-3}, Ms is the weight of the dry soil sample in g, and Vs is the volume of the dry soil sample in cm^3.

Particle density of casing materials was measured using volumetric flask method (Flint and Flint, 2002). The samples were weighed (20 g) and transferred to a volumetric flask. Then, 15 ml of ethanol (with 0.789 g cm^{-3} density and 99.6% purity) was added to the volumetric flask. The set (soil + volumetric flask + alcohol) was manually shaken for 1 minute so that alcohol could penetrate the soil capillaries and was kept at rest for 15 minutes. After this period, a burette containing alcohol (50 ml) was used to complete the volume up to 50 ml, and the volume of alcohol used was noted. Particle density was calculated according to Equation

$$\text{Particle density} = \frac{Ma}{Vt - Vu}$$

Ma: is the mass of the dry soil, Vt: is the volume of the volumetric flask (ml), Vu: is the alcohol volume used to complete the 50 ml of the volumetric flask containing the soil sample

Soil porosity is defined as the volumetric percentage of total pore space in soil. These pore spaces are occupied by air and water. Porosity was calculated as per the formula given below (Jain and Shrivastava, 2023)

$$\%\ \text{Solid space} = \frac{\text{Bulk density}}{\text{Particle density}} \times 100$$

$$\text{Porosity}\ \% = 100 - \%\ \text{solid space}$$

B. Chemical properties

Chemical properties such as nitrogen, total organic carbon (TOC) and C:N ratio was analyzed for each casing soil raw material. Soil organic carbon was estimated following Walkley and Black (1934) wet digestion method. Nitrogen was estimated using Micro Kjeldalh method (Jackson, 1973).

Statistical analysis

Data were analyzed by one-factor ANOVA using OPSTAT and the statistical significance of differences between sample means determined by conducting Tukey's HSD test. The results are compared with critical difference at 5% significance.

RESULTS

A total of five raw materials were taken as casing raw material i.e. 2-year-old farm yard manure (FYM), 2-year-old spent mushroom substrate (SMS), loam soil, burnt rice husk (BRH), Paddy straw digest (PSD) and decomposed coir pith (CP) along with casing soil mixture used by at ICAR-DMR, Solan (80% coco-peat + 20% FYM) as control. All the raw materials were analyzed for their physical and chemical properties i.e pH, electrical conductivity (EC), water holding capacity (WHC), bulk density (BD), particle density (PD), porosity, nitrogen, total organic carbon (TOC) and C:N ratio (Table 1 and 2; Fig 1 and 2). Among all the ingredients evaluated decomposed coco-peat, FYM and soil showed the physical parameters near to the sphagnum peat-based casing soil but still have variations. Burnt rice husk and SMS

Table 1. Physical properties of different casing raw material

	pH	EC (µs/cm)	TDS (µg/l)	BD (g/cm³)	PD (g/cm³)	WHC (%)	Porosity (%)
Coir pith	6.57	1.26	0.79	0.11	0.53	75	79
Burnt rice husk	9.28	5.42	3.39	0.48	1.91	49	74
Soil	6.77	0.52	0.33	1.20	2.41	39	50
Farm yard manure	7.13	1.52	0.95	0.45	1.70	58	73
Spent mushroom substrate	7.62	5.41	3.38	0.17	0.97	38	82
Paddy straw digest	7.10	3.02	1.51	0.41	3.30	70	54
Standard for casing soil	~7-8	<500	<1000	0.30-0.40	1-1.2	75-80	80-85
CD (0.05)	0.35	0.27	0.051	0.08	0.23	5.07	3.77

Table 2. Chemical properties of different casing raw material

	Nitrogen (%)	Oxidizable Carbon (%)	Total Organic Carbon (%)	C/N ratio
Coir Pith	0.56	38.18	49.25	87.95
Burnt rice husk	0.14	6.54	8.44	60.26
Soil	0.19	2.61	3.35	18.06
Farm yard manure	0.61	24.00	36.96	51.03
Spent mushroom substrate	2.13	25.61	33.03	15.51
Paddy straw digest	0.88	28.40	36.70	41.70
Standard for casing soil	<1.20	~40-50	~51-64	~50-70
CD (0.05)	0.17	3.12	4.12	6.24

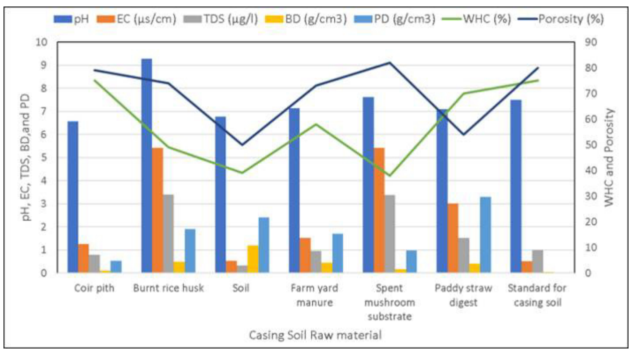

Fig. 1. Physical properties of different casing raw material in comparison with reported standard parameters

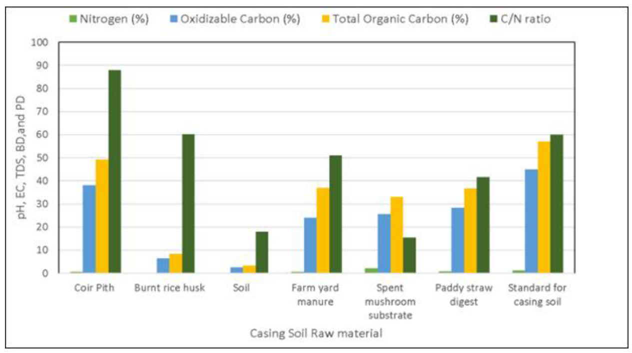

Fig. 2. Chemical properties of different casing raw material in comparison with reported standard parameters

although showed good water holding capacity and porosity but had maximum pH, EC and TDS amongst all the ingredients and were leached down to bring those parameters in range.

The chemical parameters i.e. nitrogen, oxidizable carbon, total organic carbon and C:N ratio of all the raw materials were also analyzed. All the raw material showed the chemical parameter within the range except spent mushroom substrate, which showed higher nitrogen content (2.13 %), which showed the improper decomposition of spent mushroom substrate.

Combinations of different raw material have been formulated and their Physical and chemical properties were analyzed. pH of all the combinations ranged between 6.61 to 7.58 and was adjusted to ~7.5 using calcium carbonate or lime powder. Electrical conductivity ranged between 0.89 µs/cm in Coir pith +Soil (50+50) and 4.22 µs/cm in PSD + SMS (50+50). TDS ranged between 0.56 µg/l in coir pith + soil (50+50) to 2.47 µg/l in PSD + SMS (50+50). All the combinations were properly leached to reduce the electrical conductivity and TDS below 500 µs/cm and <1000 µg/l, respectively. Bulk density of different

Table 3. Physical properties of 25 combinations of different casing material used for the evaluation trial

	pH	EC (µs/cm)	TDS (µg/l)	BD (g/cm³)	PD (g/cm³)	WHC (%)	Porosity (%)
Coir pith + Lime (90+10)	7.56	1.01	0.71	0.10	0.48	67.50	71.10
Coir pith + FYM (80+20)	6.68	1.31	0.82	0.18	0.76	71.60	77.80
Coir pith + FYM (50+50)	6.85	1.39	0.87	0.28	1.12	66.50	76.00
Coir pith + FYM (20+80)	7.02	1.47	0.92	0.38	1.47	61.40	74.20
Coir pith + FYM (10+90)	7.07	1.49	0.93	0.42	1.58	59.70	73.60
Coir pith + Soil (80+20)	6.61	1.11	0.70	0.33	0.91	67.80	73.20
Coir pith + Soil (70+30)	6.63	1.04	0.65	0.44	1.09	64.20	70.30
Coir pith + Soil (50+50)	6.67	0.89	0.56	0.66	1.47	57.00	64.50
Coir pith + SMS (80+20)	6.78	2.09	1.31	0.12	0.62	67.60	79.60
Coir pith + SMS (70+30)	6.89	2.51	1.57	0.13	0.66	63.90	79.90
Coir pith + SMS (60+40)	6.99	2.92	1.83	0.13	0.71	60.20	80.20
FYM + BRH (90+10)	7.35	1.91	0.90	0.45	1.72	57.10	73.10
FYM + BRH (80+20)	7.56	2.30	0.86	0.46	1.74	56.20	73.20
FYM + Soil (70+30)	7.02	1.22	0.76	0.68	1.91	52.30	66.10
FYM + Soil (50+50)	6.95	1.02	0.64	0.83	2.06	48.50	61.50
FYM + Soil (60+40)	6.99	1.12	0.70	0.75	1.98	50.40	63.80
FYM + SMS (80+20)	7.23	2.30	1.44	0.39	1.55	54.00	74.80
FYM + SMS (50+50)	7.38	3.47	2.17	0.31	1.34	48.00	77.50
PSD + Coir pith (50+50)	6.84	2.14	1.15	0.26	1.92	72.50	66.50
PSD + Coir pith (60+40)	6.89	2.32	1.22	0.29	2.19	72.00	64.00
PSD + FYM (50+50)	7.12	2.27	1.23	0.43	2.50	64.00	63.50
PSD + FYM (60+40)	7.11	2.42	1.29	0.43	2.66	65.20	61.60
PSD + SMS (60+40)	7.31	3.98	2.26	0.31	2.37	57.20	65.20
PSD + SMS (50+50)	7.36	4.22	2.45	0.29	2.14	54.00	68.00
Control	6.68	1.31	0.82	0.18	0.76	71.60	77.80
Standard for casing soil	~7-8	<500	<1000	0.30-0.40	1-1.2	75-80	80-85
CD (0.05)	0.06	0.19	0.11	0.04	0.13	1.56	1.27

combinations ranged from 0.1 g/cm3 to 0.43g/l, which was in range of standard peat-based casing material. Particle density ranged between 0.48 g/cm3 to 2.66 g/cm3. The lowest particle density was achieved in coir pith with 10% lime powder. Bulk and Particle density refers to physical structure of the casing soil and lower values shows loose structure of casing and supports better growth of button mushroom fruit bodies. Water holding capacity is one of the most important parameters for a good casing soil and 75-80% WHC refers to a good casing soil. The maximum WHC was observed in Coir pith + FYM (80+20) combination followed by Coir pith + soil (80+20), Coir pith + SMS (80+20), Coir pith + lime (90+10) combinations. All these combinations were statistically at par with respect to WHC. Other combinations showed varying WHC between 40-65 %. Porosity of casing soil refers to air spaces available in the casing soil which support better oxygen availability in casing soil and support fructification in button mushroom. The porosity of different combinations ranged from 61 to 80 % with a maximum in Coir pith + SMS (60+40) and were near to the standard peat-based casing soil.

All the combinations were also evaluated for their chemical parameters such as carbon, nitrogen and C:N ratio and compared with the standard peat-based casing material (Table 4). The results showed that carbon percent in the casing soil combinations ranged between 20.16 to 46.79. The carbon percent in standard peat-based casing soil is reported to be 51 – 64%. The nearest carbon percent was observed in combinations where coir pith, SMS and FYM were used. Nitrogen percent is reported to be <1.20% in the standard peat-based casing soil. Most of the combinations showed nitrogen percent in range. C:N ratio ranged between 25.26 to 82.45. The C:N ratio reported to be good for button mushroom casing is 50-70 and most of the casing soil have C:N ratio near to the standard.

Table 4. Chemical properties of 25 combinations of casing materials used for the evaluation trial

Combinations	Carbon	Nitrogen	C/N Ratio
Coir pith + Lime (90+10)	39.40	0.56	70.36
Coir pith + FYM (80+20)	46.79	0.57	82.09
Coir pith + FYM (50+50)	43.11	0.59	73.68
Coir pith + FYM (20+80)	39.42	0.60	65.70
Coir pith + FYM (10+90)	38.19	0.61	63.12
Coir pith + Soil (80+20)	40.07	0.49	82.45
Coir pith + Soil (70+30)	35.48	0.45	79.02
Coir pith + Soil (50+50)	26.30	0.38	70.13
Coir pith + SMS (80+20)	46.01	0.87	52.64
Coir pith + SMS (70+30)	44.38	1.03	43.05
Coir pith + SMS (60+40)	42.76	1.19	35.99
FYM + BRH (90+10)	34.11	0.56	60.58
FYM + BRH (80+20)	31.26	0.52	60.57
FYM + Soil (70+30)	26.88	0.48	55.53
FYM + Soil (50+50)	20.16	0.40	50.39
FYM + Soil (60+40)	23.52	0.44	53.20
FYM + SMS (80+20)	36.17	0.91	39.58
FYM + SMS (50+50)	35.00	1.37	25.54
PSD + Coir pith (50+50)	42.98	0.72	59.69
PSD + Coir pith (60+40)	41.72	0.75	55.48
PSD + FYM (50+50)	38.33	0.75	51.45
PSD + FYM (60+40)	38.00	0.77	49.23
PSD + SMS (60+40)	35.23	1.38	25.53
PSD + SMS (50+50)	34.87	1.38	25.26
Control	46.79	0.57	82.09
Standard for casing soil	~51-64	<1.20	~50-70
CD (0.05)	1.47	0.11	4.17

All the 25 casing soil combinations were evaluated in cropping experiment with 5 replications of 3 bags of 10 kg compost each. Results in table 5 indicated that Coir pith + FYM (50+50), Coir pith + Soil (70+30) and Coir pith + Lime (90+10) yielded highest in terms of mushroom fruit bodies. All the three treatments yielded statistically at par to each other. Based on the yield data, a total of eight treatments were selected for further experimentations.

Table 5. Casing soil formulations used for experiment and yield

Treatment	Combinations used	Yield (kg/ 100kg compost)
T1	Coir pith + Lime (90+10)	13.23
T2	Coir pith + FYM (80+20)	11.03
T3	Coir pith + FYM (50+50)	13.95
T4	Coir pith + FYM (20+80)	11.91
T5	Coir pith + FYM (10+90)	11.48
T6	Coir pith + Soil (80+20)	11.21
T7	Coir pith + Soil (70+30)	13.41
T8	Coir pith + Soil (50+50)	10.64
T9	Coir pith + SMS (80+20)	9.19
T10	Coir pith + SMS (70+30)	11.12
T11	Coir pith + SMS (60+40)	10.21
T12	FYM + BRH (90+10)	8.76
T13	FYM + BRH (80+20)	9.77
T14	FYM + Soil (70+30)	8.96
T15	FYM + Soil (50+50)	10.06
T16	FYM + Soil (60+40)	8.33
T17	FYM + SMS (80+20)	6.90
T18	FYM + SMS (50+50)	6.96
T19	PSD + Coir pith (50+50)	5.61
T20	PSD + Coir pith (60+40)	6.35
T21	PSD + FYM (50+50)	5.37
T22	PSD + FYM (60+40)	3.74
T23	PSD + SMS (60+40)	4.04
T24	PSD + SMS (50+50)	10.28
T25	Control	10.06
	CD(5%)	0.68

A total of eight treatments were selected for final yield evaluation trial. The final trial was conducted at a larger scale with 5 replications of 10 bags of 10 kg compost per bag. Among all the treatments, highest yield of 16.92 kg/100 kg compost was obtained in the treatment Coir pith + lime (90+10) followed by Coir pith + Soil (80+20). The ANOVA results indicate that there is a significant difference among the treatment means at 1 % level of significance.

Table 6. Eight selected combinations for yield trial

Treatment	Combinations	Yield (kg/ 100kg compost)
T1	Coir pith + lime (90+10)	16.92
T2	Coir pith + FYM (80+20)	13.06^{c}
T3	Coir pith +FYM (50+50)	12.14 ^{d}
T4	Coir pith +FYM (20+80)	9.04 ^{e}
T5	Coir pith +FYM (10+90)	7.89 ^{f}
T6	Coir pith + Soil (80+20)	15.33 ^{a}
T7	Coir pith +Soil (70+30)	14.99 ^{ab}
T8	Coir pith +SMS (70+30)	14.48 ^{b}
CD (0.05)		0.82

Note: The means with different Letters as superscripts are significant ($P < 0.05$). The means with same letters or having common letter(s) are not significantly different

DISCUSSION

Mycelial colonized compost is covered with a casing soil during the mushroom-growing phase in order to promote the production of fruit bodies (Flegg and Wood, 1985). According to Flegg and Wood (1985) and Visscher (1988), the casing layer serves the following purposes: (a) to provide water for the growth and development of mycelium, which in turn leads to sporophores; (b) to prevent desiccation of the compost; (c) to support the development of sporophores; and (d) to prevent significant structural breakdown after repeated watering. Furthermore, the microbiological and chemical properties of the casing layer must be suitable for sporophore initiation. In many European nations, casing material has been made from a combination of peat and chalk or lime (Edwards and Flegg, 1953). However, peat extraction is getting harder, and some nations have plans to phase out the use of peat in professional horticulture.

In India, peat is not available for button mushroom casing. Farmers use different types of casing material such as decomposed FYM, decomposed spent mushroom substrate, decomposed coir pith, soil, burnt rice husk, etc. Farmers get fairly good crop of button mushroom but the yield obtained is always inconsistent and lesser than the yield in western countries. In the present investigation, we have tried to use different raw materials in different combinations to standardize the casing soil combination so that a good and consistent crop can be harvested.

The primary determinants of white button mushroom yield are the physical characteristics of the casing soil, such as pH, bulk density, porosity, and water-holding capacity. The mushroom mycelium has grown better at slightly basic pH levels (7.6 and 8.1). incorporating calcium hydroxide or carbonate into mixes (Rangel *et al.*, 2006). In the present study, pH levels were kept between 7.5 – 8.0 using calcium carbonate/lime powder. Electrical conductivity indicates the amount of soluble salts in the casing soil and has also significant effect on fruiting of button mushroom. A higher or lower value of EC significantly inhibits mushroom production (Hayes, 1981). In the present study, we have tried to keep electrical conductivity <500 μS/cm in all the combinations. Previous researches reported that (Rangel *et al.*, 1996), adding calcium carbonate creates a more adequate environment for mushroom development and fructification.

Water-holding capacity is a crucial factor for a successful mushroom crop and is strongly correlated with porosity, permeability, and the material's physical and chemical makeup. The amount of material that can be used for casing on mushroom beds is limited by the relatively low or high bulk density. Low bulk density results in uncontrolled water drainage from the casing layer to the substrate, even though the material has a high water-holding capacity while high bulk density limits the porosity of casing soil and thereby affecting air permeability. Therefore, to bring the bulk density into range, any material with extremely low or high bulk densities needs to be supplemented with some other material (Rangel *et al.*, 2006). In the present study, we tried to balance the water holding capacity and bulk density by combining two casing soil raw material.

The C/N ratio plays an important role in button mushroom fructification. The presence of low levels of nitrogen and unavailable carbon sources in coconut fiber makes it suitable as a casing material, since transition from vegetative growth to fruiting is promoted by casing media with a low content of readily digestible nutrients (Hayes, 1981). In our results also, coir pith supplemented with lime powder and FYM proved to be better casing soil due to higher C:N ratio.

In earlier studies also, different casing treatments has been studied on the production of button mushroom by various researchers. Rehman *et al.* (2016) recorded good yields in casing mixture containing farmyard manure while Kaur *et al.* (2017) evaluated farm yard manure (FYM), biogas slurry (BS), burnt rice husk (BRH), spent compost (SC), coir pith (CP), and sandy soil (SS). Some other studies also evaluated one year old spent compost, sand and soil (Mantel, 1973), Farm yard manure + three years old spent compost (Shandilya and Agarwala, 1983), Farm yard manure+ forest soil (Singh *et al.*, 1985), FYM + waste compost + soil, (Saini and Prasher, 1992), Burnt rice husk, farm yard manure and soil (Saini and Prashar, 1993), Spent compost + FYM (Singh *et al.*, 2001), Farm yard manure (FYM) + loam soil (Raina *et al.*, 2002), Well rotten farmyard manure and coir pith (Suman and Paliyal, 2004), Vermicompost leached + FYM (Jariyal and Shandilya, 2005), Press mud + coir pith (Bhatt *et al.*, 2006), Spent compost, farm yard manure, sand and garden soil (Singh *et al.*, 2007), Coconut coir pith + vermicompost + FYM + sand (Ram and Holker, 2009), FYM + spent compost + sand + soil (Ratnoo and Doshi, 2012), Farm Yard

Manure and Spent mushroom Substrate (Suman, 2012), FYM : garden soil : sand (Sharma *et al.*, 2013), Coconut coir pith + vermicompost + FYM + saw dust + sand (Chandra *et al.*, 2014).

In the present study, we have evaluated a total of 25 combinations and selected 8 combinations based on yield performance. The maximum biological efficiency during the present study was obtained in Coir pith + lime (90+10) followed by Coir pith + Soil (80+20).

CONCLUSION

From the study, it could be concluded that coir pith is one of the most suitable material for casing soil in button mushroom cultivation but coir pith having very good water holding capacity but very low bulk density, allows frequent water drainage in to the substrate which is not desirable for the casing soil. Thus, combining coir pith along with some other material, which can increase the bulk density and not affecting the water holding capacity can be a better casing soil. In the present study also, coir pith along with Lime powder, FYM, loam soil and SMS proved to be better casing material than other tested combinations.

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