



Impact of Organic Amendments on Morphology and Yield Attributes of *Pleurotus ostreatus* Cultivated on Cereal Substrates

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Abstract: This study investigated the impact of diverse organic supplements on the yield and morphological characteristics of *Pleurotus ostreatus*, commonly known as Oyster mushrooms. Utilizing locally available supplements, including cereal flour (wheat, rice, maize), pulse flour (soybean, gram, chickpea, lentil, and black gram) and cereal brans (wheat and rice) the experiment assessed their effects on cereal substrate composed of wheat and rice straw at concentrations of 2, 4 and 6 per cent. Among the cereal substrates, rice straw proved to be the most favourable for oyster mushroom cultivation. Soybean flour supplementation on rice straw at 6 per cent concentration gave the highest mean biological yield (195.56) and biological efficiency (97.78%). The highest number of fruit bodies (35.51), pileus diameter (8.05 cm) and stalk length (4.96 cm) were at 6 per cent concentration, while the maximum stalk width (1.95 cm) at 4 per cent soybean flour supplementation. This study highlights the beneficial impact of soybean flour fortification on rice straw in enhancing both morphological characteristics and yield in *Pleurotus ostreatus*.

Keywords: *Pleurotus ostreatus*, Supplementation, Organic additives, Biological efficiency

The genus *Pleurotus* belongs to phylum Basidiomycota and is popularly called as "Oyster mushroom". It is also referred to as "*Dhingri*" in India. It is the third largest cultivated mushroom in the world and second largest cultivated mushroom in India (Royse et al 2017). There are about 40 species of *Pleurotus*, which are found in both tropical and temperate climates. Amongst these spp. *Pleurotus eryngii*, *Pleurotus citrinopileatus*, *Pleurotus flabellatus*, *Pleurotus ostreatus*, *Pleurotus djamor var. roseus*, and *Pleurotus florida* have been successfully cultivated using various form of lignocellulosic waste (Bumanlag et al., 2018). *P. ostreatus* is one of many species in this genus, which is widely favoured due to its taste, flavor, high nutritional values and therapeutic qualities (Nowacka-Jechalke et al., 2018, Adebayo et al., 2018). The composition of substrates significantly influences the physicochemical characteristics of mushrooms, playing a crucial role in their productivity and biological efficiency (Belletini et al., 2019). Oyster mushroom grow on variety of substrates, such as paddy straw, maize cobs, vegetable plant leftovers, bagasse, etc. For a long time, wheat straw and sawdust have been the primary lignocellulosic residues used in *Pleurotus* substrate formulations worldwide (Elattar et al., 2019). The cereal straws such as rice, oat, and barley, as well as sugarcane bagasse and grasses also serve as raw materials when these agro-wastes are locally available (Jesus et al., 2023). Mushroom substrates are enriched by adding highly nutritious supplement that provide nutrients to accelerate mycelium growth. Substrates alone may not yield

best result; other ingredients or additives are typically added to them to increase the yield.

Substrate supplementation is a farming technique that involves physically adding nutritious additives to a substrate during the process of removing, the combination of raw ingredients, at spawning or during casing (Pardo-Gimenez et al., 2016). Addition of the supplements with basal substrate has been a common practice to enhance the yield, nutritional and medicinal value by supplying the precise nutrients needed for the growth of the mycelium, which is a component of mushrooms (Naraian et al., 2016). Supplementation substrates play a vital role in promoting growth often by supplying nitrogen through sources including cotton seed meals, wheat bran, and rice bran. Although supplementing the substrate material leads to improved growth but there are limitations involved, high supplementation of substrate may lead to contamination together with reduced yield of the mushrooms. Supplementation led to significant yield increase and even providing up to 34.4 per cent of increment as compared to non-supplementation with deffated pistachio meal for *Pleurotus ostreatus* (Pardo-Giménez et al., 2016).

Mushrooms can utilize nutritional supplements to boost yield by 10 to 20 per cent, sometimes even more, without compromising quality. It is essential to evaluate the types of nutrients, the optimal timing for their application, the cost of the supplements, and the potential economic benefits beforehand (Pardo-Giménez et al., 2018). So when alternative additives are added, mushrooms can grow well

and produce more fruiting bodies. This is typically done by supplementing the substrate with cereal bran such as wheat, soybean, corn, or rice (Josephine 2015, Jesus et al., 2023). *Pleurotus ostreatus* cultivated on the palm waste substrate supplemented with rice bran and wheat bran produced better quality mushrooms (Elkanah et al., 2022). The majority of additives are made of organic resources such as cow dung, palm kernel cake (PKC), groundnut cake (GC), horse gram, cowpea, rice bran, and chicken dung that have proven effective in enhancing mushroom production. Numerous research studies have documented the use of various supplements such as rice bran, wheat bran, corn cobs, corn waste, wheat straw, and banana leaves as substrate supplements for cultivating oyster mushrooms (Muswati et al., 2021, Adebayo et al., 2021, Onyeka et al., 2018, Odunmbaku and Adenipekun 2018).

MATERIAL AND METHODS

The present investigation was conducted at Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya in Palampur in Centre for Mushroom Research and Training Unit, Department of Plant Pathology.

Spawn production: Spawn were prepared by standard procedure (Nidhi 2022).

Substrate preparation: Chopped wheat and rice straw, approximately 4-5cm in length, underwent a dual preparation process. Initially, the straw was placed in gunny bags and soaked overnight in fresh water to achieve a moisture level of 70-75 per cent. Following soaking, excess water was drained, and the pre-soaked straw underwent pasteurization by immersion in hot water at 75°C for one and a half hours. After pasteurization, the straw was spread on a plastic sheet and allowed to cool. Moisture content was adjusted to around 65 per cent by assessing it through palm squeezing. Sterilized organic additives including wheat, rice, maize flour, lentil, chickpea, gram, black gram, soybean as well as rice and wheat brans were individually mixed with wheat and rice substrate at three different concentrations based on dry weight before spawning. Subsequently, the spawn was mixed with the substrate, and the mixture was filled into polypropylene bags under aseptic conditions. The bags, tied securely at the top, underwent aeration optimization through 10 to 15 sterile pin-made holes. The spawn run then took place in a growing room with incubation at a temperature of 21-25°C and humidity maintained at 80 per cent.

Cropping and harvesting: After the white mycelium had completely covered the substrates, after about 10-12 days the bags were cut open with a sharp, sterilized blade to expose the substrate surface and allow the initiation of pinheads. For the growth of the fruit body, the optimal

environmental conditions of temperature *i.e.* between 20 to 25°C and relative humidity between 70 and 85 per cent were maintained. Ventilation of 2-3 hours per day was given for maintaining CO₂ in the growing room. At regular intervals, observations on the number of days required for pinhead formation were recorded. Bags were watered twice a day. At full maturity, fruiting bodies were harvested. The fruit bodies were harvested before the fruit body curled and its gills were fully developed because over matured fruit bodies become fragile.

Observation recorded

- i. Number of fruiting body
- ii. Size of fruiting body: The pileus and stalk diameters were recorded by cutting the fruiting body into two parts, the length of the mushroom stalk was recorded.
- iii. Biological yield (BE): Biological yield in g/Kg was calculated by weighing the whole cluster of fruit bodies without removing the straw.
- iv. Economic yield (EY): Economic yield in g/Kg was calculated by weighing all the fruiting bodies after removing the straw.
- v. Biological efficiency: Biological efficiency of total harvests was calculated by using the formula

$$\text{Biological Efficiency (\%)} = \frac{\text{Fresh weight of mushroom (g)}}{\text{Dry weight of substrate (g)}} \times 100$$

Statistical analysis: The data were analysed by using OPSTAT software (Steel et al 1997).

RESULTS AND DISCUSSION

Effect of Cereal Flour Supplementation

Effect on yield parameters of *Pleurotus ostreatus* : The significantly mean maximum biological yield (187.24 g/kg), economical yield (170.79 g/kg) and biological efficiency (92.70%) was in rice flour supplementation (Table 1, Plate 1) followed by wheat flour. Irrespective of the additives, the significantly maximum biological yield (192.54g/kg), economical yield (178.38g/kg) and biological efficiency (96.41%) was recorded when wheat substrate supplemented with rice flour at 6 per cent concentration. Significantly mean minimum (140.32g/kg) biological yield, economical yield (130.53g/kg) and biological efficiency (70.12%) was observed in control. Rice flour was the effective additive in wheat substrate for *Pleurotus ostreatus*. Kumar et al (2020) reported *Pleurotus sapidus* and *Pleurotus flabellatus* gave highest yield when wheat straw supplemented with rice flour @2.5 per cent.

Effect on morphological characters of *Pleurotus ostreatus*: Significantly mean maximum number of fruit bodies (28.55), pileus diameter (7.53 cm) and stalk width (1.57 cm) in rice flour supplementation (Table 2) followed by

wheat flour whereas, mean highest stalk length was reported in wheat flour additive (4.05 cm) followed by rice and maize flour. Mean minimum number of fruit bodies (15.32), pileus diameter (6.50 cm), stalk length (3.18) and stalk width (1.34 cm) was found in control. Irrespective of the additives, significantly maximum number of fruit bodies (30.73) was observed at 6 per cent concentration and stalk width (1.92 cm) at 2 per cent concentration of rice flour additive whereas, pileus diameter (7.84 cm) and stalk length (4.56) in wheat flour at 6 per cent. Soam et al. (2018) and Kumar et al. (2020) also reported maximum stalk length and width of *P. ostreatus* after adding rice flour as compare to control.

Effect of Pulse Flour Supplementation

Effect on yield parameters of *Pleurotus ostreatus*:

Among five pulse flour additives, significantly mean maximum biological yield (181.09 g/kg), economical yield (162.99 g/kg) and biological efficiency (90.76%) was in soybean flour (Table 3) followed by chickpea flour whereas, mean minimum biological yield (140.32 g/kg), economical

yield (130.53 g/kg) and biological efficiency (70.12%) was in control. Irrespective of additives, significant maximum biological yield (185.23 g/kg), economical yield (166.92g/kg) and biological efficiency (92.50%) was at 6 per cent concentration after adding soybean flour and minimum biological yield (140.32 g/kg), economical yield (130.53g/kg) and biological efficiency (70.12%) in control. The results emphasize the positive impact of pulse flour fortification, with soybean flour demonstrating superior effects on the yield parameters of *Pleurotus ostreatus*. Singh et al. (2017) observed that supplementing wheat straw with various pulse flours resulted in maximum yield with pigeon pea flour followed by soybean flour, while the control exhibited the minimum yield.

Effect on morphological characters of *Pleurotus ostreatus*: Significantly mean maximum number of fruit bodies (24.76), stalk length (4.12 cm) and stalk width (1.63 cm) was observed in soybean flour additive followed by lentil flour whereas, mean maximum pileus diameter in chickpea

Table 1. Effect of cereal flour supplementation on the yield parameters of *Pleurotus ostreatus* on wheat straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Wheat	171.33	180.52	174.75	175.53	153.30	164.49	159.73	159.17	85.51	89.57	89.66	88.25
Rice	180.62	188.56	192.54	187.24	168.35	176.62	178.38	170.79	91.28	94.41	96.41	92.70
Maize	168.25	179.69	176.80	174.92	152.12	160.45	158.26	156.94	84.58	88.34	87.32	86.75
Control	140.32	140.32	140.32	140.32	130.53	130.53	130.53	130.53	70.12	70.12	70.12	70.12
Mean	165.13	172.27	171.10		153.08	155.52	154.48		83.35	85.83	85.60	
CD (p=0.05)												
Supplements (A)			5.85		Supplements (A)		3.41		Supplements (A)		3.63	
Supplements (B)			5.04		Supplements (B)		NS		Supplements (B)		NS	
Interaction (A×B)			NS		Interaction (A×B)		5.91		Interaction (A×B)		NS	

Table 2. Effect of cereal flour supplementation on the morphological characters of *Pleurotus ostreatus* on wheat straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Wheat	24.24	27.37	30.48	27.70	6.92	7.10	7.84	7.24	3.59	4.00	4.56	4.05	1.12	1.45	1.48	1.35
Rice	26.54	28.38	30.73	28.55	7.25	7.81	7.52	7.53	3.42	3.79	4.20	3.80	1.92	1.37	1.42	1.57
Maize	22.20	23.56	25.42	23.73	6.82	7.50	7.50	7.17	3.29	3.56	3.92	3.59	1.00	1.27	1.45	1.24
Control	15.32	15.32	15.32	15.32	6.50	6.50	6.50	6.50	3.18	3.18	3.18	3.18	1.00	1.00	1.00	1.00
Mean	22.33	23.66	25.49		6.87	7.12	7.34		3.37	3.63	3.97		1.26	1.27	1.34	
CD (p=0.05)																
Supplements (A)		0.63		Supplements (A)		0.16		Supplements (A)		0.09		Supplements (A)		0.03ff		
Supplements (B)		0.55		Supplements (B)		0.13		Supplements (B)		0.08		Supplements (B)		0.02		
Interaction (A×B)		1.10		Interaction (A×B)		0.27		Interaction (A×B)		0.16		Interaction (A×B)		0.05		

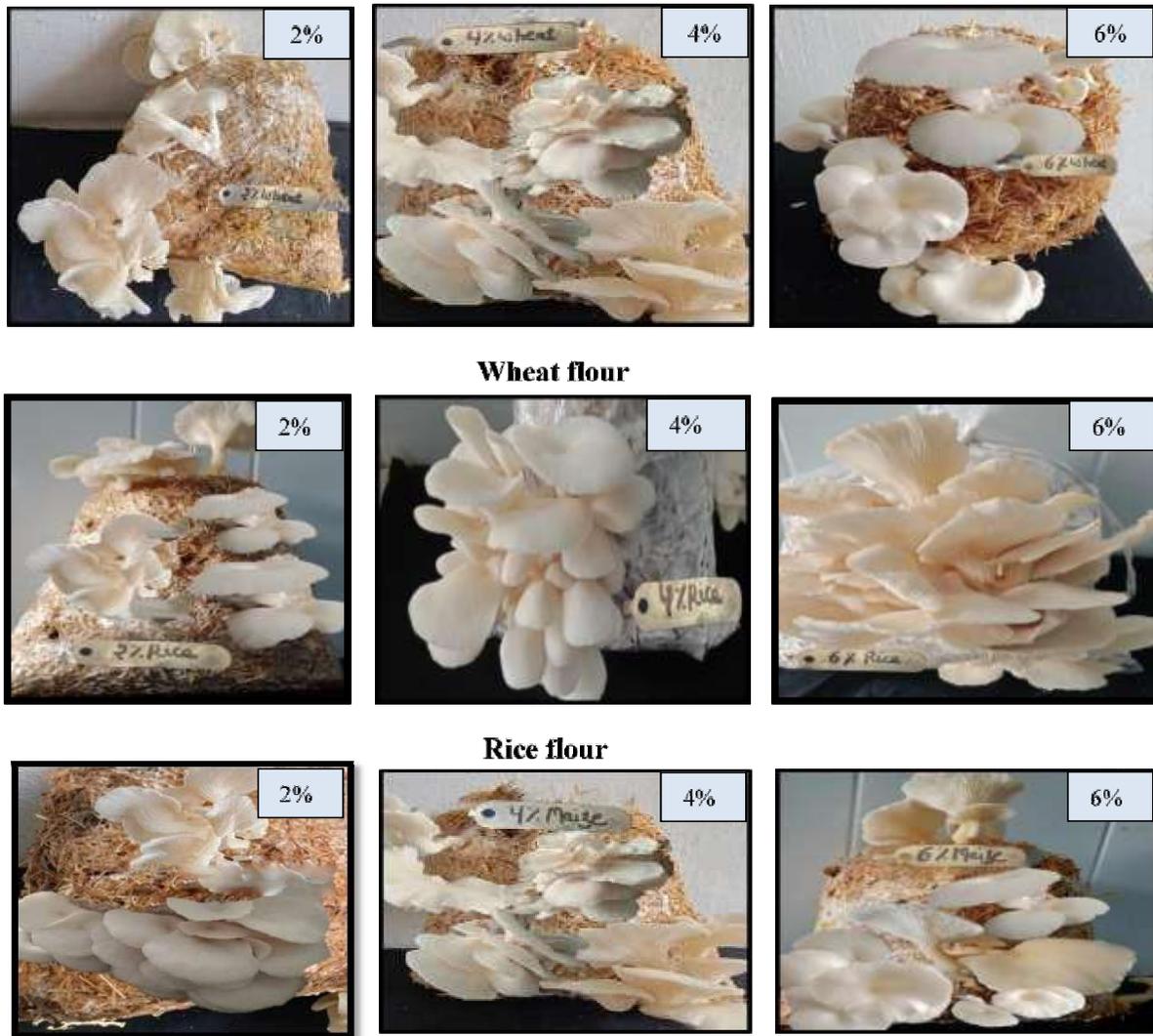


Plate 1. Cereal flour supplementation on yield of *Pleurotus ostreatus* on wheat substrate

Table 3. Effect of pulse flour supplementation on the yield parameters of *Pleurotus ostreatus* on wheat straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Soybean	177.49	180.54	185.23	181.09	159.58	162.46	166.92	162.99	88.50	91.27	92.50	90.76
Chickpea	162.56	169.24	160.15	163.99	152.42	154.17	150.23	152.27	81.28	84.62	80.07	81.99
Lentil	142.52	148.56	150.24	147.11	129.21	130.46	129.62	129.76	71.26	74.28	75.12	73.56
Gran	158.27	160.52	163.75	160.85	142.23	144.56	146.23	144.34	79.85	80.26	81.52	80.54
Black gram	155.62	152.69	161.54	156.62	144.23	137.52	149.73	143.83	77.21	76.34	80.52	78.02
Control	140.32	140.32	140.32	140.32	130.53	130.53	130.53	130.53	70.12	70.12	70.12	70.12
Mean	156.13	158.65	160.21		143.03	143.28	145.54		78.04	79.48	79.98	
C.D.(p=0.05)												
Supplements (A)		4.03		Supplements (A)		3.78		Supplements (A)		1.99		
Supplements (B)		2.85		Supplements (B)		NS		Supplements (B)		1.41		
Interaction (A×B)		NS		Interaction (A×B)		NS		Interaction (A×B)		NS		

flour supplementation (7.07 cm) followed by lentil and soybean flour additive (Table 4). However, mean minimum fruit bodies (15.32), pileus diameter (6.50 cm), stalk length (3.18 cm) and stalk width (1.00 cm) was in control. Irrespective of different additives, significantly maximum number of fruit bodies (26.15) and stalk width (1.83 cm) in soybean flour at 6 per cent concentration and pileus diameter (7.35 cm) at highest concentration of lentil flour, stalk length (4.35 cm) at 4 per cent soybean flour whereas, minimum fruit bodies (15.30) in chickpea flour and pileus diameter (6.42 cm) in gram flour at 2 per cent concentration, stalk length (3.18 cm) and stalk width (1.00 cm) was in control. Singh et al (2017) observed that increased supplement dose of soybean improves the morphological characters of *Pleurotus ostreatus*.

Effect of Cereal Bran Supplementation

Effect on yield parameters of *Pleurotus ostreatus*: The

significantly mean maximum biological yield (165.61g/kg), economical yield (149.51g/kg) and biological efficiency (82.77%) was observed in wheat bran supplementation followed by rice bran whereas, mean minimum biological yield (140.32g), economical yield (130.53g) and biological efficiency (70.12%) in control (Table 5). Irrespective of brans, maximum biological yield (167.19 g/kg), economical yield (156.52 g/kg), biological efficiency (83.59%) was observed at 4 per cent concentration of wheat bran and minimum biological yield (140.32g/kg), economical yield (130.53g/kg), biological efficiency (70.12%) in control. Rout et al (2016) also reported superior yield in wheat straw supplemented with rice bran followed by wheat bran.

Effect on morphological characters of *Pleurotus ostreatus* : Significantly mean maximum number of fruit bodies (22.35), maximum pileus diameter (6.75 cm), mean stalk width (1.32 cm) was observed in wheat bran as additive

Table 4. Effect of pulse flour supplementation on the morphological characters of *Pleurotus ostreatus* on wheat straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Soybean	22.54	25.60	26.15	24.76	6.56	6.72	7.00	6.76	3.82	4.35	4.20	4.12	1.42	1.64	1.83	1.63
Chickpea	15.30	17.26	18.39	16.98	6.82	7.12	7.29	7.07	3.62	3.97	4.32	3.97	1.36	1.28	1.54	1.39
Lentil	22.47	23.85	20.19	22.17	6.45	6.92	7.35	6.91	3.42	3.67	3.92	3.67	1.14	1.26	1.35	1.25
Gram	18.64	15.92	20.75	18.44	6.42	6.71	7.00	6.71	3.52	3.74	3.56	3.61	1.16	1.27	1.20	1.21
Black gram	18.53	17.58	15.37	17.16	6.53	6.64	6.82	6.66	3.45	3.52	3.93	3.66	1.12	1.42	1.21	1.25
Control	15.32	15.32	15.32	15.32	6.50	6.50	6.50	6.50	3.18	3.18	3.18	3.18	1.00	1.00	1.00	1.00
Mean	18.80	19.26	19.36		6.55	6.77	6.99		3.50	3.94	4.27		1.20	1.31	1.35	
CD (p=0.05)																
Supplements (A)	0.43				Supplements (A)			0.14	Supplements (A)			0.11	Supplements (A)			0.04
Supplements (B)	0.30				Supplements (B)			0.10	Supplements (B)			0.08	Supplements (B)			0.03
Interaction (A×B)	0.74				Interaction (A×B)			0.24	Interaction (A×B)			0.19	Interaction (A×B)			0.06

Table 5. Effect of cereal bran supplementation at different concentrations on the yield parameters of *Pleurotus ostreatus* on wheat straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Wheat	165.43	167.19	164.21	165.61	148.27	156.52	149.73	149.51	82.62	83.59	82.10	82.77
Rice	158.24	162.17	164.34	161.58	142.56	140.17	149.21	145.98	79.12	81.56	82.67	81.12
Control	140.32	140.32	140.32	140.32	130.53	130.53	130.53	130.53	70.12	70.12	70.12	70.12
Mean	154.66	150.56	156.29		140.45	142.41	143.16		77.29	78.42	78.30	
CD (p=0.05)												
Supplements (A)	5.02				Supplements (A)			3.56	Supplements (A)			2.08
Supplements (B)	NS				Supplements (B)			NS	Supplements (B)			NS
Interaction (A×B)	NS				Interaction (A×B)			6.16	Interaction (A×B)			NS

followed by rice bran supplementation whereas, mean maximum stalk length in rice bran (3.72 cm) followed by wheat bran (Table 6). However, significantly mean minimum number of fruit bodies (15.32), pileus diameter (6.50 cm), stalk length (3.18 cm) and stalk width (1.00 cm) was in control. Irrespective of the bran supplementation, maximum number of fruit bodies (23.46) was observed at 4 per cent, pileus diameter (6.95 cm) at 6 per cent, stalk width (1.54 cm) at 6 per cent of wheat bran and stalk length (3.80 cm) at 2 per cent of rice bran supplementation whereas, the minimum fruit bodies (15.32), pileus diameter (6.50 cm), stalk length (3.18 cm) and stalk width (1.00 cm) was in control. This study emphasizes the positive influence of cereal bran fortification on morphological characters in *Pleurotus ostreatus*. Rout et al. (2016) reported improvements in morphological character when wheat straw supplemented with rice bran followed by wheat bran.

Effect of different concentrations of organic supplementation on yield parameters and morphological characters of *Pleurotus ostreatus* on rice straw

Effect of Cereal Flour Supplementation

Effect on yield parameters of *Pleurotus ostreatus*: The significantly mean maximum biological yield (195.35 g/kg), economical yield (184.31 g/kg) and biological efficiency (97.67%) was reported in wheat flour supplementation followed by rice flour (Table 7). Irrespective of the cereal flour amendments, significantly maximum (198.62 g/kg) biological yield, economical yield (187.92 g/kg) and biological efficiency (99.31%) was recorded when rice substrate supplemented with wheat flour at 6 per cent concentration followed by 4 per cent concentration. Thereafter, significantly mean minimum (165.42g/kg) biological yield, economical yield (152.46 g/kg) and biological efficiency (81.21%) was in control. All treatments demonstrated significant superiority over the control, emphasizing the positive impact of cereal flour supplementation on *Pleurotus ostreatus* cultivation on rice straw.

Effect on morphological characters of *Pleurotus ostreatus*: Significantly mean maximum number of fruit bodies (26.81) was observed in maize flour supplementation maximum pileus diameter (7.92 cm) and stalk width (1.48

Table 6. Effect of cereal bran supplementation on the morphological characters of *Pleurotus ostreatus* on wheat straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Wheat	20.86	23.46	22.72	22.35	6.58	6.71	6.95	6.75	3.56	3.78	3.40	3.58	1.17	1.25	1.54	1.32
Rice	18.00	22.56	20.53	20.37	6.60	6.73	6.82	6.72	3.80	3.72	3.64	3.72	1.24	1.12	1.46	1.27
Control	15.32	15.32	15.32	15.32	6.50	6.50	6.50	6.50	3.18	3.18	3.18	3.18	1.00	1.00	1.00	1.00
Mean	18.06	20.45	19.52		6.56	6.65	6.75		3.51	3.56	3.41		1.14	1.12	1.33	
CD (p=0.05)																
Supplements (A)		0.55		Supplements (A)		0.15		Supplements (A)		0.08		Supplements (A)		0.02		0.02
Supplements (B)		0.55		Supplements (B)		0.15		Supplements (B)		0.08		Supplements (B)		0.02		0.02
Interaction (A×B)		0.94		Interaction (A×B)		NS		Interaction (A×B)		0.15		Interaction (A×B)		0.04		0.04

Table 7. Effect of cereal flour supplementation on the yield parameters of *Pleurotus ostreatus* on rice straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Wheat	192.41	195.00	198.62	195.35	180.57	184.43	187.92	184.31	96.20	97.50	99.31	97.67
Rice	180.52	184.71	187.93	184.39	170.53	173.27	175.42	173.07	90.26	91.35	93.96	91.86
Maize	178.31	180.74	184.23	181.09	164.48	167.36	172.54	168.13	89.15	90.37	92.11	90.54
Control	165.42	165.42	165.42	165.42	152.46	152.46	152.46	152.46	81.21	81.21	81.21	81.21
Mean	179.17	181.47	184.05		167.01	169.38	172.09		89.20	90.11	91.65	
CD (p=0.05)												
Supplements (A)			4.09	Supplements (A)			3.94	Supplements (A)			1.92	
Supplements (B)			3.54	Supplements (B)			3.47	Supplements (B)			1.66	
Interaction (A×B)			NS	Interaction (A×B)			NS	Interaction (A×B)			NS	

cm) in wheat flour as additive whereas, stalk length (3.66 cm) in wheat and rice flour supplementation (Table 8). Significantly mean minimum number of fruit bodies (17.54), pileus diameter (5.83 cm), stalk length (3.20 cm) and stalk width (1.00 cm) was recorded in control. Irrespective of additives, maximum number of fruit bodies (32.74), pileus diameter (8.05 cm), stalk length (3.81 cm) and stalk width (1.62 cm) was recorded at 6 per cent concentration of wheat flour additive however, the minimum fruit bodies (17.54), pileus diameter (5.83 cm) and stalk width (1.00 cm) was observed in control, while, stalk length (3.15 cm) at 2 per cent concentration of maize flour. The 6 per cent concentration of the supplements led to improvements in morphological characters. Kumar et al (2020) also reported *Pleurotus sapidus* and *Pleurotus flabellatus* maximum number of sporophore@2.5 per cent and maximum width @ 2.0 per cent of rice flour supplementation followed by wheat flour.

Effect of Pulse Flour Supplementation

Effect on yield parameters of *Pleurotus ostreatus*:

Significantly mean maximum biological yield (195.56 g/kg), economical yield (171.87 g/kg) and biological efficiency (97.78%) was in soybean flour addition followed by chickpea flour (Table 9). Irrespective of the pulse flour, maximum biological yield (198.80 g/kg), economical yield (187.80 g/kg) and biological efficiency (99.40%) was recorded when rice substrate supplemented with soybean flour supplementation at 6 per cent concentration followed by 4 per cent concentration of same additive. Whereas, mean minimum biological yield (165.42g/kg), economical yield (152.46 g/kg) and biological efficiency (81.21%) was in control. Bhadana (2014) also reported Pigeon pea flour supplements increased the yield of *P. florida* and *P. djamor*.

Effect of Pulse Flour Supplementation

Effect on morphological characters of *Pleurotus*

Table 8. Effect of cereal flour supplementation at different concentrations on the morphological characters of *Pleurotus ostreatus* on rice straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Wheat	25.79	30.53	32.74	29.69	7.80	7.92	8.05	7.92	3.46	3.72	3.81	3.66	1.25	1.58	1.62	1.48
Rice	25.76	29.48	26.20	27.14	6.82	6.74	6.90	6.82	3.52	3.65	3.80	3.66	1.25	1.37	1.47	1.35
Maize	26.42	25.68	28.44	26.81	7.12	7.46	7.62	7.40	3.15	3.26	3.59	3.33	1.20	1.37	1.56	1.38
Control	17.54	17.54	17.54	17.54	5.83	5.83	5.83	5.83	3.20	3.20	3.20	3.20	1.00	1.00	1.00	1.00
Mean	23.88	25.80	26.23		6.89	6.99	7.10		3.33	3.46	3.60		1.18	1.33	1.42	
CD (p=0.05)																
Supplements (A)				0.66	Supplements (A)			0.17	Supplements (A)			0.06	Supplements (A)			0.03
Supplements (B)				0.57	Supplements (B)			0.14	Supplements (B)			0.06	Supplements (B)			0.02
Interaction (A×B)				1.14	Interaction (A×B)			NS	Interaction (A×B)			0.11	Interaction (A×B)			0.05

Table 9. Effect of pulse flour supplementation on the yield parameters of *Pleurotus ostreatus* on rice straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Soybean	192.37	195.52	198.80	195.56	180.42	184.39	187.80	171.87	96.68	97.26	99.40	97.78
Chickpea	174.35	178.72	182.21	178.43	163.27	167.45	180.73	170.48	87.17	89.53	91.10	89.27
Lentil	168.52	172.39	170.16	170.36	156.42	161.78	160.49	159.56	84.26	86.19	85.53	85.32
Gran	172.48	180.74	176.31	176.51	161.42	169.37	164.45	165.08	86.25	90.37	88.15	88.26
Black gram	164.31	168.46	160.40	164.39	154.38	156.72	149.47	153.52	82.86	84.23	80.20	82.43
Control	165.42	165.42	165.42	165.42	152.46	152.46	152.46	152.46	81.21	81.21	81.21	81.21
CD (p=0.05)												
Supplements (A)				3.52	Supplements (A)			3.56	Supplements (A)			2.45
Supplements (B)				2.49	Supplements (B)			2.52	Supplements (B)			NS
Interaction (A×B)				NS	Interaction (A×B)			6.17	Interaction (A×B)			NS

ostreatus: Significantly mean maximum number of fruit bodies (32.08) and maximum pileus diameter (7.92 cm) in soybean flour supplementation, whereas, stalk length (4.67 cm) and stalk width (1.61 cm) in addition of chickpea flour (Table 10). Significantly mean minimum number of fruit bodies (17.54), pileus diameter (5.83 cm), stalk length (3.20 cm) and stalk width (1.00 cm) was in control. Irrespective of supplementation, maximum number of fruit bodies (35.51) and pileus diameter (8.05 cm) in soybean flour, stalk length (4.96 cm) in chickpea at 6 per cent concentration and stalk width (1.95 cm) at 4 per cent concentration of soybean flour. Bhadana (2014) also reported pigeon pea flour increased number of sporophores of *P. florida* and *P. djamor*. Maximum sporophores yield and average numbers of sporophores were in *P. flabellatus* and *P. djamor* respectively in pigeon pea flour.

Effect of Cereal Bran Supplementation

Effect on yield parameters *Pleurotus ostreatus*: Among

two cereal bran, significantly mean maximum biological yield (184.66 g/kg), economical yield (173.43 g/kg) and biological efficiency (94.46%) was observed in rice substrate with rice bran supplementation followed by wheat bran and minimum in control (Table 11). Whereas, irrespective of bran additives, maximum (188.38 g/kg) biological yield, economical yield (176.29 g/kg) and biological efficiency (94.19 %) was recorded when substrate supplemented with rice bran supplementation at 6 per cent concentration followed by 4 per cent concentration of same additive and minimum (165.42 g/kg) biological yield, economical yield (152.46 g/kg) and biological efficiency (81.21%) was recorded in control. Increased in the bran concentration increased the yield in rice bran supplementation but in wheat bran the maximum yield was observed at 4 per cent concentration. Buendia et al. (2016) also reported that addition of rice bran supplements to the substrate significantly improves biological efficiency of mushrooms. Tripathy and Nayak (2022) showed the highest

Table 10. Effect of pulse flour supplementation on the morphological characters of *Pleurotus ostreatus* on rice straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Soybean	28.26	32.49	35.51	32.08	7.80	7.92	8.05	7.92	3.57	3.72	4.32	3.87	1.82	1.95	1.20	1.59
Chickpea	20.52	23.69	24.16	22.79	7.24	7.46	7.51	7.40	4.45	4.60	4.96	4.67	1.32	1.64	1.86	1.61
Lentil	24.62	25.47	26.56	25.55	6.25	6.59	6.76	6.53	3.67	3.74	4.16	3.86	1.24	1.46	1.50	1.40
Gram	18.29	22.62	20.38	20.43	6.67	6.82	7.41	6.97	3.49	3.83	4.00	3.77	1.20	1.28	1.30	1.26
Black gram	22.64	23.29	25.61	23.85	6.74	6.83	6.90	6.82	3.62	3.75	3.94	3.77	1.26	1.47	1.49	1.41
Control	17.54	17.54	17.54	17.54	5.83	5.83	5.83	5.83	3.20	3.20	3.20	3.20	1.00	1.00	1.00	1.00
Mean	21.31	23.52	29.13		6.75	6.89	7.04		3.67	3.81	4.10		1.31	1.47	1.36	
CD (p=0.05)																
Supplements (A)				0.61	Supplements (A)			0.15	Supplements (A)			0.09	Supplements (A)			0.03
Supplements (B)				0.43	Supplements (B)			0.10	Supplements (B)			0.06	Supplements (B)			0.02
Interaction (A×B)				1.05	Interaction (A×B)			0.26	Interaction (A×B)			0.16	Interaction (A×B)			0.05

Table 11. Effect of cereal bran supplementation at different concentrations on the yield parameters of *Pleurotus ostreatus* on rice straw

Flour	Biological yield (g/kg) concentration (%)			Mean	Economical yield (g/kg) concentration (%)			Mean	Biological efficiency (%) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6	
Wheat	170.52	178.39	172.64	173.85	150.27	166.54	161.80	159.54	85.26	89.54	86.32	87.04
Rice	180.17	185.42	188.38	184.66	168.52	175.47	176.29	173.43	90.47	92.71	94.19	94.46
Control	165.42	165.42	165.42	165.42	152.46	152.46	152.46	152.46	81.21	81.21	81.21	81.21
Mean	172.04	176.41	175.48		157.08	164.82	163.52		85.65	87.82	87.24	
CD (p=0.05)												
Supplements (A)				3.33	Supplements (A)			3.71	Supplements (A)			2.18
Supplements (B)				3.33	Supplements (B)			3.71	Supplements (B)			NS
Interaction (A×B)				NS	Interaction (A×B)			6.42	Interaction (A×B)			NS



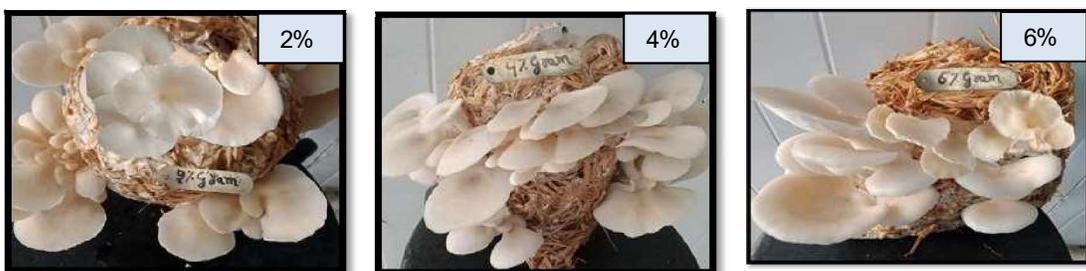
Soybean flour



Chickpea flour



Lentil flour



Gram flour



Black gram flour

Plate 2. Effect of pulse flour supplementation on yield parameters of *Pleurotus ostreatus* on rice substrate

Table 12. Effect of cereal bran supplementation on the morphological characters of *Pleurotus ostreatus* on rice straw

Flour	Fruit bodies (no.) concentration (%)			Mean	Pileus diameter (cm) concentration (%)			Mean	Stalk length (cm) concentration (%)			Mean	Stalk width (cm) concentration (%)			Mean
	2	4	6		2	4	6		2	4	6		2	4	6	
Wheat	18.25	20.64	20.72	19.87	6.85	6.95	7.21	7.00	3.64	3.92	4.20	3.92	1.27	1.36	1.39	1.34
Rice	22.38	24.56	27.29	24.74	6.35	6.39	6.40	6.38	3.29	3.57	3.63	3.50	1.56	1.59	1.60	1.58
Control	17.54	17.54	17.54	17.54	5.83	5.83	5.83	5.83	3.20	3.20	3.20	3.20	1.00	1.00	1.00	1.00
Mean	19.39	20.91	21.85		6.34	6.39	6.48		3.38	3.56	3.68		1.28	1.32	1.33	
CD (p=0.05)																
Supplements (A)				0.58	Supplements (A)			0.13	Supplements (A)			0.10	Supplements (A)			0.03
Supplements (B)				0.58	Supplements (B)			NS	Supplements (B)			0.10	Supplements (B)			0.02
Interaction (A×B)				1.01	Interaction (A×B)			NS	Interaction (A×B)			0.17	Interaction (A×B)			0.04

biological yield of *Pleurotus ostreatus* was also obtained from paddy straw and wheat bran (90:10) followed by paddy straw and wheat bran (95:5).

Effect on morphological characters of *Pleurotus ostreatus*: The significantly maximum number of fruit bodies (24.74) and stalk width (1.58 cm) was observed in rice bran, whereas, maximum pileus diameter (7.00 cm) and stalk length (3.92 cm) in wheat bran supplementation as compared to control (Table 12). Irrespective of bran supplementation, maximum number of fruit bodies (27.29) and stalk width (1.60 cm) in rice flour supplementation at 6 per cent, while, pileus diameter (7.21 cm) and stalk length (4.20 cm) in wheat bran at 6 per cent concentration. Minimum number of fruit bodies (17.54), pileus diameter (5.83 cm), stalk length (3.20 cm) and stalk width (1.00 cm) was in control. Tripathy and Nayak (2022) who reported that paddy straw with wheat bran (90:10) supplementation gave maximum number of fruiting bodies of *Pleurotus* sp.

CONCLUSION

Bio fortification of cereal substrate with organic additives had a positive effect on morphological parameters and biological efficiency of *P. ostreatus*. Rice straw among cereal substrate performed better and gave better yield and improved morphological characters. Addition of supplements in rice straw with wheat flour (cereal), soybean flour (pulse) and rice bran (cereal bran) at 6 per cent concentration enhanced the yield and improved morphological parameters. It was concluded that increasing in the supplementation dose helped to increase every aspect of yield and morphological characteristics. Supplementation had a positive impact on the cultivation of *Pleurotus ostreatus*.

REFERENCES

- Adebayo EA, Elkanah FA, Afolabi FJ, Ogundun OS, Alabi TF and Oduoye OT 2021. Molecular characterization of most cultivated *Pleurotus* species in Sub-Western Region Nigeria with development of cost effective cultivation protocol on palm oil waste. *Heliyon* 7(2): 145-149.
- Adebayo EA, Martínez-Carrera D, Morales P, Sobal M, Escudero H and Meneses ME 2018. Comparative Study of Antioxidant and Antibacterial Properties of the Edible Mushrooms (*Pleurotus levis*, *P. ostreatus*, *P. pulmonarius* and *P. tuber-regium*). *International Journal of Food Science and Technology* 53(5): 1316-1330.
- Bellettini MB, Fiorda FA, Maievas HA, Teixeira GL, Ávila S, Hornung PS, Júnior AM and Ribani RH 2019. Factors Affecting Mushroom *Pleurotus* spp. *Saudi Journal of Biological Sciences* 26(4): 633-646.
- Bhadana NK 2014. *Studies on production technology and major disease management of oyster mushroom*. Ph.D. thesis, SVPUA&T, Meerut pp 30-35.
- Bumanlag CPB, Kalaw SP and Dulay RMR 2018. Optimum Conditions for Mycelia Growth and Basidiocarp Production of *Pleurotus djamor* on Corn Based Media. *International Journal of Biology and Pharmaceutical Allied Science* 7(4): 558-575.
- Buendia M, Raquel P, Arturo PG and Jose AJV 2016. Reuse of degraded *Pleurotus ostreatus* (Jacq.) P. Kumm. substrate by supplementation with wheat bran quantitative parameters. *Mycology* 7: 53-63.
- Elattar AM, Hassan S and Awd-Allah SF 2019. Evaluation of Oyster Mushroom (*Pleurotus ostreatus*) Cultivation Using Different Organic Substrates. *Alexandria Science Exchange Journal* 40: 427-440
- Jesus G, Lavoranti O, Schäfer G, Oliveria G, Silva R and Cuquel F 2023. Nutrient uptake in supplemented substrate by oyster mushroom. *World Journal of Microbiology and Biotechnology* 39(7): 175.
- Josephine RM 2015. A review on oyster mushroom. *International Journal of Current Research* 7: 11225-11227
- Kumar S, Singh G, Singh G, Mishra P, Sachan SK and Sengar SK 2020. Effect of different cereals flour additives on sporophores production of oyster mushroom (*Pleurotus sapidus* and *Pleurotus flabellatus*). *International Journal of Chemical Studies* 8(1): 698-701.
- Muswati C, Simango K, Tapfumaneyi L, Mutetwa M and Ngezimana W 2021. The effects of different substrate combinations on growth and yield of oyster mushroom (*Pleurotus ostreatus*). *International Journal of Agronomy* <https://doi.org/10.1155/2021/9962285>
- Naraian R, Singh MP and Siya R 2016. Supplementation of basal substrate to boost up substrate strength and oyster mushroom yield: An overview of substrates and supplements. *International Journal of Current Microbiology and Applied Science* 5(5): 543-553.
- Nidhi 2022. *Fortification of substrates to produce bio-enriched oyster*

- mushrooms*. MSc. Dissertation, Department of Plant Pathology, CSKHPKV, Palampur, India.
- Nowacka-Jechalke N, Nowak R, Juda M, Malm A, Lemieszek M, Rzeski W and Kaczyński Z 2018. New Biological Activity of the Polysaccharide Fraction from *Cantharel luscibarius* and its Structural Characterization. *Food Chemistry* **268**: 355-361.
- Odunmbaku OK and Adenipekun CO 2018. Cultivation of *Pleurotus ostreatus* (Jacq Fr.) Kumm on *Gossypium hirsutum* Roxb. (cotton waste) and *Gmelinaarborea* L. Sawdust. *International Food Research Journal* **25**(3): 1140-1145.
- Onyeka EU, Udeogu E, Umelo C and Okechie MA 2018. Effect of Substrate Media on Growth, Yield and Nutritional Composition of Domestically Grown Oyster Mushroom (*Pleurotus ostreatus*). *African Journal of Plant Science* **12**(7): 141-147.
- Pardo-Giménez A, Carrasco J, Roncero JM, Álvarez-Ortí M, Zied DC and Pardo-González JE 2018. Recycling of the biomass waste defatted almond meal as a novel nutritional supplementation for cultivated edible mushrooms. *Acta Scientiarum Agronomy* **40**: e39341
- Pardo-Gimenez A, Catalan L, Carrasco J, Alvarez-Orti M, Zied D and Pardo J 2016. Effect of supplementing crop substrate with defatted pistachio meal on *agaricus bisporus* and *Pleurotus ostreatus* production. *Journal of the Science of Food and Agriculture* **96**(11): 3838-3845.
- Rout MK, Mohapatra KB and Mohanty P 2016. Influence of Substrate, Organic Additive and Period of Cultivation on Biological Efficiency of *Pleurotus sajor-caju*. *Advance Life Science* **5**(1): 133-136.
- Royse DJ, Baars J and Tan Q 2017. *Current Overview of Mushroom Production in the World*, pp 5-13. In: Zied D C and Pardo-Giménez A (eds). *Edible and Medicinal Mushrooms*. Winchester, UK: John Wiley & Sons, Ltd.
- Singh S, Singh G, Kumar V, Kumar B and Kumar A 2017. Assessment of different organic supplements (pulses flour) on growth and yield of oyster mushroom. *International Journal of Pure and Applied Bioscience* **5**(2): 101-106.
- Soam A, Singh G, Mohit, Ahmad S, Kumar S and Katiyar S 2018. Studies on effect of different organic additives wet basis cereal flour on fungal disease incidence and yield of oyster mushroom. *Journal of Pharmacognosy and Phtyochemistry* **7**(4): 3222-3224.
- Tripathy A and Nayak A. 2022. Studies on agronomic supplementation for production of oyster mushroom (*Pleurotus ostreatus*). *International Journal of Advances in Engineering and Management* **4**(9): 173-180.

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