

Print ISSN : 0972-8813  
e-ISSN : 2582-2780

[Vol. 23(3) September-December 2025]

# Pantnagar Journal of Research

(Formerly International Journal of Basic and  
Applied Agricultural Research ISSN : 2349-8765)



G.B. Pant University of Agriculture & Technology  
Pantnagar, U.S. Nagar; Uttarakhand, Website : [gbpuat.res.in/PJR](http://gbpuat.res.in/PJR)



## ADVISORY BOARD

### Patron

**Prof. Manmohan Singh Chauhan**, Ph.D., Vice-Chancellor, G.B. Pant University of Agriculture and Technology, Pantnagar, India

### Members

**Prof. S. K. Verma**, Ph.D., Director Research, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Jitendra Kwatra**, Ph.D., Director, Extension Education, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. S.S. Gupta**, Ph.D., Dean, College of Technology, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. A.H. Ahmad**, Ph.D., Dean, College of Veterinary & Animal Sciences, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Alka Goel**, Ph.D., Dean, College of Community Science, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. R.S. Jadoun**, Ph.D., Dean, College of Agribusiness Management, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Lokesh Varshney**, Ph.D., Dean, College of Post Graduate Studies, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Avdhesh Kumar**, Ph.D., Dean, College of Fisheries, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Subhash Chandra**, Ph.D., Dean, College of Agriculture, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Prof. Ramesh Chandra Srivastava**, Ph.D., Dean, College of Basic Sciences & Humanities, G.B.P.U.A.T., Pantnagar, India

## EDITORIAL BOARD

### Members

**A.K. Misra**, Ph.D., Ex-Chairman, Agricultural Scientists Recruitment Board, Krishi Anusandhan Bhavan I, New Delhi, India & Ex-Vice Chancellor, G.B. Pant University of Agriculture & Technology, Pantnagar

**Anand Shukla**, Director, Reefberry Foodex Pvt. Ltd., Veraval, Gujarat, India

**Anil Kumar**, Ph.D., Director, Education, Rani Lakshmi Bai Central Agricultural University, Jhansi, India

**Ashok K. Mishra**, Ph.D., Kemper and Ethel Marley Foundation Chair, W.P. Carey Business School, Arizona State University, U.S.A.

**Binod Kumar Kanaujia**, Ph.D., Professor, School of Computational and Integrative Sciences, Jawahar Lal Nehru University, New Delhi, India

**D. Ratna Kumari**, Ph.D., Associate Dean, College of Community / Home Science, PJTSAU, Hyderabad, India

**Deepak Pant**, Ph.D., Separation and Conversion Technology, Flemish Institute for Technological Research (VITO), Belgium

**Desirazu N. Rao**, Ph.D., Honorary Professor, Department of Biochemistry, Indian Institute of Science, Bangalore, India

**G.K. Garg**, Ph.D., Ex-Dean, College of Basic Sciences & Humanities, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Humnath Bhandari**, Ph.D., IRRI Representative for Bangladesh, Agricultural Economist, Agrifood Policy Platform, Philippines

**Indu S Sawant**, Ph.D., Principal Scientist, ICAR National Research Centre for Grapes, Pune, India

**Kuldeep Singh**, Ph.D., Director, ICAR - National Bureau of Plant Genetic Resources, New Delhi, India

**Muneshwar Singh**, Ph.D., Ex-Project Coordinator AICRP- LTFE, ICAR, Indian Institute of Soil Science, Bhopal, India

**Omkar**, Ph.D., Professor (Retd.), Department of Zoology, University of Lucknow, India

**P.C. Srivastav**, Ph.D., Professor (Retd.), Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, India

**Prashant Srivastava**, Ph.D., Soil Contaminant Chemist, CSIRO, Australia

**Puneet Srivastava**, Ph.D., Director, Water Resources Center, Butler-Cunningham Eminent Scholar, Professor, Biosystems Engineering, Auburn University, United States

**R.K. Singh**, Ph.D., Ex-Director & Vice Chancellor, ICAR-Indian Veterinary Research Institute, Izatnagar, U.P., India

**Ramesh Kanwar**, Ph.D., Charles F. Curtiss Distinguished Professor of Water Resources Engineering, Iowa State University, U.S.A.

**S.N. Maurya**, Ph.D., Professor (Retired), Department of Gynaecology & Obstetrics, G.B. Pant University of Agri. & Tech., Pantnagar, India

**Sham S. Goyal**, Ph.D., Professor Emeritus, Faculty of Agriculture and Environmental Sciences, University of California, Davis, U.S.A.

**Umesh Varshney**, Ph.D., Honorary Professor, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore, India

**V.D. Sharma**, Ph.D., Dean Life Sciences, SAI Group of Institutions, Dehradun, India

**V.K. Singh**, Ph.D., Director, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India

**Vijay P. Singh**, Ph.D., Distinguished Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, Department of Biological and Agricultural Engineering, Texas A & M University, U.S.A.

### Editor-in-Chief

**K.P. Raverkar**, Professor, G.B. Pant University of Agriculture and Technology, Pantnagar, India

### Assistant Managing Editor

**Jyotsna Yadav**, Ph.D., Research Editor, Directorate of Research, G.B. Pant University of Agriculture and Technology, Pantnagar, India

### Technical Manager

**S.D. Samantaray**, Ph.D., Professor & Head, Department of Computer Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India

### Development

**Dr. S.D. Samantaray**, Professor & Head

**Brijesh Dumka**, Developer & Programmer

## CONTENTS

- Frogeye leaf spot (*Cercospora sojina* K. Hara) in soybean: Emerging challenges, resistance genetics and sustainable management strategies** 337  
SANJEEV KUMAR, LAXMAN SINGH RAJPUT, HEMANT SINGH MAHESHWARI,  
VANGALA RAJESH, M. RAJENDAR REDDY, PAWAN SAINI, PALAK SOLANKI, JYOTI KAG,  
MANOJ KUMAR YADAV, JAYWANT KUMAR SINGH and SHIKHA SHARMA
- Impact of establishment methods and weed management practices on growth and yield attributes of rice (*Oryza sativa* L.)** 350  
HIMANSHU, S.K. YADAV, D.K. SINGH and PRATIMA ARYA
- Integrated weed management practices in wheat (*Triticum aestivum* L.) under the humid sub-tropical condition of Uttarakhand** 355  
SHRUTI SINGH, SHIV VENDRA SINGH and RASHMI SHARMA
- Foliar supplementation of micronutrients on Palash [*Butea monosperma* (Lam.) Taub.] for enhanced productivity of rangeenilac, *Kerria lacca* (Kerr, 1782) (Hemiptera: Kerridae)** 361  
PURNIMA KEKTI, P.K. NETAM, DAMINI NISHAD and SOURABH MAHESHWARI
- Lagged effects of weather variables on *Helicoverpa armigera* (Hübner) larval population during rabi season** 367  
RAJNNI DOGRA and MEENA AGNIHOTRI
- Influence of nutrients on the flowering attributes of the guava cv. Sardar** 377  
RAKHI GAUTAM, PRATIBHA and A.K. SINGH
- Sequential functional screening and trait-based association of chickpea rhizobacterial isolates using multiple correspondence analysis** 384  
DEEPANJALI GUPTA, KIRAN P. RAVERKAR, NAVNEET PAREEK, POONAM GAUTAM,  
SHRI RAM and AJAY VEER SINGH
- Evaluation of neutralizing post-vaccination antibody response against Peste des petits ruminants virus in Pantja goat breed of Uttarakhand, India** 396  
ANUJ TEWARI, AMISHA NETAM, RAJESH KUMAR, SAUMYA JOSHI, S.K. SINGH and  
R.K. SHARMA
- Arbuscular Mycorrhizal Fungi (AMF) Root Colonisation and Glomalin Variability Across Bamboo Species Integrating UV-Vis Spectral Characterisation** 402  
SHAMLI SHARMA, A.K. VERMA and ASHUTOSH DUBEY
- Comparative pyrolysis of agricultural biomass for bio-oil production and in vitro antifungal analysis of developed bio-oil based formulations** 412  
VAIBHAV BADONI, ASHUTOSH DUBEY, R. N. PATERIYA and A.K. VERMA
- Computational exploration of curcumin-p-coumaric acid bioconjugates as potential inhibitors of  $\beta$ -catenin in breast cancer stem cells** 423  
ANANYA BAHUGUNA and SHIV KUMAR DUBEY

<b>Molecular Docking Analysis of Curcumin–Glucose Conjugate as Potential Modulators of Breast Cancer Stemness via <math>\beta</math>-Catenin Inhibition</b> ROHIT PUJARI, MUMTESH SAXENA and SHIV KUMAR DUBEY	431
<b>Assessment of <i>Schizophyllum commune</i> and <i>Trametes hirsuta</i> as efficient laccase-producing white-rot fungi</b> RUKHSANA BANO, DIKSHA BHARTI and AJAY VEER SINGH	438
<b>Drought stress mitigation and enhancement of maize growth facilitated by the plant growth–promoting bacterium <i>Serratia</i> sp. SRK14</b> ASHISH KUMAR and AJAY VEER SINGH	444
<b>Effect of adding turmeric, ginger and black pepper on biochemical parameters of <i>Cyprinus carpio</i></b> KIRTI SHARMA, DAISY RANI1, MADHU SHARMA and TARANG SHAH	454
<b>Design and Development of a Four-Wheel Remotely Controlled Weeding Machine</b> SANDEEP KUMAR SAROJ , JAYANT SINGH, SUMIT KUMAR and SACHIN CHAUDHARY	460
<b>Analyzing farmers perception towards climate change in Nainital district of Uttarakhand</b> ABHISHEK KUMAR and ARPITA SHARMA KANDPAL	466
<b>Study on information seeking behavior of female students of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand related to menstruation</b> POOJA TAMTAand SUBODH PRASAD	472

## Assessment of *Schizophyllum commune* and *Trametes hirsuta* as efficient laccase-producing white-rot fungi

RUKHSANA BANO, DIKSHA BHARTI and AJAY VEER SINGH\*

*Department of Microbiology, College of Basic Sciences and Humanities, G. B. Pant University of Agriculture and Technology, Pantnagar-263145 (U. S. Nagar, Uttarakhand)*

*\*Corresponding author's email id: ajaygbpuat@gmail.com*

**ABSTRACT:** White-rot fungi are important microbial resources in industrial and environmental applications due to their ability to produce ligninolytic enzymes. Among these, laccases and extracellular blue copper oxidases are of particular interest because of their broad substrate specificity and lignin-degrading potential. In this study, two previously identified white-rot fungal isolates *Trametes hirsuta* (PSF7) and *Schizophyllum commune* (WRPF6), were evaluated for laccase production using guaiacol as substrate. Both isolates exhibited significant enzymatic activity indices of  $1.3 \pm 0.024$  mm and  $1.12 \pm 0.022$  mm, respectively. PSF7 showed the highest laccase activity, reaching 97.92 U/mL on the 12th day of incubation, followed by WRPF6 at 55.63 U/mL on the 15th day. Laccase oxidized guaiacol using molecular oxygen as the electron acceptor, highlighting the strong oxidative enzyme systems of these isolates. These findings suggest that PSF7 and WRPF6 are promising candidates for diverse industrial and biotechnological applications, including biofuel production from lignocellulosic biomass, textile dye degradation, and food or pharmaceutical processing.

**Keywords:** Guaiacol, Laccase, lignin, *Schizophyllum commune*, *Trametes hirsuta*, white rot fungus

Laccases possess high redox potential and catalyze oxidative transformation and ring cleavage of diverse aromatic compounds, a property attributed to their multicopper oxidase structure with interconnected cupredoxin-like domains folded into a compact globular conformation. Their wide range of substrate specificity, catalytic versatility, and ecological importance make them key enzymes in lignin degradation and aromatic compound transformation (Janusz *et al.*, 2020). Fungal laccases are generally monomeric glycoproteins, though dimeric and multimeric forms have also been reported across different species (Giardina *et al.*, 2010). Basidiomycete fungi are well known for their ability to produce a range of extracellular enzymes that contribute to lignin degradation. Key enzymes include laccases (benzenediol:oxygen oxidoreductases) and several peroxidases, such as MnP, LiP, and VP. LiP acts as a diarylpropane:hydrogen-peroxide oxidoreductase, catalyzing C–C bond cleavage, whereas MnP functions as a Mn(II):hydrogen-peroxide oxidoreductase. VP exhibits the combined catalytic capabilities of both LiP and MnP, enabling it to oxidize a broader spectrum of lignin-derived

compounds (Pozdnyakova *et al.*, 2018). White rot basidiomycetes are viewed as the most efficient natural producers of laccase and other ligninolytic enzymes due to their superior ability to mineralize lignin compared to other microorganisms (Rabha *et al.*, 2023). Species such as *Trametes versicolor*, *Pleurotus ostreatus*, *Phanerochaete chrysosporium*, *Ceriporiopsis subvermispora*, and *Lentinula edodes* have been extensively studied for their strong ligninolytic capabilities and high laccase yields (Birhanli *et al.*, 2013). Laccase-producing fungi play a major role in the bioremediation of aromatic pollutants, dyes, xenobiotics, and various industrial contaminants owing to their oxidative versatility (Zhuo and Fan, 2021). Laccases also have wide industrial applications, including dye decolorization, pulp delignification, wastewater detoxification, and environmentally friendly processing in the textile, food, and paper industries (Arregui *et al.*, 2021). Their ability to catalyze oxidation under mild conditions makes them suitable for green and sustainable processing technologies (Mate and Alcalde, 2017). In lignocellulosic biomass pretreatment, biological methods utilizing white-rot fungi provide a sustainable alternative to

conventional physicochemical processes that often require high energy and may generate inhibitory compounds (Kumar and Sharma, 2017). Recent studies have demonstrated that laccase from white-rot fungi, including *L. betulina* and *Trametes* spp., can effectively depolymerize lignin and enhance the digestibility and bioconversion efficiency of lignocellulosic materials (Kumar *et al.*, 2022; Cui *et al.*, 2021). Therefore, the present study aims to evaluate and quantify laccase production by selected white-rot fungal isolates to assess their potential applicability in the biodegradation of lignin from lignocellulosic biomass.

## MATERIALS AND METHODS

### *Collection and maintenance of ligninolytic fungal cultures*

Two previously identified ligninolytic fungal cultures, *viz.*, *Schizophyllum commune* (WRPF6) and *Trametes hirsuta* (PSF7), were obtained from the Department of Microbiology, College of Basic Science and Humanities, GBPUA&T Pantnagar, Uttarakhand. The fungal cultures were reactivated using the spot inoculation method on PDA plates. After inoculation, the plates were maintained at 25–27°C for seven days.

### *Qualitative screening of cultures for laccase production*

The fungal cultures were screened qualitatively for laccase activity using PDA medium supplemented with 0.01% (v/v) guaiacol (Pandey *et al.*, 2018; Kiiskinen *et al.*, 2004). Each culture was centrally inoculated onto Petri plates and incubated at 28 ± 1 °C for 5–10 days under static conditions. The appearance of a dark-red to reddish-brown zone surrounding the fungal mycelium due to oxidation of guaiacol indicated laccase activity. Plates without fungal inoculation served as negative controls. The level of extracellular laccase production was quantified by calculating the relative enzyme activity index using the formula:

$$I_{laccase} = \frac{\text{Diameter of the colored halozone (in mm)}}{\text{Diameter of colony (in mm)}}$$

### *Quantitative estimation of laccase enzyme*

Fungal cultures were cultivated for laccase production following the method described by Kalra *et al.* (2013). Based on the relative laccase activity observed in the qualitative plate assay, the isolates were grown in a laccase-inducing liquid medium composed of the following components (g/L<sup>-1</sup> w/v): KH<sub>2</sub>PO<sub>4</sub> 50, glucose 3.0, MgSO<sub>4</sub>·7H<sub>2</sub>O 1.0, NH<sub>4</sub>NO<sub>3</sub> 12.5 mM, KCl 0.5, Tween 20 0.2, veratryl alcohol 1 mM, FeSO<sub>4</sub> 0.001, trace metal solution 0.1%, and pH 5.0 at 28±1°C for 24 days. After incubation, the crude enzyme was extracted by centrifugation at 10,000 rpm at 4°C for 10 minutes. The obtained supernatant was used as the crude laccase enzyme. The reaction mixture included 1 mL of diluted crude enzyme and 3 mL of sodium acetate buffer (10 mM), pH 5.5. After that, 1.0 mL of guaiacol (2mM) was added as substrate. Mixed the solution and incubated at 30°C for 15 minutes. After incubation, laccase activity was indicated by the development of a brown colour. Afterwards, the absorbance was measured at 450 nm against a blank, which contained 1.0 mL of distilled water instead of crude enzyme in the reaction mixture. 1 unit of laccase enzyme activity is defined as the amount of enzyme needed to oxidize one μmol of guaiacol/minute. The activity (Unit /mL) was determined according to the following formula:

$$\text{Enzyme activity ( Unit/ml )} = \frac{A * V}{t * e * v}$$

Where A (Absorbance), V (Total volume of the reaction mixture), t (Incubation time), e (Extinction coefficient) and v denotes the volume of crude enzyme solution (mL)

### *Statistical Analysis*

The experiment was performed three times, and the resulting data were analyzed using the Statistical Package for the Social Sciences (SPSS) software. Enzyme activity measurements were subjected to one-way analysis of variance (ANOVA). Before ANOVA, the dataset was subjected to a square root transformation to achieve normality and stabilize variance. Statistical significance was considered at p < 0.05, and mean comparisons were done using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

### *Qualitative screening of selected isolates based on I<sub>lac</sub> plate assay*

Qualitative screening for laccase production by the selected microbial isolates was performed on guaiacol-amended agar medium. Guaiacol serves as the primary carbon source and chromogenic substrate for laccase, and its enzymatic oxidation leads to the formation of a distinct dark brick-red to brown halo surrounding the colonies. The microbial isolate PSF7 exhibited the maximum I<sub>lac</sub> value of 1.30±0.024 mm (Fig. 1A), followed by WRPF6 followed with an I<sub>lac</sub> value of 1.12±0.022 mm (Fig. 1B). The absence of a dark halo confirms that the medium components and guaiacol substrate do not spontaneously oxidize or change colour in the absence of the laccase enzyme (Fig. 1C). The results of the qualitative screening for laccase production using the guaiacol-amended agar medium are presented in Table 1. The data quantifies the laccase activity using the relative enzyme activity index (I<sub>lac</sub>), which is calculated as the ratio of the diameter of the coloured halo zone to the diameter of the colony (in mm). Among them, PSF7 exhibited the maximum I<sub>lac</sub> value (1.30 mm), followed by WRPF6 (1.12mm). The critical difference at 5% level was provided for each measurement, 0.049 for PSF7 and 0.042 for

WRPF6, showing that the difference between means was statistically significant.

### *Quantification of extracellular laccase enzyme activity*

The two isolates selected from the preliminary screening were subjected to quantitative laccase activity analysis. The cultures were incubated in a laccase-inducing liquid medium for 24 days, during which samples were collected at regular intervals. The culture broth was centrifuged to obtain the supernatant containing the crude enzyme, and quantitative assays were performed at 3-day intervals. The evaluation revealed distinct strain-specific differences in laccase production (Fig. 2), which visually confirms the superiority of PSF7 as a laccase producer in the tested conditions, as it achieved a higher enzyme titer and reached its peak production earlier compared to WRPF6. This difference underscores the importance of selecting high-performing fungal strains for biotechnological applications. The initial activity of the isolate PSF7 started at a low (0.96± 0.004 U/mL) on day 3, and increased moderately up to day 9 (20.02 ±0.511 U/mL). The highest activity was exhibited, reaching its maximum production of 97.92 ± 2.395 U/mL on the 12th day of incubation. The activity dropped sharply to 33.38 ±0.069 U/mL on day 15 and

**Table 1: Relative activity indices of laccase enzymes of two fungal cultures as determined by plate assay**

S. No.	Fungal cultures	Relative enzyme activity indices (mm)		CD (5%)
		Laccase (I <sub>lac</sub> )		
1	<i>Trametes hirsuta</i> (PSF7)	1.30±0.024		0.049
2	<i>Schizophyllum commune</i> (WRPF6)	1.12±0.022		0.042

CD, critical difference

**Table 2: In-vitro laccase enzyme activities (U/mL) in culture extract of selected fungal cultures**

Fungal cultures	Extracellular Laccase enzyme activities (U/mL) at different time intervals (d)							
	3	6	9	12	15	18	21	24
<i>Trametes hirsuta</i> (PSF7)	0.96±0.004	2.44±0.005	20.02±0.511	97.92±2.395	33.38±0.069	14.68±0.099	7.04±0.059	4.82±0.015
<i>Schizophyllum commune</i> (WRPF6)	1.04±0.026	4.08±0.096	9.79±0.194	19.28±0.249	55.63±0.573	12.75±0.046	7.86±0.094	2.59±0.043

SEm±: a (cultures) = 0.184; b (time period) = 0.300; a\*b (interaction) = 0.519

CD (5%): a (cultures) = 0.524; b (time period) = 0.855; a\*b (interaction) = 1.482

CD, critical difference; SEM, standard error of mean; d, days

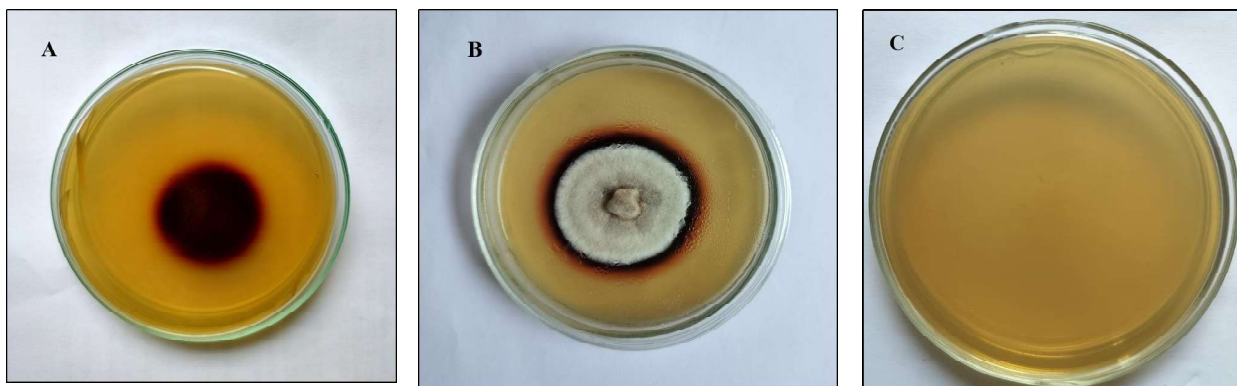


Fig. 1: Qualitative detection of laccase enzyme activity by (A) *Trametes hirsuta* (PSF7); (B) *Schizophyllum commune* (WRPF6); (C) Control (untreated) plate assay of laccase

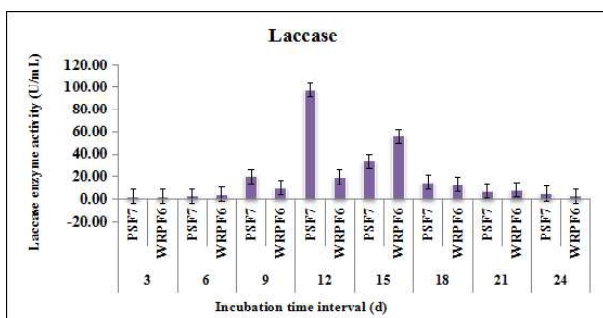


Fig.2: Laccase activity in the crude enzyme extracts of the selected fungal cultures, *Trametes hirsuta* (PSF7) and *Schizophyllum commune* (WRPF6), measured at different incubation intervals over 24 days

continued to decrease until the final measurement on day 24 ( $4.82 \pm 0.015$  U/mL). Similarly, the initial activity of WRPF6 was slightly higher compared to PSF7 on day 3 ( $1.04 \pm 0.026$  U/mL) and reached its peak activity later than PSF7, achieving  $55.63 \pm 0.573$  U/mL on the 15 days of incubation. After that, the activity decreased significantly, reaching  $2.59 \pm 0.043$  U/mL by day 24, demonstrating significant enzymatic potential under the same fermentation conditions (Table 2).

The findings from the qualitative and quantitative laccase assays confirmed that the high enzyme activity of the isolates, particularly PSF7, was consistent with literature on wood-rotting fungi. These observations are consistent with recent studies reporting that wood-rotting fungi and other ligninolytic microorganisms often display higher qualitative laccase activity on guaiacol plates due to their robust oxidative enzyme systems and multiple laccase isoenzymes (Umar et al., 2023;

Sharma et al., 2023; Pandey et al., 2018). Recent literature further emphasizes that isolates demonstrating higher  $I_{lac}$  values frequently possess enhanced extracellular enzyme secretion capabilities, making them potential candidates for downstream biotechnological applications. For instance, higher guaiacol-oxidizing laccase activity has been strongly associated with improved performance in dye decolorization, bioremediation, and lignocellulosic biomass conversion processes (Alhomaidi et al., 2023). Similarly, kinetic characterization of guaiacol-oxidizing fungal laccases suggests that strains with strong guaiacol reactivity often exhibit favourable catalytic parameters such as lower  $K_m$  and higher  $V_{max}$ , strengthening their utility in industrial enzyme production (Saad Abd El-latif et al., 2024). The appearance of a colored zone is a widely accepted indicator of extracellular laccase production and continues to be routinely used due to its reliability, rapid detection, and cost-effectiveness (Elsaba et al., 2023). These findings highlight the biotechnological promise of potent isolates such as PSF7 and WRPF6, which may serve as efficient candidates for large-scale laccase production and downstream industrial or environmental applications.

Several studies indicate that laccase productivity in *Trametes hirsuta* varies by strain and culture conditions, with higher enzyme yields recorded under optimized incubation (Li et al., 2016; Wang et al., 2024). Bagewadi et al. (2017) reported that *Trichoderma harzianum* strain HZN10 produced laccase activities of 63 U/g, 55 U/g, and 53 U/g when



grown on rice straw and sugarcane bagasse substrates. The present results highlight clear variation in laccase synthesis between the two fungal isolates, with PSF7 exhibiting markedly higher enzymatic activity. The isolates, particularly PSF7, are efficient candidates for large-scale laccase production and various downstream industrial or environmental applications. This difference underscores the importance of selecting high-performing fungal strains for biotechnological applications that rely on strong oxidative enzyme systems, including lignocellulose degradation, dye decolorization, and environmental bioremediation.

## CONCLUSION

The present study demonstrates that fungal cultures PSF7 and WRP6 possess significant potential for ligninolytic enzyme production, particularly laccase. Qualitative and quantitative screening confirmed their efficiency as laccase producers. These fungi represent valuable resources for sustainable industrial and environmental applications. Future work may focus on optimizing culture conditions, including substrate, pH, temperature, and inducer supplementation, as well as exploring enzyme stabilization or immobilization to enhance laccase yield and industrial applicability.

## ACKNOWLEDGEMENTS

The authors sincerely acknowledge G.B. Pant University of Agriculture and Technology, for its valuable institutional support and essential research facilities.

## REFERENCES

- Alhomaiddi, E.A., Umar, A., Alsharari, S.S. and Alyahya, S. (2023). Evaluation of Lacc134 oxidoreductase of *Ganoderma multistipitatum* in detoxification of dye wastewater under different nutritional conditions. *Microbiology Research*, 14(3), 1398-1412.
- Abd El Latif, A. S., Zohri, A. N. A., El Aref, H. M. (2024). Kinetic studies on optimized extracellular laccase from *Trichoderma harzianum* PP389612 and its capabilities for azo dye removal. *Microbial Cell Factories*, 23: 150.
- Arregui, L., Ayala, M., Gómez-Gil, X., Gutiérrez-Soto, G., Hernández-Luna, C. E., Herrera De Los Santos, M. and Valdez-Cruz, N. A. (2021). Laccases: structure, function, and potential application in water bioremediation. *Microbial Cell Factories*, 18(1): 200.
- Bagewadi, Z. K., Mulla, S. I. and Ninnekar, H. Z. (2017). Purification and immobilization of laccase from *Trichoderma harzianum* strain HZN10 and its application in dye decolorization. *Journal of Genetic Engineering and Biotechnology*, 15(1): 139–150.
- Birhanli, E., Erdogan, S., Yesilada, O. and Onal, Y. (2013). Laccase production by newly isolated white rot fungus *Funaliatrogii*: effect of immobilization matrix on laccase production. *Biochemical Engineering Journal*, 71: 134–139.
- Cui, T., Yuan, B., Guo, H., Tian, H., Wang, W., Ma, Y., Li, C. and Fei, Q. (2021). Enhanced lignin biodegradation by consortium of white rot fungi: microbial synergistic effects and product mapping. *Biotechnology for Biofuels*, 14(1): 162.
- Elsaba, A. M., Mahmoud, M., Abdel Karim, G. S., Abdelra of, M. and Othman, A. M. (2023). Production of a novel laccase from *Ceratorhiza hydrophila* and assessing its potential in natural dye fixation and cytotoxicity against tumor cells. *Journal of Genetic Engineering and Biotechnology*, 21: 14.
- Giardina, P., Faraco, V., Pezzella, C., Piscitelli, A., Vanhulle, S. and Sannia, G. (2010). Laccases: A never-ending story. *Cellular and Molecular Life Sciences*, 67(3): 369–385.
- Janusz, G., Pawlik, A., Świdarska-Burek, U., Polak, J., Sulej, J., Jarosz-Wilkolazka, A. and Paszczyński, A. (2020). Laccase properties, physiological functions, and evolution.

- International Journal of Molecular Sciences*, 21(3): 966.
- Kalra, K., Chauhan, R. and Shavez, M. (2013). Isolation of laccase producing *Trichoderma* spp. and effect of pH and temperature on its activity. *International Journal of Chemistry and Technology Research*, 5(5): 2229–2235.
- Kiiskinen, L. L., Rättö, M. and Kruus, K. (2004). Screening for novel laccase producing microbes. *Journal of Applied Microbiology*, 97(3): 640–646.
- Kumar, A. K. and Sharma, S. (2017). Recent updates on different methods of pretreatment of lignocellulosic feedstocks: a review. *Bioresources and Bioprocessing*, 4(1): 7.
- Kumar, V. P., Sridhar, M. and Gopala Rao, R. (2022). Biological depolymerization of lignin using laccase harvested from the autochthonous fungus *Schizophyllum commune* employing various production methods and its efficacy in augmenting in vitro digestibility in ruminants. *Scientific Reports*, 12(1): 11170.
- Li, S., Tang, B., Liu, Y., Chen, A., Tang, W. and Wei, S. (2016). High-level production and characterization of laccase from a newly isolated fungus *Trametes* sp. LS-10C. *Biocatalysis and Agricultural Biotechnology*, 8: 278–285.
- Mate, D. M. and Alcalde, M. (2017). Laccase: a multi-purpose biocatalyst at the forefront of biotechnology. *Microbial Biotechnology*, 10(6): 1457–1467.
- Pandey, R. K., Tewari, S. and Tewari, L. (2018). Lignolytic mushroom *Lenzites elegans* WDP2: Laccase production, characterization, and bioremediation of synthetic dyes. *Ecotoxicology and Environmental Safety*, 158: 50–58.
- Pozdnyakova, N. N., Balandina, S. A., Dubrovskaya, E. V., Golubev, C. N. and Turkovskaya, O. V. (2018). Lignolytic basidiomycetes as promising organisms for the mycoremediation of PAH-contaminated environments. In *IOP Conference Series: Earth and Environmental Science*, 107: 012071.
- Rabha, J., Devi, S. P., Das, S., Roy, N. and Jha, D. K. (2023). Microbial conversion of biomass to value-added chemicals. In *Value-Addition in Agri-food Industry Waste Through Enzyme Technology*, Pp. 37–64.
- Umar, A., Abid, I., Antar, M. (2023). Electricity generation and oxidoreductase potential during dye discoloration by laccase producing *Ganoderma gibbosum* in fungal fuel cell. *Journal of King Saud University – Science*, 35: 102948.
- Wang, C., Jia, Y., Luo, J., Chen, B. and Pan, C. (2024). Characterization of thermostable recombinant laccase F from *Trametes hirsuta* and its application in delignification of rice straw. *Bioresource Technology*, 392: 130382.
- Zhuo, R. and Fan, F. (2021). A comprehensive insight into the application of white rot fungi and their lignocellulolytic enzymes in the removal of organic pollutants. *Science of the Total Environment*, 778: 146132.

Received: December 04, 2025

Accepted: December 23, 2025