

## *Pleurotus* cultivation: a sustainable way to utilize agrowaste

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Received May 21, 2021; accepted January 29, 2022.  
Delo je prispelo 21. maja 2021, sprejeto 29. januarja 2022

### *Pleurotus* cultivation: a sustainable way to utilize agrowaste

**Abstract:** In the present study two species of *Pleurotus* namely *Pleurotus florida* (Mont.) Singer and *Pleurotus ostreatus* (Jacq.) P.Kumm. were cultivated using three different agrowaste substrates such as paddy straw, sugarcane bagasse, banana leaves and its mixture in equal proportion. The fastest colonization and maximum numbers of heads were produced on paddy straw substrate. Banana leaves and paddy straw substrates reported the highest yield of mushroom fruitbodies, biological efficiency and biomass loss in *P. florida* and *P. ostreatus*. It was noticed that the growth and development of fruitbodies on sugarcane bagasse was minimum and development of competitor moulds was observed on it. In the selected substrates banana leaves possess the highest percentage of nitrogen, carbon and cellulose. The results showed the possibility of utilizing different agrowaste for cultivation of oyster mushroom, which will boost the income of farmers.

**Key words:** growth parameters; mushrooms cultivation; yield; different substrates; oyster mushroom

### Gojenje ostrigarjev (*Pleurotus*): trajnosten način uporabe odpadkov iz kmetijstva

**Izvleček:** V raziskavi sta bili gojeni dve vrsti ostrigarja (*Pleurotus*), *Pleurotus florida* (Mont.) Singer in *Pleurotus ostreatus* (Jacq.) P.Kumm. na treh različnih gojiščih iz kmetijskih odpadkov in sicer na riževi slami, odpadkih predelave sladkornega trsa, listih bananovca in njihovih mešanicah v enakih deležih. Najhitrejša kolonizacija in največje število trosnjakov sta bila dosežena, ko je bil substrat riževa slama. Mešanica listov bananovca in riževe slame sta dali največji pridelek trosnjakov, največjo biološko učinkovitost in največjo izgubo biomase pri gojenju obeh vrst. Opaženo je bilo, da sta bila rast in razvoj trosnjakov najslabša na substratu iz ostankov predelave sladkornega trsa zaradi kompeticije s plesnimi. Izbrani listi bananovca so imeli največji odstotek dušika, ogljika in celuloze. Rezultati so pokazali možnost uporabe različnih odpadkov v kmetijstvu za gojenje ostrigarjev, kar bi povečalo prihodke kmetov.

**Ključne besede:** rastni parametri; gojenje gob; pridelek; različni substrati; ostrigarji

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## 1 INTRODUCTION

India has diverse agro-climatic zones which are suitable for cultivating wide range of plants including food crops, cash crops and horticultural products. Burgeoning demand for food throughout the world has led to an exponential increase in food production as anywhere in the world all over India. The advancement of agricultural production has undoubtedly resulted in increased amount of agricultural waste and agro-industrial waste. A significant growth of agricultural waste is prone to occur globally if developing countries continue to step up farming systems. This organic waste should be handled carefully in a sustainable way to avoid unwanted environmental side effects. Agricultural waste also termed as crop residue which includes field residues as well as processed residues. In most of the states of India, crop residues are mainly utilized for animal feed.

Many countries leverage crop residues produced by farming practices in different directions. It has been used in a processed or unprocessed form depending on the desired application. Potential alternatives include livestock feed, composting, bio-energy production and deployment in other extended farming activities like cultivation of mushrooms. Several nations including Japan, China, Nepal, Malaysia, Nigeria, Indonesia, Thailand and Philippines are using their agricultural waste to develop bio-energy and fertilizers (Lohan et al., 2018).

Mushroom cultivation has become popular throughout the world. Edible fungi production can greatly enhance sustainability, economic strength of the farmers. Diversification in agriculture sector is inevitable because of some key factors like population growth, food scarcity, poverty and malnutrition among developing and underdeveloped countries. Mushroom cultivation is an ideal method which possesses unique advantages than other waste management technologies. It helps the farmers to increase their income effectively by utilizing their own agricultural land waste. This kind of management has drawn more and more attention because of the nutritious output from waste. Mushroom cultivation can help to mitigate hunger and improve livelihoods by providing a fast-growing nutritious food supply and a stable source of employment and wealth (Rachna et al., 2013).

Nearly 355 million tones of crop residues are produced every year. In this, about 170 million is left out for burning and manure preparation. If India utilizes one percent of these waste, it will become a top mushroom producing country in the world (Tewari and Pandey, 2002). Among the entire cultivated mushroom, oyster mushroom possesses many advantages due to rapid mycelial growth, great colonization potential, easy and eco-

nomical cultivation techniques and suitable for cultivating under different climatic conditions.

The present study was carried out to find out the possibilities in utilization of agrowaste for the cultivation of edible mushroom and its effect on growth performance and morphological parameters.

## 2 MATERIALS AND METHODS

### 2.1 COLLECTION OF AGRICULTURAL WASTE MATERIAL

Agro waste materials such as paddy straw, sugarcane bagasse and banana leaves were used for the present study. Paddy straw and banana leaves were collected from farmers and sugarcane bagasse was purchased from sugarcane vendors. The water content of the substrates were completely removed by drying in dried sun light. It was stored in airtight bags to be used for the cultivation.

### 2.2 PURCHASE OF SPAWN

Sorghum grain based spawn of *Pleurotus florida* and *Pleurotus ostreatus* were procured from certified cultivation centre, MSM Mushroom Corner, Mushroom Cultivation Training and Seed Sale, Rediyarpatti, Tirunelveli and used for the present study.

### 2.3 CULTIVATION OF MUSHROOM

The selected agro-wastes were cut into small pieces and soaked in water for 12 – 14 hours and sterilized at 121 °C for 20 -30 minutes by using pressure cooker. After sterilization, it was cooled down in a clean room by shade drying to remove the excess water content present in the sterilized substrate. The sterilized substrates were filled in polypropylene bags to a height of 8 cm approximately. A handful of grain based spawns were sprinkled over the layer. Likewise, few layers were placed on the bag. Holes were made on the bags to facilitate ventilation. The spawned bags were kept under 22 °C–25 °C temperature and required humidity of 85 % was maintained in the cropping room.

### 2.4 EXPERIMENTAL DESIGN

Selected species were cultivated by bag method using three different agrowaste as substrates.

Substrates were collected from the farmers and mar-

ket place. Substrates were dried in the sun light and then cooked in the pressure cooker for 20 minutes to sterilize.

Substrate A: Paddy straw (PS)

Substrate B: Sugarcane bagasse (SB)

Substrate C: Banana leaf (BL)

Substrate D: 1:1:1 ratio of paddy straw, sugarcane bagasse, banana leaf (MIX)

## 2.5 GROWTH PARAMETER ANALYSIS

### 2.5.1 Colonizing period (spawn run)

Spawn run refers to the period during which mycelia spread and colonize the substrate so that it is completely covered. It is a vegetative stage in the development of the fungus which requires specific conditions to be successful (Oei, 1991). Number of days required for the colonization of fungal mycelium in the substrate is counted from the day of inoculation.

### 2.5.2 Pinheads and fruit bodies developed

Pinheads and fruiting bodies developed on the substrate were counted manually.

### 2.5.3 Yield

After the maturation the fruit bodies were hand-picked and immediately weighed using electronic balance (in gram unit).

### 2.5.4 Biological efficiency (Carvalho et al., 2012)

Biological efficiency is a term frequently used in the mushroom industry to describe the potential of the macro fungus to yield fruiting body (mushroom) from a known mass of substrate.

$$\text{Biological efficiency (\%)} = \frac{\text{Fresh mass of mushroom}}{\text{Dry mass of the substrate}} \times 100$$

### 2.5.5 Organic mass loss (Carvalho et al., 2012)

Organic mass loss of the substrate was calculated by using the following formula:

$$\text{Organic mass loss (\%)} = \frac{(\text{Initial substrate dry mass} - \text{residual})}{\text{Initial substrate dry mass}} \times 100$$

(residual – final mass of the substrate present in the mushroom cultivation bag after last yield)

## 2.5.6 Morphological parameters

Length and width of stipe and pileus were measured immediately after harvesting with the help of thread and measuring scale.

## 3 RESULTS AND DISCUSSION

### 3.1 COLONIZING PERIOD (SPAWN RUN)

Spawn run duration differs depending on species type and substrate used. The substrates used for the present study directly affect the time to attain the maximum mycelial growth and also take part in the yield attribute. Time required for completion of spawn running in *P. florida* and *P. ostreatus* varied on different substrates ranged from 15 to 17 days and 22 to 37 days respectively (Table 1). In both the species, the lowest time required for the completion of spawn run was recorded in PS (15 days in *P. florida* and 22 days in *P. ostreatus*). Longest time required for the completion of spawn run (17 days) was noticed in *P. florida* cultivated on BL and in *P. ostreatus* (37 days) cultivated on SB. Between the two species of *Pleurotus*, *P. florida* showed the fastest colonization of mycelia than *P. ostreatus*. Among the substrates used for the present study, colonization was fastest on PS in both the species than other substrates.

Differences in spawn run duration among species were evident in the studies conducted by Ashraf et al. (2013) comparing three *Pleurotus* species (*Lentinus sajor-caju* (Fr.) Fr., *Pleurotus ostreatus* and *Pleurotus djamor* Rumph. Ex Fr.) Boedijn) on three different wastes (cotton waste, wheat straw and paddy straw). Our findings in the present experiment are almost similar to the findings of Lalithadevi and Many (2014) who reported that spawn running day was between 16–25 days on paddy straw. The findings of the spawn run on sugarcane bagasse did not agree with the report of Hossain (2017) who stated that *P. ostreatus* completed the spawn run in 17 days on sugarcane bagasse. Increase in number of days for spawn running on lingo-cellulosic waste materials might be due to slow hyphal growth of mushroom on substrates (Mandel et al., 2005).

Mycelium development and colonization is the initial step, which provides suitable internal environment for the development of basidiocarp. Thus, exponential growth of mycelium is a key feature in mushroom cultivation (Sharma et al., 2013). The variation in the days

might be due to the difference in the chemical constituents and C : N ratio of the substrates (Bhatti et al., 1987). These results were similar to the findings of Vanathi et al. (2016) they have cultivated *P. florida* and reported 16–19 days for spawn running, it was highest in sugarcane trashes. Iqbal et al. (2016) reported that oyster mushroom cultivated upon sugarcane bagasse took 28.5 days for spawn running. The present study is corroborated with these findings. The occurrence of influential proportion of lignin, hemicellulose and alpha-cellulose in the growing medium was the assumed factor for higher rate of spawn running in banana leaves and rice straw substrate (Mondal et al., 2010).

### 3.2 NUMBER OF PINHEADS AND PERCENTAGE OF FRUITBODIES DEVELOPED FROM PINHEADS

*Pleurotus* species produced significantly different numbers of pinheads on different substrates (Table 1). In both the species, maximum numbers of pinheads (212 in *P. florida* and 51 in *Pleurotus ostreatus*) were recorded on PS followed by pinheads developed on the MIX in *P. florida* (137) and banana leaves (33) in *P. ostreatus* while minimum numbers of pinheads were observed on SB (32 in *P. florida* and 12 in *P. ostreatus*). Between the two species of *Pleurotus*, *P. florida* showed the highest number of pin heads (212) than *P. ostreatus* (51). From the present study, it was concluded that maximum numbers of heads were noticed on PS in both the species than other substrates. The percentage of fruit bodies developed from heads was very low (39 %) on PS though maximum numbers of pinheads produced on the same. In both the species, the highest percentage of fruit bodies developed from pinheads was maximum on BL (74 % in *P. florida*

and 84 % in *P. ostreatus*) followed by the MIX (68 % in *P. florida* and 75 % in *P. ostreatus*).

Our findings are further supported by Hague (2004) and Al Amin (2004), who reported that the highest number of pinheads of Oyster mushroom was found on paddy straw. Minimum numbers of pinheads were observed on sugarcane bagasse (12). Almost similar results reported Hasan et al. (2015) who observed minimum number of pinheads of oyster mushroom on sugarcane bagasse. The results were in accordance with the findings of Al Amin (2004) who reported maximum number of primordia and fruiting bodies of oyster mushroom on paddy straw. Formation of higher number of fruiting bodies may be due to the occurrence of glucose, fructose and trehalose in the substrate (Kitamoto et al., 1995). Poppe (1973) reported that presence of indole acetic acid (IAA) induces the formation of maximum fruiting body of mushroom.

### 3.3 TOTAL YIELD (G)

The present study confirmed that the use of different substrates brought about a significant effect on yield of *P. florida* and *P. ostreatus* (Table 1). In *P. florida*, the harvest yield ranged from 158 g to 622 g while in *P. ostreatus*, the harvest yield ranged from 102 g to 588 g. From the present study, we concluded that there was a difference in the yield between the selected *Pleurotus* species however, the difference is not significant. In *P. florida*, the average yield of mushroom fruitbodies was the highest on BL (622 g) followed by mushroom fruitbodies cultivated on PS (583 g) while in *P. ostreatus*, the average yield of mushroom fruitbodies was maximum on PS (588 g) followed by mushroom fruitbodies cultivated on BL (571 g). In both the species, minimum yield was obtained in mushroom fruitbodies cultivated on SB (102 g in *P.*

**Table 1:** Effect of different substrates on the growth performance of *Pleurotus florida* and *Pleurotus ostreatus*

| Species             | Substrates | Spawn running days | Yield (gram) | No. of pin heads | Fruiting body Developed From Pinheads (%) | Biological Efficiency (%) | Organic Mass Loss (%) |
|---------------------|------------|--------------------|--------------|------------------|---|---------------------------|-----------------------|
| <i>P. florida</i>   | PS         | 15 ± 0.71          | 583 ± 18     | 212 ± 17         | 39.2                                      | 77.7                      | 26.9                  |
|                     | SB         | 16 ± 2             | 158 ± 21     | 32 ± 5           | 54.2                                      | 21.1                      | 15.7                  |
|                     | BL         | 17 ± 1.5           | 622 ± 30     | 110 ± 11         | 73.6                                      | 82.9                      | 39.6                  |
|                     | MIX        | 16 ± 1             | 460 ± 16     | 137 ± 16         | 67.8                                      | 61.3                      | 24.8                  |
| <i>P. ostreatus</i> | PS         | 22 ± 0.6           | 588 ± 21     | 51 ± 9           | 66.2                                      | 78.4                      | 26.3                  |
|                     | SB         | 37 ± 1.5           | 102 ± 17     | 12 ± 4           | 63.9                                      | 13.6                      | 12.5                  |
|                     | BL         | 29 ± 1             | 571 ± 37     | 33 ± 8           | 83.8                                      | 76.1                      | 24.1                  |
|                     | MIX        | 28.7 ± 1.5         | 526 ± 12     | 29 ± 7           | 75  | 70.1                      | 21.6                  |

*ostreatus* and 158 g *P. florida*). The increase in the yield of *P. florida* and *P. ostreatus* on PS is due to easier way of getting sugars from cellulosic substances (Ponmurgan et al., 2007). Superiority of paddy straw over other substrates in cultivation of *Pleurotus* species with respect to yield had been reported earlier by Pala et al. (2012). Our results also agree with the result of Ragunathan et al. (1996) who reported that maximum yield was obtained by cultivation *Lentinus sajor-caju* on paddy straw.

### 3.4 BIOLOGICAL EFFICIENCY (%)

The highest percentage biological efficiency of *P. florida* was found on BL (82.9 %) followed by PS (77.7 %) while in *P. ostreatus* the highest percentage biological efficiency was noticed on PS (78.4 %) followed by BL (76.1 %) as given in Table 1. Higher biological efficiency of different substrates represents their higher suitability for the cultivation of mushroom. The lowest biological efficiency (21.1 % in *P. florida* and 13.6 % in *P. ostreatus*) was obtained on SB. Our results agree with the result of Sardar et al. (2016) who reported that lowest biological efficiency was obtained on sugarcane bagasse.

### 3.5 PERCENTAGE OF BIOMASS LOSS

The mushroom has the ability to degrade lignocellulosic materials during the idiophase stage following severe nitrogen and carbon depletion (Manson et al., 1989). In *P. ostreatus*, biomass loss was maximum (26.3 %) in PS while in *P. florida*, biomass loss was maximum in BL (39.6 %) which shows that degradation and solubilization was more intensive in the PS and BL.

### 3.6 EFFECT OF SUBSTRATE ON LENGTH AND DIAMETER OF PILEUS AND STIP

Among mushroom quality characteristics, pileus diameter, stipe length, stipe diameter are very important attributes (Mondal et al., 2010). Maximum length of pileus and stipe ( $7.3 \pm 0.8$  cm and  $3.1 \pm 0.6$  cm) was obtained on paddy straw while maximum width of pileus and stipe ( $8.4 \pm 1.8$  cm and  $1.8 \pm 0.1$  cm) was noticed on SB and MIX respectively.

In the present study, maximum length and width of pileus was obtained ( $11.3 \pm 2.2$  cm and  $21.5 \pm 6.7$  cm) on BL followed by the MIX ( $11.3 \pm 3.4$  cm and  $20.3 \pm 6.1$  cm) respectively. The minimum length and width of pileus was noted ( $5.8 \pm 0.8$  cm and  $8.2 \pm 2.9$  cm) on SB. Our results are in consistence with the findings of Sardar

et al. (2016) who observed minimum diameter of pileus ( $4.10 \pm 0.07$  cm) on sugarcane bagasse.

Stipe length and width of *P. ostreatus* was observed on different substrates in the present study and significant difference on different substrates used was found. Maximum length of stipe ( $3.1 \pm 1.5$  cm) was obtained on the MIX and PS alone ( $3.0 \pm 1.5$  cm). Similarly, maximum width of stipe ( $2.6 \pm 1.1$  cm) was obtained PS alone and on the MIX ( $2.3 \pm 0.7$  cm). Minimum length of stipe ( $1.3 \pm 0.3$  cm) was observed on BL while the minimum width was noticed ( $1.2 \pm 0.3$  cm) on SB.

Between the two species, *P. ostreatus* showed the maximum length and width of pileus than *P. florida*. From the present study, it was concluded that maximum length and width of pileus were noticed on BL and MIX than other substrates. Oyster mushroom quality depends on the length of stipe. Mondal et al. (2010) found that the higher the stipe length, the poorer the quality of the mushroom. Hence growers should use substrates that do not promote excessive growth of stipe length at the expense of marketable yield.

The size of the fruiting bodies is depended on the water holding capacity of the substrate (Chukwurah et al., 2013) and environmental conditions (Sanchez, 2004). It was also identified temperature, relative humidity, fresh air and compact material as the major external factors that affect stalk length, stalk width and mushroom cap shape AMGA (2004). The quality of oyster mushrooms relies upon its stalk length, higher the stalk length lesser will be the mushroom quality (Zadrazil, 1978).

## 4 CONCLUSION

In all over the world edible mushrooms are eaten and appreciated for their flavor, economic and ecological values and medicinal properties. Two species of *Pleurotus* namely *Pleurotus florida* and *Pleurotus ostreatus* were cultivated using three different substrates such as paddy straw, sugarcane bagasse, banana leaves and their mixture in 1:1:1 ratio. These three different substrates were investigated to determine the growth and yield of *Pleurotus* species. *P. florida* showed the fastest colonization cultivated on paddy straw and maximum numbers of pin heads were observed in the same species on the same substrate. In both the species, the percentage of fruitbodies developed from pin heads was maximum on banana waste. *P. ostreatus* showed the maximum length and diameter of pileus on banana waste. In both the species, yield of mushroom fruitbodies, biological efficiency and biomass loss were high on banana waste and paddy straw. Growth parameters and yield were found to be low in both the species cultivated on sugarcane bagasse. It is

**Table 2:** Effect of different substrate on the morphological parameters of *Pleurotus florida* and *Pleurotus ostreatus* (Results with standard deviation)

| Treatment | <i>Pleurotus florida</i> |            |             |            | <i>Pleurotus ostreatus</i> |            |             |            |
|-----------|--------------------------|------------|-------------|------------|----------------------------|------------|-------------|------------|
|           | Pileus                   |            | Stipe       |            | Pileus                     |            | Stipe       |            |
|           | Length (cm)              | Width (cm) | Length (cm) | Width (cm) | Length (cm)                | Width (cm) | Length (cm) | Width (cm) |
| PS        | 7.3 ± 0.8                | 8.2 ± 0.7  | 3.1 ± 0.6   | 1 ± 0.3    | 9.8 ± 2.2                  | 18.5 ± 7.8 | 3 ± 1.5     | 2.6 ± 1.1  |
| SB        | 6.7 ± 1.2                | 8.4 ± 1.8  | 1.4 ± 0.7   | 1.1 ± 0.4  | 5.8 ± 0.8                  | 8.2 ± 2.9  | 2.6 ± 1     | 1.2 ± 0.3  |
| BL        | 7.0 ± 0.9                | 10.7 ± 2.6 | 1.7 ± 0.2   | 1.7 ± 0.5  | 11.3 ± 2.2                 | 21.5 ± 6.7 | 1.3 ± 0.3   | 2 ± 0.4    |
| MIX       | 6.1 ± 1.3                | 8.1 ± 1.3  | 2.7 ± 0.4   | 1.8 ± 0.1  | 11.3 ± 3.4                 | 20.3 ± 6.1 | 3.1 ± 1.5   | 2.3 ± 0.7  |

concluded that mushrooms are a clear example of how low value waste, which is produced primarily through activities of the agricultural, forest and food processing industries can be converted to higher value material useful to mankind.

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