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Amit Upadhayay
Institute of Agriculture Training
and Research, Prem Nagar
Dehradun, Uttarakhand, India

Aditi Bisht
Department of Environment
Science, School of Allied Science,
Dev Bhoomi Uttarakhand
University, Dehradun,
Uttarakhand, India

Manmohan Singh Bisht
Institute of Agriculture Training
and Research, Premnagar
Dehradun, Uttarakhand, India

Naveen Nautiyal
Institute of Agriculture Training
and Research, Premnagar
Dehradun, Uttarakhand, India

Uttam Kumar
Alpine Group of Institutes,
Dehradun, Uttarakhand, India

Ashish Upadhyay
Department of Agriculture, Tula's
Institute, Dehradun, Uttarakhand,
India

Vaishali Thapa
Institute of Agriculture Training
and Research, Premnagar
Dehradun, Uttarakhand, India

Corresponding Author:
Aditi Bisht
Department of Environment
Science, School of Allied Science,
Dev Bhoomi Uttarakhand
University, Dehradun,
Uttarakhand, India

Pine sawdust-based mushroom cultivation: A cost-effective strategy for livelihood improvement in Uttarakhand

Amit Upadhayay, Aditi Bisht, Manmohan Singh Bisht, Naveen Nautiyal, Uttam Kumar, Ashish Upadhyay and Vaishali Thapa

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Abstract

The present study was conducted to evaluate the suitability of pine sawdust as a substrate for the cultivation of oyster mushroom (*Pleurotus florida*), utilizing locally available forest litter from Uttarakhand. Spawn was prepared using wheat grains following standard sterilization techniques, and the substrate was chemically treated prior to spawning. The results showed that spawn run was completed in 34.67 days, while pinhead initiation and fruiting body formation were observed at 41 and 46.67 days, respectively. Yield was highest in the first flush (1503.33 g), followed by the second (902.67 g) and third flush (450.33 g), indicating a gradual decline in productivity across successive flushes. The use of pine sawdust offers several benefits, including efficient utilization of forest waste, reduction of environmental pollution, and conversion of low-value biomass into a high-value nutritional product. Additionally, it provides an eco-friendly, cost-effective cultivation method and creates opportunities for income generation and livelihood improvement among rural communities. Thus, pine sawdust can be considered a sustainable substrate for oyster mushroom cultivation in forest-rich regions.

Keywords: *Pleurotus florida*, Pine sawdust, livelihood improvement, Sustainable cultivation, Forest biomass

Introduction

Uttarakhand, India's 27th state, is blessed with large forest resources, making it one of the places with significant forest wealth and natural biodiversity. Because they keep the environment in balance, these woods are an essential natural resource for both humans and wildlife. The total area of Uttarakhand is 53,483.36 km², of which around 65% is covered by forests and roughly 93% is made up of mountainous terrain (Negi & Kumar, 2016) [12].

The forests of Uttarakhand cover several altitude zones and change in nature with increasing elevation. Broad-leaved deciduous forests are widespread in the low-lying Tarai and Doon plains. Dense pine forests spread upward into the valleys and mid-altitudes. Coniferous forests that have evolved to harsher climates are found in the icy alpine regions, while mixed oak forests flourish further up in the temperate belt (Sati *et al.*, 2018) [16]. People living in rural areas of Uttarakhand rely on forest resources (CEDAR 2010) for essentials like fuelwood, fodder, and food. They also practice community-based forest management through local councils known as *Van Panchayats*, a system that was first introduced in 1920 (Phartiyal *et al.*, 2006) [14].

Approximately 16% of Uttarakhand's total forest area (between 1000 and 1800 m asl) is covered by Chir Pine (*Pinus roxburghii*) forests (Negi, 2019) [11]. Pine commonly known as "chir pine" or "long needle pine", is a native species of the Himalayan region (Kaushik *et al.*, 2010). It is among the most widely distributed forest trees in Uttarakhand (Khanduri & Sharma (2000); Kala (2004) and Kaushik *et al.*, (2010)) [8, 5, 6]. In the forests of Uttarakhand, five distinct species of pine are naturally found growing in the wild. These include *Pinus roxburghii*, locally known as chir pine; *P. wallichiana*, commonly called blue pine; *P. gerardiana*, referred to as chilgoza pine; *P. kesia*, known as Khasi pine; and *P. bhutanica*, which is recognized as Bhutan white pine (Pandey and Nautiyal, 2025) [13].

Since ancient times, people have depended on these pine trees for a variety of functions. A significant amount of this state's annual income comes from chir pine, which is also a common source of various commercially significant raw materials including resin, timber, turpentine oil, etc (Singh *et al.*, 2017) ^[17].

Chir Pine forests are mainly responsible for the spread of forest fires. The chir pine tree is an economically significant species due to its high resin content. However, the same characteristic makes its needle litter extremely flammable and susceptible to forest fires. Every year, pine trees are burned to eliminate needle litter, which makes it difficult for people and livestock to walk through the forest areas (Chandran *et al.*, 2011) ^[3].

The forests of Uttarakhand are mostly underutilized while being commercially viable and a significant source of income for rural people. The reason for this is the forest areas are far away and not easy to reach (Sati and Bandooni 2018) ^[16]. Its more sustainable use is limited by the cliffs and slopes. On the other hand, human activities such as forest fires, overgrazing, cutting trees for fodder and fuel, along with the removal of leaf and wood litter from the forest floor, have emerged as major pressures on plant diversity in the Uttarakhand Himalaya (Malik *et al.*, 2016) ^[10].

The primary aim of this study was to explore the use of pine sawdust in oyster mushroom cultivation, turning locally available forest waste into a sustainable agricultural resource. By utilizing this material, the study aimed to promote eco-friendly practices while generating income and livelihood opportunities for local communities, especially since the environmental conditions in the region are highly favourable for oyster (*Pleurotus florida*) mushroom production.

2. Materials and Methods

2.1 Mushroom culture and spawn preparation: The pure culture of *P. florida* was obtained from the Directorate of Mushroom Research (DMR), Solan, Himachal Pradesh.

Wheat grains were washed thoroughly to remove impurities and then boiled until soft but intact. The boiled grains were drained and shade-dried to remove excess moisture. After drying, the grains were mixed with calcium sulphate (2%) and calcium carbonate (0.5%) to maintain pH 6.5–7.0. The prepared grains were filled up to three-fourths in polyethylene bags, plugged with non-absorbent cotton, and sterilized at 121°C for 1.5 hours. After cooling, the bags were inoculated with master spawn under sterile conditions and incubated at 25 ± 1°C until complete colonization.

2.2 Substrates preparation: For the sterilization of substrate the method is used as followed:

For chemical sterilization, substrate such as Pine sawdust was soaked in fresh water overnight to achieve a moisture content of approximately 70–75%. After soaking, the excess water was allowed to drain off then the pre-soaked straw was submerged in a 200-liter metal drum containing a solution of lime @ 15g per kg straw, 125 ml formalin and carbendazim @ 15 g per 100 litres of water.

After both treatments, the substrates were then left to attain a moisture content of about 65% before spawning.

2.3 Spawning and incubation: The substrates were layered into polythene bags, and a multi-layered spawning technique was used, applying spawn at a rate of 2% after that the spawned bags are incubated in the cropping room under controlled conditions, maintaining a temp. of 21–25°C and R.H. around 70–80% to

facilitate spawn run.

2.4 Harvesting: The fruiting bodies were harvested before curling of fruit body and well-formed gills, because over matured fruit body is fragile and difficult to handle. Harvesting was done by hand holding the stipes at the base and twisting lightly.

3. Results and Discussion

Pleurotus florida growth on pine sawdust had distinct phenological phases with total colonization of the substrate and development of fruiting bodies within the predicted experimental period. The spawn run was accomplished with 34.67 days and pinheads have appeared at 41 days revealed in figure I. The fruiting body formation was observed at 46.67 days, which is the beginning of reproductive stage. It indicated complete colonization of the substrate by mycelium. Pinhead initiation was recorded at 41 days, followed by the initiation of fruiting bodies at 46.67 days. These observations indicate that the developmental stages progressed steadily on pine sawdust, though the duration for each stage was relatively extended. Comparative evidence, however, shows that these are duration is considerably lengthened. In case of *P. florida*, wheat straw gave spawn run in 18.25 days and pinhead formation in 22.38 days, whereas other *Pleurotus* species on wheat straw produced spawn run in 18–21 days followed by pinhead formation in 5–7 days (Jamil *et al.*, 2019; Thakur *et al.*, 2025) ^[4, 18]. Tirkey *et al.*, 2017 ^[19] reported 15–21 days for mycelium run and 17–26 days for primordium initiation of *P. florida* on different substrates. Sawdust substrates resulted in least days for pin head formation for *P. florida* than corn cobs, which was not observed on pine sawdust, as Kinge *et al.*, 2016 ^[9] reported. This indicates that pine sawdust alone is not as good as other sawdust types or other substrates for *P. florida* production.

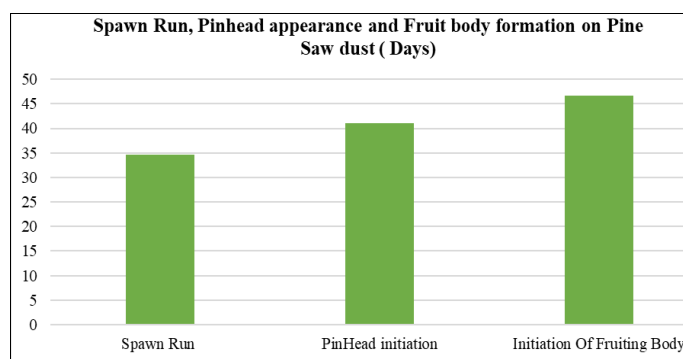


Fig 1: Time Required for Spawn Run, Pinhead Initiation, and Fruiting on Pine Sawdust

In terms of quantitative productivity of the substrate, the productivity of *Pleurotus florida* growing on pine sawdust is shown to be the highest in the first flush (1503.33 g) revealed in figure II (1503.33 g), followed by the second flush (902.67 g), and the third flush (450.33 g). These observations indicate that the yield decreased progressively with each successive flush, with maximum production obtained during the initial harvesting stage. The loss of oyster mushroom yield in successive flushes on pine sawdust is consistent with mushroom cultivation patterns, and is based on the depletion of the nutrients available and changes in the mushroom's physiology throughout the production cycle. The observed yield pattern (highest in first flush (1503.33 g), lowest in second flush (902.67 g) and lowest in third flush (450.33 g)) confirmed the trend seen in several

studies. Another study by Khan *et al.* (2012) ^[7] found that the yield of *Pleurotus ostreatus* was "maximum" in the first flush, followed by the second and third flush, while Ram *et al.* (2013) ^[15] reported "maximum" yield in the 1st and 2nd flush, but reduced yield in 3rd flush. The decrease is probably a result of a lack of nutrients in the substrate and changes in enzyme activity. Bánfi *et al.* (2015) reported that the activities of the lignocellulolytic enzymes measured which are important in the degradation of the substrate exhibited different trends depending on the cultivation cycles, with the highest activities in flush and harvest stage for cellulose and hemicellulose degrading enzymes. This is the first flush, and its concentration has practical importance for cultivation efficiency and economic planning in the mushroom cultivation.

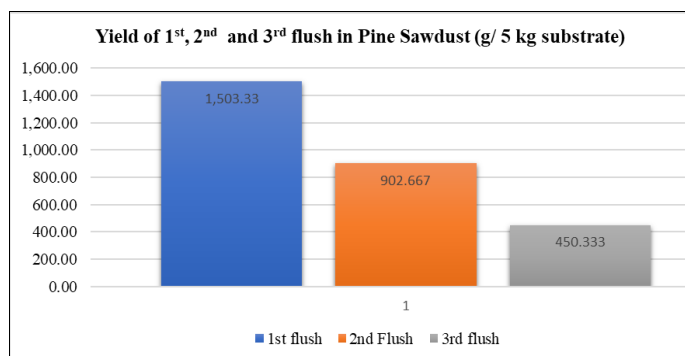


Fig 2: Yield Variation Across First, Second, and Third Flushes on Pine Sawdust (g/5 kg Substrate)

4. Conclusion

The present study proved that the pine sawdust which is abundantly available in forest area of Uttarakhand is an economically and ecologically viable and effective alternative substrate for production of oyster mushroom (*Pleurotus florida*). The substrate however, had a slight delay in the spawn run and in the initiation of fruiting compared to conventional substrates and was successful in crop establishment but yielded a satisfactory total yield. Biological efficiency was at its best during the first flush and was decreasing gradually through the successive production cycles.

The pine sawdust has not only a biological feasibility but because it is a by-product of pine trees, it can solve two major problems in the region: waste management and income generation and livelihood diversification for the rural population. The direct use of this underutilized resource in mushroom farming is aligned with sustainable agricultural practices and optimizing the use of resources in areas rich in biodiversity.

Recommendations

1. Further research is needed to assess the nutritional value of mixing pine sawdust with the agriculture residues that contain high levels of nitrogen (such as wheat straw, rice bran or pulse husks) to shorten the spawn run phase time and reduce the initiation time for fruiting.
2. Efficacy of different pre-treatments (either physical, such as composting or leaching, or biological) of pine sawdust to degrade complex lignocellulosic bonds and possible resinous inhibitors that might retard colonization rate should be evaluated.
3. An extensive cost benefit analysis needs to be done to determine the net economic gain for rural smallholders for collection, processing and spawn cost versus the regional

market for *Pleurotus florida*.

4. In Uttarakhand, local agricultural extension centers and co-operative societies should prepare localized training modules to transfer this cultivation technology to the rural communities in the state to promote eco-entrepreneurship and offer sustainable employment.

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