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Comparative Evaluation of Sawdust with Different Casing Materials for the Production of *Agaricus bisporus* (Lange) Imbach under Natural Bamboo Hut Conditions

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Abstract

Studies were conducted to evaluate leached sawdust as a casing substrate for the cultivation of *Agaricus bisporus* either alone or in combination with other substrates at College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh, India during the year 2018–2020. Out of seven casing media evaluated alone, coconut coir pith performed best in terms of all production parameters like time for spawn run (20.3 days) and pinning (15.7 days), sporocarps' number (55.33), yield (0.679 kg 5 kg^{-1} compost) and biological efficiency (33.95%). The efficiency of sawdust- leached improved with the addition of other casing substrates. In commercial trial, combination of sawdust - leached with coconut coir pith, spent compost and farmyard manure (1:1v/v) performed better as compared to control (FYM+local soil), but a combination of sawdust- leached+coconut coir pith (1:1v/v) proved to be the best in terms of sporocarps' number (88.00) and yield (1.271 kg 10 kg^{-1} compost) despite of the delay in time for spawn run (26 days) and pinning (24.3 days). Casing media also affected the biological efficiency of compost which varied from 10.50% in local soil to 34.05% in sawdust-leached+farmyard manure (1:1v/v) in different experiments. Cap diameter was recorded to be maximum (41.37 mm) in 2 years old spent compost and minimum (34. 27 mm) in sawdust- leached while, stipe length ranged from 14.17 mm in vermicompost-leached to 22.90 mm in sawdust- leached+farmyard manure (1:1v/v). However, fruit bodies harvested from all the casing treatments including standard check were found to be silky smooth and firm to compact.

Keywords: *Agaricus bisporus*, sawdust, casing, yield, biological efficiency

1. Introduction

Agaricus bisporus (Lange) Imbach, commonly known as white button mushroom belongs to family Agaricaceae of the class Basidiomycetes. This mushroom is very popular throughout the world and is cultivated in over 70 countries and on every continent, except Antarctica. In India, the total white button mushroom production is estimated at 94676 tonnes (Sharma et al., 2017). During the cultivation of white button mushrooms, casing plays a pivotal role for the proper fruitification. It is generally done to make a surface where uniform fruitification can take place and it also provides anchorage and essential reserves for developing sporophores of mushrooms (Jarial et al., 2005). To achieve a high yield, it is necessary to use an adequate casing layer which may supply environmental conditions favourable to mushroom fructification (Colauto et al., 2011). The casing

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layer to be added on the substrate must not be toxic and needs not to have a sandy texture; however it has to be porous to facilitate gas exchange, or else enable appropriate aeration, water holding capacity and also capacity to liberate water without changing its structure (Zied et al., 2012).The diversity of soils available with different physical, chemical and biological characteristics is a limiting factor for the standardization of the soil as a casing layer (Dias et al., 2013).

Different types of casing materials are being used by mushroom growers in different countries depending upon their local availability.In Europe, peat moss and chalk powder is used, whereas, loam soil is widely used in U.S.A. However, due to unavailability of peat in India (Maheshwari, 2013), traditionally farmyard manure (FYM)+loam soil and FYM+three years old spent compost, after the addition of calcium carbonate are being used for casing under Indian conditions(Jarial et al., 2005). But the major problem with the conventionally used casing material is the procurement of farmyard manure, due to which many materials are being tested as its alternative for casing the mushroom beds. Many workers have also tried spent mushroom compost as well as coconut coir pith and other locally available materials as substrate for casing mushroom beds and obtained higher yields and quality characters (Adibian and Mami, 2015; Barry et al., 2016; AL-Dulayme et al., 2019; Singh et al., 2020).

Huge quantities of saw dust and other organic wastes are generated annually through the processes of agricultural, forest and food processing industries. Mushroom yield can be increased, if these locally available waste materials can be used as casing material for the production of white button mushroom (Kaur et al., 2017).

It was therefore, proposed to use sawdust for casing purpose during the present investigations. Sawdust is generally considered as a timber-industrial waste and contributes to environmental pollution. Sawdust is one of the major waste resulting from wood exploitation and processing, which stored in uncontrolled conditions may be an important factor of environmental pollution. (Deac et al.,2016). Wood dust causes irritation of the eyes, nose and throat. Skin irritation caused by wood is often mechanical. Some woods itself contain chemicals that are irritant, like teak, mansonia and radiata pine can cause eye irritation, skin dermatitis, resulting in redness and blistering (Traumann et al., 2014). So, disposal of such substrate is a challengeable problem throughout the world. Therefore, by using sawdust as a casing material, the problem of its disposal can be solved to a certain extent and mushroom growers will also be benefited.

2. Materials and Methods

The experiments were conducted in a completely randomized design under natural bamboo hut and laboratory conditions in the Department of Plant Pathology, College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh, India during 2018–2020. Six casing substrates viz., sawdust, spent compost (2 years old), coconut coir pith, farmyard manure (2 years old) and vermicompost along with standard check (farmyard manure+local soil; 3:1; v/v) were used in present investigations. All these casing substrates were procured locally from in and around Neri, Hamirpur. The sawdust and vermicompost so procured was leached for fourteen days. To leach these materials, both sawdust as well as vermicompost was filled in a big jute sack each and the sacks were hung with the top of sacks half open. Water was added to the sacks with the help of a mug from the opened tops till the water drops started coming out from the bottom of the sack, so, as to leach out the excessive nutrients from these materials. The same process was repeated twice a day up to fourteen days. On the fifteenth day after the completion of leaching, the sacks were taken down and the leached materials were kept in the mushroom hut for use in the experiment. Pure culture of *A. bisporus* was procured from Department of Plant Pathology, COHF, Neri, Hamirpur and maintained on malt extract agar (MEA) medium for further use in different experiments, whenever necessary. Master culture and spawn were made on wheat grains by following standard procedure (Suman and Sharma, 2005).Compost (prepared by short method of composting) for the conduction of research trials was procured from a local seller in Hamirpur city and used for production of *A. bisporus*. Compost was thorough spawned at the rate of 0.75%. These spawned compost bags were wrapped tightly on the top so as to maintain the moisture level. The compost was normally ready for casing between 15-17 days. All the test casing materials were chemically treated with Formalin (12.5%)+Bavistin (0.1%)+Nuvan (0.1%) prior to case the mushroom beds. The moisture level of casing was adjusted to 60 per cent before casing it on the spawn run compost unless otherwise stated. Mushrooms were picked as and when they were ready for picking by twisting them anti clock wise lightly. The mushrooms were cut at the base of the stipe in order to avoid adhering of casing soil to the sporophores. Mushrooms were counted, weighed from each replicated bag and yield was recorded upto 56 days of cropping period.

2.1. Preliminary evaluation

In order to study the effect of individual casing materials all. all the seven substrates were evaluated for the production of *A.bisporus* in completely randomized design with three replications in each treatment during the year 2018-2019. After spawning, compost was filled in growing bags having capacity of 5 kg and kept on shelves under natural bamboo hut conditions. After complete colonization of mycelium in the compost, different test casing materials were applied and data on time taken for spawn run (days), time taken for pin head formation (days), number of fruit bodies and yield (g 5 kg^{-1} of compost) upto 56 days after casing of mushroom beds were recorded. Biological efficiency (%) of all the tested casing substrates was calculated further by adopting following formula (Chang et al., 1981):

Biological efficiency (%) = (Fresh weight of the mushroom)/(Dry weigh of the substrate)×100

Additionally, quality parameters *viz*., cap diameter (mm), stipe length (mm), roughness and toughness of fruit bodies were also recorded. For observing the roughness and toughness of the fruit bodies, following scale was devised:

Grade	Toughness	Smoothness
1	Soft	Extremely Rough
2	Spongy	Rough
3	Hard	Moderately rough
4	Firm	Moderately smooth
5	Compact	Silky smooth

Based on the results of preliminary experiment, best four casing media were selected for next experiment along with sawdust-leached and were tested in all the possible combinations with sawdust-leached. A standard check was also maintained to compare the results. Experiment was laid out during 2018-2019 in completely randomized design under natural bamboo hut conditions with a total of thirteen treatments having three replications per treatment (Table 1). The data were recorded in terms of time taken for spawn run (days), time taken for pin head formation (days), number of fruit bodies and yield (g 5 kg^{-1} of compost) and quality parameters upto 56 days after casing of mushroom beds. Based on these results best four combinations were selected for final evaluation in a commercial (10 kg compost) trial.

2.2. Evaluation of best casing combinations on yield parameters of Agaricus bisporus

Based on the performance in terms of cumulative yield of different casing combinations in the second experiment, best four combinations were selected and compared with their individual treatments and standard check in a commercial trial using 10 kg capacity growing compost bags. Experiment was conducted during 2019-20 cropping season in a completely randomized design with three replications in each treatment. Data were recorded as in case of preliminary experiment.

3. Results and Discussion

3.1. Preliminary evaluation

It is evident from the data presented in Table 1 that shortest time for spawn run (20.3 days) next to control (19.3 days) was recorded when the mushroom growing bags were cased with coconut coir pith which was statistically at par with rest all treatments. However, maximum time for spawn run was recorded when mushroom bags were cased with local soil and spent compost- 2 years old i.e. 21.7 days in each case, respectively. As far as the time for initiation of fruit body was concerned, minimum time was observed in sawdust (11.3 days) which was statistically at par with farmyard manure- 2 years old (12.3 days) which was further statistically at par with spent compost- 2 years old (13 days). However, maximum time for primordia initiation was recorded in control (21.7 days), which was statistically at par with local soil (21days) as well as in vermicompost-leached (20.7 days). Number of fruit bodies was recorded to be maximum in case of coconut coir pith (55.3) which was significantly followed by control (52.00), farmyard manure- 2 years old (40.33) and spent compost- 2 years old (39.67). However, latter two treatments were statistically at par with each other in terms of number of fruit bodies. Minimum number of fruit bodies (28.00) was however, recorded when vermicompost-leached was used as a casing substrate which was significantly followed by loam soil (30.00) and sawdust- leached (33.33).

As far as the yield of mushrooms was concerned, mean maximum yield (0.679 kg 5 kg^{-1} compost) was recorded in coconut coir pith which was significantly followed by control (0.550 kg 5 kg^{-1} compost) and spent compost- 2 years old (0.532 kg 5 kg^{-1} compost). Significantly mean minimum yield (0.210 kg 5 kg^{-1} compost) was recorded in mushroom bags

Table 1: Effect of different casing substrates on the yield parameters of *Agaricus bisporus*

Casing medium	Time taken for spawn run (days)	Time taken for pinning (days)	Number of fruit bodies	Yield (kg 5 kg^{-1} compost)	Biological efficiency (%)
Sawdust-leached	20. 7	11.3	33.33	0.351	17.57 (24.77)
Farmyard manure-2 years old	21.0	12.3	40.33	0.499	24.95 (29.95)
Vermicompost- leached	21.3	20.7	28.00	0.337	16.87 (24.24)
Local soil	21. 7	21.0	30.00	0.210	10.50 (18.90)
Coconut coir pith	20.3	15.7	55.33	0.679	33.95 (35.62)
Spent compost- 2 years old	21. 7	13.0	39.67	0.532	26.62 (31.63)
SEd±	0.7	0.6	0.89	0.007	0.25
CD (p=0.05)	1.5	1.3	1.93	0.014	0.53

Figures in parenthesis indicate angular transformed values when cased with local soil significantly followed by the yield in vermicompost- leached (0.337 kg 5 kg^{-1} compost) and sawdust-leached (0.351 kg 5 kg^{-1} compost).

A perusal of the data reveals that biological efficiency was recorded to be maximum (33.95%) in mushroom bags cased with coconut coir pith followed by control (27.53%) while, it was found to be minimum (10.50%) in mushroom bags cased with local soil.

3.2. Effect of different combinations of casing substrates with sawdust-leached on yield parameters of Agaricus bisporus

It is evident from the data (Table 2) that shortest time for spawn run (18.7 days) was recorded when the mushroom bags were cased with sawdust-leached+farmyard manure (3:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (19 days; 2:1; v/v), sawdust-leached+farmyard manure (20 days; 1:1; v/v). However, the longest time for spawn run (22 days) was recorded when mushroom bags were cased with sawdust-leached+vermicompost-leached (3:1; v/v) which was statistically at par with sawdust-leached+vermicompost-leached (21.7 days; 1:1; v/v), sawdust-leached+spent compost (21.3 days; 3:1; v/v), sawdust-leached+spent compost (21 days; 1:1; v/v), sawdust-leached+farmyard manure (21 days; 2:1; v/v), sawdust- leached+spent compost (20.7 days; 2:1; v/v) and control (20.7 days).

As far as the time taken for pin head formation was concerned, the shortest time (11.3 days) was recorded in sawdust-leached+farmyard manure (2:1; v/v)which was statistically at par with sawdust-leached+farmyard manure (12.3 days; 1:1; v/v) while, the longest time (20.7 days) for the formation of pin-head was recorded when the mushroom bags were cased with standard check which was statistically at par with sawdust-leached+coconut coir pith (19.7 days; 3:1; v/v) which was further statistically at par with sawdust- leached+coconut coir pith (18.7 days; 2:1; v/v) .

Number of fruit bodies was recorded to be maximum (55.00) when mushroom bags were cased with sawdust-leached+farmyard manure (1:1; v/v) which was significantly followed by control (47.00). The latter was statistically at par with sawdust-leached+vermicompost-leached (45.67; 1:1; v/v), sawdust-leached+coconut coir pith (42.67; 1:1; v/v), sawdust-leached+spent compost (42.67; 1:1; v/v) and sawdust-leached+spent compost (40.67; 2:1; v/v). However, the minimum number of fruit bodies (16.67) was recorded when mushroom bags were cased with sawdust-leached+vermicompost-leached (3:1; v/v).

Average yield was recorded to be maximum (0.681 kg 5 kg^{-1} of compost) when the mushroom bags were cased with sawdust-leached+farmyard manure (1:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (0.680 kg 5 kg^{-1} compost; 1:1; v/v) followed significantly by sawdust-leached+farmyard manure 0.(652 kg 5 kg^{-1} compost; 2:1; v/v) and sawdust-leached+spent compost (0.617 kg 5 kg^{-1} compost; 1:1; v/v). Significantly minimum yield (0.275 kg 5 kg^{-1} compost) was recorded in bags cased with sawdust-leached+vermicompost-leached (3:1; v/v) followed by the bags cased with sawdust-leached+vermicompost-leached (0.393 kg 5 kg^{-1} compost; 2:1; v/v).

Biological efficiency was recorded to be maximum (34.05%) in mushroom bags cased with sawdust-leached+farmyard manure (1:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (34.00%; 1:1; v/v). However, minimum (13.77%) biological efficiency was recorded in mushroom bags cased with sawdust-leached+vermicompost-leached (3:1; v/v) next to sawdust-leached+vermicompost-leached (19.65%; 2:1; v/v).

3.3. Evaluation of best combinations of sawdust- leached with different casing substrates

A perusal of data presented in Table 3 reveals that average shortest time (19days) for spawn run was recorded when the growing mushroom bags were cased with farmyard manure- 2 years old alone which was statistically at par with sawdust-leached+vermicompost-leached (20.7 days; 1:1; v/v) and sawdust- leached+farmyard manure (21.3 days; 1:1; v/v). However, mean maximum time (26.3 days) for spawn run was recorded when mushroom bags were cased with sawdust-leached+spent compost (1:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (26 days; 1:1; v/v), sawdust-leached alone (24.3 days), spent compost- 2 years old (23.7 days), control (23.7 days) and vermicompost-leached (23.3 days).

As far as the time taken for initiation of fruit body was concerned, mean minimum time (16 days) was observed in coconut coir pith alone followed significantly by spent compost-2 years old alone (19 days) which was statistically at par with farmyard manure-2 years old alone (19.7 days), sawdust-leached+spent compost (20.3 days; 1:1; v/v), sawdust-leached+vermicompost-leached (20.7 days; 1:1; v/v), vermicompost-leached alone (20.7 days) and sawdust-leached+farmyard manure (21 days; 1:1; v/v).

While, average maximum time (26.7 days) for the initiation of primordia was recorded in control treatment followed significantly by sawdust- leached+coconut coir pith (24.3 days; 1:1; v/v).

As far as number of fruit bodies was concerned, it was observed to be maximum (88.00) in the mushroom bags cased with sawdust- leached+coconut coir pith (1:1; v/v) which was statistically at par with sawdust-leached+spent compost (86.00; 1:1; v/v) which was further statistically at par with sawdust-leached+farmyard manure (82.33; 1:1; v/v). While, the average minimum number of fruit bodies (52.00) was observed in case of mushroom bags cased with vermicompost-leached alone followed significantly by sawdust-leached alone as well as farmyard manure-2 years old alone which produced equal number of fruit bodies (58.67).

Table 2: Effect of different casing substrate combinations on the yield parameters of *Agaricus bisporus*

Casing medium	Ratio (v/v)	Time taken for spawn run (days)	Time taken for pinning (days)	Number of fruit bodies	Yield (kg 5 kg^{-1} compost)	Biological efficiency (%)
Sawdust- leached+coconut coir pith	(1:1)	19.0	13.7	42.67	0.680	34.00 (35.63)
Sawdust- leached+coconut coir pith	(2:1)	20.7	18.7	34.00	0.497	24.85 (29.89)
Sawdust- leached+coconut coir pith	(3:1)	21.6	19.7	25.67	0.423	21.17 (27.38)
Sawdust- leached+spent compost	(1:1)	21.0	16.7	42.67	0.617	30.88 (33.75)
Sawdust- leached+spent compost	(2:1)	20.7	16.3	40.67	0.547	27.38 (31.54)
Sawdust- leached+spent compost	(3:1)	21.3	167	34.33	0.427	21.38 (27.53)
Sawdust-leached+vermicompost-leached	(1:1)	21.7	18.0	45.67	0.522	26.10 (30.71)
Sawdust-leached+vermicompost-leached	(2:1)	20.3	17.7	26.33	0.393	19.65 (26.30)
Sawdust-leached+vermicompost-leached	(3:1)	22.0	14.7	16.67	0.275	13.77 (21.77)
Sawdust- leached+farmyard manure	(1:1)	20.0	12.3	55.00	0.681	34.05 (35.68)
Sawdust- leached+farmyard manure	(2:1)	21.0	11.3	38.33	0.652	32.63 (34.82)
Sawdust- leached+farmyard manure	(3:1)	18.7	14.3	28.67	0.562	28.12 (32.01)
Control (farmyard manure+local soil)		20.7	20.7	47.00	0.570	28.50 (32.25)
SEd		0.70	0.60	3.44	0.006	0.19
CD (p=0.05)		1.5	1.2	7.12	0.012	0.46

Figures in parenthesis indicate angular transformed values

However, mean yield was recorded to be maximum (1.271 kg 10 kg^{-1} compost) in the mushroom bags cased with sawdust-leached+coconut coir pith (1:1; v/v) which was significantly followed by sawdust-leached+spent compost (1.248 kg 10 kg^{-1} compost; 1:1; v/v), sawdust-leached+farmyard manure (1.218 kg 10 kg^{-1} compost; 1:1; v/v), coconut coir pith alone (1.193 kg 10 kg^{-1} compost) and control (1.110 kg 10 kg^{-1} compost). However, significantly minimum yield of *A. bisporus* (0.897 kg 10 kg^{-1} compost) was recorded in vermicompost-leached alone followed by sawdust- leached alone (0.954 kg 10 kg^{-1} compost).

Biological efficiency was recorded to be maximum (31.77%) in mushroom bags cased with sawdust-leached+coconut coir pith (1:1; v/v) which was significantly followed by sawdust-leached+spent compost (31.20%; 1:1; v/v). However, minimum (22.44%) biological efficiency was recorded in mushroom bags cased with vermicompost-leached next to sawdust-leached (23.85%).

3.4. Effect of different casing substrates on morphological characters of Agaricus bisporus

Different morphological characters like cap diameter, stipe length, roughness, toughness and shape of fruit bodies of *A. bisporus* were recorded during all the production trials and are presented in the Table (s) 4, 5 and 6.

It is evident from the data presented in Table 4 that mean maximum cap diameter (39.57 mm) of mushroom fruit bodies was observed in mushroom bags cased with standard check

Table 3: Effect of selected casing substrates on the yield parameters of *Agaricus bisporus*

Casing medium	Time taken for spawn run (days)	Time taken for pinning (days)	No. of fruit bodies	Yield (kg 10 kg^{-1} compost)	Biological efficiency (%)
Sawdust- leached+farmyard manure (1:1)	21.3	21.0	82.33	1.218	30.45 (33.48)
Sawdust- leached+spent compost (1:1)	26.3	20.3	86.00	1.248	31.20 (33.94)
Sawdust- leached+coconut coir pith (1:1)	26.0	24.3	88.00	1.271	31.77 (34.30)
Sawdust- leached+vermicompost- leached (1:1)	20.7	20.7	63.67	0.999	24.98 (29.98)
Spent compost- 2 years old	23.7	19.0	72.00	1.097	27.43 (31.57)
Farmyard manure- 2 years old	19.0	19.7	58.67	0.985	24.64 (29.75)
Coconut coir pith	21.0	16.0	79.44	1.193	29.82 (33.09)
Vermicompost- leached	23.3	20.7	52.00	0.897	22.44 (28.64)
Sawdust- leached	24.3	21.7	58.67	0.954	23.85 (29.22)
Control (farmyard manure+local soil)	23.7	26.7	77.33	1.110	27.75 (31.18)
SEd	1.5	1.1	2.22	0.06	0.10
CD (p=0.05)	3.9	2.3	4.67	0.13	0.21

Figures in parenthesis indicate angular transformed values

i.e. farmyard manure+local soil (1:1) which was statistically at par with farmyard manure-2 years old (39.17 mm). However, mean minimum cap diameter (34.27 mm) was recorded in mushroom fruit bodies harvested from bags cased with sawdust-leached which was statistically at par with coconut coir pith (34.37 mm) and vermicompost-leached (35.47 mm). The latter two treatments were further statistically at par with local soil (35.63 mm).

As far as the stipe length was concerned, the average longest stipe length (22.83 mm) was recorded in the mushrooms harvested from bags cased with spent compost-2 years old which was statistically at par with sawdust-leached (21.77 mm) significantly followed by farmyard manure-2 years old (19.10 mm) being statistically at par with coconut coir pith (18.67 mm), control (18.27 mm) and local soil (16.33 mm). However, the mean shortest stipe length of mushrooms was observed in the mushroom bags when cased with vermicompost-leached (14.17mm) which was statistically at par with local soil (16.33 mm). As far as toughness and smoothness of the fruit bodies were concerned, firm or compact fruit bodies were obtained from all the casing substrates except for local soil, where the fruit bodies were comparatively moderately smooth in texture.

Morphological characters *viz*., cap diameter, stipe length, toughness and smoothness were also recorded in the treatment combination experiment and the data have been presented the Table 5.

It is apparent from the data presented in Table 5 that the average largest cap diameter (39.40 mm) was recorded in mushrooms harvested from bags cased with sawdust-leached+coconut coir pith (3:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (39.23 mm ; 2:1; v/v), sawdust-leached+spent compost (39.07 mm ; 3:1; v/v) and sawdust-leached+vermicompost-leached (38.63 mm;1:1; v/v). However, the average smallest cap diameter (35.20 mm) was recorded in mushroom bags when cased with sawdust-leached+spent compost (1:1; v/v) which was statistically at par with sawdust-leached+coconut coir pith (35.60 mm; 1:1; v/v), sawdust-leached+farmyard manure (35.77 mm; 1:1; v/v), sawdust-leached+farmyard manure (35.87 mm ; 2:1; v/v) and sawdust-leached+vermicompost-leached (36.63 mm;2:1; v/v).

Table 4: Morphological characters of *Agaricus bisporus* as affected by different casing media

Casing medium	Cap diameter (mm)	Stipe length (mm)	Tough-ness	Smooth-ness
Sawdust- leached	34.27	21.77	5.00	5.00
Farmyard manure- 2 years old	39.17	19.10	5.00	5.00
Vermicompost-leached	35.47	14.17	4.00	5.00
Local soil	35.63	16.33	4.00	4.00
Coconut coir pith	34.37	18.67	5.00	5.00
Spent compost- 2 years old	37.13	22.83	4.00	5.00
Control (farmyard manure+local soil)	39.57	18.27	5.00	5.00
SEd	0.60	1.59		
CD (p=0.05)	1.29	3.44		

Stipe length was recorded to be longest (22.90 mm) in mushrooms harvested from bags cased with sawdust-leached+farmyard manure (1:1; v/v) which was statistically at par with sawdust-leached+vermicompost-leached (22.70 mm; 2:1; v/v),sawdust-leached+spent compost (22.40 mm; 1:1; v/v), sawdust-leached+farmyard manure (22.20 mm; 3:1; v/v), sawdust-leached+vermicompost-leached (22.13 mm ; 1:1; v/v), sawdust-leached+coconut coir pith (21.80 mm; 1:1; v/v), sawdust-leached+coconut coir pith (21.57 mm ; 2:1; v/v) and sawdust-leached+spent compost (21.40 mm ; 2:1; v/v). However, the shortest stipe length (17.43 mm) was observed in mushroom bagscased with sawdust-leached+coconut coir pith (3:1; v/v) which was statistically at par with sawdust-leached+vermicompost-leached (17.90 mm; 3:1; v/v) and control (18.00 mm). As far as toughness and smoothness of the fruit bodies were concerned, firm or compact and silky-smooth fruit bodies were obtained from all the casing substrates.

Various morphological characters recorded from different treatment combinations of casing substrates used in the final commercial trial have been presented in the following Table 6.

A perusal of data reveals that the largest cap diameter (41.37 mm) was recorded in mushroom bags when cased with spent compost-2 years old which was statistically at par with sawdust-leached+farmyard manure (39.80 mm; 1:1; v/v), sawdust-leached+spent compost (39.37 mm; 1:1; v/v) and farmyard manure-2 years old (38.67 mm).

However, the smallest cap diameter (35.10 mm) was observed in mushrooms harvested from bags cased with vermicompost-leached which was statistically at par with sawdust-leached+vermicompost-leached (35.17 mm; 1:1; v/v) and coconut coir pith alone (35.55mm).

As far as the stipe length was concerned, it was recorded to be longest (21.23 mm) in mushroom bags cased with sawdust-leached+spent compost (1:1; v/v) which was statistically at par with sawdust-leached (19.87 mm) and sawdust-leached+coconut coir pith (1:1;v/v; 19.80 mm) while, the

Table 5: Morphological characters of *Agaricus bisporus* as affected by different casing combinations

Casing medium	Ratio (v/v)	Cap diameter (mm)	Stipe length (mm)	Toughness	Smoothness
Sawdust- leached+coconut coir pith	(1:1)	35.60	21.80	5.00	5.00
Sawdust- leached+coconut coir pith	(2:1)	39.23	21.57	5.00	5.00
Sawdust- leached+coconut coir pith	(3:1)	39.40	17.43	5.00	5.00
Sawdust- leached+spent compost	(1:1)	35.20	22.40	5.00	5.00
Sawdust- leached+spent compost	(2:1)	37.13	21.40	5.00	5.00
Sawdust- leached+spent compost	(3:1)	39.07	20.50	5.00	5.00
Sawdust- leached+vermicompost-leached	(1:1)	38.63	22.13	4.00	5.00
Sawdust- leached+vermicompost-leached	(2:1)	36.63	22.70	4.00	5.00
Sawdust- leached+vermicompost-leached	(3:1)	36.87	17.90	4.00	5.00
Sawdust- leached+farmyard manure	(1:1)	35.77	22.90	5.00	5.00
Sawdust- leached+farmyard manure	(2:1)	35.87	19.73	5.00	5.00
Sawdust- leached+farmyard manure	(3:1)	37.27	22.20	5.00	5.00
Control (farmyard manure+local soil)		35.63	18.00	5.00	5.00
SEd±		0.74	0.84		
CD (p=0.05)		1.53	1.74		

Table 6: Morphological characters of *Agaricus bisporus* as affected by selected casing media

Casing medium	Cap diameter (mm)	Stipe length (mm)	Toughness	Smoothness
Sawdust- leached+farmyard manure (1:1)	39.80	18.70	5.00	5.00
Sawdust- leached+spent compost (1:1)	39.37	21.23	5.00	5.00
Sawdust- leached+coconut coir pith (1:1)	38.20	19.80	5.00	5.00
Sawdust- leached+vermicompost-leached (1:1)	35.17	18.40	4.00	5.00
Spent compost- 2 years old	41.37	16.80	4.00	5.00
Farmyard manure- 2 years old	38.67	17.13	5.00	5.00
Coconut coir pith	35.55	17.87	5.00	5.00
Vermicompost- leached	35.10	16.17	4.00	5.00
Sawdust- leached	38.07	19.87	5.00	5.00
Control (farmyard manure+local soil)	38.03	15.87	5.00	5.00
SEd±	1.13	0.96		
CD (p=0.05)	2.37	2.01		

shortest stipe length (15.87 mm) was recorded in mushrooms harvested from control which was statistically at par with vermicompost-leached (16.17mm), spent compost-2 years old (16.80 mm) and farm yard manure-2 years old (17.13 mm). As far as toughness and smoothness of the fruit bodies were concerned, firm or compact and silky smooth fruit bodies were obtained from all the casing substrates. These findings are in close conformity with the findings of Jarial and Shandilya (2005) who also reported that morphological characters like stalk length, cap diameter, toughness and smoothness etc. did not differ with respect to different casing media used.

During the present investigations out of seven different casing media evaluated alone or in combination with sawdust-leached including standard check, coconut coir pith performed best in terms of all production parameters like, time taken for spawn run, time taken for pin head formation, number of fruit bodies harvested and yield of *A.bisporus.* Sawdust-leached did not perform well when used alone as casing material but its efficiency improved with the addition of other casing substrates including coconut coir pith at the top followed by spent compost- 2 years old / farmyard manure- 2 years old, and vermicompost-leached. However, the proportion of saw dust-leached in the combination treatments proved to be of utmost importance because with the increase in proportion of sawdust- leached in the casing mixture reduction in the production efficiency of casing mixture was observed.

In the commercial production trial also, the combination of sawdust- leached with coconut coir pith, farmyard manure- 2 years old, spent compost- 2 years old and vermicompost-leached, the increase in the production efficiency of each material was recorded. These results are in accordance with the work of Kim et al. (1998) who reported that when 30 percent sawdust was added to clay loam soil and used as casing material for *A. bisporus* cultivation, the mushroom yield was increased up to 28 per cent. During present studies, however, combination of sawdust-leached+coconut coir pith (1:1; v/v), sawdust- leached+farmyard manure-2 years old (1:1; v/v) and sawdust- leached+spent compost-2 years old (1:1; v/v) performed better as compared to standard check (FYM+LS), but a combination of sawdust- leached+coconut coir pith (1:1; v/v) proved to be the best amongst the all three combinations in terms of total number of sporocarps and mushroom yield despite of delay in time to spawn run and time to pinning. Coconut coir pith has been used by various workers in combination with different materials in varying ratios and has been proved to be best casing material comparable to peat (Gimenez and Gonzalez, 2008; Doshi et al., 2012; Chandra et al., 2014; Kaur et al., 2017), however, combination of sawdust-leached+coconut coir pith has never been evaluated by any worker so these findings cannot be compared with any published data.

Biological efficiency in the present investigations was found to be ranging from 10.50-34.05% which was in close proximity of the findings of de Siqueira et al. (2009) who reported biological efficiency of *A. blazeiss. Heinemann* to be ranging from 15.90 to 54.60 per cent. Results are further supported by de Siqueira et al. (2011) who reported the biological efficiency of *A. brasiliensis* to range from 34.52-44.28%. Owaid et al. (2017) further support our findings as they reported the biological efficiency of *A. bisporus* to vary from 20.80 to 29.3%.

4. Conclusion

Sawdust-leached could be used as a casing material for cultivation of *A. bisporus* in combination with coconut coir pith, spent compost or farmyard manure (1:1,v/v). These casing combinations had proved better than standard substrate (FYM+loam soil 1:1, v/v) in terms of mushroom yield, quality parameters as well as biological efficiency of compost.

The use of sawdust-leachedcombined with other substrates especially coconut coir-pith would help in reducing its disposal problem and environmental pollution.

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