The effect of eco enzyme and leri water on the media composition of growth and yield of oyster mushrooms (*Pleurotus ostreatus*)

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Abstract. Oyster mushrooms (Pleurotus ostreatus) produce extracellular enzymes such as lignin peroxidase, manganese peroxidase, and laccase, which play an important role in breaking down lignin and decomposing woody materials in forest ecosystems. This mushroom is also known for its medicinal value and high nutritional quality. Its therapeutic benefits include antioxidant and anti-inflammatory activities, cholesterol-lowering effects, hypertension prevention, and the ability to inhibit the growth of cancer cells. However, production levels often fluctuate and remain unstable. This research was conducted to improve mushroom yield by enriching the substrate with additional nutrients. Eco-enzyme was applied to the growing media at concentrations of 10 ml L^{-1} and 15 ml L^{-1}, while rice washing water was added at 30 ml and 40 ml per baglog. The variables observed included mycelial growth rate, time of pinhead formation, number of pinheads, total fresh weight of fruit bodies, diameter of the pileus cap, stipe length, and number of fruit bodies produced. The treatment with 15 ml L^{-1} eco-enzyme resulted in the highest values for pinhead production, fresh fruit body weight, cap diameter, and total fruit bodies harvested. Overall, the combination of eco-enzyme and rice washing water demonstrates strong potential for improving oyster mushroom productivity as a nutritious food source.

1 Introduction

White oyster mushrooms (*Pleurotus ostreatus*) are a type of mushroom with a white to grayish-white cap, shaped like an oyster shell, and growing in clusters. Oyster mushrooms are a type of mushroom that has high economic value as a food ingredient. This mushroom contains an extracellular compound such as lignin peroxidase, manganese peroxidase and laccase, which effectively break down lignin to decompose the hard lignin matrix in tree trunks and wood debris in forest ecosystems. In addition, this mushroom also has medicinal

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properties that are good for therapeutic benefits, as well as being nutritious and delicious. In addition to having a delicious taste, oyster mushrooms are also known as a food ingredient rich in antioxidants, with various health benefits such as helping to lower cholesterol levels, preventing high blood pressure (hypertension), and inhibiting the growth of cancer cells. Oyster mushrooms are also a nutritious food source rich in protein, making them a promising alternative food option. In 100 grams of oyster mushrooms, there are about 367 calories, 10.5–30.4% protein, 56.6% carbohydrates, 1.7–2.2% fat, as well as various vitamins and minerals, including 0.20 mg of thiamine, 4.7–4.9 mg of riboflavin, 77.2 mg of niacin, and 314.0 mg of calcium [1].

The demand for oyster mushrooms, both domestically and on a larger scale, has not been fully met. Limited production is due to a lack of technological mastery and limited production facilities, resulting in a shortage of farmers cultivating oyster mushrooms. According to Central Statistics Agency (2024) data, mushroom production in Indonesia tends to decline from 692,428 kg/year in 2021 to 527,758 kg/year in 2022. Meanwhile, in 2023, there was a significant decline, reaching 537,866 kg. These data indicate that mushroom production in Indonesia is increasing annually.

Eco-enzymes, which are liquid extracts generated from fermenting organic waste such as fruit and vegetable residues, can be applied to improve mushroom yield and quality. These solutions are produced through a fermentation process involving organic materials mixed with sugar and water over a specific duration. During fermentation, microorganisms break down the organic substrates into beneficial compounds, including enzymes, amino acids, and various nutrient elements. Eco-enzymes offer several advantages, serving not only as liquid organic fertilizers but also as natural pest deterrents and environmentally friendly cleaning agents [2].

Leri water, or rice washing water, is the liquid residue produced during the rinsing of rice prior to cooking. While commonly thrown away, this by-product actually contains a range of valuable organic substances and mineral elements, such as carbohydrates, nitrogen, phosphorus, potassium, magnesium, sulfur, iron, and vitamin B1 [3]. Creating an optimal growing medium is crucial for oyster mushroom farmers, as it directly supplies the nutrients required for mushroom growth and development. If the composition and nutrient content of the growing medium are inadequate, mycelium growth may be inhibited, which can disrupt the cultivation process and reduce oyster mushroom yields. Therefore, the nutrients in raw materials or added ingredients must meet the specific nutritional requirements of oyster mushrooms [4].

Rosnina et al. [5], reported that applying eco-enzyme at a dose of 20 ml/L produced a very significant impact on several key growth stages of mushrooms, including the onset of pinhead formation, the number of pinheads, the diameter of the pileus cap, and the total fruiting bodies. In line with these findings, Budirahaju et al. [6], showed that leri water application also had a significant effect on the radial growth rate of mycelia and the yield of oyster mushrooms, evaluated every seven days up to 49 days after inoculation. Their research further demonstrated that providing 50 ml/L of leri water per baglog produced the most favorable results in increasing the number of fruit bodies.

2 Research methods

This study was carried out in the experimental garden and the Agroecotechnology Laboratory of the Faculty of Agriculture, University of Malikussaleh, from May to July 2025. The materials used included oyster mushroom spawn, 70% alcohol for sterilization, sawdust, bran, lime ($CaCO_3$), eco-enzyme, and leri (rice-washing water). The equipment employed in this research consisted of an autoclave, spirit

lamp, analytical balance, stationery, camera, spatula, caliper, ruler, shovel, labeling paper, polypropylene plastic, cotton, baglog covers and neck rings, rubber bands, a spray bottle, a syringe, and paper bags.

This research employed a completely randomized design with a factorial pattern. The first factor was the eco-enzyme treatment (E), which included three levels: E0 = 0 ml L^{-1}, E1 = 10 ml L^{-1}, and E2 = 15 ml L^{-1}. The second factor was the application of leri water, also arranged in three levels: L0 = 0 ml L^{-1}, L1 = 30 ml L^{-1}, and L2 = 40 ml L^{-1}. The collected data were evaluated using analysis of variance (ANOVA), and when significant differences occurred, the Duncan Multiple Range Test (DMRT) at the 5% level was applied. All statistical analyses were conducted using SAS software.

3 Results and discussion

3.1 Mycelium growth rate/completed spawn run

Based on Table 1, reveal that the treatment of giving *eco-enzyme* and leri water did not shows any significant difference. There is no effect that combination of *eco-enzyme* and leri water application on the mycelium growth rate.

Table 1. The effect of application eco-enzyme (E) and providing water (L) on the variable of mycelial growth rate.

Treatment	Radial growth rate (cm)
Applicaton of *Eco-enzyme* (E)	
E0 (*Eco-enzyme* 0 ml L-^{1}/baglog)	23,38 a
E1 (*Eco-enzyme* 10 ml L-^{1}/baglog)	23,61 a
E2 (*Eco-enzyme* 15 ml L-^{1}/baglog)	23,66 a
Applicaton of leri water (L)	
L0 (0 ml L-^{1}/baglog)	22,98 a
L1 (Leri water 30 ml L-^{1}/baglog)	23,31 a
L2 (Leri water 40 ml L-^{1}/baglog)	24,35 a

Note: The numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test

Based on Table 1, the eco-enzyme treatment did not significantly affect the radial growth rate during the completed spawn run of the media baglog. The highest value was observed in the E2 treatment (eco-enzyme 15 L^{-1}baglog) at 23.66 cm, while the lowest value was in the E0 treatment (without eco-enzyme) at 23.38 cm. Similarly, the application of leri water did not significantly influence the mycelial growth rate to completed of the spawn run in the media baglog. The highest value was recorded in the L2 treatment (leri water 40 ml L^{-1} baglog) at 24.35 cm, and the lowest found without application (leri water 0 ml L^{-1} baglog) at 22.98 cm at 24.35 cm, and the lowest found without application (leri water 0 ml L^{-1}/baglog) at 22.98 cm.

3.2 Number of pinheads

The results showed that neither the eco-enzyme nor the leri water treatments had no significant effect on the timing of the first appearance of the fruiting body (unpublished data), meanwhile application of eco-enzyme gave t had a highly significant effect on the number of pinheads at the first harvest, and a significant effect at the second and fifth harvests. The leri water treatment did not have a significant effect on the number of pinheads. Combinations of eco-enzyme and leri water treatments are presented in Table 2.

Table 2. Effect of eco-enzyme (E) and leri water (L) application on the number of pinheads.

Treatment	Number of *Pinheads*				
Eco-enzyme Administration	**1st Harvest**	**2nd Harvest**	**3rd Harvest**	**4th Harvest**	**5th Harvest**
E0 (Eco-enzyme 0 ml L^{-1})	6.14 b	8.11 b	8.88 a	8.32 a	7.96 a
E1 (Eco-enzyme 10 ml L^{-1})	9.44 a	8.55 ab	8.66 a	8.63 a	8.41 a
E2 (Eco-enzyme 15 ml L^{-1})	10.40 a	9.99 a	8.77 a	8.94 a	8.48 a
Providing leri Water					
L0 (Leri water 0 ml L^{-1})	7.96 a	8.88 a	9.03 a	8.76 a	7.94 a
L1 (Leri water 30 ml L^{-1})	8.29 a	9.44 a	8.77 a	8.26 a	8.46 a
L2 (Leri water 40 ml L^{-1})	7.74 a	8.33 a	8.51 a	8.78 a	8.44 a

Note: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test

Based on Table 2, the application of eco-enzyme resulted in the highest number of pinheads in the E2 treatment (eco-enzyme 15 ml/L water) during harvests 1, 2, 4, and 5, with values of 10.40, 9.99, 8.94, and 8.48, respectively. The lowest values in these harvests were observed in the E0 (control) treatment. In contrast, during harvest 3, the highest number of pinheads was found in the E0 treatment (8.88), while the lowest was in the E1 treatment (eco-enzyme 10 ml/L water) at 8.66.

The leri water treatment showed no significant differences across harvests. The highest number of pinheads was found in the L1 treatment for harvests 1, 2, and 5; in the L0 treatment for harvest 3; and in the L2 treatment for harvest 4. The lowest numbers of pinheads were recorded in the L2 treatment for harvests 1, 2, and 3, in the L1 treatment for harvest 4, and in the L2 treatment for harvest 3.

3.3 Total fresh weigh of oyster mushroom

The analysis of variance showed that the eco-enzyme treatment resulted in significant differences in the total fresh weight of the fruit body in harvests 1 and 5, while no significant differences were observed in harvests 2 and 3. The leri water treatment showed a significant difference in harvest 1, but not in harvests 2, 3, 4, or 5. Combinations of eco-enzyme and leri water treatments on the total fresh weight of the fruit body are presented in Table 3.

Based on Table 3, the treatment of *eco-enzyme* administration shows that the heaviest total fresh weight of mushroom fruit bodies was found in the E2 treatment *(eco-enzyme* 15 ml/l water) in observations 1 2, 3, 4 and 5 with values of 28.17g, 29.31g, 19.69g, 18.94g, and

20.21g, showing a significant difference with the E0 treatment (control) 19.33g at harvest 1, not significantly different from harvests 2 and 3. The leri water treatment was significantly different at harvest 1 with the highest value being in the L2 treatment 29.45g, the lowest value being in the L0 treatment (control), while at harvests 2, 3, 4 and 5 showed no significant difference with the highest value being in the L1 treatment with a value of 27.94g, 19.77g, and at harvests 4 and 5 the highest value was in L2, namely 39.42g, the lowest value was in the treatment L0 (control) 25.12g and 19.34g.

Table 3. Effect of giving eco-enzyme (E) and giving leri water (L) on the total fresh weight of the fruit body.

Treatment	Fresh Weight of Mushroom Fruit Body (g)				
Eco-enzyme Administration E0 (Control)	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
E1 *(Eco-enzyme* 10 ml/l water)	19.33 b	25.12 a	19.34 a	17.75 b	19.66 ab
E2 *(Eco-enzyme* 15 ml/l water)	26.47 a	25.26 a	18.88 a	18.76 a	19.50 b
E1 *(Eco-enzyme* 10 ml/l water)	28.17 a	29.31 a	19.65 a	18.94 a	20.21 a
Providing Leri Water L0 (Control)	20.42 b	24.89 a	19.03 a	18.27 a	19.84 a
L1 (30 ml Leri Water/baglog)	24.09 ab	27.94 a	19.77 a	18.53 a	19.54 a
L2 (Leri Water 40 ml/baglog)	29.45 a	26.86 a	19.08 a	18.65 a	19.99 a

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

The results of the analysis of variance showed that the combination of *eco-enzyme* and leri water treatments was significantly different on the total fresh weight of the fruit body at harvest 1, the combination of *eco-enzyme* and leri water treatments on the total fresh weight variables of the fruit body are presented in Table 4.

Table 4. Combination of *eco-enzyme* (E) and water (L) treatments on the total fresh weight of the fruit body.

Treatment	Total Fresh Weight of Fruit Body
	Average Fruit Body Weight at Harvest
Control (E0) + L0 (control)	11.76 c
Control (E0) + 30 ml L^1	20.34 b
Control (E0) + 40 ml/ L^1	25.89 ab
Eco-enzyme 10 ml L^1 + Water 0 ml L^1	25.60 ab
Eco-enzyme 10 ml/L + water 30 ml L^1	23.85 ab
Eco-enzyme 10 ml L^1 + water 40 ml L^1	29.95 ab
Eco-enzyme 15 ml/L +Control (L0)	23.91 ab
Eco-enzyme 15 ml L^1 + water 30 ml L^1	29.95 ab
Eco-enzyme 15 ml L^1+ water 40 ml L^1	32.53 a

Note: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

Based on Table 4, the combination shows significantly different results between the provision of *eco-enzyme* and leri water on the total fresh weight variable of the fruit body at harvest 1, the highest number of *pinheads* is found in the E2L2 combination *(eco-enzyme* 15

ml/l + leri water 40 ml/ baglog), while the lowest treatment combination is the E0L0 treatment *(eco-enzyme* 0 ml/l + leri water 0 ml/baglog).

3.4 Pileus cap diameter

The results of the analysis of variance showed that the treatment of giving *eco-enzyme* was significantly different on the variable of mushroom fruit cap diameter in observation 1 and was not significantly different in observations 2, 3. The leri water treatment showed no significant difference in observations 1, 2 and 3, there was a combination of *eco-enzyme* and leri water on the variable of mushroom fruit cap diameter as shown in Table 5.

Table 5. Effect of giving *eco-enzyme* (E) and giving water (L) on the diameter of mushroom fruit caps water.

Treatment	***Pileus* Cap Diameter**				
Eco-enzyme	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
E0 (Control)	49.21 b	44.24 a	41.33 a	39.02 ab	39.20 a
E1 *(Eco-enzyme* 10 ml/l water)	51.56 ab	45.72 a	40.74 a	38.94 b	38.91 a
E2 *(Eco-enzyme* 15 ml/l water)	59.38 a	48.26 a	40.64 a	39.58 a	39.03 a
Providing Leri Water					
L0 (Control)	56.14 a	44.74 a	39.60 a	39.00 a	39.25 a
L1 (30 ml Leri Water/baglog)	49.03 a	47.85 a	41.91 a	39.12 a	39.00 a
L2 (Leri Water 40 ml/l	54.98 a	45.63 a	41.00 a	39.42 a	38.89 a

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

Based on Table 5, the largest fruit cap diameter was observed in the E2 treatment (eco-enzyme 15 ml/L of water) during harvests 1 and 2, with measurements of 59.38 cm and 48.26 cm, respectively. The smallest diameters were found in the E0 (control) treatment, measuring 49.21 cm and 44.74 cm. Meanwhile, in observations for harvests 3, 4, and 5, the highest cap diameters were recorded in the E0 (control) treatment, with values of 41.33 cm, 39.02 cm, and 39.20 cm.

The lowest value was in treatment E2 *(eco-enzyme* 15 ml/l of water) 40.64 cm for harvest 3 and harvests 4 and 5. The lowest value was in treatment E1 *(eco- enzyme* 10 ml/l of water. The treatment with running water showed no significant difference with the highest value being treatment L0 (control) 56.14 cm and 39.25 cm. The lowest value was in treatment L1 49.03 cm, while for harvests 2, 3 and the 4 highest values were in the L1 treatment *(eco-enzyme* 10 ml/l water) with values of 47.85 cm, 41.91 cm and 41.91 cm, while the lowest values were in the L0 (control) treatment of 44.24, 39.60 cm and 39.00 cm.

The variance analysis indicated that the combined application of eco-enzyme and leri water produced a significant effect on the fruit cap diameter at the first harvest. The effects of these combined treatments on the fruit body diameter are presented in Table 6.

Based on Table 6, the combination treatments showed significant differences in fruit body diameter at the first harvest. The largest fruit cap diameter was obtained from the E2L0 combination (eco-enzyme 15 ml/L + no leri water), while the smallest diameter was recorded in the E0L1 treatment (no eco-enzyme + 30 ml/baglog leri water).

Table 6. Combination of *eco-enzyme* (E) and water (L) treatments on the fruit cap diameter.

Treatment	***Pileus* Cap Diameter**
	Evarerage pileus cap (Cm)
Control (E0) + Control (L0)	47.02 b
Control (E0) + 30 ml of water/baglog (L1)	45.25 b
Control (E0) + 40 ml of water/baglog (L2)	55.37 ab
Eco-enzyme 10 ml/l water (E1) + Control (L0)	55.82 ab
Eco-enzyme 10 ml/l water (E1) + leri water 30 ml/baglog (L1)	47.48 b
Eco-enzyme 10 ml/l water (E1) + leri water 40 ml/baglog (L2)	51.37 ab
Eco-enzyme 15 ml/l water (E2) + Control (L0)	65.60 a
Eco-enzyme 15 ml/l water (E2) + leri water 30 ml/baglog (L1)	54.36 ab
Eco-enzyme 15 ml/l water (E2) + leri water 40 ml/baglog (L2)	58.20 ab

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

3.5 Oyster mushroom stipe length

The analysis of variance indicated that the eco-enzyme treatment did not produce significant differences in stalk length across observations 1, 2, and 3. Similarly, the leri water treatment showed no significant effects on oyster mushroom stalk length in observations 1, 2, and 3. No significant interaction effects were found between the eco-enzyme and leri water treatments, as shown in Table 7.

Table 7. The effect of giving *eco-enzyme* (E) and giving water (L) on the stipe length of oyster mushroom.

Treatment	Oyster Mushroom Stipe Length (Cm)				
Eco-enzyme Administration	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
E0 (Control)	3.77 a	3.65 a	2.75 a	3.01 a	3.79 a
E1 (Eco-enzyme 10 ml L1)	3.90 a	3.73 a	3.06 a	3.13 a	3.50 a
E2 (Eco-enzyme 15 ml L1)	4.41 a	3.77 a	2.93 a	3.04 a	3.68 a
Providing Leri Water					
L0 (Control)	3.83 a	3.66 a	2.90 a	2.97 a	3.53 a
L1 (30 ml Leri Water L1)	4.19 a	3.91 a	2.98 a	3.23 a	3.80 a
L2 (40 ml Leri Water L1)	4.06 a	3.58 a	2.86 a	2.98 a	3.64 a

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test

Based on Table 7, the eco-enzyme treatment did not produce significant differences in stalk length across all observations. The longest stalks were recorded in the E2 treatment (eco-enzyme 15 ml/L of water) during the first and second harvests, measuring 4.44 cm and 3.77 cm, respectively. The shortest stalks in these harvests were observed in the E0 (control) treatment, with lengths of 3.77 cm and 3.65 cm. In the third and fourth harvests, the greatest

stalk lengths were found in the E1 treatment (eco-enzyme 10 ml/L), at 3.06 cm and 3.13 cm, while the shortest stalks were again noted in the E0 (control) treatment, at 2.75 cm and 3.01 cm.

The analysis of variance showed that the combined application of eco-enzyme and leri water produced significant differences in oyster mushroom stalk length in observations 1 and 3. These results indicate that the interaction between eco-enzyme and leri water affected stalk length at both measurement points. The effects of these combined treatments on the fruit body diameter variable are presented in Table 8.

The combination of the treatment of giving eco-enzyme and giving leri water on the variable of the fruit body diameter is seen in Table 8.

Table 8. The effect of combination of *eco-enzyme* and giving leri water on the stipe length of oyster mushroom

Description: According to the 5% DMRT test, numbers followed by identical letters in the same column do not differ significantly

Treatment	Oyster mushroom stipe length	
	1st observation	3rd observation
Control (E0) + Control (L0)	3,83(2,07) ab	2,83 ab
Control (E0) + leri water 30 ml/baglog (L1)	4,17(2,15) ab	2,54 b
Control (E0) + leri water 40 ml/baglog (L2)	3,31(1,94) ab	2,88 ab
Eco-enzyme 10 ml/l water (E1) + control (L0)	3,17(1,90) b	2,99 ab
Eco-enzyme 10 ml/l water (E1) + leri water 30 ml/baglog (L1)	3,97(2,11) ab	3,23 a
Eco-enzyme 10 ml/l water (E1) + leri water 40 ml/baglog (L2)	4,56(2,25) a	2,97 ab
Eco-enzyme 15 ml/l water (E2) + control (L0)	4,48(2,23) ab	2,87 ab
Eco-enzyme 15 ml/l water (E2) + leri water 30 ml/baglog (L1)	4,44(2,21) ab	3,17 ab
Eco-enzyme 15 ml/l water (E2) + leri water 40 ml/baglog (L2)	4,32(2,19) ab	2,74 ab

Based on Table 8, the interaction between eco-enzyme and leri water resulted in significant differences in oyster mushroom stipe length during the first and third harvests. In the first harvest, the longest stipe was produced by the E1L2 treatment combination (eco-enzyme 10 ml/L + leri water 40 ml/baglog), while the shortest was observed in the E1L0 treatment (eco-enzyme 10 ml/L + no leri water). In the third harvest, the longest stipe was recorded in the E1L1 treatment (eco-enzyme 10 ml/L + leri water 30 ml/baglog), whereas the shortest stipe length occurred in the E0L1 treatment (no eco-enzyme + leri water 30 ml/baglog).

Although eco-enzyme and leri water did not show significant effects when applied separately, their combination produced a notable impact on oyster mushroom stalk length in both the first and third observations. In the first observation, the longest stalk was obtained from the E1L2 treatment (eco-enzyme 10 ml/L + leri water 40 ml/baglog), while the shortest occurred in the E1L0 treatment (eco-enzyme 10 ml/L without leri water). In the third observation, the E1L1 treatment (eco-enzyme 10 ml/L + leri water 30 ml/baglog) produced the longest stalk, whereas the E0L1 treatment (no eco-enzyme + leri water 30 ml/baglog) resulted in the shortest.

3.6 Number of fruiting bodies

The variance analysis showed that the eco-enzyme treatment had a significant effect on the number of fruit bodies in the first harvest, but no significant differences were observed in harvests 2, 3, 4, and 5. The application of leri water also produced a significant effect in the first observation but showed no significant differences in observations 2, 3, 4, and 5. No significant interaction was found between eco-enzyme and leri water treatments for the number of fruit bodies, as presented in Table 9.

Table 9. The effect of giving eco-enzyme (E) and giving water (L) on the number of fruiting bodies.

Treatment	Number of Fruiting Bodies				
Eco-enzyme Administration	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
E0 (Control)	7.66 b	6.88 a	4.88 a	5.04 a	5.24 a
E1 *(Eco-enzyme* 10 ml/l water)	7.99 ab	7.18 a	4.85 a	5.50 a	5.19 a
E2 *(Eco-enzyme* 15 ml/l water)	9.59 a	7.85 a	5.37 a	5.37 a	5.71 a
Providing Leri Water					
L0 (Control)	6.92 b	6.92 a	5.29 a	5.21 a	5.38 a
L1 (30 ml Leri Water/baglog)	8.74 a	7.18 a	5.14 a	5.11 a	5.32 a
L2 (Water Leri 40 ml/l water	9.59 a	7.81 a	4.66 a	5.59 a	5.43 a

Note: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

Based on Table 9, the eco-enzyme treatment had a significant effect during the first observation. The highest number of fruit bodies was obtained from treatment E2 (eco-enzyme 15 ml/L of water), with an average of 9.59, while the lowest was recorded in the control treatment (E0) at 7.66. However, in harvests 2, 3, 4, and 5, no significant differences were observed among the treatments. The highest numbers of fruit bodies in these harvests were observed in treatment E2 (15 ml/L eco-enzyme), with values of 7.85, 5.37, 5.37, and 5.71 respectively, whereas the lowest values occurred in treatment E0 (control) at 6.88 and in treatment E1 (10 ml/L eco-enzyme) at 4.85. The leri water treatment showed significant differences only in the first harvest, where treatment L2 (40 ml/baglog) produced the highest number of fruit bodies at 9.59. For harvests 2, 3, 4, and 5, no significant differences were observed. The highest fruit body counts were found in treatment L2 (40 ml/baglog) for harvests 2, 4, and 5, and in treatment L1 (30 ml/baglog) for harvest 3.

4 Discussion

4.1 The effect of application eco-enzyme

The pinhead count variable showed that applying eco-enzyme at a dose of 15 ml/L (E2) had a highly significant effect in the first harvest and a significant effect in the second harvest. This response is likely attributed to the nutrients present in the eco-enzyme, which help increase the number of pinheads in oyster mushrooms. In particular, the potassium content is essential, as it plays a key role in cell division and overall growth, including the formation of

pinheads. Potassium (K) is an essential macronutrient for the growth and development of oyster mushrooms. This result aligns with the findings of Andhika et al. [7], who reported that white oyster mushrooms require various nutrients for optimal growth, such as lignin, carbohydrates (cellulose and glucose), protein, nitrogen, fiber, phosphorus (P), potassium (K), calcium (Ca), and vitamins.

The use of the E2 eco-enzyme treatment significantly increased the fresh weight of oyster mushroom fruit bodies harvested on days 1 and 5. This improvement is likely attributed to the eco-enzyme's ability to boost nutrient availability and enhance the substrate structure. This result is in line with Laksono [8], ho noted that eco-enzymes supply carbohydrates, proteins, vitamins, and minerals that contribute to mushroom cap development.

Significant increases in cap diameter were also observed in harvests 1 and 4 following E2 eco-enzyme application. This may be because the nutrients in the eco-enzyme are more readily absorbed by the mushrooms, resulting in greater growth compared to water alone. This observation is supported by Nangoi et al. [9], who found that water supplementation helps meet the complex nutritional requirements for carbohydrates, proteins, minerals, and vitamins during the fruit cap growth stage.

Eco-enzyme also significant increase of mushroom yield at first harvest, likely due to the potassium in eco-enzymes being absorbed by the fungi. The additional nutrients provide more food for the fungi compared to using only wood powder as a substrate. Ginting et al. [10] also found that eco-enzyme, as a liquid organic fertilizer derived from agricultural waste, contains amylase, maltase, and glucose, which serve as energy sources for mushroom.

However, eco-enzyme application did not show significant effects on mycelium growth rate, the timing of the first appearance of pinheads, the number of pinheads harvested in harvests 3, 4, and 5, fresh weight in harvests 2, 3, and 4, cap diameter in harvests 2, 3, and 4, stem length in harvests 1–5, or the number of fruit bodies in harvests 2 and 3. This may be due to the eco-enzyme dose being insufficient for optimal oyster mushroom growth, as also reported by Penida et al. [11]. White oyster mushrooms lack chlorophyll and cannot perform photosynthesis for autotrophic nutrition, making them reliant on alternative nutrient sources such as eco-enzymes.

4.2 The effect of giving leri water (Rice washing water)

Based on the analysis of variance, the application of leri water resulted in a significant increase in the number of fruit bodies in the first harvest. This effect is likely due to the presence of nutrients such as N, P, K, C, and other essential elements in leri water that support oyster mushroom growth. These results are consistent with Suprapto et al. [12], who reported that oyster mushrooms require adequate carbon, nitrogen, vitamins, and minerals for optimal development. The key vitamins influencing oyster mushroom growth include thiamine (vitamin B1), nicotinic acid (vitamin B3), pantothenic acid (vitamin B5), biotin (vitamin B7), and pyridoxine (vitamin B6).

The application of leri water did not produce significant differences in the variables of mycelial growth rate, the initial appearance of potential fruiting bodies (pinheads), the number of pinheads, the total fresh weight of the fruiting bodies, the cap diameter, the stalk length, or the number of fruiting bodies in harvests 2, 3, 4, and 5. This is presumed to be due to the insufficient dosage of leri water, which resulted in oyster mushroom growth that was not significantly different. This aligns with Ikhsan [13], who stated that inadequate nutrient availability for mushrooms leads to uneven growth and development in white oyster mushrooms, and that nutrient deficiencies in the substrate can disrupt mycelial growth.

4.3 The application of eco-enzyme and leri water

Based on the variance analysis, the combined application of eco-enzymes and leri water significantly influenced several growth parameters of white oyster mushrooms. In particular, this combination notably increased the number of pinheads at the second harvest, the total fresh weight of the fruiting bodies at the first harvest, the cap diameter at the first harvest, and the stalk length at both the first and second harvests. This impact is likely attributed to the ability of eco-enzymes and leri water to enhance and stimulate fungal growth.

These results are in line with Suparti et al. [14], ho found that leri water contains key nutrients—including phosphorus, nitrogen, calcium, vitamin B1, carbon, and sulfur—that contribute to improving mushroom productivity and fruit body weight. Likewise, Warisno [15] highlighted the importance of these nutrients in supporting overall mushroom growth and development.

Phosphorus is vital for the formation of the vegetative structures of mushrooms, including the cap, fruiting body, and root system. Carbon serves as a fundamental building block for cell formation and acts as an energy source for cellular metabolism. Nitrogen is essential for protein synthesis and fat formation, and it also contributes to accelerating the growth rate and yield of oyster mushrooms.

4.4 Combination of eco-enzyme and leri water

The variance analysis indicated that the combined use of eco-enzyme and leri water significantly affected several growth characteristics of white oyster mushrooms. These effects were observed in the number of pinheads per harvest, the total fresh weight of fruiting bodies in the first harvest, the cap diameter in the first harvest, and the stipe length in both the first and second harvests. This response is likely due to the ability of eco-enzyme and leri water to enhance fungal growth.

This result is consistent with the findings of Suparti et al. [14], which reported that leri water contains essential compounds such as phosphorus, nitrogen, calcium, vitamin B1, carbon, and sulfur that contribute to higher productivity and fruit body weight in mushrooms. Similarly, Warisno [15] emphasized the importance of these nutrients in mushroom development. Phosphorus supports the formation of vegetative structures such as caps, fruiting bodies, and the mycelial system; carbon serves as a fundamental substrate for cell construction and an energy source for metabolic processes; and nitrogen is crucial for protein synthesis, fat formation, and accelerating the overall growth rate of mushroom.

5 Conclusion

1. The use of eco-enzymes enhances both the growth rate and the production of white oyster mushrooms. Applying the eco-enzyme at a concentration of 15 ml per liter of water produced the most optimal outcomes for the growth and yield of white oyster mushroom cultivation.
2. The application of 40 ml L^{-1} of leri water per baglog resulted in the most favorable outcomes for mycelial development and the total fresh weight of white oyster mushroom fruiting bodies.
3. The application of eco-enzyme 15 ml L^{-1} together with Leri water 40 ml L^{-1} increases the yield of white oyster mushroom.

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