Mycopath (2014) 12(1): 9-15 **Research Article**

Growth and yield performance of oyster mushroom on different substrates

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Abstract

Cultivation of mushrooms on lignocellulosic wastes represents one of the most economic organic recycling processes. In this research, three *Pleurotus* species viz., *P. nebrodensis, P. ostreatus* and *P. eryngii* were cultivated on cotton waste, saw dust, paddy straw and mixture of these substrates (cotton waste + saw dust, cotton waste + paddy straw, saw dust + paddy straw + cotton waste). Mycelial growth (days), stalk length and diameter (mm), emergence of primordia (days), time period from primordial initiation to harvesting (days), number of fruiting bodies, average individual weight of fruiting bodies (g), number of flushes, total yield (kg), interval between flushes (days) and biological efficiency were recorded. Amongst the three fungi, *P. ostreatus* showed the best growth and productivity. Saw dust gave the best results in spawn running, time interval between primordial initiation to harvesting stage and in number of flushes. Combination of saw dust, paddy straw and cotton waste gave the best results in emergence of primordia, fruiting bodies weight, moisture percentage, biological efficiency and total yield.

Keywords: Biological efficiency, lignocellulosic, *Pleurotus* spp., primordia, substrates.

Introduction

Malnutrition is the main constrict in developing countries. Mushrooms with high nutritional value have been identified as excellent food source to reduce nutrition deficiency (Eswaran and Ramabadran, 2000). Mushrooms have the ability to convert cellulosic plant waste materials into highly nutritious fruit bodies (Quimio, 1998). Therefore, agricultural and industrial organic wastes are used to grow commercially oyster mushrooms. Cultivation of oyster mushroom on different agro wastes like cotton stalks, waste paper, maize cobs, cotton waste, wheat and paddy straw are utilized for achieving higher bioefficiency (Marimuthu, 1995). In Pakistan and Zimbabwe ordinary method used for cultivation of oyster mushroom i.e. polypropylene bag as well as tray method (Oei, 2003). So environment may be less harmed due to utilization and recycling of waste materials (Hayes, 1978). Average estimated yield of mushrooms from one square meter area is about 20-35 Kg after a cultivation period of 4-7 weeks (Buchanan and Barnes, 2003). It is low-calorie food and its nutritional value is 27 calories per 100 g of mushroom (USDA, 2010). It can generate and enhance employment opportunities tremendously. Further, mushroom offers vast export chances and by concentrating on these opportunities (Dundar *et al*., 2008).

Different substrates with different compositions like 50+50% of saw dust and wheat straw, 75+25% of saw dust and leaves and 50+50% of wheat straw and leaves have been utilized to grow mushroom. It was found that rice straw mixed with 3% powder of cotton seed enhanced mushroom production and protein level in *Pleurotus florida* (Shashirekha *et al*., 2005). Shahid *et al.* (2006) determined suitability of sawdust for the maximum yield (646.9 g), and the number of primordia formation (2:1). On dry weight basis, the highest protein contents (11%) were observed in fruiting body grown on sugarcane bagasse and on wheat straw. Lowest protein content (7.81%) was observed in that grown on rice straw (Sarker *et al*., 2007). Ngezimana *et al*. (2008) studied various crop residues can be used in producing oyster mushrooms either as main substrates or in combinations with supplements.

Combinations of soybean straw and groundnut haulms were inferior to the combinations of wheat straw, leaves and stalks of pigeon pea and cotton stalks. An increase in yield was recorded by the addition of rice bran, gram powder and groundnut oilseed cakes in the substrate (Mane *et al*., 2007). Therefore, current study was performed to investigate growth performance of *P. ostreatus, P. nebrodensis P. eryngii* on three different substrates i.e. cotton waste, paddy straw and wheat straw and on their combinations.

Materials and Methods

Research work was accomplished at Mushroom Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad during 2012-2013.

Wheat straw, paddy straw and cotton waste were used as substrate. Substrates were soaked in water. Three percent lime was mixed in cotton waste to maintain its pH. After soaking, the substrates were piled up and covered with polythene sheet. Substrates were allowed to ferment for 7 days. Substrates then spread on floor for evaporation of excess moisture and which was finally maintained at 70%. Followings the combination of substrates were utilized for cultivation.

T_1: Cotton waste
T_2: Paddy straw
T_3: Saw dust
T_4: Saw dust: Paddy straw = 1: 1
T_5: Cotton waste: Paddy straw = 1: 1
T_6: Cotton waste: Saw dust =1:1
T_7: Paddy straw: Cotton waste: Saw dust = 1:1:1

Each of substrate (300 g) was filled in polypropylene bags (6×8) cm and pasteurized by local methods. Inoculums of the fungus were given under aseptic conditions, and during spawn running the temperature was 22-26 °C. The experiment was laid out according to completely randomized design under two-way factorial. Time required for accomplishment of spawn running, emergence of primordia, harvesting stage after primordia initiation, number of fruit bodies, stalk length (mm), stalk diameter (mm), average individual weight of fruiting bodies, biological efficiency, intervals between flushes of mushroom, number of flushes and yield of each bag and total yield (kg) were recorded.

Result and Discussion

Time required (days) for spawn running

Amongst the different substrates used during current investigation, all three fungi took minimum number of days (14 ± 0.33) for spawn running on cotton waste (T_1) followed by on cotton waste: paddy straw (T_5), paddy straw (T_2) and cotton waste: saw dust (T_6) (Table 1). *P. ostreatus* showed the significantly rapid growth on different substrates as compared to rest of two fungi. Rana *et al*. (2007) found that mycelial growth in wet composts was improved possibly because of improved aeration.

Time taken (in days) for emergence of primordia

Saw dust (T_3) showed minimum days 6.44 ± 0.57 followed by paddy straw (T_2), saw dust: paddy straw (T_4), cotton waste (T_1) and cotton waste: saw dust (T_6) with 6.55 ± 0.33, 6.66 ± 0.88, 6.77 ± 0.57 and 6.89 ± 0.66 days, respectively to reach primordia initiation. Among the species, *P. ostreatus* took minimum number of days 6.52 ± 0.65. Among interaction studies, *P. eryngii* was recorded best in terms of time taken (in days) for emergence of primordia by taking minimum number of days 5.00 ± 0.79 while grown on T_6 (cotton waste: saw dust) (Table 2).

Khan *et al*. (2001) observed that after spawn running primordial formations took 7-8 days. It took different durations for primordial emergence in coir fibre soybean Stover and cotton stalk substrate. Perhaps early primordial emergence could be dependent upon nutrient contents in substrate. As nutrient contents exhausted by mycelium, probably the artificial application of nitrogen rich source during the mycelial growth give good results regarding early primordial initiation.

Time taken (in days) for harvesting stage

On cotton waste (T_1) fungi took minimum number of days for complete mushroom formation. Amongst the other treatments, T_2 (paddy straw), T_7 (paddy straw: cotton waste: saw dust), T_4 (saw dust: paddy straw), T_6 (cotton waste: saw dust) and T_3 (saw dust) found effective as harvesting stages was reached within 5 days. Among the species, *P. ostreatus* took minimum number of days (4.09 ± 0.16). All the interaction means were non significant. The response of different species of *Pleurotus* on different substrate was different possibly due specific nutritional requirement of each species (Table 3).

In this regard, Ragunathan and Swaminathan (2003) compared growth of *P. sajor-caju, P. platypus* and *P. citrinopileatus* on cotton stalk, coir fiber, sorghum stover and mixtures of these substrates. They recorded 21-30 days for primordial initiation after spawning and with the maximum yield on cotton stalks with *P. sajor-caju* and *P. citrinopileatus*, while *P. platypus* yielded best on sorghum stover.

Number of fruit bodies

All three *Pleurotus* species produces maximum number of fruit bodies on saw dust (T_3)

followed by paddy straw (T_2), wheat straw (T_1) and cotton waste: paddy straw (T_5). Among interaction studies, *P. ostreatus* were recorded best in terms of number of fruit bodies while grown on T_3 (saw dust) (Table 4). Yildiz *et al*. (2002) recorded maximum number of *P. ostreatus* on wheat straw followed by waste paper and leaves of hazelnut.

Interval between flushes of mushroom

The maximum yield of 23.66 ± 0.57 g and 23.57 ± 0.52 was noticed on saw dust: paddy straw (T_4) and paddy straw (T_2), respectively among flushes. Among the species, *P. eryngii* exhibited the highest yield (28.76 ± 0.81) followed by *P. nebrodensis* (22.00 ± 0.92) having no significant differences between two fungi. Among interaction studies, *P. eryngii* grown on T_5 were recorded best in terms of yield in flushes by producing 31.00 ± 1.16 (Table 5).

Das and Mukharjee (2007) used weed plants as *Lantana camara*, *Teohrosia purpurea*, *Cassia sophera*, *Ageratum conzoides*, *Parthenium argentatum*, *Sida acuta* and *Leonotis* spp. They encountered the problem of low yield on flushes for these substrates but they suggested the addition of rice straw in the weed plants based substrate to overcome the problem. Mendez *et al*. (2005) reported the decrease in nitrogen contents of the substrate in later flushes of harvest. According to Rossi *et al*. (2003) biological efficiency of mushroom on 2nd flush was 66.7% lower as compared to 1st flush.

Stalk length and diameter

Amongst the various substrates used, the treatments like T_4, T_5 and T_7 having saw dust as a substrate revealed the significantly maximum height of stalk (40.75 ± 0.57 mm). Among the species, *P. eryngii* showed the maximum length 44.91 ± 0.81mm followed that of 37.81 ± 0.92 mm by *P. nebrodensis* (Table 6 and 7). Dundar *et al*. (2008) found maximum length by *P. sajor-caju* than for *P. ostreatus* and *P. eryngi* on wheat stalk substrate.

The significantly greater stalk diameter (17.75 ± 0.86 mm) was acquired by fungi grown on T_4 (saw dust: paddy straw). *P. nebrodensis* showed the greatest stalk diameter (14.39 ± 0.81 mm). Baysal *et al*. (2003) reported the treatments which have low yield produce better size in diameter.

Average individual weight of fruiting body

The maximum individual weight 20.68 ± 0.35 g among flushes was procured on T_7 (saw dust: cotton waste: paddy straw). *P. ostreatus* gave maximum individual weight (9.11 ± 0.85 g) of the fruiting body (Table 8). Heltay (1987) observed that average single fruit body weight of 49 g, which varied with every stalk diameter.

Number of flushes

The significantly maximum number of flushed were again recorded on T_7 (saw dust: cotton waste: paddy straw) and T_4 (saw dust: paddy straw) and *P. ostreatus* gave the maximum flushes (Table 9). Shahid *et al*. (2006) studied maximum flushes formation depend on type of substrates, temperature flexibility, humidity level and quality of spawn.

Table 1: Effect of substrates on time required (days) for spawn running.

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	14.2 j	14.2 j	14.3 j	14.3 G
T_2 (Paddy Straw) PS	16 i	18.3 d-f	18.6 c-e	17.6 D
T_3 (Saw Dust) SD	19.6 bc	21.6 a	20.0 b	20.4 A
T_4 (SD+PS)	16.6 g-i	18.3 d-f	19 b-d	17.9 C
T_5 (CW+PS)	15.6 i	16.3 hi	18.3 d-f	16.7 E
T_6 (CW+SD)	16.6 g-i	17.3 f-h	16 i	16.6 F
T_7 (PS+CW+SD)	18.3 d-f	17.7 e-g	19.6 bc	18.5 B
Mean	16.7 C	17.7 B	17.9 A	17.4

*Means sharing same letter in a row or in a column are statistically non-significant ($P \leq 0.05$).

Table 2: Effect of substrates on time taken (days) for emergence of primordia.

Treatments	Fungal species *P. ostreatus*	*P. nebrodensis*	*P. eryngii*	Mean
T_1 (Cotton Waste) CW	6 c-e	7.4 bc	7 cd	6.8 C
T_2 (Paddy Straw) PS	5.6 de	7.3 bc	6.6 cd	6.5 E
T_3 (Saw Dust) SD	6.6 cd	6 c-e	6.6 cd	6.4 F
T_4 (SD+PS)	6.3 c-e	6.3 c-e	7.3 bc	6.6 D
T_5 (CW+PS)	7 cd	7.4 bc	6.3 c-e	6.9 B
T_6 (CW+SD)	6.6 cd	9 a	5 e	6.8 C
T_7 (PS+CW+SD)	7.4 bc	7.3 bc	8.7 ab	7.8 A
Mean	6.5 C	7.2 A	6.7 B	11.3

Table 3: Effect of substrates on time taken (days) for harvesting stage after primordia initiation.

Treatments	Fungal species *P. ostreatus*	*P. nebrodensis*	*P. eryngii*	Mean
T_1 (Cotton Waste) CW	4 f	5.33 de	6.33 b-d	5.22 E
T_2 (Paddy Straw) PS	4 f	5.33 de	7.66 a	5.66 D
T_3 (Saw Dust) SD	4.33 ef	5.66 d	7.66 a	5.88 B
T_4 (SD+PS)	4.33 ef	6 cd	7.34 ab	5.89 A
T_5 (CW+PS)	4 f	6 cd	7.33 ab	5.77 C
T_6 (CW+SD)	4 f	6.33 b-d	7.33 ab	5.88 B
T_7 (PS+CW+SD)	4 f	6.33 b-d	7 a-c	5.77 C
Mean	4.09 C	5.85 B	7.23 A	5.72

Table 4: Effect of substrates on number of fruiting bodies.

Treatments	Fungal species *P. ostreatus*	*P. nebrodensis*	*P. eryngii*	Mean
T_1 (Cotton Waste) CW	8 ab	6.6 c-e	2j	5.53 C
T_2 (Paddy Straw) PS	7.66 bc	5.66 ef	3.66 hi	5.66 B
T_3 (Saw Dust) SD	9 a	4.33 g-i	6.33 de	6.55 A
T_4 (SD+PS)	7 b-d	3.33 i	5 fg	5.11 F
T_5 (CW+PS)	8 ab	3.66 hi	4.66 f-h	5.45 D
T_6 (CW+SD)	5.66 ef	4.66 f-h	3.33 i	4.55 G
T_7 (PS+CW+SD)	7.66 bc	3.66 hi	5 fg	5.44 E
Mean	7.56 A	4.55 B	4.2 C	4.43

Table 5: Effect of substrates on yield of mushroom (g).

Treatments	Fungal species *P. ostreatus*	*P. nebrodensis*	*P. eryngii*	Mean
T_1 (Cotton Waste) CW	16.33 i-k	21efg	27.33 bc	21.56 E
T_2 (Paddy Straw) PS	18 g-j	24 de	28.66 a-c	23.55 B
T_3 (Saw Dust) SD	15.66 jk	23.33 de	20.0 b	19.66 G
T_4 (SD+PS)	16.33 i-k	25.33 cd	29.33 ab	23.66 A
T_5 (CW+PS)	16.66 h-k	19.33 f-i	31 a	22.33 C
T_6 (CW+SD)	13.66 k	21.33 ef	27.33 bc	20.77 F
T_7 (PS+CW+SD)	16.66 h-k	19.66 f-h	29.66 ab	21.99 D
Mean	16.18 C	21.99 B	64.43 A	11.3

*Means sharing same letter in a row or in a column are statistically non-significant (P≤0.05).

Table 6: Effect of substrates on stalk length (mm).

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	27.91 ij	30.53 h-j	43.87 b	34.10 D
T_2 (Paddy Straw) PS	23.55 kl	39.29 cd	38.66 de	33.83 E
T_3 (Saw Dust) SD	21.27 l	40.67 b-d	35.17 e-g	32.37 G
T_4 (SD+PS)	23.64 kl	40.60 b-d	56.07 a	40.10 B
T_5 (CW+PS)	35.17 e-g	30.48 h-j	31.77 g-i	32.47 F
T_6 (CW+SD)	31.77 g-i	33.61 f-h	37.48 d-f	34.28 C
T_7 (PS+CW+SD)	38.09 de	41.25 b-d	43.32 bc	40.88 A
Mean	27.55 C	37.81 B	44.91 A	36.75

Table 7: Effect of substrates on stalk diameter (mm).

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	11.58 b-e	9.24 d-g	12.63 b-d	11.15 B
T_2 (Paddy Straw) PS	7.24 fg	10.69 c-f	11.13 b-e	9.68 G
T_3 (Saw Dust) SD	11.71 b-e	7.31 fg	11.89 b-e	10.31 E
T_4 (SD+PS)	9.94 d-g	33.56 a	9.74 d-g	17.74 A
T_5 (CW+PS)	8.93 e-g	13.88 bc	10.02 d-g	10.94 C
T_6 (CW+SD)	10.68 c-f	14.47 b	6.81 g	10.65 D
T_7 (PS+CW+SD)	8.67 e-g	11.60 b-e	8.99 e-g	9.75 F
Mean	9.82 C	14.39 A	10.71 B	11.64

Table 8: Effect of substrates on average individual weight of fruiting body (g).

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	18.27 c-e	14.14 e-i	12.05 hi	14.82 G
T_2 (Paddy Straw) PS	20.28 b-d	13.65 g-i	14.49 r-i	16.14 E
T_3 (Saw Dust) SD	17.72 c-f	11.98 hi	24.02 b	17.90 C
T_4 (SD+PS)	21.20 bc	10.86 i	20.29 b-d	17.45 D
T_5 (CW+PS)	15.10 e-h	34.14 a	6.38 j	18.54 B
T_6 (CW+SD)	17.62 c-f	17.08 d-g	12.04 hi	15.58 F
T_7 (PS+CW+SD)	23.58 b	23.07 b	15.41 e-h	20.68 A
Mean	19.11 A	17.84 B	14.95 C	17.3

Table 9: Effect of substrates on number of flushes.

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	2.66 ab	2.66 ab	2.0 bc	2.44 D
T_2 (Paddy Straw) PS	3.0 a	2.33 ab	1.33 c	2.22 E
T_3 (Saw Dust) SD	2.0 bc	2.66 ab	2.0 bc	2.22 E
T_4 (SD+PS)	3.0 a	2.66 ab	2.33 ab	2.66 B
T_5 (CW+PS)	2.66 ab	2.33 ab	2.0 bc	2.33 C
T_6 (CW+SD)	2.66 ab	3.0 a	2.33 ab	2.66 B
T_7 (PS+CW+SD)	3.0 a	2.66 ab	2.67 ab	2.78 A
Mean	2.71 A	2.61 B	2.09 C	2.47

*Means sharing same letter in a row or in a column are statistically non-significant ($P \leq 0.05$).

Table 10: Effect of substrates on biological efficiency.

Treatments	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	20.23 c	17.10 c-f	10.72 g	16.01 F
T_2 (Paddy Straw) PS	27.91 b	14.02 e-g	14.94 d-g	18.95 B
T_3 (Saw Dust) SD	14.12 e-g	12.63 fg	18.75 cd	15.16
T_4 (SD+PS)	26.66 b	11.44 g	15.10 d-g	17.73 D
T_5 (CW+PS)	16.45 c-f	34.20 a	5.48 h	18.71 C
T_6 (CW+SD)	20.43 c	20.91 c	11.70 g	17.68 E
T_7 (PS+CW+SD)	29.64 ab	29.30 b	17.89 c-e	25.61 A
Mean	22.20 A	19.94 B	13.51 C	18.55

Table 11: Effect of substrates on total yield of mushroom (g).

Treatment	Fungal species			Mean
	P. ostreatus	***P. nebrodensis***	***P. eryngii***	
T_1 (Cotton Waste) CW	48.02 de	37.66 f-h	24.11 ik	36.59 G
T_2 (Paddy Straw) PS	60.84 c	31.71 g-j	19.74 kl	37.43 F
T_3 (Saw Dust) SD	35.44 g-i	31.68 g-j	48.05 de	38.39 E
T_4 (SD+PS)	63.60 bc	28.54 h-k	46.57 d-f	46.23 B
T_5 (CW+PS)	38.94 e-g	77.14 a	12.76 l	39.28 D
T_6 (CW+SD)	46.19 d-f	51.24 d	27.87 i-k	41.76 C
T_7 (PS+CW+SD)	70.75 ab	69.21 a-c	40.43 e-g	60.13 A
Mean	51.96 A	46.74 B	31.36 C	43.35

*Means sharing same letter in a row or in a column are statistically non-significant ($P \leq 0.05$).

Biological efficiency and total yield of mushroom (g)

Like previous results, substrates in combination of saw dust: cotton waste: paddy straw (T_7) found the most biological efficient for the growth and the total yield of the *Pleurotus* spp. *P. ostreatus* found the best in terms of biological efficiency in flushes by producing 34.20 ± 1.02% (Table 10 and 11).

Mona *et al*. (2009) for biological efficiency (BE %) sawdust recorded the highest BE being 65.22%, while sugar cane bagasse had the lowest one being 45.71%. So far, different findings have documented different substrates for the growth of oyster mushroom. Khan *et al*. (2001) and Obaidi *et al*. (2003) noticed cotton waste and saw dust, respectively as the good substrates to obtained highest yield of mushroom. Wang *et al*. (2010 obtained the maximum yield of *P. sajor-caju* on cotton waste substrate.

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