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Substrate-driven variations in growth, productivity and quality of oyster mushroom (*Pleurotus spp.*)

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Abstract

The present investigation was carried out to assess the influence of different agro-waste substrates on the growth and yield performance of oyster mushroom (*Pleurotus spp.*) under controlled conditions. The experiment was laid out in a Completely Randomized Design comprising thirteen treatments involving various lignocellulosic substrates and their combinations. The results revealed statistically significant differences among treatments for all the parameters evaluated. Among the substrates, wheat straw demonstrated superior performance by recording the shortest duration for spawn run (12.18 days), pinhead initiation (15.27 days) and first harvest (19.34 days), indicating rapid mycelial colonization and early fructification. Yield attributes were markedly influenced by substrate type, wherein wheat straw registered the highest number of fruiting bodies (28.52), average fruit body weight (13.76 g), total yield (392.68 g per bag) and biological efficiency (98.17%), and was found to be significantly superior over other treatments. The treatment comprising paddy straw and wheat straw (1:1) and the enriched substrate also exhibited comparatively higher yield performance. In contrast, sawdust substrate resulted in significantly lower yield (189.43 g per bag) and biological efficiency (47.28%), along with delayed growth. The enhanced performance of wheat straw may be attributed to its favorable lignocellulosic composition, optimal aeration and moisture retention capacity, which collectively facilitate efficient mycelial proliferation and higher productivity. The findings of the study indicate that wheat straw is the most suitable substrate for maximizing growth and yield of oyster mushroom, while other agro-waste substrates may be utilized as viable alternatives for sustainable mushroom production.

Keywords: Oyster mushroom, *Pleurotus spp.*, agro-waste substrates, wheat straw, growth parameters, yield, biological efficiency, lignocellulosic biomass, mushroom cultivation, sustainable production

Introduction

Mushrooms have emerged as an important component of human nutrition and sustainable agriculture owing to their high-quality protein, essential amino acids, vitamins and biologically active compounds with proven health benefits. Among cultivated edible mushrooms, oyster mushroom (*Pleurotus spp.*) occupies a prominent position due to its remarkable adaptability, rapid growth rate and ability to utilize a wide range of lignocellulosic substrates. The genus *Pleurotus* is endowed with efficient enzymatic machinery capable of degrading complex polymers such as cellulose, hemicellulose and lignin, thereby enabling the conversion of low-value agricultural residues into nutritionally rich food biomass (Chang and Miles, 2004; Sánchez, 2010; Adebayo and Martínez-Carrera, 2015) [4, 20, 1]. This unique biological efficiency has attracted considerable attention in recent years, particularly in the context of sustainable waste management and circular bioeconomy (Royse *et al.*, 2017; Grimm and Wösten, 2018) [19, 7].

Substrate plays a pivotal role in determining the growth, yield and overall productivity of oyster mushroom, as it serves both as a physical support and a source of nutrients for mycelial development. Numerous studies have demonstrated that the composition, structure and physicochemical properties of the substrate significantly influence spawn run, primordia initiation and fruit body formation (Baysal *et al.*, 2003; Philippoussis, 2009) [3, 17]. In tropical and subtropical regions, agro-residues such as paddy straw and wheat straw have been widely recognized as ideal substrates due to their favorable lignocellulosic composition,

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porosity and moisture retention capacity (Kalita *et al.*, 1997; Jandaik and Kapoor, 1975; Das and Mukherjee, 2007) ^[10, 9, 5]. However, the seasonal availability and competing uses of these substrates necessitate the exploration of alternative agro-wastes for sustainable mushroom production.

In recent years, increasing emphasis has been placed on the utilization of diverse agricultural by-products such as maize straw, ragi straw, sugarcane bagasse and groundnut shells as potential substrates for oyster mushroom cultivation. These materials are abundantly available in many parts of India but remain underutilized or are often disposed of through environmentally detrimental practices such as open burning (Pandey *et al.*, 2012; Sharma *et al.*, 2013) ^[14, 21]. Several researchers have reported that incorporation of such agro-wastes, either alone or in combination with conventional substrates, can significantly influence growth dynamics and yield performance of *Pleurotus* spp. (Pathania *et al.*, 2017; Alananbeh *et al.*, 2014; Hoa *et al.*, 2015) ^[15, 2, 8]. Furthermore, supplementation of substrates with nutrient-rich additives like wheat bran has been shown to enhance biological efficiency and improve yield attributes by optimizing the carbon to nitrogen ratio (Yang *et al.*, 2013; Obodai *et al.*, 2003) ^[22, 13].

Despite the availability of substantial literature, the comparative performance of locally available agro-waste substrates under specific agro-climatic conditions remains inadequately documented. Particularly, limited information is available on the suitability of region-specific residues such as ragi straw in relation to conventional substrates like wheat and paddy straw. Therefore, a systematic evaluation of these substrates is essential to identify efficient, cost-effective and sustainable alternatives for oyster mushroom cultivation. In this context, the present investigation was undertaken to study the effect of different agro-waste substrates on growth and yield performance of oyster mushroom (*Pleurotus* spp.), with a view to standardizing suitable substrate combinations for enhanced productivity and efficient agro-waste utilization.

Materials and Methods

A systematic experimental study was conducted during February, 2026 at the Mushroom Production Unit of Sri Krishnadevaraya College of Horticultural Sciences. The experimental site is geographically situated at 14.68° N latitude and 77.60° E longitude, at an altitude of approximately 350 m above mean sea level, and falls under the semi-arid tropical climatic zone of southern India. The region is characterized by low and erratic rainfall with relatively high temperature fluctuations. During the course of experimentation, the ambient temperature ranged from 22.4 °C to 28.7 °C, while relative humidity varied between 68.3 and 82.6 percent. The microclimatic conditions inside the mushroom cropping unit were regulated through periodic water spraying and controlled ventilation to maintain relative humidity between 75 and 85 percent, which is considered optimal for oyster mushroom cultivation (Chang and Miles, 2004; Sánchez, 2010) ^[4, 20].

The experiment was laid out in a Completely Randomized Design (CRD) comprising thirteen treatments with three replications. The treatments consisted of different

lignocellulosic agro-waste substrates, namely paddy straw, wheat straw, sawdust, sugarcane bagasse, groundnut shells, ragi straw and maize straw, along with their combinations in equal proportions (1:1) and an enriched substrate supplemented with wheat bran at 10 percent level. All substrates were procured locally and processed by chopping into small pieces of 3-5 cm length to ensure uniformity and ease of handling. The chopped substrates were soaked in clean water for 12-16 hours to achieve adequate hydration, followed by pasteurization through hot water treatment at 65-70 °C for one hour. Excess water was drained to maintain substrate moisture content at approximately 65-70 percent prior to spawning, as recommended for optimal mycelial growth (Philippoussis, 2009; Royse *et al.*, 2017) ^[17, 19].

Grain spawn of oyster mushroom (*Pleurotus* spp.) was procured from ICAR-Indian Institute of Horticultural Research. Spawning was carried out at the rate of 3-5 percent (w/w) under aseptic conditions to minimize contamination. The spawned substrate was filled into perforated polyethylene bags (60 × 30 cm), compacted uniformly and arranged in a hanging bed system. The bags were incubated in a dark room under the hanging bed method at a temperature of 24-26 °C to facilitate rapid and uniform mycelial colonization. Upon completion of spawn run, the bags were transferred to the cropping room, where diffused light, adequate aeration and high relative humidity (75-85%) were maintained to promote pinhead initiation and fruit body development (Adebayo and Martínez-Carrera, 2015; Grimm and Wösten, 2018) ^[1, 7].

Observations were recorded on growth parameters including days required for complete spawn run, pinhead initiation and first harvest. Yield parameters such as number of fruiting bodies, average fruit body weight, total yield per bag and biological efficiency were recorded at each harvest. Morphological characteristics including pileus diameter, stipe length and stipe thickness were measured using standard procedures. Biological efficiency was calculated as the ratio of fresh weight of mushrooms harvested to the dry weight of substrate, expressed as percentage (Royse *et al.*, 2017) ^[19]. The experimental data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for Completely Randomized Design as described by Gomez and Gomez, (1984) ^[6] and the significance of treatment differences was tested at 5 percent level of probability.



Fig 1: Manual chopping and preparation of substrates



Fig 2: Pasteurization of substrates with hot water



Fig 3: Filling of perforated polyethylene bags with spawn-inoculated substrate.



Fig 4: Spawn-inoculated substrate bags arranged for incubation

Results

The results of the present study indicated significant differences among various agro-waste substrates with respect to growth, yield, morphological and quality parameters of oyster mushroom (*Pleurotus* spp.). The variation among treatments clearly demonstrates the influence of substrate composition on mycelial development, fruiting behaviour and productivity. The findings are presented and discussed under the following headings:

Growth Parameters

The growth parameters of oyster mushroom were markedly influenced by the nature of the agro-waste substrates

employed. Statistically significant differences were observed among treatments with respect to days required for spawn run, pinhead initiation and first harvest (Table .1). Wheat straw (T₁) exhibited superior performance by recording the minimum duration for spawn run (12.18 days), pinhead initiation (15.27 days) and first harvest (19.34 days), indicating rapid mycelial colonization and early fructification. This was followed by maize straw (T₆) and the combination of paddy straw and wheat straw (T₇), which also supported relatively faster growth. In contrast, sawdust (T₂) significantly delayed the growth cycle, recording the maximum duration for spawn run (20.47 days), pinhead initiation (25.63 days) and first harvest (30.28 days). The observed variations clearly demonstrate the critical influence of substrate composition and structure on mycelial proliferation and developmental kinetics.

Yield Parameters

The yield attributes of oyster mushroom were significantly affected by the substrate treatments, with pronounced differences observed in number of fruiting bodies, average fruit body weight, total yield and biological efficiency (Table .1). Wheat straw (T₁) was found to be significantly superior, registering the highest number of fruiting bodies (28.52), average fruit body weight (13.76 g), total yield (392.68 g per bag) and biological efficiency (98.17%). The enhanced productivity under wheat straw may be attributed to its optimal lignocellulosic composition and favorable physical properties that support efficient nutrient utilization. The next best performance was recorded in paddy straw + wheat straw (T₇), followed by the enriched substrate (T₁₂) and maize straw (T₆), which exhibited comparable yield potential. Conversely, sawdust (T₂) resulted in significantly lower yield (189.43 g per bag) and biological efficiency (47.28%), reflecting its limited suitability as a sole substrate. The differences among treatments were statistically significant, underscoring the importance of substrate selection in maximizing productivity.

Morphological Parameters

Significant variation was observed in morphological attributes of oyster mushroom as influenced by different substrates (Table. 2). Wheat straw (T₁) produced fruit bodies with superior morphological characteristics, recording the maximum pileus diameter (7.96 cm), stipe length (4.48 cm) and stipe thickness (1.46 cm), which were significantly higher than those recorded in other treatments. The treatments involving paddy straw + wheat straw (T₇) and enriched substrate (T₁₂) also demonstrated improved morphological development, suggesting a positive influence of balanced substrate composition on fruit body formation. In contrast, sawdust (T₂) resulted in significantly reduced pileus diameter (5.72 cm), stipe length (3.26 cm) and stipe thickness (1.08 cm), indicating poor morphological expression. These findings highlight the role of substrate quality in determining the structural attributes of fruiting bodies.

Table 1: Effect of Different Agro-Waste Substrates on Growth, Yield and Biological Efficiency of Oyster Mushroom (*Pleurotus ostreatus*)

Treatment	Spawn Run (days)	Pinhead Initiation (days)	First Harvest (days)	No. of Fruiting Bodies	Avg. Weight (g)	Yield per Bag (g)	Biological Efficiency (%)
T ₀ -Paddy straw	14.23	18.37	22.46	24.36	12.48	304.27	76.42
T ₁ -Wheat straw	12.18	15.27	19.34	28.52	13.76	392.68	98.17
T ₂ -Sawdust	20.47	25.63	30.28	18.27	10.36	189.43	47.28
T ₃ -Sugarcane bagasse	16.34	20.58	24.39	22.41	11.84	265.38	66.34
T ₄ -Groundnut shells	18.29	23.41	27.57	20.36	11.12	226.57	56.64
T ₅ -Ragi straw	15.16	19.28	23.24	23.18	12.06	279.42	69.86
T ₆ -Maize straw	13.27	17.36	21.38	26.43	12.94	342.16	85.54
T ₇ -Paddy + Wheat straw (1:1)	13.14	16.29	20.26	27.36	13.22	361.52	90.38
T ₈ -Paddy + Sawdust (1:1)	17.46	22.38	26.47	21.47	11.38	244.26	61.07
T ₉ -Paddy + Bagasse (1:1)	15.37	19.46	23.35	23.56	12.14	286.21	71.55
T ₁₀ -Paddy + Ragi straw (1:1)	15.24	19.31	23.29	23.29	12.08	281.34	70.33
T ₁₁ -Paddy + Maize straw (1:1)	14.18	18.26	22.33	25.18	12.76	321.46	80.37
T ₁₂ -Paddy + Wheat bran (10%)	13.06	16.18	20.17	26.58	13.08	347.82	86.96
S.Ed (±)	0.59	0.73	0.82	0.84	0.41	9.26	2.31
C.D (P = 0.05)	1.21	1.49	1.69	1.72	0.84	19.02	4.74

Table 2: Effect of Different Agro-Waste Substrates on Morphological and Quality Parameters of Oyster Mushroom (*Pleurotus ostreatus*)

Treatment	Pileus Diameter (cm)	Stipe Length (cm)	Stipe Thickness (cm)	Moisture Content (%)	Dry Matter (%)	Crude Protein (%)
T ₀ -Paddy straw	6.84	3.92	1.24	88.42	11.58	21.36
T ₁ -Wheat straw	7.96	4.48	1.46	90.18	9.82	24.74
T ₂ -Sawdust	5.72	3.26	1.08	85.63	14.37	18.42
T ₃ -Sugarcane bagasse	6.48	3.74	1.18	87.26	12.74	20.58
T ₄ -Groundnut shells	6.14	3.58	1.13	86.48	13.52	19.86
T ₅ -Ragi straw	6.62	3.86	1.21	87.94	12.06	21.18
T ₆ -Maize straw	7.28	4.16	1.34	89.12	10.88	23.06
T ₇ -Paddy + Wheat straw (1:1)	7.54	4.32	1.39	89.68	10.32	23.84
T ₈ -Paddy + Sawdust (1:1)	6.26	3.64	1.16	86.92	13.08	20.14
T ₉ -Paddy + Bagasse (1:1)	6.68	3.92	1.23	87.86	12.14	21.42
T ₁₀ -Paddy + Ragi straw (1:1)	6.61	3.88	1.22	87.74	12.26	21.28
T ₁₁ -Paddy + Maize straw (1:1)	7.12	4.08	1.31	88.86	11.14	22.64
T ₁₂ -Paddy + Wheat bran (10%)	7.36	4.22	1.36	89.94	10.06	24.12
S.Ed (±)	0.21	0.14	0.06	0.52	0.52	0.63
C.D (P = 0.05)	0.43	0.29	0.12	1.07	1.07	1.29

Table 3: Effect of Different Agro-Waste Substrates on Economics of Oyster Mushroom (*Pleurotus ostreatus*) Cultivation

Treatment	Cost of Cultivation (₹)	Gross Return (₹ @ 200/kg)	Net Return (₹)	B:C Ratio
T ₀ -Paddy straw	580.00	608.54	28.54	1.05
T ₁ -Wheat straw	600.00	785.36	185.36	1.31
T ₂ -Sawdust	620.00	378.86	-241.14	0.61
T ₃ -Sugarcane bagasse	590.00	530.76	-59.24	0.90
T ₄ -Groundnut shells	600.00	453.14	-146.86	0.75
T ₅ -Ragi straw	585.00	558.84	-26.16	0.95
T ₆ -Maize straw	595.00	684.32	89.32	1.15
T ₇ -Paddy + Wheat straw (1:1)	605.00	723.04	118.04	1.20
T ₈ -Paddy + Sawdust (1:1)	600.00	488.52	-111.48	0.81
T ₉ -Paddy + Bagasse (1:1)	590.00	572.42	-17.58	0.97
T ₁₀ -Paddy + Ragi straw (1:1)	590.00	562.68	-27.32	0.95
T ₁₁ -Paddy + Maize straw (1:1)	600.00	642.92	42.92	1.07
T ₁₂ -Paddy + Wheat bran (10%)	610.00	695.64	85.64	1.14

Quality Parameters

The quality parameters of oyster mushroom, particularly moisture content, dry matter and crude protein content, were significantly influenced by the substrate treatments (Table .2). Wheat straw (T₁) recorded the highest moisture content (90.18%) and crude protein content (24.74%), indicating superior nutritional quality. The enriched substrate (T₁₂) and the combination of paddy straw and wheat straw (T₇) also exhibited comparatively higher protein content, reflecting the beneficial effect of nutrient supplementation and substrate synergy. In contrast, sawdust (T₂) recorded the lowest moisture content (85.63%) and crude protein content

(18.42%), indicating inferior quality. The significant variation observed among treatments suggests that substrate composition plays a crucial role not only in yield but also in determining the nutritional attributes of oyster mushroom.

Economics

The economic analysis further substantiated the superiority of wheat straw (Table. 3). Among the treatments, T₁ (100% Wheat straw) recorded the highest gross return (₹ 785.36 per 10 bags), net return (₹ 185.36) and benefit: cost ratio (1.31), indicating its economic feasibility and profitability. This was followed by T₇ (Paddy straw + wheat straw) and T₆

(Maize straw), which also exhibited favourable returns. In contrast, T₂ (sawdust) recorded negative net returns and the lowest B:C ratio (0.61), indicating its uneconomical nature for oyster mushroom cultivation.

Overall, the results clearly demonstrated that substrate selection not only influences biological performance but also determines the economic viability of oyster mushroom production, with wheat straw emerging as the most productive and profitable substrate under the present conditions.

Discussion

The findings of the present investigation unequivocally establish that the nature and composition of agro-waste substrates exert a decisive influence on the growth dynamics and yield performance of oyster mushroom (*Pleurotus ostreatus*). The significantly reduced duration for spawn run, pinhead initiation and first harvest observed in wheat straw clearly indicates its superior suitability as a substrate, which may be attributed to its optimal lingo-cellulosic composition, favourable carbon to nitrogen ratio and well-aerated structure. Such conditions facilitate rapid enzymatic degradation and efficient mycelial colonization, ultimately leading to early fructification. These observations are in close conformity with the earlier reports of Jandaik and Kapoor (1975)^[9], Kalita *et al.*, (1997)^[10], Das and Mukherjee (2007)^[5], Sharma *et al.* (2013)^[21] and Pathania *et al.*, (2017)^[15], who emphasized the pivotal role of substrate quality in determining the growth kinetics of oyster mushroom. The delayed growth observed in sawdust further substantiates the findings of Baysal *et al.*, (2003)^[3] and Philippoussis (2009)^[17], wherein compact substrate structure and reduced porosity were identified as limiting factors for mycelial proliferation.

The marked enhancement in yield attributes under wheat straw, as evidenced by higher number of fruiting bodies, increased average fruit body weight, greater total yield and superior biological efficiency, can be ascribed to improved nutrient availability and efficient bioconversion of lignocellulosic components into fungal biomass. The results are in agreement with those reported by Royse *et al.*, (2017)^[19], Kumar *et al.*, (2019)^[12] and Pandey *et al.*, (2012)^[14], who documented maximum productivity of *Pleurotus* spp. on wheat straw-based substrates. Furthermore, the relatively high yield recorded in mixed substrates such as paddy straw and wheat straw, as well as in nutrient-enriched treatments, highlights the beneficial effect of substrate diversification and supplementation in optimizing substrate characteristics. Similar synergistic effects of substrate combinations have been reported by Alananbeh *et al.*, (2014)^[2], Obodai *et al.*, (2003)^[13], Yang *et al.*, (2013)^[22] who attributed enhanced productivity to improved nutrient balance and structural properties of the substrate matrix.

The variation observed in morphological parameters, particularly pileus diameter and stipe dimensions, further reinforces the influence of substrate on fruit body development. The superior morphological traits recorded in wheat straw may be linked to enhanced nutrient assimilation and favourable micro-environmental conditions that support uniform differentiation and expansion of fruiting bodies. These findings are in consonance with the reports of Hoa *et al.*, (2015)^[8], Kulshreshtha *et al.*, (2014)^[11] who reported significant improvement in morphological attributes under substrates with better aeration and nutrient status.

Conversely, the inferior morphological characteristics observed in sawdust-based treatments may be attributed to restricted nutrient availability and suboptimal physical conditions.

The quality attributes of oyster mushroom, particularly crude protein content, were also markedly influenced by substrate type. The higher protein content recorded in wheat straw and enriched substrates suggests enhanced nitrogen assimilation and metabolic activity, which are critical for protein biosynthesis. These results are in agreement with the findings of Ragunathan and Swaminathan (2003)^[18], Patil *et al.*, (2010)^[16], Adebayo and Martínez-Carrera (2015)^[1] and Sánchez (2010)^[20], who reported improved nutritional quality of oyster mushroom under substrates rich in available nutrients. The comparatively lower protein content observed in sawdust further corroborates earlier reports indicating its limited nutritive value (Kulshreshtha *et al.*, 2014; Sharma *et al.*, 2013)^[11, 21].

From an economic standpoint, the superiority of wheat straw (T₁) was further evident by its higher net returns and benefit:cost ratio, which may be attributed to its enhanced productivity coupled with relatively lower input cost. The favourable economic performance of paddy straw + wheat straw (T₇) and maize straw (T₆) further indicates that partial substitution or diversification of substrates can sustain profitability, particularly under conditions of limited availability of wheat straw. These findings are in agreement with earlier reports suggesting that substrate optimization not only improves yield but also enhances economic returns in mushroom cultivation systems. Conversely, the negative net returns observed in sawdust (T₂) highlight its unsuitability as a sole substrate, owing to its poor physical properties and limited nutrient availability.

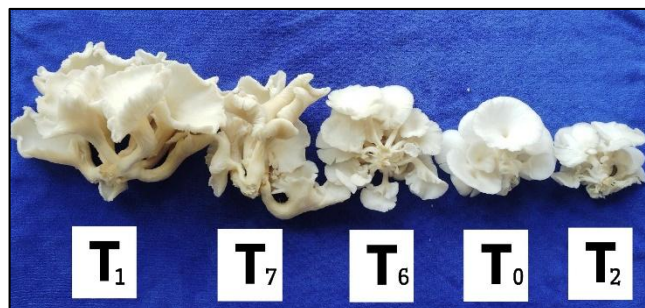


Fig 5: Effect of different substrates on the number and growth of mushroom fruiting bodies.

Accordingly, the findings of the present investigation emphasize that the substrate selection is a critical determinant of both biological efficiency and economic feasibility in oyster mushroom production, and emphasizes the importance of utilizing locally available agro-residues in an optimized manner to achieve sustainable and profitable cultivation systems.

Conclusion

The outcomes of the present experiment unequivocally demonstrate that agro-waste substrates significantly influence the growth, yield and economic returns of oyster mushroom (*Pleurotus ostreatus*). Among the treatments, T₁ (100% wheat straw) proved to be superior by recording the minimum crop duration and maximum yield (392.68 g per bag) with higher biological efficiency, which was further reflected in its highest net return and benefit:cost ratio. The

enhanced performance of wheat straw may be attributed to its favourable lignocellulosic composition, optimal aeration and moisture retention, which facilitate efficient mycelial colonization and fruiting.

Substrate combinations such as T₇ (Paddy straw + wheat straw) and enriched substrate T₁₂ (Paddy straw + wheat bran) also exhibited appreciable yield and economic improvement, highlighting the positive effect of substrate supplementation and blending. In contrast, substrates like sawdust and groundnut shells were found to be less suitable, as they resulted in lower yield and poor economic returns. Overall, wheat straw can be recommended as the most efficient and economically viable substrate; however, under conditions of its limited availability, alternative agro-residues may be judiciously utilized as supplementary substrates to sustain productivity and profitability in oyster mushroom cultivation.

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Dr. N. Narayana Reddy, Associate Dean, Sri Krishnadevaraya College of Horticultural Sciences with mushroom unit members and students during a practical training session

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