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Comparative study on the effect of different agro-wastes on growth parameters and yield performance of *Pleurotus citrinopileatus* mushroom

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Abstract
The present study aimed to evaluate the efficacy and sustainability of different locally available substrates for the cultivation of Golden oyster mushroom (*Pleurotus citrinopileatus*). Growth, yield parameters, and biological efficiency were assessed on substrates including paddy straw, wheat straw, soybean straw, sugarcane bagasse, bajra straw, jowar straw, rajmah straw, and spent button mushroom substrate. Spawn run duration ranged from 19.58 to 22.99 days, with T_2 (wheat straw) recording the shortest (19.58 days) and T_4 (sugarcane bagasse) the longest (22.99 days). No mycelial growth was observed in T_8 (spent button mushroom substrate). Pinhead formation was earliest in T_5 (bajra straw) at 23.13 days and took longest time in T_4 at 26.52 days. Time from pinhead to first harvest ranged between 5.33 and 8.24 days, being shortest in T_2 and longest in T_7 (rajmah straw). The second harvest occurred between 16.63 and 20.95 days, with T_2 being the shortest and T_7 the longest. For the third harvest, T_2 again recorded the shortest time (26.85 days), and T_7 the longest (31.67 days). The average fruiting duration from incubation ranged from 28.93 days in T_5 to 37.01 days in T_7. Yield per kg dry substrate varied from 621.03 to 932.17 g, with the highest in T_2 (932.17 g/kg), followed by T_5 (837.46 g/kg), T_1 (829.45 g/kg), and T_3 (747.11 g/kg), while T_4 recorded the lowest yield (621.03 g/kg). Among the evaluated substrates, wheat straw proved to be the most effective for Golden oyster mushroom cultivation, owing to its favorable influence on growth, yield, and biological efficiency.

Keywords: Golden oyster mushroom, straws, growth, yield, biological efficiency

Introduction
Mushrooms refer to the fruiting bodies of fungi belonging to the divisions Ascomycota and Basidiomycota. These fleshy, spore-producing structures play a key role in fungal reproduction, with spores functioning similarly to seeds in higher plants. Mushrooms are saprophytic in nature, thriving on dead and decaying organic matter while contributing to the decomposition process. They derive nutrients from their substrate through fine, thread-like structures called mycelia, which are typically not visible from the surface. Mushrooms have been regarded as a delicacy for thousands of years, with references found in ancient Roman and Greek literature. Since antiquity, humans have been fascinated by the diverse shapes, sizes, and colours of mushrooms, especially those that emerge after rainfall.

The oyster mushroom (*Pleurotus* spp.) was first cultivated by Flank in Germany in 1917. Traditional ecological knowledge, passed down through generations, highlights the use of mushrooms both as food and medicine, underscoring their cultural and nutritional significance (Pereira *et al*. 2012) [1]. Oyster mushrooms possess the ability to convert readily available, underutilized lignocellulosic agricultural waste into protein-rich, marketable food. They are a rich source of vitamins such as B1, B2, and K, along with essential minerals like sodium, calcium, iron, and phosphorus, as well as protein (Caglarirmak, 2007) [2]. Commonly known as the Golden oyster mushroom, *Pleurotus citrinopileatus* is an edible species from the family *Pleurotaceae*, predominantly found in Asia (Zhang *et al*. 1994) [3]. Its commercial cultivation is widely practiced in countries like China, Korea, Japan, and India. Due to its high heat requirement, *P. citrinopileatus* is typically grown in tropical or subtropical regions, and in temperate zones during summer.

This species is favoured for its rapid mycelial growth, high polymer-degrading ability, and vibrant appearance. Its attractive colour, quick development, suitability in mixed mushroom cultivation, and notable resistance to high temperatures make it a potential alternative to the more commonly cultivated species such as *Pleurotus ostreatus*, *P. pulmonarius*, and *P. sajor-caju* (Pandey *et al*. 2012) [4]. This study including, paddy straw, wheat straw, soybean straw, sugarcane bagasse, bajra straw, jowar straw, rajmah straw and spent button mushroom substrate focuses on the impact of these substrates on growth and yield parameters of Golden oyster mushroom.

Material and Methods

The research was conducted at All India coordinated Research Project on Mushroom, College of Agriculture, Pune (MS). The pure culture for *Pleurotus citrinopileatus* was procured from the ICAR-Directorate of Mushroom Research at Chambaghat, Solan (HP).

Spawn substrate and master spawn preparation

Wheat grains served as the base substrate for preparing the master spawn. The grains were thoroughly washed, then boiled for 25-30 minutes and left to air dry overnight. The following day, calcium carbonate and calcium sulfate were added at 4% of the grain weight to regulate pH and prevent clumping. The treated grains were filled into conical flasks and sterilized in an autoclave at 22 psi for 1.5 hours. Under sterile conditions in a laminar airflow chamber, the grains were inoculated with *Pleurotus citrinopileatus* culture. The inoculated flasks were then incubated at 25±1 °C for about 15 days until the grains were fully colonized by the mycelium, forming the mother spawn.

Preparation of commercial spawn

To prepare commercial spawn, the mother spawn was aseptically transferred into sterilized polypropylene bags containing pre-autoclaved wheat grains. Each bag was filled with 500 grams of moist, sterile wheat grains, and inoculated with four to six spatula scoops of mother spawn. The bags were shaken vigorously to ensure uniform distribution and incubated at 25±1 °C for 7 to 10 days. Once the mycelium fully colonized the substrate, the commercial spawn was deemed ready for use.

Substrate preparation and sterilization

A variety of agricultural by-products—including wheat straw, paddy straw, soybean straw, sugarcane bagasse, bajra straw, jowar straw, rajmah straw, and spent button mushroom substrate were utilized for cultivating Golden oyster mushrooms. The straw materials were chopped into 3-5 cm pieces and soaked for 16-18 hours in water treated with chemicals (Bavistin at 7.5 g and formaldehyde at 125 ml per 100 L of water) using gunny bags. After soaking, excess water was drained. To process the spent mushroom substrate, it was moistened to 70% using distilled water, filled into gunny bags, and autoclaved at 121 °C for one hour. After sterilization, the substrates were cooled to 25±1 °C.

Bed filling and spawning

Spawning was carried out in a chamber that had been disinfected with 2% formaldehyde 48 hours prior. When the moisture content of the substrate dropped to around 65%, it was packed into high-density polythene bags (45 × 30 cm, 100 gauge). Each bag contained 3 kg of wet substrate (equivalent to 1 kg of dry straw) and was layer-inoculated with wheat grain spawn at 2% of the wet weight. The top of each bag was tied securely, and 20-25 small holes were made to allow airflow, along with additional drainage holes at the bottom.

Incubation and spawn run

After spawning, the bags were placed on iron racks in the incubation room, maintained at a temperature of 21-29 °C with proper light, air circulation, and 70-85% relative humidity. These conditions were sustained until full colonization, which occurred within 19-22 days, resulting in the substrate turning completely white with mycelial growth. The bags were then opened to initiate fruiting.

Cropping

Pinhead formation began 3-5 days after the bags were opened. All necessary environmental factors—temperature, humidity, ventilation, and light—were carefully controlled to support the growth of pinheads and fruiting bodies. The appearance of pinheads was closely monitored, and watering was done twice daily to maintain optimal moisture levels during cropping.

Harvesting

Watering was stopped one day before harvesting. Harvesting took place between the 29th and 31st day after bag opening, once the mushroom clusters were fully matured. Mushrooms were harvested by gently twisting them off to avoid damaging surrounding pinheads. Each harvested mushroom was individually weighed and counted for each replication. The yield was recorded precisely, and biological efficiency was calculated to assess overall productivity.

Biological efficiency

The biological efficiency was calculated using the following formula,

$$\text{Biological efficiency (\%) (B.E.)} = \frac{\text{Fresh weight of mushrooms}}{\text{Dry weight of substrate used}} \times 100$$

Statistical analysis

The data collected for various observations was analyzed using CRD. The standard statistical methods as described by Panse and Sukhmate (1985) [5] was followed for statistical significance and an online OPSTAT application.

Results

Growth performance

The observations, such as the days required for pinhead formation, spawn run, and first, second and third harvest were recorded.

Days required for spawn run

During the incubation period, observations for the spawn run were recorded. The spawn run findings were statistically non-significant. The number of days required for spawn run ranged from 19.58 to 22.99 days (Table 1, Fig 1). Among the observed treatments, Treatment T_2 (wheat straw) required shortest period for spawn run of 19.58 days. The treatment T_3 (Soyabean straw), T_5 (bajra straw), and treatment T_1 (paddy straw) required 19.69, 20.56 and 20.72 days respectively to

complete the incubation period. Whereas, treatment T_4 (sugarcane bagasse) took the longest time for completing the spawn run (22.99 days). In contrast in the treatment T_8 (spent button mushroom substrate) development of mycelial growth was not observed even after 25 days of incubation.

Days required for pinhead formation

On the completion of incubation phase, beds were moved to the growing room. Spawn run was followed by the emergence of pinheads on opening the beds with the growth of mycelium. The data presented in table 4.2 showed that, treatment T_5 (Bajra straw) required shortest period for the development of pinhead, with an average of 23.13 days. This treatment was followed by treatment T_2 (wheat straw) which required 24.47 days for pinhead formation. Treatment T_7 (rajmah straw) required 28.77 days for pinhead formation. The number of days required for formation of pinheads ranged from 23.13 to 28.77 days. Treatment T_5 (bajra straw) resulted in the early production of pinhead following the spawn run.

Table 1: Effect of different substrates on days required for spawn run and pinhead formation of Golden oyster mushroom

Treatment	Days required for	
	Spawn run	Pinhead formation
T_1-Paddy straw	20.72	25.34
T_2-Wheat straw	19.58	24.94
T_3-Soybean straw	19.69	24.47
T_4-Sugarcane bagasse	22.99	26.87
T_5-Bajra straw	20.56	23.13
T_6-Jowar straw	21.58	26.52
T_7-Rajmah straw	21.63	28.77
T_8-Spent button mushroom substrate	0.00	0.00
SE(m)±	0.76	0.94
CD (0.05)	NS	2.87

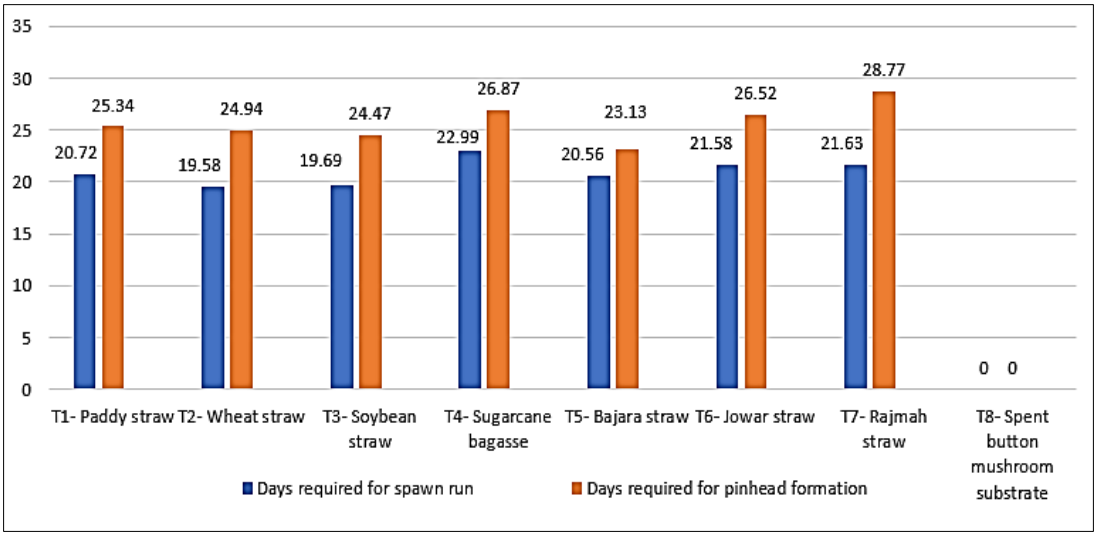

Fig 2: Effect of different substrates on days required for spawn run and pinhead formation of Golden oyster mushroom

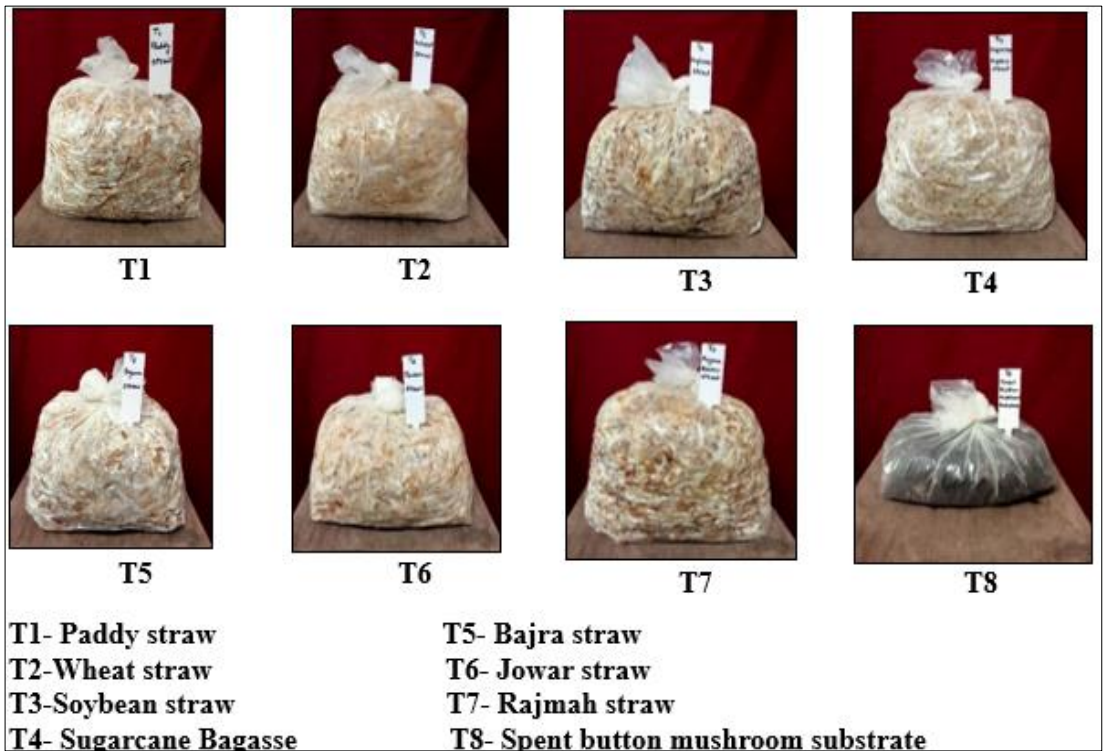

Plate 2: Effect of different substrates on spawn run in Golden oyster mushroom.

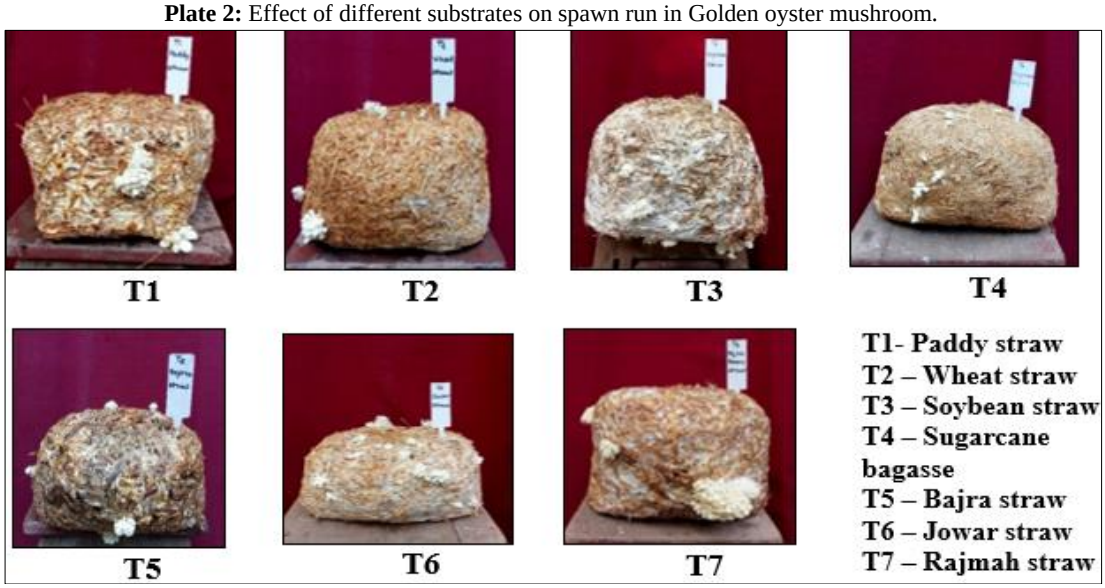

Plate 3: Effect of different substrates on pinhead formation of Golden oyster mushroom.

Days required for harvesting

After the formation of pinhead and development of fruiting bodies, harvesting was carried out three times. The number of days required for first, second and third harvest were recorded (Table 2, Fig. 2).

First harvest

The data from the Table 2 suggests that, the treatment T_2 (wheat straw) required fewest days for first harvest (5.33 days), which was found to be at par with treatment T_1 (paddy straw), T_3 (soybean straw) and treatment T_5 (bajra straw) which took 5.50 days, 5.67 days and 5.80 days respectively. In contrast, the treatment T_7 (rajmah straw) required longest period (8.24 days) for the first harvest.

Second harvest

In case of days required to get second harvest, treatment T_2 (wheat straw) took the shortest duration of 16.63 days, which was recorded to be at par with treatment T_1 (paddy straw) 17.72 days, treatment T_5 with (bajra straw) and treatment T_4 (sugarcane bagasse) took 18.66 days and 19.60 days respectively. Whereas, treatment T_7 (rajmah straw) took the longest time (20.95 days) for the second harvest.

Third harvest

The recorded data from Table 2 revealed that, the treatment T_2 (wheat straw) required

fewest days for the third harvest (26.85 days), which was comparable to the treatment T_1 (paddy straw) which required 27.12 days for final harvest. Treatment T_7 (rajmah straw) required longest period (31.67 days) for the third harvest. The treatment T_2 (paddy straw) required the shortest duration for the first, second and third harvest after shifting the beds to growing room, which was followed by treatment T_1 (paddy straw). Whereas treatment T_7 (rajmah straw) took the longest time for harvest. (Table 2 and Fig.2).

Total days required for fruiting

From the table 2, it is observed that treatment T_5 (bajra straw) required minimum number of days for development of fruits since incubation (28.93 days) followed by treatment T_3 (soybean straw) 30.14 days and treatment T_1 (wheat straw) 30.27 days. The maximum days for the development of fruits were required by treatment T_7 (rajmah straw) 37.01 days.

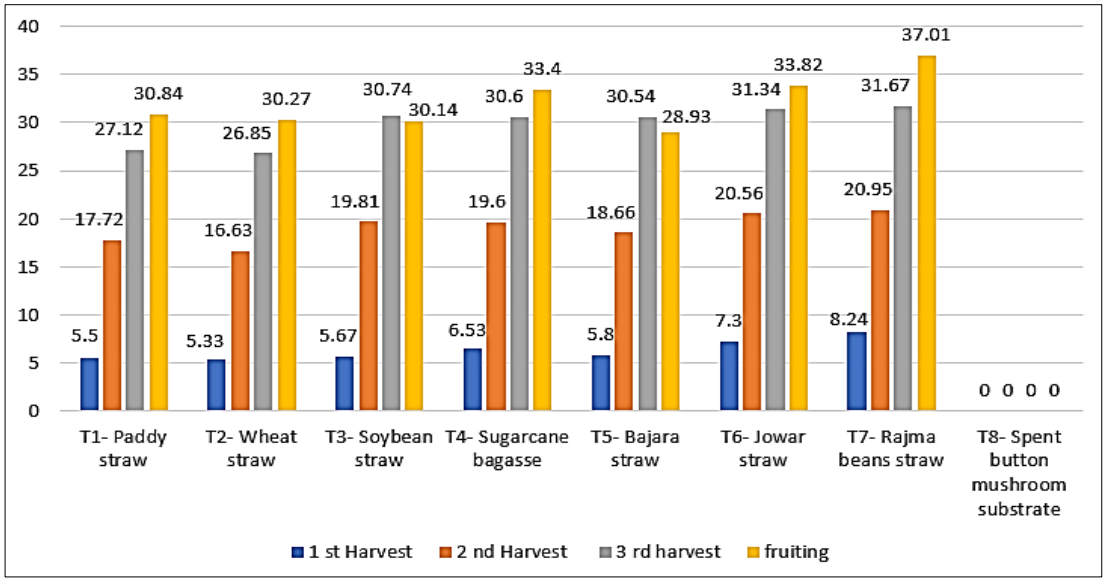

Fig 2: Effect of different substrates for days required for harvest and fruiting of Golden oyster mushroom

Table 2: Effect of different substrates for days required for harvest of Golden oyster Mushroom

Treatments	Days required for harvest			Total no. days required for fruiting
	1st	2nd	3rd	
T_1-Paddy straw	5.50	17.72	27.12	30.84
T_2-Wheat straw	5.33	16.63	26.85	30.27
T_3-Soybean straw	5.67	19.81	30.74	30.14
T_4-Sugarcane bagasse	6.53	19.60	30.60	33.40
T_5-Bajra straw	5.80	18.66	30.54	28.93
T_6-Jowar straw	7.30	20.56	31.34	33.82
T_7-Rajmah straw	8.24	20.95	31.67	37.01
T_8-Spent button mushroom substrate	0.00	0.00	0.00	0.00
SE(m)±	0.57	0.52	0.53	2.81
CD (0.05)	1.75	1.58	1.61	6.13

Yield of Golden oyster mushroom

Yield

The yield obtained from various substrates was measured separately during the first, second, and third harvests. The cumulative yield (g) per kilogram of dry substrate was calculated and is depicted in Table 3 and Figure 3. Among the treatments, T_2 (wheat straw) exhibited the highest yield of 932.17 g/kg dry substrate. This was followed by T_5 (bajra straw) with 837.46 g/kg, T_1 (paddy straw) with 829.45 g/kg, and T_3 (soybean straw) yielding 747.11 g/kg. In contrast, the lowest yield was observed in T_4 (sugarcane bagasse) at 621.03 g/kg dry substrate.

Biological efficiency

To study the effect of various treatments on the biological efficiency of Golden oyster mushroom, the formula described by Chang and Miles (1989) [6] was applied, with the outcomes presented in Table 3 and Fig. 3. The results revealed that Treatment T_2 (wheat straw) achieved the highest biological efficiency at 93.21%, which was significantly greater compared to the other treatments. This was followed by Treatment T_5 (bajra straw) with 83.74%, Treatment T_1 (paddy straw) with 82.94%, and Treatment T_3 (soybean straw) with 74.71%. The lowest efficiency was recorded in Treatment T_4 (sugarcane bagasse) at 62.10%.

Table 3: Effect of different substrates on yield (g/kg dry substrate) and biological efficiency (%) of Golden oyster mushroom

Treatment	Total yield (g) per kg dry substrate	Biological efficiency (%)
T_1-Paddy straw	829.45	82.94
T_2-Wheat straw	932.17	93.21
T_3-Soybean straw	747.11	74.71
T_4-Sugarcane bagasse	621.03	62.10
T_5-Bajra straw	837.46	83.74
T_6-Jowar straw	676.83	67.68
T_7-Rajmah straw	705.16	70.51
T_8-Spent button mushroom substrate	0.00	0.00
SE(m)±	32.51	3.25
CD (0.05)	99.57	9.95

Discussion

Growth performance

Growth parameters consists of days required for formation of pinhead, spawn run, and first, second, and third harvest.

Days required for spawn run

Spawn run duration ranged from 19.58 to 22.99 days and was statistically non-significant. Treatment T_2 (wheat straw)

showed the shortest duration (19.58 days), followed by treatment T_3, treatment T_5, and treatment T_1. Treatment T_4 (sugarcane bagasse) recorded the longest period (22.99 days). No mycelial growth was observed in T_8 (spent substrate) even after 25 days.

According to Gogoi and Adhikary (2002) [7], the time required for spawn run for *Pleurotus citrinopileatus* in paddy straw and sugarcane bagasse was 16 and 20 days, respectively. Atila (2017) [8] found that the spawn running time for *Pleurotus citrinopileatus* varied between 20 to 24.20 days. According to Deshmukh (2024) [9], the period required for spawn run in *Pleurotus eryngii* ranged from 16.24 to 39.91 days. Nagre (2024) [10] recorded that, it took 16.41 to 19.08 days for spawn run in oyster mushroom (*Pleurotus sajor-caju*) on different substrates.

Days required for pinhead formation

After incubation, beds were shifted to the growing room, where pinheads formed upon opening. Pinhead initiation ranged from 23.13 to 28.77 days (Table 4.2). T_5 (bajra straw) showed the earliest pinhead formation (23.13 days), followed by T_2 (wheat straw) at 24.47 days. The latest was recorded in T_7 (rajmah straw) at 28.77 days.

According to Stamets (1993) [11], it takes 3-5 days for the development of pinheads after spawn run. In the instance of *Pleurotus citrinopileatus* cultivated on wheat straw, sawdust and combinations, Preethy and Anubselvi (2021) [12] found that, pinheads were produced between second to third week after bed preparation. According to Dhobale (2023) [13], After the spawn run it took 3.70 to 7.80 days for the formation of pinhead in *Pleurotus sajor-caju*, cultivated on wheat straw and sterilized with varied concentrations of hydrated lime.

Days required for harvesting

Days required for first, second and third harvest along with total days required for fruiting were recorded.

Treatment T_2 (wheat straw) consistently recorded the shortest duration for all three harvests—5.33 days (first), 16.63 days (second), and 26.85 days (third)—followed by Treatment T_1 (paddy straw). Treatment T_7 (rajmah straw) took the longest time across all stages, with 8.24, 20.95, and 31.67 days, respectively. Treatments T_1, T_3, T_4, and T_5 showed comparable results in early harvests but were slightly delayed compared to Treatment T_2.

According to the findings of Gogoi and Adhikary (2002) [7], it took 25 days for first harvest for *Pleurotus citrinopileatus* in paddy after pinhead formation. According to Shaha *et al*. (2004) [14], during oyster mushroom cultivation fruiting bodies appear after 3-6 weeks after pinhead initiation and 27-34 days later after spawn inoculation. They also reported that, the crop of oyster mushroom harvested in three flushes with maximum yield in first flush followed by second and third flush. As per the findings of Atalia (2017) [8] it took 29.8 to 35.4 days for the first harvest of *Pleurotus citrinopileatus* on different substrates. Deshmukh (2024) [9] recorded that in *Pleurots eryngii* the time required for first, second and third harvest ranged between 6.14 to 11.01 days, 15.65 to 20.37 days and 23.79 to 25.30 days respectively.

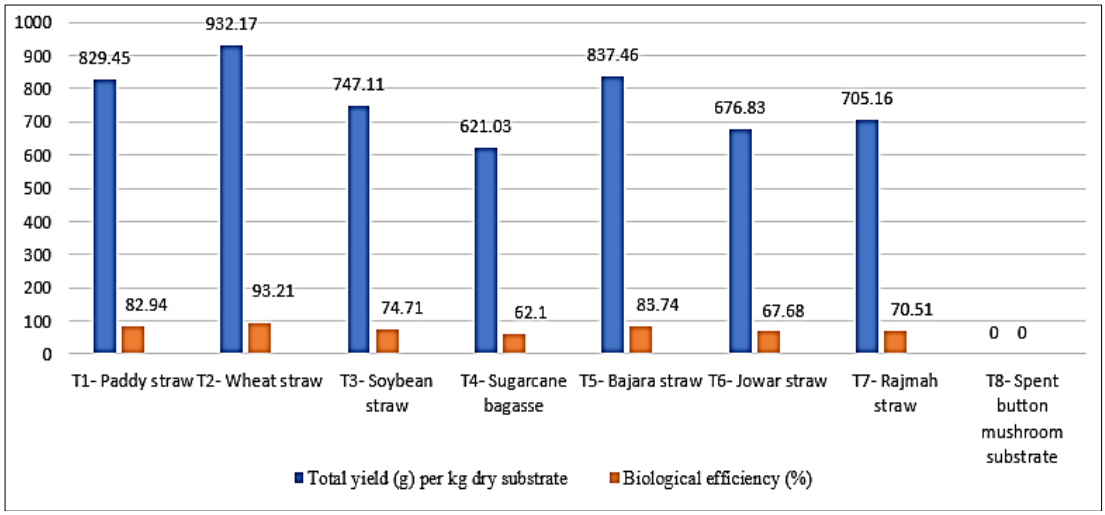

Fig 3: Effect of different substrates on yield (g/kg dry substrate) and biological efficiency (%) of Golden oyster mushroom

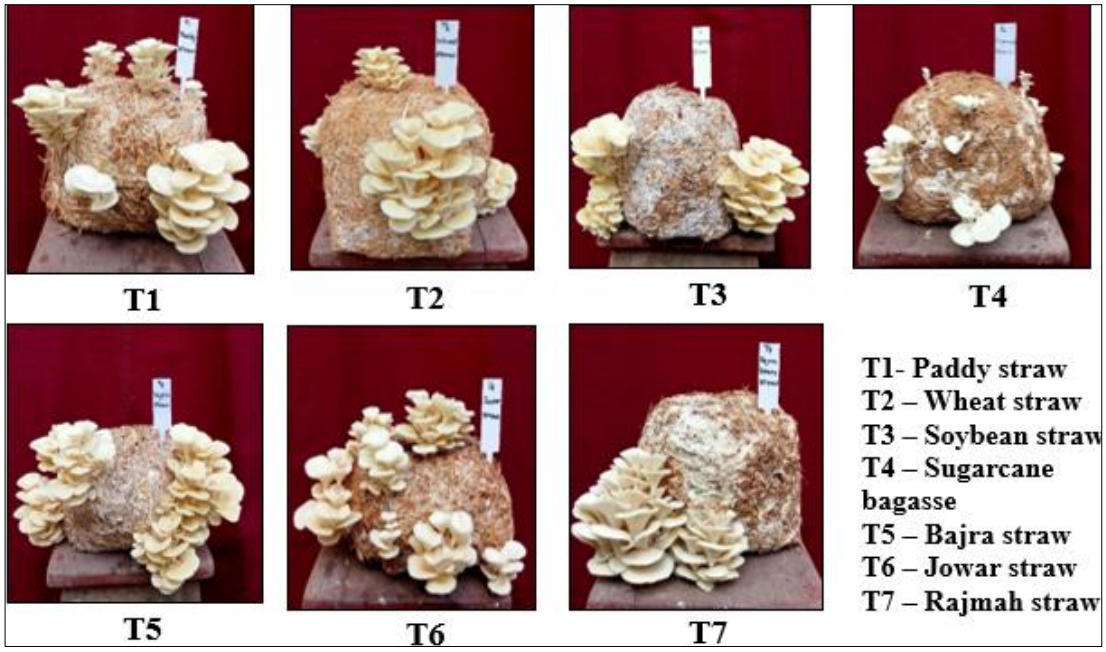

Plate 3: Effect of different substrates on yield performance of golden oyster mushroom.

Total days required for fruiting

The total days required for fruiting ranged between 28.93 days (Treatment T_5) to 37.01 days in (Treatment T_7). According to the findings of Gogoi and Adhikary (2002) [7], it took 49 days for formation of fruit of Golden oyster mushroom from the day of incubation.

Yield of Golden oyster mushroom

Yield ranged from 621.03 to 932.17 g/kg dry substrate, highest in T_2 (wheat straw) and lowest in T_4 (sugarcane bagasse). Treatment T_2 was followed by Treatment T_5, T_1, and T_3 in yield performance The present results are in agreement with Yang *et al*. (2013) [15], who observed improved biological yields when wheat and rice straw were enriched with cotton hull. Likewise, Preethy and Anubselvi (2021) [12] reported yields between 750-800 g using paddy straw as the cultivation substrate. Gogoi and Adhikary (2002) [7] noted that sugarcane bagasse resulted in the lowest yield, up to 750 g. Deshmukh (2024) [9] documented *Pleurotus eryngii* yields ranging from 312.55 to 726.46 g/kg of dry substrate. Similarly, Patil (2010) [16] found yield variations in wild oyster mushroom species ranging from 555.2 to 956.50 g/kg dry substrate.

Biological efficiency

Biological efficiency ranged from 62.10% to 93.21%, highest in T_2 (wheat straw) and lowest in T_4 (sugarcane bagasse). T_2 was followed by Treatment T_5, T_1, and T_3The results align with those reported by Gogoi and Adhikary (2002) [7], who achieved 62% biological efficiency using sugarcane bagasse and 95% with paddy straw for *Pleurotus citrinopileatus* cultivation. In a similar study, Magdziak *et al*. (2021) [17] used wheat straw as a control substrate, recording a biological efficiency of 82%. Deshmukh (2024) [9] also reported biological efficiency between 31.25% and 72.64% for king oyster mushroom grown on different substrates.

Conclusion

From the results, it could be concluded that, the treatment T_2 (wheat straw) required minimum days for spawn run (19.58 days) and 24.94 days for pinhead formation after spawn run. Treatment T_5 (bajra straw) required minimum days for pinhead formation (23.13 days). The treatment T_2 (wheat straw) required minimum days for 1st, 2nd and 3rd harvest (5.33, 16.63 and 26.85 days respectively). Treatment T_5 (Bajra straw) required minimum days for fruiting (28.93 days). Also, treatment T_2 wheat straw recorded highest biological efficiency (93.21%) with total yield of 932.14 g/kg dry substrate. Thus, it could be inferred that the treatment T_2 (wheat straw) was found to be superior over the evaluated substrates in terms of growth and yield parameters. This straw can be recommended for the cultivation of golden oyster mushroom.

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