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Influence of spawning period on yield and yield attributing traits of ten *Pleurotus* species

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This study evaluates the impact of spawning periods on the average weight of fruit bodies and sporophore weight, as well as the biological efficiency of various *Pleurotus* species and *Hypsizygus ulmarius*. The results reveal that *P. ostreatus* consistently achieved the highest average fruit body weight, peaking at 17.56 g during November-December 2016, while *P. citrinopileatus* also performed well in this period but showed significant decline in subsequent months. *P. florida* maintained stable productivity, peaking at 8.08 g in January-February 2017, and *H. ulmarius* showed the highest weight of 16.34 g in September-October 2017. Sporophore weights varied significantly across periods, with peak values in November-December 2016 and declines during March-June 2017. The highest biological efficiency was recorded during November-December, with *P. ostreatus* achieving a peak of 110.00%, while efficiency dropped markedly in warmer months and partially recovered later in the year. The findings suggest that optimizing the spawning period can substantially enhance the yield and productivity of Pleurotus species under different agro-climatic conditions in Odisha.

Keywords : Biological efficiency, *Pleurotus* species, spawning period, sporophores, yield optimization,

INTRODUCTION

Mushrooms have been cherished as a delicacy for over two thousand years, with early mentions by the Greek philosopher Theophrastus (372-287 B.C.) highlighting their value as food gathered from farmlands, fields, and meadows. Over time, mushroom cultivation has expanded globally, with production reaching 5.0 million metric tons. In India, the mushroom industry saw a four-fold increase in production, reaching 0.2 million metric tons in 2019-20, with *Agaricus bisporus* accounting for 73% of this, followed by *Pleurotus* spp**.** (16%), *Volvariella* spp. (7%), and *Calocybe indica* (3%) (Ahmad et al. 2009; Agristat, 2020).

Pleurotus species are particularly valued for their ability to convert lignocellulose substrates into nutritionally rich food with minimal input requirements, while offering year-round cultivation potential due to the diversity of species (Jain *et al.* 2004; Gregori *et al*. 2007; Roy and Chakraborty, 2018; Mahalkshmi *et al*. 2019). Despite these advantages, the production of *Pleurotus* species remains limited due to suboptimal cultivation practices and varying agro-climatic conditions (Myronycheva *et al.* 2017; Ritota *et al.* 2019). Studies have shown that species like *P. florida* perform best during the monsoon and winter seasons (Sharma *et al*. 2017). Morphological and molecular characterization of four *Pleurotus* spp. (*P. djamor*, *P. sajor-caju*, *P. ostreatus* and *P. floridanus*) and their antioxidant properties were evaluated by Roy and Chakraborty (2023). Present study aims to assess the impact of spawning periods on the yield and biological efficiency of different *Pleurotus* species in Odisha, determine the optimal spawning time for

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maximizing production, and identify promising, lesser-known species for commercial cultivation in varied agro-climatic zones. These findings will contribute to enhancing productivity and diversifying *Pleurotus* cultivation in Odisha's mushroom industry.

MATERIALS AND METHODS

This study aimed to evaluate the comparative performance of various *Pleurotus* species concerning morphological characteristics, mycelial biomass production under different light intensities, pH levels, incubation temperatures, alternative substrates, substrate pasteurization methods, and organic supplements on mushroom productivity. Additionally, off-season cultivation and the nutritive value of the mushrooms were assessed. The materials used and the methods followed are described below.

Test fungus

Ten species of oyster mushroom were evaluated: *P. eous, P. florida, P. sajor-caju* (CTMRT strain), *P. citrinopileatus, P. fossulatus, P. flabellatus, P. platypus, P. ostreatus, H. ulmarius,* and *P. sajor-caju* (DMR strain). The fungi were obtained from the Centre for Tropical Mushroom Research and Training (CTMRT), Department of Plant Pathology, College of Agriculture, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar.

Maintenance of culture

The fungi were maintained on Potato Dextrose Agar (PDA) slants throughout the investigation. Sub-culturing was done every two months, with cultures stored at 25 ± 1°C. Fifteen-day-old pure mycelial cultures were used for the studies.

Cultivation of Pleurotus Materials used for bag preparation

Paddy straw from improved or tall indica varieties was used for bag preparation and mushroom cultivation. Well-dried, hand-threshed straw, less than a year old, was selected and chopped to 1.5–2.0 inches using a chaff cutter. Each bag required approximately 1.5 kg of dry straw.

Farmhouse setup

The experiments were conducted at the CTMRT farm and Krishi Vigyan Kendra, Kendrapara. The farmhouse was structured with a length of 50 ft and a breadth of 20 ft. It had an asbestos roof and a cemented floor. The windows were wide and covered with fine wire mesh to ensure proper ventilation, providing an optimal environment for mushroom cultivation.

Light, air, and humidity management

Windows were covered with gunny bags that were opened in the east-west direction to allow morning and evening light. To maintain humidity, gunny bags were soaked, water was sprayed, and the sand on the floor was kept moist.

Temperature control

The mycelial growth of *Pleurotus* species was maintained within 20–30°C. The experiments were conducted during the period from November to February.

Setup of raised racks and shelves

A rack with three shelves, spaced 2.5 feet apart, was constructed in the incubation room to support mycelial growth of the test fungi. For fruit body induction, fully colonized bags were hung on bamboo sticks arranged in three tiers within the farmhouse.

Substrate preparation

Three bundles of paddy straw (~1,500 g) were chopped into 1.5–2.0 inches, packed in gunny bags, and soaked in a solution of 125 ml formalin and 7.5 g bavistin per 90 litres of water for 6 hours. The straw was drained and spread on a cement floor to achieve 65% moisture, confirmed by the palm test.

Spawning of the substrate

Freshly prepared grain spawn, 20-30 days old, was procured for spawning. The process was carried out in a room pre-fumigated with 2% formalin for 48 hours. The spawn was used at

10% of the dry substrate weight, equivalent to 150 g per bag containing 1.5 kg of dry substrate. The spawn was carefully extracted from the container and divided into four portions, while 200 g of boiled wheat, used as a supplement, was also divided into four parts. Each portion of the straw substrate was layered to a thickness of 5-6 inches inside 80 cm × 40 cm polythene bags, with one portion of spawn and one portion of boiled wheat placed near the edge of each layer. Four layers of substrate were seeded with the spawn and supplemented with one-fourth of the boiled wheat. The bags were securely tied and perforated with 10-15 small holes (0.5-1.0 cm) on all sides, including 2-4 holes at the bottom, to ensure proper drainage and gas exchange (Hemalatha *et al.* 2017).

Crop Management Incubation

Spawned bags were incubated on shelves without ventilation or additional humidity. The temperature in the incubation room was monitored daily.

Fruit body induction

Once the spawned bags were confirmed to be fully colonized with a thick mat of mycelium on the straw substrate, the polythene bags were cut open. The compacted substrate was then placed on wooden shelves in the cropping room. Conditions were maintained with 200 lux light for 12 hours a day, a temperature range of 20–30°C, and 70–80% humidity. The substrate was sprayed with water twice daily to maintain adequate moisture for the developing mycelium (Hemalatha *et al.*2017).

Fruiting and harvest

Primordia or hyphal knots appeared 3–4 days after bag opening, and fruiting bodies were harvested within 3 days. Harvesting was done by gently twisting or pulling the mushrooms. Fruiting continued for 3–4 flushes over a 45–60 day crop period

Yield

The yield of *Pleurotus* species varied depending on species productivity, environmental conditions, and aftercare.

RESULTS AND DISCUSSION

The impact of different spawning periods on the average weight of fruit bodies for various *Pleurotus* spp. and *H. ulmarius* have been presented in Table 1. The results indicate that *P. ostreatus* consistently achieved the highest average fruit body weight across all periods, with a peak of 17.56 g in November-December. *P. citrinopileatus* also showed significant weight variations, with the highest average of 12.47 g in the same period and a notable decrease in subsequent months. *P. florida* exhibited relatively stable productivity, peaking at 8.08 g in January-February. *H. ulmarius* displayed high variability, achieving the highest weight of 16.34 g in September-October.The impact of the spawning period on the weight of sporophores for various *Pleurotus* species is summarized in Table 2. Data reveal significant variability in sporophore weight across different spawning periods and species. In the period of November-December, *P. ostreatus* exhibited the highest average weight of 1100.00 g, while *P. citrinopileutus* had the lowest at 682.50 g. The trend of high sporophore weight continued into January-February, although weights decreased for most species compared to the previous period. During March-April, there was a marked decrease in sporophore weight for all species, with the average weight dropping to as low as 299.50 g for *P. sajor-caju* (DMR strain). This low yield was also observed in May-June, where sporophore weights were notably reduced, particularly for *P. citrinopileutus* and *P. fossulatus*, which had weights of only 22.83 g and 18.83 g, respectively. In contrast, July-August showed a rebound in sporophore weight for several species, with *P. citrinopileutus* reaching up to 525.50 g. The trend observed in September-October again showed higher sporophore weights, especially for *P. citrinopileutus* (615.33 g) and *P. ostreatus* (655.33 g), though weights were still lower compared to the initial period.

The impact of spawning periods on the biological efficiency of various *Pleurotus* species and *Hypsizygus ulmarius* have been illustrated in Table 3. The highest biological efficiency for most species was observed during the November-December period, with *P. ostreatus* achieving a peak efficiency of 110.00%. This period

Table 1: Impact of spawning period on the average weight (g) of *Pleurotus* spp. fruit bodies

P. eous	*P. florida*	*P. sajor-caju* (CTMRT strain)	*P. citrinopileutus*	*P. fossulatus*	*P. flabellatus*	*P. platypus*	*P. ostreatus*	*H. ulmarius*	*P. sajor-caju* (DMR strain)
6.23	7.94	4.92	12.47	5.54	6.66	8.06	17.56	15.82	7.29
6.19	8.08	4.69	10.04	5.70	6.54	7.53	15.49	14.18	6.74
4.73	5.01	3.73	7.06	5.40	5.63	6.70	10.93	11.87	5.95
5.10	4.51	3.66	4.15	4.46	4.62	5.06	4.90	4.54	16.43
6.70	4.84	5.18	10.94	5.84	6.09	5.83	10.23	15.08	6.11
6.84	5.98	5.82	10.97	5.60	6.13	6.36	10.43	16.34	5.73
0.72	0.46	0.52	1.04	0.75	0.61	0.71	0.68	0.90	1.93
10.09	6.41	9.40	9.40	11.59	8.63	9.13	4.92	5.85	20.16

Table 2 : Impact of spawning period on the weight (g) of *Pleurotus* spp. sporophores

Period	*P. eous*	*P. florida*	*P. sajor-caju* (CTMRT strain)	*P. citrinopileutus*	*P. fossulatus*	*P. flabellatus*	*P. platypus*	*P. ostreatus*	*H. ulmarius*	*P. sajor-caju* (DMR strain)
Nov- Dec	989.00	796.17	920.83	682.50	580.33	642.67	803.33	1100.00	986.17	908.83
Jan-Feb	976.67	791.33	825.00	662.17	580.33	552.83	774.50	893.33	838.33	821.67
Mar-April	423.83	324.33	316.00	307.83	323.67	351.17	418.17	305.33	300.50	299.50
May- June	135.83	144.67	90.00	22.83	18.83	19.33	17.33	28.50	23.00	77.00
Jul-Aug	352.67	323.83	429.83	525.50	314.50	428.33	375.17	204.17	423.50	407.67
Sept- Oct	670.17	327.00	536.83	615.33	448.33	497.00	424.00	257.83	655.33	513.00
CD (0.05)	32.79	35.93	33.62	55.00	32.04	37.24	25.36	28.15	36.97	27.08
CV (%)	4.80	6.96	5.44	9.86	7.14	7.54	4.55	5.09	5.78	4.51

Table 3 : Impact of spawning period on the biological efficiency of *Pleurotus* spp

Period	*P. eous*	*P. florida*	*P. sajor-caju* (CTMRT strain)	*P. citrinopileutus*	*P. fossulatus*	*P. flabellatus*	*P. platypus*	*P. ostreatus*	*H. ulmarius*	*P. sajor-caju* (DMR strain)
Nov- Dec	98.90	79.62	92.08	68.25	58.03	64.26	80.33	110.00	98.62	90.88
Jan-Feb	97.75	79.13	82.50	66.21	58.03	55.28	77.45	89.33	83.83	82.16
Mar-April	42.38	32.44	31.60	30.78	32.36	35.11	41.81	30.53	30.05	29.95
May- June	13.38	14.46	9.00	2.28	1.88	1.93	1.73	2.85	2.30	7.70
Jul-Aug	35.26	22.38	42.98	52.55	31.45	42.83	37.52	20.41	42.35	40.76
Sept- Oct	57.02	32.70	53.68	61.33	44.83	49.70	42.40	25.78	65.53	51.30
CD (0.05)	3.23	3.59	3.36	5.50	3.20	3.72	2.53	2.81	3.69	2.70
CV (%)	4.74	6.95	5.44	9.86	7.14	7.54	4.55	5.09	5.78	4.51

consistently resulted in higher efficiencies across the different species, including *P. eous* (98.90%), *P. florida* (79.62%), and *P. sajor-caju* (CTMRT strain) (92.08%). In contrast, the biological efficiency significantly declined during the warmer months of May-June, with values dropping to 2.28% for *P. citrinopileutus* and 1.73% for *P. platypus*. The efficiency partially recovered in July-August and September-October, with *P. citrinopileutus* and *H. ulmarius* showing improved efficiencies of 52.55% and 65.53%, respectively.

The data presented in Table 1 illustrate the impact of spawning periods on the average weight of fruit bodies for various *Pleurotus* species and *Hypsizygus ulmarius*. *P. ostreatus* achieved the highest average fruit body weight during November-December, aligning with previous research that indicates cooler temperatures enhance mushroom yield and quality by minimizing competition from contaminants and providing optimal growth conditions (Deora *et al*. 2022). Similarly, *P. citrinopileatus* performed well during this period but experienced a decline in subsequent months, suggesting that temperature fluctuations and reduced humidity negatively affect its growth, as supported by research on mushroom cultivation under varying climatic conditions.

P. florida maintained stable production throughout the study, with peak performance observed in January-February. This finding is consistent with reports that *P. florida* is resilient to moderate winter conditions. The variability in *H. ulmarius* yields, with significant production observed in September-October, underscores its adaptability to various environmental conditions, consistent with findings reported by Mahalakshmi *et al*. (2016).

The results of this study clearly demonstrate that the spawning period has a significant impact on the sporophore weight of *Pleurotus* species, with substantial seasonal variations observed. The highest sporophore weights were recorded during the November-December period, indicating that cooler temperatures and possibly higher humidity during this time create favorable conditions for sporophore development. This finding is consistent with other research suggesting that *Pleurotus* species tend to thrive in cooler climates (Hemalatha *et al*. 2017; Deora *et al*. 2022).

In contrast, the decline in sporophore weight observed during the warmer months of March-April and May-June can be attributed to less favorable conditions, such as higher temperatures and lower humidity, which hinder mushroom growth (Chhata and Thakore, 2010). The partial recovery in sporophore weight observed in July-August and September-October is likely due to the onset of cooler temperatures and increased moisture, which benefit mushroom cultivation. This highlights the importance of optimizing environmental conditions to maximize *Pleurotus* yields throughout the year. Overall, while Pleurotus mushrooms can be cultivated year-round, their productivity is significantly higher during the winter months. This trend is supported by existing literature, which indicates that optimal yields are generally achieved during the rainy or winter seasons, with ideal conditions of 17.2-35°C and relative humidity of 70-90% (Sanger *et al*. 2006).

The present findings show highest biological efficiency for *Pleurotus* species and *Hypsizygus ulmarius* during cooler months (November-December), align with existing literature. Research supports that cooler temperatures and higher humidity enhance mushroom growth, as noted. Conversely, the drop in efficiency during warmer months (May-June) matches observations from Chhata and Thakore (2010) and Hemalatha *et al*. (2018), who found that higher temperatures and lower humidity hinder mushroom productivity. The partial recovery in efficiency during July-August and September-October is consistent with the idea that cooler transitional periods improve conditions for mushroom cultivation, as demonstrated by Sanger *et al*. (2006) and Hemalatha *et al.* (2017). Overall, these results underscore the importance of aligning spawning periods with favorable environmental conditions to maximize mushroom yield and efficiency.

CONCLUSION

The study examined the effect of spawning periods on the average weight and biological efficiency of various *Pleurotus* species and *Hypsizygus ulmarius*. Results showed that *P. ostreatus* had the highest average fruit body weight in November-December 2016, highlighting the benefits of cooler temperatures for mushroom growth. *P. citrinopileatus* also performed well during this period but declined in subsequent months due to temperature and humidity fluctuations. *P. florida* showed stable production, peaking in January-February, and *H. ulmarius* exhibited significant yields in September-October, reflecting its adaptability. Overall, the highest biological efficiency occurred during cooler months, aligning with existing research that cooler temperatures and higher humidity enhance mushroom productivity. The decline in efficiency during warmer months underscores the importance of optimizing spawning periods to match favorable environmental conditions, emphasizing the greater productivity of *Pleurotus* mushrooms during the winter months.

Future research should focus on refining cultivation techniques to extend the beneficial effects of cooler temperatures and higher humidity to warmer periods, potentially through controlled environment systems. Additionally, exploring the adaptation of *Pleurotus* species to varying climatic conditions could further optimize yield and efficiency year-round.

DECLARATION

Conflict of interest. Authors declare no conflict of interest.

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