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*Full Length Research Paper*

# Improved techniques to enhance the yield of paddy straw mushroom (*Volvariella volvacea*) for commercial cultivation

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**Cultivation of *Volvariella volvacea* in circular compact bed method recorded maximum yield of 972.8 g/bed (biological efficiency of 23.8%). Seeding the beds with 15 and 20 days old spawn with well developed chlamydospores contributed for significantly higher yields. Oil palm bunch waste in combination with rice straw or alone recorded significantly higher yields of 876.3 and 832 g/bed, and cotton waste, in combination with rice straw or alone, recorded 841.6 g and 778 g/bed, respectively. *In vitro* evaluation of the micronutrient based boosters VVB1 ($CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm + $Na_2HPO_4$ 50 ppm) and VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm) produced profuse mycelium with aerial silky strands, early chlamydospore formation (20.8 and 21.8 days) and increased chlamydospore density ($7.8 \times 10^2$ and $7.2 \times 10^2$ spores/ml). Yields of 960 g/bed with more number of sturdy fruiting bodies were observed in beds sprayed with VVB1. *V. volvacea* can be successfully cultivated from March to September with 18 to 20% biological efficiency. Storage of *V. volvacea* at egg stage in air tight plastic box at deep freeze (-20°C) conditions remained intact until 36 h without spoilage.**

**Key words:** Paddy straw mushroom, *Volvariella volvacea*, boosters, bed methods, cultivation techniques.

## INTRODUCTION

Paddy straw mushroom (*Volvariella volvacea*) being the third most important cultivated mushroom in the world is well known for its pleasant flavor and taste. No other vegetable or cultivated mushroom can be served as a table dish within a short time from its planting, but *V. volvacea* can do this as it comes to harvest on 10th day. The climatic conditions prevailing in India are best suited for the cultivation of this mushroom. Many researchers have exploited the biological and practical knowledge of *Volvariella* sp. (Su and Seth, 1940; Thomas et al., 1943; Sangeetha, 2002), cultivation techniques for commercialization still remains to be in infant stage in India owing to its poor and unstable yields. Nutrients provided by the substrates is the most important factor affecting the yield of mushrooms.

The role of extracellular enzymes like cellulases, hemicellulases and lignases is pivotal to the production of any mushroom fruiting body which is affected by the various nutrients and physical factors that have a bearing on the biological efficiency of the crop. Similarly, the pectinolytic enzymes found at the button stage of *Phellorina inquinans* are believed to play an important role in the initiation of primordia and enlargement of the fruiting bodies (Sharma and Anila, 1984). Likewise, it is possible that certain enzymes play key role in the developmental stages of *Volvariella* sp. For the inductions of such enzymes, specific nutrients might be essential to trigger the enzyme production for higher growth, chlamydospore formation and development of fruiting bodies of *V. volvacea*.

Though supplementation of substrates with

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proteinaceous materials have been tried to increase the yield, use of micronutrients for yield enhancement has not been investigated to a larger extent. Therefore, attempts were made to develop micronutrient based boosters to increase the productivity of *V. volvacea*. Also, studies on the identification of high yielding strain, appropriate bed method, quality of spawn, substrate substitution and favourable season for the cultivation of *V. volvacea* for enhanced yields and post harvest storage for extending the shelf life were explored so that the technology can be utilized for cultivation of this mushroom on a large scale.

## MATERIALS AND METHODS

### Culture

The *V. volvacea* isolate PS 1 obtained from the Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore was used for the studies.

### Testing the different bed types for cultivation of *Volvariella volvacea*

The different bed methods are as follows:

1. Square compact (30 × 30 cm),
2. Circular compact (45 cm diameter, 30 cm height),
3. Bundle (hollow) (5 × 4 layers + 2 layers opened at the top),
4. Bundle (compact) (4 × 5 layers + 2 bundles opened at the top),
5. Cylindrical bed (alternate layers of paddy straw and spawn).

Hollow beds, square compact beds and circular compact beds were prepared using rice straw twists, where as bundle method of beds preparation were done by preparing rice straw as bundles; for each bed, 4 kg of dry rice straw were used. In cylindrical bed method, 1 kg rice straw was used to prepare one bed. In cylindrical bed method, four beds were considered as one replication (which make 4 kg dry rice straw) in order to maintain uniformity of straw usage with other methods. Paddy straw spawn bits at 2% dry weight basis were used, and steamed coarsely ground horse gram powder was sprinkled over the spawn bits (at 2% dry weight basis). The treatments were replicated four times in completely randomized design and placed in blue poly houses (blue silpauline sheet of 250 gauge thickness), where a temperature of 35 to 37°C and relative humidity of 75 to 80% were recorded throughout the cropping period. Observations on the days for complete spawn run (DFSR), days for pin head formation (DFPF), days for button formation (DFBF), yield parameters in relation to average number of eggs/bed, average weight of individual egg and biological efficiency (%) were recorded. The pest and disease incidence were also recorded. Biological efficiency (%) = [Fresh weight of harvested fruiting bodies (g) × 100]/ Dry weight of substrate used (g).

### Quality of spawn

Fresh and good quality rice straw bits (one to two inches) were soaked in water for 6 h, and dried under shade up to 65% moisture content. The rice straw substrate was supplemented with steamed horse gram powder at 2% (dry weight basis) and the contents were packed in polypropylene bags (18 × 20 inches; 150 gauge thickness) and autoclaved (1.46 kg/cm$^2$ for 90 min). On the next day, the seven days old *V. volvacea* culture (9 mm disc) was inoculated, and the bags were incubated at room temperature. After complete spawn run, they were used to seed the mushroom beds at different incubation intervals (12, 15, 20, 25, 30 and 40 days) in circular compact beds as described above. Beds were placed in the blue poly house with three replications in completely randomized design. Observations were recorded with respect to DFSR, DFPF, DFBF and yield parameters as described earlier.

### Partial substitution with agricultural residues for enhancing the yield of *V. volvacea*

The substrates such as banana leaf waste, cotton waste, sugarcane trash, water hyacinth, oil palm bunch waste, maize stubbles/trash and rice straw were tried individually and with partial substitution along with rice straw (1:1). Circular compact beds were prepared as described above. The beds were replicated thrice in completely randomized design. Observations were recorded with respect to DFSR, DFPF, DFBF and yield parameters as described.

### Testing the effect of boosters in enhancing the yield of *V. volvacea*

#### *In vitro screening*

*In vitro* effects of combinations of micronutrients were tested individually and in combinations at different concentrations to study their effect on the growth of *V. volvacea* in liquid broth Richards's medium by inoculating a 5 mm disc of *V. volvacea*. Based on the growth of mycelium in the micronutrients VVBI ($CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm + $Na_2HPO_4$ 50 ppm and VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm), the observations on mycelial growth were observed on 15th day after inoculation. The micronutrients based boosters VVB1 and VVB 2 were added to plain agar medium and the seven day old *V. volvacea* culture (5 mm disc) were inoculated at the center and observations pertaining to mycelial growth, and chlamydospore formation were also recorded.

### Effect of boosters in enhancing the yield of *V. volvacea*

The micronutrient based booster VVBI ($CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm + Na $_2HPO_4$ 50 ppm) and VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm) were imposed on the paddy straw beds by two methods.

#### *Soaking*

The rice straw twists were soaked in VVB1 and VVB2 (each at 600 ppm concentration) for 12 h and then beds were prepared

#### *Spraying*

The boosters VVB1 and VVB2 were sprayed separately (each at 600 ppm concentration) on the paddy straw beds at the time of pinhead formation (100 ml/bed).

#### *Soaking and spraying*

The rice straw twists were soaked and also sprayed with boosters VVB1 and VVB2 as described above. Each bed was prepared

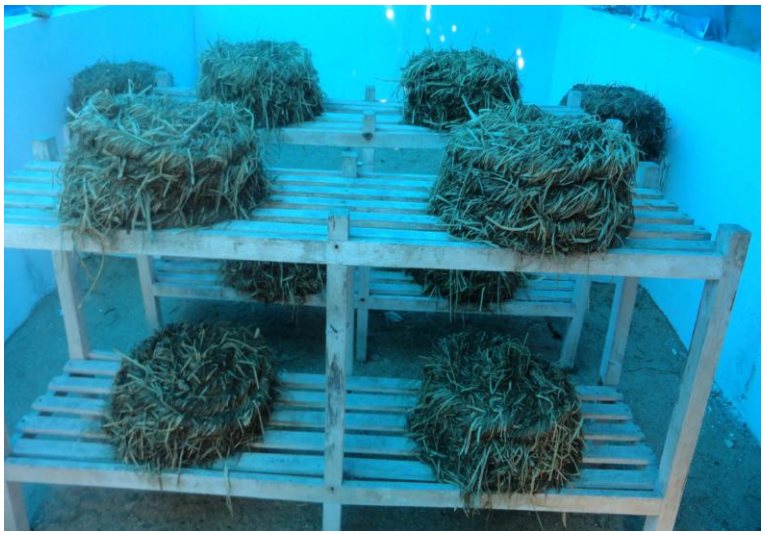

**Figure 1.** Circular compact bed method.

using 4 kg rice straw, replicated thrice in completely randomized design. Observations were recorded with respect to DFSR, DFPF, DFBF and yield parameters as described earlier.

#### Seasonal productivity of *V. volvacea*

In order to find out the maximum yielding periods for cultivation of paddy straw mushroom, circular compact beds (45 cm diameter, 30 cm height, 3 kg paddy straw substrate) were prepared during the first week of every month starting from January 2009 to December 2009 and placed in the polyhouse after spawning. 10 beds were prepared every month in completely randomized design. The temperature and relative humidity inside the polyhouse were recorded regularly for making correlations.

#### Post harvest preservation of *V. volvacea*

The harvested mushrooms at egg stage were preserved in different packages to study the shelf life of *V. volvacea*. The treatments included packing 10 mushrooms (at egg stage) in polypropylene bags (100 gauge) both open and sealed, paper envelope, punnet packing, and air tight plastic box. The packages were placed in room temperature (28°C), refrigerated conditions, and in deep freezer (-20°C), and the observations on veil opening, microbial spoilage (bacteria), texture, specific odour and liquefaction were recorded.

#### Statistical analysis

Statistical software (AGRES) was used for the analysis of the data

## RESULTS AND DISCUSSION

### Different bed methods influencing the yield of *Volvariella volvacea*

Several cultivation methods are used for the cultivation of *Volvariella* spp. in the tropics with varying temperature (30 to 35°C) and relative humidity (75 to 85%) (Quimio, 1993). However, the traditional methods of cultivation of paddy straw mushroom vary with countries, states and even regions. In the present study, wide variations in the bioefficiency of *V. volvacea* were observed with different types of beds. Circular compact beds gave significantly higher yield of 972.8 g/bed (23.8% biological efficiency). Early formation of the pinheads and buttons were also observed (on 6th and 7th day, respectively) in these beds. The increased weight and more number of buttons which contributed to maximum yield in circular compact bed might be due to the homogeneity of growing conditions in such beds (Figure 1). The next best treatment was square compact bed with the yield of 711.2 g/bed (17.5% biological efficiency) (Table 1). The variability in bioefficiency may be attributed to certain physical factors such as temperature, aeration, wetness and compactness of the beds. Circular compact bed might have experienced homogenous moisture level and bed temperature between the layers, which would have facilitated better proliferation of the mycelium, production of more pinheads, and buttons with ultimate increase in yield. In square compact bed, the straw became loose at the corners and disturbed the mycelium. Similar reports were made by Sangeetha (2002). Contrarily, hollow beds were reported to give more yield as reported (Garcha et al., 1989). Although, in our study in the hollow beds due to free movement of air, uniform temperature and moisture between the layers in the bed could not be maintained, resulting in reduced yield.

### Quality of spawn

In our study, beds prepared with 15 and 20 days old *V.*

**Table 1.** Effect of different bed types on the yield of paddy straw mushroom.

| Bed type | DFSR | DFPF | DFBF | Average buttons/bed (number) | Average weight per button (g) | Yield/bed (g) | B.E. (%) |
|---|---|---|---|---|---|---|---|
| Square bed | 7.3±0.37 | 8.5±0.22 | 10.5±0.52 | 28.0±1.40 | 25.0±1.25 | 711.2±35.56 | 17.5±0.88 |
| Circular compact | 6.5±0.17 | 8.0±0.37 | 10.0±0.26 | 38.0±1.01 | 25.0±0.66 | 972.8±25.74 | 23.8±0.63 |
| Bundle (Hollow) | 7.5±0.30 | 10.0±0.36 | 11.0±0.44 | 21.0±0.84 | 24.0±0.96 | 512.4±20.50 | 12.6±0.50 |
| Bundle (compact) | 7.3±0.15 | 8.5±0.36 | 11.0±0.22 | 22.0±0.44 | 22.0±0.44 | 484.0±9.68 | 12.1±0.24 |
| Cylindrical bed | 7.5±0.30 | 10.0±0.40 | 11.5±0.46 | 17.6±0.70 | 25.0±1.00 | 440.0±17.60 | 11.0±0.44 |

Results are mean ± standard deviation of 4 replications. DFSR, Days for spawn run; DFPF, days for pin head formation; DFBF, days for button formation; BE, biological efficiency.

**Table 2.** Influence of age of the spawn on the yield of paddy straw mushroom.

| Age of spawn | Colony morphology | DFSR | DFPF | DFBF | Average buttons/bed (number) | Average weight/button (g) | Yield/bed (g) | B.E. (%) |
|---|---|---|---|---|---|---|---|---|
| 12 | ++ | 5.3±0.27 | 7.3±0.19 | 9.3±0.47 | 25.0±1.25 | 25.0±1.25 | 625.0±31.25 | 15.6±0.78 |
| 15 | +++ | 6.0±0.16 | 7.0±0.28 | 9.0±0.24 | 30.7±0.81 | 24.0±0.63 | 736.8±19.49 | 18.4±0.49 |
| 20 | +++ | 6.0±0.24 | 7.3±0.15 | 9.3±0.37 | 31.7±1.27 | 25.0±1.00 | 792.5±31.70 | 19.8±0.79 |
| 25 | + | 6.00.12 | 7.3±0.29 | 9.3±0.19 | 24.6±0.49 | 26.6±0.53 | 654.4±13.09 | 16.4±0.33 |
| 30 | + | 7.7±0.31 | 10.3±0.27 | 12.3±0.49 | 24.0±0.96 | 24.6±0.98 | 590.4±23.62 | 14.8±0.59 |
| 40 | + | 8.0±0.21 | 11.7±0.54 | 13.7±0.36 | 20.7±0.55 | 20.0±0.53 | 414.0±10.95 | 10.4±0.28 |

Results are mean ± standard deviation of 3 replications. +, Suppressed growth; ++, actively growing mycelium; +++, well developed chlamydospores; DFSR, days for spawn run; DFPF, days for pin head formation; DFBF, days for button formation; B.E., biological efficiency.

*volvacea* spawn (+++ type with well developed chlamydospores) recorded significantly higher yields (792.5 and 736.8 g/bed, respectively). Beds prepared with 12 day spawn (++ type with actively growing mycelial stage) were next to the best treatment, and were on par with the beds prepared with 25 and 30-day-old spawn (+ type with suppressed colonies) (Table 2). Very poor yield (414.0 g/bed) was obtained in beds prepared with 40-day-old spawn. Delayed pinhead formation and reduced number of buttons were observed in this case. Contamination with weed mould like *Coprinus comatus* was observed in beds seeded with more old spawn. In fact, C*. comatus* dominated and put forth sporophores more quickly than the mushroom fungus in such beds. The present study clearly depicts the direct correlation between chlamydospore formation and maximum yield. Formation of chlamydospores can be detected macroscopically as brownish red patches in the spawn. Possibly, in the spawn of 15 and 20 days old spawn, the well-developed chlamydospores might have served as good reservoirs with several nutrients for early and better proliferation of mycelium, and ultimately result in the maximum yield.

**Substitution with agricultural residues for yield increase in *V. volvacea***

Mushrooms have been reported to be capable of transforming nutritionally worthless wastes into protein rich food and have been confirmed to be sources of single cell protein. Substrates like stover, saw dust, cotton waste, cocoa bean shell, and sawdust-Gliricidia mixture (Belewu, 2003; Belewu and Lawal, 2003), rice straw, water lilly and banana leaves (Oei, 2003) were reported to be suitable substrates for the cultivation of edible mushroom. In our studies, oil palm bunch waste in

**Table 3.** Substitution with different substrates to enhance the yield of paddy straw mushroom.

| Treatment | DFSR | DFPF | DFBF | Average number of buttons/bed | Average weight/ button (g) | Average yield/bed (g) | B.E. (%) |
|---|---|---|---|---|---|---|---|
| Banana waste | 7.7±0.38 | 9.7±0.49 | 11.0±0.55 | 22.0±1.10 | 25.0±1.25 | 549.3±27.47 | 13.7±0.69 |
| Cotton waste | 6.7±0.18 | 8.0±0.21 | 10.0±0.26 | 32.0±0.85 | 24.3±0.64 | 778.0±20.58 | 19.2±0.51 |
| Water hyacinth | 7.0±0.28 | 8.7±0.35 | 9.7±0.39 | 15.7±0.63 | 22.3±0.89 | 350.3±14.01 | 8.7±0.35 |
| Sugarcane trash | 6.0±0.12 | 8.0±0.16 | 9.0±0.18 | 22.0±0.44 | 23.9±0.48 | 527.3±10.55 | 13.2±0.26 |
| Maize stubbles/trash | 8.3±0.33 | 10.7±0.43 | 12.0±0.48 | 16.0±0.64 | 25.0±1.00 | 400.0±16.00 | 10.0±0.40 |
| Rice straw | 6.0±0.16 | 7.0±0.19 | 8.0±0.21 | 30.8±0.81 | 25.0±0.66 | 770.0±20.37 | 19.5±0.52 |
| Oil palm bunch waste | 6.0±0.26 | 10.0±0.46 | 13.0±0.60 | 32.0±1.26 | 26.0±0.09 | 832.0±38.13 | 20.8±0.95 |
| Oil palm bunch waste + paddy straw (1:1) | 6.3±0.27 | 7.3±0.26 | 9.3±0.34 | 35.0±1.26 | 25.0±0.90 | 876.3±31.58 | 21.9±0.79 |
| Banana waste + rice straw (1:1) | 6.6±0.37 | 7.0±0.28 | 7.7±0.31 | 26.0±1.04 | 23.0±0.92 | 598.0±23.92 | 14.9±0.60 |
| Cotton waste + rice straw (1:1) | 6.7±0.18 | 8.0±0.32 | 9.0±0.36 | 32.3±1.29 | 26.0±1.04 | 841.6±33.64 | 21.0±0.84 |
| Water hyacinth + rice straw (1:1) | 7.3±0.33 | 8.7±0.44 | 10.0±0.50 | 27.0±1.35 | 21.0±1.05 | 567.0±28.35 | 14.2±0.71 |
| Rice straw + sugarcane trash (1:1) | 6.7±0.18 | 8.0±0.21 | 9.3±0.25 | 30.0±0.79 | 23.0±0.67 | 691.3±18.29 | 17.3±0.46 |
| Maize stubbles/trash+ rice straw (1:1) | 8.3±0.33 | 9.7±0.39 | 11.0±0.44 | 21.3±0.85 | 21.7±0.81 | 462.0±18.48 | 11.6±0.46 |

Results are mean ± standard deviation of 3 replications. DFSR, days for spawn run; DFPF, days for pin head formation; DFBF, days for button formation; B.E., biological efficiency.

combination with rice straw or alone recorded significantly higher yields of 876.3 and 832 g/bed (21.9 and 20.8% bioefficiency). Similarly, cotton waste in combination with rice straw or alone recorded 841.6 and 778 g/bed respectively (21 and 19.2% bioefficiency) and they were on par with the commonly used rice straw (19.5 % bioefficiency) (Table 3). In treatments substituted with sugarcane bagasse, banana waste and water hyacinth gave reduced yields with the bioefficiency ranging from 10 to 5%. Our study coincides with Pramod et al. (2004) which reported the maxmimum bioefficiency of 31% in oil palm bunch waste. Combination of rice husk and cotton waste (Akinyele and Akinyosoye, 2005), water hyacinth + cotton waste, cotton waste + rice straw, Kalar grass (Saeed et al., 1994) for yield enhancement of paddy straw mushroom were reported. Tripathi et al. (2009, 2011) reported that wheat straw with rice bran gave significantly good yields for both *V. volvacea* and *V. diplasia*. It is clear from the above study that oil palm bunch waste and cotton waste can be used solely or substituted with paddy straw to enhance the yield of paddy straw mushroom, and as an alternative substrate to paddy straw.

## Yield enhancing boosters for *V. volvacea*

### *In vitro* screening

The micronutrient based boosters VVB1 and VVB2 were selected as best performing based on the aerial silky strands which indicated the virulent growing nature of mycelium. The micronutrient combinations VVB1 ($CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm + $Na_2HPO_4$ 50 ppm) produced aerial silky strands up to 5 cm with mycelial dry weight of 0.7 g and VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm) produced profuse mycelium with aerial silky strands up to 2 cm with mycelial dry weight of 0.8 g as compared to other micronutrients in liquid medium (data not shown). *In vitro* effect of boosters in solid agar medium showed no significant difference among the treatments in the days taken for the mycelium to cover the Petri dish. However, early chlamydospore formation was observed in both the micronutrient treatments (20.8 and 21.8 days, respectively) compared to control (25 days). Increased chlamydospore density was also observed in VVB1 ($7.8 \times 10^2$ spores/ml) as compared to VVB2 ($7.2 \times 10^2$ spores/ml) and control ($6.7 \times 10^2$ spores /ml) (Table 4).

### Boosters in enhancing the yield of *V. volvacea*

In the treatments with both soaking and soaking + spraying with VVB1 ($CaCO_3$ 400 ppm + $CaCl_2$ 50

**Table 4.** *In vitro* growth of *V. volvacea* in plain agar medium impregnated with boosters.

| Treatment | Days to cover the entire Petri dish | Days for chlamydo-spore formation | Chlamydo-spore density | Size of chlamydo-spores (μ) | Chlamydo-spores × $10^2$/ml (number) |
|---|---|---|---|---|---|
| VVB1 | 4.0±0.20 | 20.8±1.04 | ++ | 50.5±2.53 | 7.8±0.39 |
| VVB2 | 4.8±0.13 | 21.8±0.58 | + | 45.4±1.20 | 7.2±0.19 |
| Control | 4.8±0.19 | 25.0±1.00 | + | 50.0±2.00 | 6.7±0.27 |

Results are mean ± standard deviation of 3 replications; +, moderate; ++, high.

**Figure 2.** Effect of booster treatment on the yield of *V.Volvacea.* Sturdy buttons in VVB1.

ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm + $Na_2HPO_4$ 50 ppm) at 600 ppm concentration, increased yields of 1012 g/bed (bioefficiency of 25.3%) were observed. Sturdiness of the buttons was also observed in this treatment compared to others (Figure 2). Spraying with VVB2 also recorded fairly good yield (913 g/bed; 22.8% bioefficiency) (Table 5). The calcium ions in the booster might be the contributing factor for induction of sturdy buttons. Spraying of kinetin, naphthalene acetic acid (NAA) and gibberelic acid at VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm) 50 ppm (Sangeetha, 2002), and 200 ppm of NAA and indoleacetic acid (IAA) (Deshpande and Tamhane, 1982) significantly increased the yield of paddy straw mushroom. Chandrasekar et al. (2001) reported that pretreatment of sugarcane bagasse by products with sodium hydroxide supported increased yield of *Pleurotus sajarcaju* up to 83.8%. They explained that increase in alkali concentration significantly increased the microbial and enzymatic digestion of straw, which in turn increased the carbohydrate utilization leading to increased sporophore yield and bioefficiency. Likewise in our study, spraying of the boosters VVB1 and VVB2 at the time of pinhead formation would have triggered the production of pectinolytic enzymes as they are believed to play a role in initiation of primordial and enlargement of fruit bodies as reported by Sharma and Anila (1994).

## Seasonal productivity of *V. volvacea*

Environmental factors generally provide tools in planning and preparation of the crop for maximum

**Table 5.** Influence of boosters in enhancing the yield of paddy straw mushroom.

| Treatment | DFSR | DFPF | DFFH | Average number of buttons/bed | Average weight/button (g) | Yield/bed (g) | B.E. (%) |
|---|---|---|---|---|---|---|---|
| **Soaking** | | | | | | | |
| VVB1 | 6.7±0.33 | 8.0±0.40 | 10.0±0.50 | 33.6±1.68 | 25.3±1.26 | 853.0±42.65 | 21.3±1.06 |
| VVB2 | 7.0±0.19 | 8.7±0.23 | 10.3±0,27 | 31.0±0.82 | 25.0±0.66 | 776.0±20.53 | 19.4±0.51 |
| **Spraying** | | | | | | | |
| VVB1 | 6.0±0.24 | 8.7±0.35 | 10.0±0.40 | 38.0±1.52 | 26.6±1.06 | 1012.0±40.48 | 25.3±1.01 |
| VVB2 | 6.0±0.12 | 8.7±0.17 | 10.0±0.20 | 37.0±0.74 | 24.7±0.49 | 913.0±18.26 | 22.8±0.46 |
| **Soaking and spraying** | | | | | | | |
| VVB1 | 6.3±0.25 | 8.0±0.32 | 10.3±0.41 | 35±1.40 | 25.7±1.03 | 934.0±37.36 | 23.4±0.94 |
| VVB2 | 6.0±0.16 | 9.0±0.45 | 10.0±0.36 | 33.0±1.19 | 25.8±0.93 | 853.0±30.76 | 21.3±0.77 |
| **Control** | 7.0±0.32 | 9.7±0.26 | 10.3±0.41 | 34.0±1.36 | 25.0±1.00 | 850.0±34.00 | 21.3±0.85 |

Results are mean ± standard deviation of 3 replications. DFSR, Days for spawn run; DFPF, days for pin head formation; DFFH, days for first harvest; B.E., biological efficiency.

yields. Development of *V. volvacea* requires a high temperatureof 28 to 35°C with relative humidity of 80 to 85% (Chang and Miles, 1993). In the present study, significantly higher yields of *V. volvacea* were obtained in the beds prepared during the months from March to June (temperature range of 34 to 36°C and relative humidity (RH) of 80 to 90%) with bioefficiency of 19.6 to 21.8% and from July to September with bioefficiency of 18.4 to 18.9% (temperature range of 33 to 34°C and relative humidity of 80 to 85%) (Table 6). The minimum temperature that prevailed during the months of January, December, February, October and November did not support production of more fruiting bodies and there by recorded lower yield. Similarly, Pani and Das (2001) also recorded the maximum yield during July when the temperature was 25.5 to 32.5°C with relative humidity of 59 to 78% in West Bengal. Our results coincided with the reports of Kumar and Singh (2002) who reported that March to September/October with a temperature range of 33 to 39°C is an ideal period for growing this tastiest mushroom.

## Post harvest preservation of *V. volvacea*

Perusal of literature shows not much work on the preservation studies of *V. volvacea.* It is well known that the mushrooms harvested at egg stage have to be consumed within 6 to 8 h after harvest; otherwise liquefaction with slimy growths is observed. The storage of *V. volvacea* at egg stage in different packages revealed that the texture of the mushrooms stored in air tight plastic box at deep freeze conditions exhibited no veil opening and did not have any particular unpleasant odour and the texture also remained intact until 36 h (Table 7). Similarly, the mushrooms remained intact with very less veil opening in plastic boxes stored at refrigerated conditions until 36 h. Other packages showed slimy nature of mushrooms with veil opening and unpleasant fowl smell along with bacterial contamination.

## Conclusion

On the basis of the present findings, it may be concluded that it is possible to obtain significantly higher yields of *V. volvacea* by cultivating in circular compact beds (45 cm diameter, 30 cm height) using 15 and 20 days old spawn with well developed chlamydospores. In places where oil palm bunch waste and cotton waste are available in plenty, it can be used solely or substituted with rice straw to enhance the yield of paddy straw mushroom. It is evidenced from the present study that the spraying with micronutrient based boosters VVB1 ($CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + $KH_2PO_4$ 50 ppm + NaCl 50 ppm+ $Na_2HPO_4$ 50

**Table 6.** Seasonal productivity of *V. volvacea* at coimbatore conditions.

| Month (2009) | Average environmental conditions in poly house | | DFSR | DFPF | Average number of buttons/bed | Average weight of fruiting body (g) | Yield/bed (g) | Biological efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| | Temperature (°C) | RH (%) | | | | | | |
| January | 29.0±1.45 | 58.5±2.92 | 8.6±0.43 | 12.2±0.61 | 12.7±0.64 | 20.3±1.01 | 265.3±13.26 | 6.6±0.33 |
| February | 29.6±0.78 | 70.8±1.87 | 7.4±0.20 | 11.2±0.30 | 22.0±0.58 | 22.3±0.59 | 491.8±13.01 | 16.4±0.43 |
| March | 34.1±1.36 | 80.2±3.21 | 6.2±0.25 | 8.2±0.33 | 30.2±1.21 | 25.3±1.01 | 782.0±31.28 | 19.6±0.78 |
| April | 36.0±0.72 | 88.3±1.77 | 6.4±0.13 | 8.4±0.17 | 31.7±0.63 | 27.0±0.54 | 859.9±17.20 | 21.5±0.43 |
| May | 37.9±1.52 | 89.1±3.56 | 6.4±0.26 | 8.2±0.33 | 32.0±1.28 | 26.0±1.04 | 822.0±32.88 | 21.8±0.87 |
| June | 34.0±0.90 | 85.0±2.25 | 6.6±0.17 | 8.8±0.23 | 31.0±0.82 | 26.8±0.71 | 832.0±22.01 | 20.8±0.55 |
| July | 33.0±1.51 | 84.1±3.85 | 6.6±0.30 | 8.8±0.40 | 23.3±1.07 | 27.0±1.24 | 755.7±34.63 | 18.9±0.87 |
| August | 33.6±1.21 | 80.2±2.89 | 6.2±0.22 | 8.0±0.29 | 30.8±1.11 | 25.8±0.93 | 797.0±28.74 | 19.9±0.72 |
| September | 34.0±1.36 | 85.1±3.40 | 6.2±0.25 | 8.0±0.32 | 27.7±1.11 | 26.7±1.07 | 737.8±29.51 | 18.4±0.74 |
| October | 30.0±1.20 | 70.4±2.82 | 7.0±0.28 | 8.8±0.35 | 27.7±1.11 | 24.0±0.96 | 664.2±26.57 | 16.0±0.64 |
| November | 30.0±1.50 | 60.1±3.01 | 10.0±0.50 | 12.4±0.62 | 27.0±1.35 | 23.3±1.16 | 630.5±31.53 | 15.8±0.79 |
| December | 27.0±0.71 | 55.0±1.46 | 10.8±0.29 | 12.4±0.33 | 13.7±0.36 | 21.0±0.56 | 286.0±7.57 | 7.2±0.19 |

Results are mean ± standard deviation of 10 replications. DFSR, Days for spawn run; DFPF, days for pin head formation; BE, biological efficiency.

**Table 7.** Post harvest storage studies of *V. volvacea.*

| S/N | Treatment | Veil open (%) | Loss in texture | Specific odour | Microbial spoilage | Liquefaction |
|---|---|---|---|---|---|---|
| 1 | Polythene bag 100 G open (room temperature) | 60 | After 12 h | Foul smell | + | Slimy |
| 2 | Polythene bag 100 G open (refrigerated) | 50 | After 24 h | Foul smell | + | Slimy |
| 3 | Polythene bag 100 G open (deep freeze -20°C) | 5 | After 24 h | Particular smell | + | Slimy |
| 4 | PP bag 100 G sealed (room temperature) | 50 | After 12 h | Foul smell when packet was opened | + | Not slimy, but bag became filled with gas |
| 5 | PP bag 100 G sealed (refrigerated) | 25 | After 24 h | Foul smell when packet was opened | - | Not slimy, but bag became filled with gas |
| 6 | PP bag 100 G sealed (deep freeze -20°C) | - | Nil | Particular smell | - | Initially not slimy, ice crystals on the mushroom, later liquefied |
| 7 | Paper envelope - (room temperature) | 95 | After 6 h | Foul smell | + | Slimy |
| 8 | Paper envelope (refrigerated) | 80 | After 10 h | Foul smell | + | Slimy |
| 9 | Paper envelope (deep freeze -20°C) | 60 | After 5 h | Foul smell | + | Slimy |
| 10 | Punnet packing- (room temperature) | 85 | After 8 h | Foul smell | + | Slimy |
| 11 | Punnet packing - (refrigerated) | 80 | After 12 h | Foul smell | + | Slimy |
| 12 | Punnet packing - deep freeze | 60 | After 10 h | Foul smell | + | Slimy |
| 13 | Plastic box (airtight) (room temperature) | 30 | After 6 h | Foul smell | + | - |
| 14 | Plastic box (airtight) - (refrigerated condition) | 5 | - | Particular odour | - | - |
| 15 | Plastic box (airtight) (deep freeze - 20°C) | - | - | Particular odour | - | - |

-, Not observed/seen; +, observed

ppm) and VVB2 ($CaCl_2$ 400 ppm + $Na_2HPO_4$ 100 ppm) possess the potential to enhance the yield of *V. volvacea* and to get sturdy eggs. Significantly higher yields of *V. volvacea* were obtained in the beds prepared during the months from March to September, with a bioefficiency ranging from 18.4 to 21.8% bioefficiency. The storage of *V. volvacea* at egg stage in air tight plastic box at deep freeze conditions exhibited no veil opening and did not have any particular unpleasant odour, and the texture also remained intact until 36 h. Cultivation of *V. volvacea* with these improved cultivation techniques along with storage techniques can certainly improve the yield and quality of mushrooms and open avenues for cultivation in a large scale on commercial basis.

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