

Journal of Biological Control, 39(3): 324–330, 2025, DOI: 10.18311/jbc/2025/49082

Research Article

First report of wood rot fungal extracts as bio-control measure against jackfruit (*Artocarpus heterophyllus* Lam) rot caused by *Rhizopus stolonifer* Vuillemin in India

S. BHARATH KUMAR[1], K. TEJASHWINI[1] and PRAVEEN KUMAR NAGADESI[1,2*]

[1]*Mycology and Plant Pathology Lab, St. Joseph's Research Innovation Council, St. Joseph's University, Bengaluru–560027, Karnataka, India*

[2]*Department of Botany, School of Life Science, St. Joseph's Research Innovation Centre, St. Joseph's University, Bengaluru–560027, Karnataka, India*

**Corresponding author E-mail:* nagadesipraveenkumar@yahoo.com

ABSTRACT: *Artocarpus heterophyllus* Lam (jackfruit) is widely cultivated in India for its high nutritional and medicinal value. However, these plants are susceptible to soft fruit rot caused by *Rhizopus stolonifer*. The infection primarily affects the inflorescence and immature fruits, with only a small percentage reaching maturity. Infected fruits exhibit characteristic symptoms, including black flocculent sporangia and cottony mycelial growth covering the flowers and young fruits. A significant number of affected fruits drop prematurely. Infected fruits were collected from Bengaluru, isolated with a potato dextrose agar (PDA) medium, and identified as *R. stolonifer*. Colonies exhibited diffuse, grey, cottony mycelia, with hyaline, aseptate hyphae, rhizoids, and stolons at their bases. Sporangia were nearly spherical (135 µm in diameter), while sporangiospores were ellipsoid to ovate, measuring 3.5-8.5 × 1.5-3.5 µm. For biocontrol, methanolic extracts ranging from 1-5% concentration of various Wood Rotting Fungi (WRF) like *Ganoderma lucidum, Ganoderma gibbosum, Trametes elegans, Pycnoporus sanguineus, Lentinus sajor-caju, Tropicoporus linteus,* and *Inonotus obliquus* were evaluated against *R. stolonifer*. At a 5% concentration, the extracts of *G. lucidum, G. gibbosum, T. elegans, P. sanguineus, L. sajor-caju, T. linteus,* and *I. obliquus* exhibited strong antifungal activity, inhibiting fungal growth by 95-100%. For the first time, all WRF extracts, except *G. lucidum*, have been reported as biocontrol agents against *R. stolonifer*, the causative agent of jackfruit rot, in India. Further research is required for the commercial utilisation of these WRF extracts as biocontrol agents against fungal plant pathogens.

KEYWORDS: Jackfruit, methanolic extracts, *Rhizopus stolonifer*, soft fruit rot, wood rot fungi

(Article chronicle: Received: 20-03-2025; Revised:11-08-2025; Accepted: 14-08-2025)

INTRODUCTION

The genus *Artocarpus* comprises about 50 species of tropical trees native to the Pacific region, as well as South and Southeast Asia, with many species producing edible fruits. *Artocarpus heterophyllus* (jackfruit) is a widely cultivated species prized for its edible flowers, fruits, and seeds, which can be eaten fresh or used in various culinary preparations. Jackfruit trees can reach heights of over 60 feet, bearing fruits that may grow longer than 2 feet and weigh up to 70 pounds. One of the common fungal diseases affecting jackfruit is *Rhizopus* rot, which thrives in regions with high rainfall or following storms. When warm, humid, and wet conditions align with the flowering and fruiting period, *Rhizopus* rot can lead to complete fruit loss (Nelson, 2005). Jackfruit suffers severe yield losses due to soft rot disease caused primarily by *Rhizopus artocarpi* (Berk. & Broome) Boedijn and occasionally by *R. stolonifer*. The disease develops rapidly under warm and humid conditions, leading to soft, watery rot and black sporangial growth, often resulting in total fruit loss during fruiting seasons. Other wood-rotting fungi, such as *Phellinus noxius* and *Ganoderma lucidum*, have also been associated with decay processes and were evaluatedin the study for their antagonistic potential against *R. artocarpi* (Duvvi *et al.*, 2018).

Wood-Decaying Fungi, primarily classified under the phyla *Basidiomycota* and *Ascomycota*, are divided into white-rot and brown-rot groups based on their distinct modes of wood degradation. White-rot fungi are capable of decomposing both lignin and cellulose entirely, while brown-rot fungi mainly break down cellulose and hemicellulose, leaving behind chemically altered lignin (Schilling *et al.*, 2020; Fukasawa *et al.*, 2011). Gaining insights into these decay processes and documenting their diversity play a crucial role in advancing ecological research and promoting sustainable forest ecosystem management. Various wood-decaying fungi, such as species belonging to *Ganoderma*, *Phellinus*, and *Trametes*, are known to synthesise diverse

secondary metabolites exhibiting potent antimicrobial and enzymatic activities capable of inhibiting plant pathogens and insect pests (Pointing, 2001; Rayner & Boddy, 1988). These attributes emphasise their significance not only in maintaining ecological balance but also in serving as potential sources for developing environmentally friendly biocontrol agents to replace chemical pesticides. Therefore, investigating their diversity, substrate specificity, and biochemical potential is essential for promoting sustainable pest management and identifying novel fungal resources with biocontrol applications. This study aims to assess the antifungal efficacy of methanolic extracts from selected wood rot fungi, including *Ganoderma lucidum, Ganoderma gibbosum, Trametes elegans, Pycnoporus sanguineus, Lentinus sajor-caju, Tropicoporus linteus,* and *Inonotus obliquus*, against *R. stolonifer*. Despite the crop's high value, limited studies exist on its fungal pathogens and eco-friendly management. Hence, this study aimed to identify the pathogenic fungi and explore biological control measures using plant and fungal extracts as sustainable alternatives to chemical fungicides.

MATERIALS AND METHODS

Study area

Infected *A. heterophyllus* (jackfruit) fruits affected by *R. stolonifer* were collected from multiple locations across Bengaluru, Karnataka, India. The selected sampling sites included St. Joseph's University, Lalbagh Botanical Garden, Cubbon Park, Ashirvad Centre, Kengeri, and Richmond Circle**,** representing a blend of urban and peri-urban settings with varied ecological conditions. St. Joseph's University and Ashirvad Centre are institutional areas with well-maintained green spaces, whereas Lalbagh and Cubbon Park serve as prominent botanical and public gardens known for their rich plant diversity. Kengeri, a suburban region, and Richmond Circle, a bustling urban centre, provided additional sample sources from residential and commercial landscapes. The diverse environmental conditions of these locations facilitated a comprehensive collection of infected jackfruit samples, ensuring a robust basis for pathogen isolation and further research.

Isolation and identification of fruit rot fungi

The infected fruit samples were collected from various places in and around Bengaluru during the late winter-to-summer transition season. The samples were isolated using Potato Dextrose Agar medium (PDA), and fruit samples were measured 5×5×1mm and removed aseptically from the infected Jackfruits. Infected fruits were collected from Bengaluru,surfacesterilised with 70% ethanol for 2 min, and washed three times with distilled water, air dried, and small pieces from the margin of lesions were inoculated onto PDA. The plates were incubated at 25±2°C. Once fungal colonies developed on the PDA plates, individual colonies were subcultured onto fresh agar slants to establish pure cultures for further analysis. The isolate obtained from naturally infected jackfruit was stained with lactophenol cotton blue and examined morphologically under a light microscope for identification (Zheng *et al.*, 2007).

Collection, fungal extraction, and biocontrol agent preparation

Wood-rotting fungal samples were collected from various locations across the Western Ghats of Karnataka, India. The specimens were packed in sterile zip-lock bags and transported to the laboratory for further analysis. Micromorphological characteristics of the fungi were examined and identified before the specimens were dried and individually stored in plastic bags. In this study, seven wood-decaying fungi, *Ganoderma lucidum, Ganoderma gibbosum, Trametes elegans, Pycnoporus sanguineus, Lentinus sajor-caju, Tropicoporus linteus, and Inonotus obliquus* were selected for investigation based on their biochemical potential relevant to sustainable pest management (Table 1).The fresh fruiting bodies of these fungi were oven-dried at 60°C and pulverised into a fine powder. To prepare the stock solution, 10g of powdered material was extracted with methanol for 24 h. After extraction, methanol was removed using distillation, and the extract was diluted in 100 mL of 20% methanol. The solution was then filtered through a muslin cloth, followed by a Whatman No. 1 filter paper. These extracts have been used in later studies (Nagadesi & Arya, 2016).

Antifungal test

Fruiting body extracts were added to 100 mL of Malt Extract Agar (MEA) medium to obtain final concentrations of 1%, 2%, 3%, 4%, and 5%. These concentrations were prepared from an initial 10% stock solution. Each concentration was tested in triplicate against fungal pathogens isolated from jackfruit. Control treatments received only distilled water. Mycelial discs of the test fungi were placed at the centre of 10 cm Petri dishes containing the supplemented medium. Control plates without any fungal extracts were also prepared for comparison. To encourage fungal development, all plates were incubated at 25 ± 2°C. The colony diameter was

Table 1. List of fungal extracts used for biocontrol and their families

S. No.	Plant	Family	Part used
1	*G. gibbosum*	Ganodermataceae	Fruiting Extract
2	*G. lucidum*	Ganodermataceae	Fruiting Extract
3	*T. elegans*	Polyporaceae	Fruiting Extract
4	*P. sanguineus*	Polyporaceae	Fruiting Extract
5	*L. sajor-caju*	Polyporaceae	Fruiting Extract
6	*T. linteus*	Hymenochaetaceae	Fruiting Extract
7	*I. obliquus*	Hymenochaetaceae	Fruiting Extract

measured following a seven-day incubation period. To assess the extracts' inhibitory impact, fungal growth in the treated plates was contrasted with that in the control plates. Using a common method (Poonia *et al.*, 2022), the degree of growth suppression was reported as a percentage of inhibition. The percentage data were transformed to angular (degree) values using the formula (Gomez & Gomez, 1984) (Figure 5).

$$\% \text{ Inhibition} = \frac{\text{Diameter of Control} - \text{diameter of Treated Set}}{\text{Diameter of Control}} \times 100$$

$$Y'(\text{degrees}) = \arcsin\left(\sqrt{\frac{x}{100}}\right) \times \frac{180}{\pi}$$

where:

- Y = transformed (angular) value in radians
- X = original percentage value (0-100)

RESULTS

Identification of disease

Soft rot caused by *R. stolonifer* has been observed affecting jackfruit flowers and fruit in and around Bengaluru, India (Figure1). This disease primarily occurs during the transition from late winter to summer (February-April), coinciding with the flowering and fruiting seasons, and results in significant fruit loss in jackfruit trees. A survey conducted during this period, with assessments at 15-day intervals, revealed that the pathogen affected approximately 15-25% of young fruits. The disease initially presents as soft, watery, brown spots on flowers and fruit. As the infection progresses, the powdery, fuzzy layer of black spores and white fungal mycelia spreads across the jackfruit's surface. The pathogen rapidly colonises young fruit, causing them to turn black, rot, shrink, and sometimes mummify. Symptoms may appear while the fruit is still attached to the tree or develop later during storage or transit. Warm, humid, and rainy conditions favour disease development, while wind, rain, and insects contribute to the dispersal of fungal spores. The infection symptoms showed a dense layer of black spores on the fruit surface. Wind, rain, or insects disperse, facilitating secondary disease cycles when the black spores produced on infected fruit are transmitted to new, healthy flowers and fruits, leading to successive rounds of infection. This cycle can continue as long as environmental conditions remain favourable, contributing to widespread disease outbreaks.

Isolation and identification of fungi

Rhizopus stolonifer (Ehrenb.) Vuill., Rev. Mycol. (Toulouse) 24: 54 (1902) [MB#119545]

Colonies on Potato Dextrose Agar (PDA) at 25°C initially appear white and cottony, later becoming densely speckled with sporangia and turning brownish-black with age. They spread rapidly via stolons, which are anchored to the substrate at various points by rhizoids. Both rhizoids and stolons range in colour from hyaline to dark brown. Sporangiophores are smooth-walled, non-septate, light brown, and simple, measuring 30-35 µm in width and 50-55 µm in length. They arise in groups of 3-5 from the stolons, directly opposite the rhizoids. Sporangia are globose to subglobose with a flattened base, initially white and becoming black at maturity, and measure 10-15 µm in diameter. They are many-spored. Columellae are 65-68 × 70-85 µm, subglobose to dorsoventrally flattened, light brownish-grey, and exhibit an umbrella-like shape upon dehiscence. The collar is poorly defined or absent, while an apophysis is present and visible beneath young columellae. Sporangiospores are 8-20 µm long, irregular in shape, ranging from round, oval, and elongate to angular, brownish-black, with homogeneous contents and a distinctly striate surface (Figure 2).

Antifungal efficacy

The antifungal efficacy of methanolic extracts from various wood rot fungi against *R. stolonifer* was assessed at concentrations ranging from 1% to 5% (Table 2). The inhibitory activity varied among the fungal extracts, with some demonstrating complete inhibition at lower concentrations. Among the tested extracts, *T. linteus* exhibited the highest antifungal activity, achieving 96.2% inhibition at 1% concentration and complete inhibition (100%) at 3% and higher concentrations. Similarly, *Ganoderma gibbosum* showed strong inhibition, reaching 91.3% at 1% and complete inhibition at 3% and above. *T. elegans* and *P. sanguineus* also displayed potent antifungal properties, both achieving 100% inhibition at 3% concentration. *L. sajor-caju* exhibited moderate efficacy, with inhibition rates increasing from 79.1% at 1% to complete inhibition at 4% concentration. *G. lucidum* followed a similar pattern, reaching full inhibition at 4% concentration. *I. obliquus* demonstrated the lowest antifungal activity, with 39.5% inhibition at 1% and requiring a 5% concentration for complete inhibition (Figures 3 and 4).

Statistical Analysis:All experiments were conducted in triplicate, and the data are expressed as mean values. Significant differences among the fungal extracts at various concentrations were evaluated using one-way ANOVA followed by Tukey's post-hoc test ($p<0.05$). The analysis revealed that *T. linteus*, *G. gibbosum*, and *L. sajor-caju* exhibited the strongest inhibitory effects even at lower concentrations, while *I. obliquus* showed relatively lower inhibition at 1-3% concentrations.

Overall, the results indicate that *T.linteus, G. gibbosum, T. elegans,* and *P. sanguineus* are the most effective fungal extracts against *R. stolonifer*, achieving complete inhibition at lower concentrations.



Figure 1. Field observations of soft rot in jackfruit (*A. heterophyllus*) fungal infection by *R. stolonifer* in Bengaluru and nearby areas.

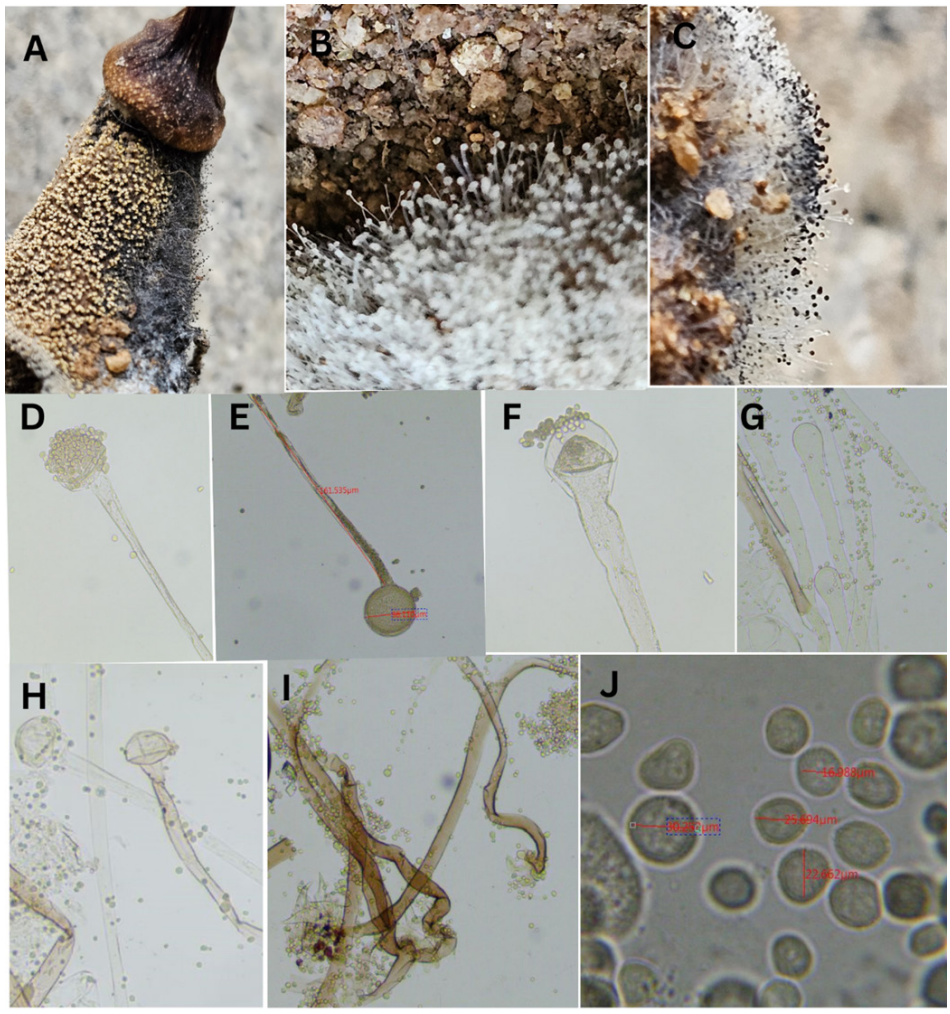


Figure 2. (A–C) Macroscopic symptoms of soft rot on infected plant material, showing sporangial formation, white mycelial growth, and black sporangia, **(D–I)** Microscopic structures observed under a light microscope, including sporangiophores, sporangia, columellae, and hyphae (100X), **(J)** Sporangiospores of *R. stolonifer*, with measurements indicating their size variation (100X).

Table 2. Antifungal inhibition activity of methanolic extracts from wood rot fungi against *Rhizopus stolonifer*

R. stolonifer					
Fungal Extract (Methanol)	Percentage of growth inhibition of R. stolonifera over the respective control				
	1%	**2 %**	**3 %**	**4 %**	**5 %**
G. lucidum	49.89	60.60	63.22	90	100
G. gibbosum	72.85	78.76	90	90	100
T. elegans	52.71	60.60	90	90	100
P sanguineus	54.03	62.65	90	90	100
L. sajor-caju	62.80	69.30	81.67	90	100
T. linteus	78.76	80.07	90	90	100
I. obliquus	38.98	45	52	81.67	100

DISCUSSION

The 20% methanolic extract of *G. lucidum* demonstrated greater efficacy in controlling soft rot fungi compared to the 5%, 10%, and 15% concentrations. This extract achieved 100% inhibition of both soft rot fungal isolates, showing significantly higher antifungal activity than the aqueous extract. Notably, this study marked the first instance of utilising fungal extracts to manage soft rot disease in jackfruits (Duvvi *et al.*, 2018). In this study, including *G. lucidum*, *G. gibbosum*, *T. elegans*, *P. sanguineus*, *L. sajor-caju*, *T. linteus*, and *I. obliquus*, were evaluated against the fruit rot fungus. At a 5% concentration exhibited strong antifungal activity, inhibiting fungal growth by 95%-100%. Two rhizospheric bacterial strains and three lactic acid bacteria exhibited strong antifungal activity against the pathogen in both *in vitro* and *in vivo* conditions. These findings suggest that these bacterial strains hold potential for controlling the fruit rot-causing fungus *R. stolonifer* (Ghosh *et al.*, 2015). The present study showed *T. linteus, Ganoderma gibbosum, T. elegans,* and *P. sanguineus* are the most effective fungal extracts against *R. stolonifer*, achieving complete inhibition at lower concentrations.Two *Trichoderma* species, *Trichoderma harzianum* and *Trichoderma viride*, were

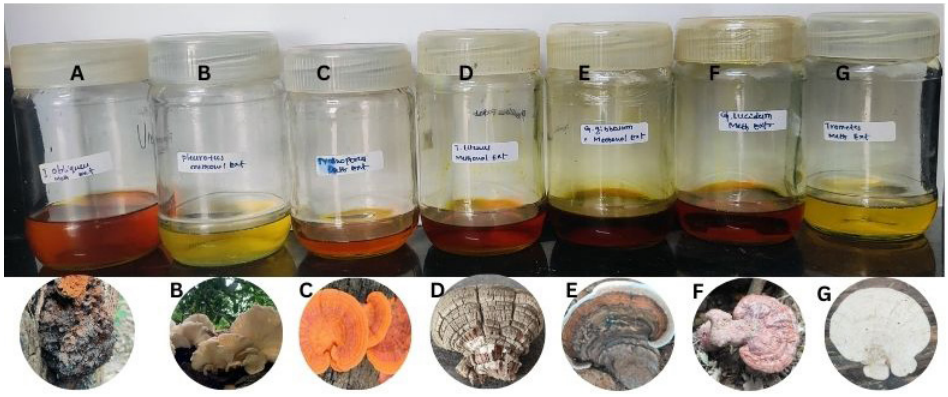


Figure 3. Methanol extract of **(A)** *I. obliquus*,**(B)** - *L. sajor-caju*,**(C)**- *P. sanguineus,* **(D)** - *T. linteus*, **(E)**- *G. gibbosum*,**(F)**- *G. lucidum,* **(G)** - *T. elegans*.

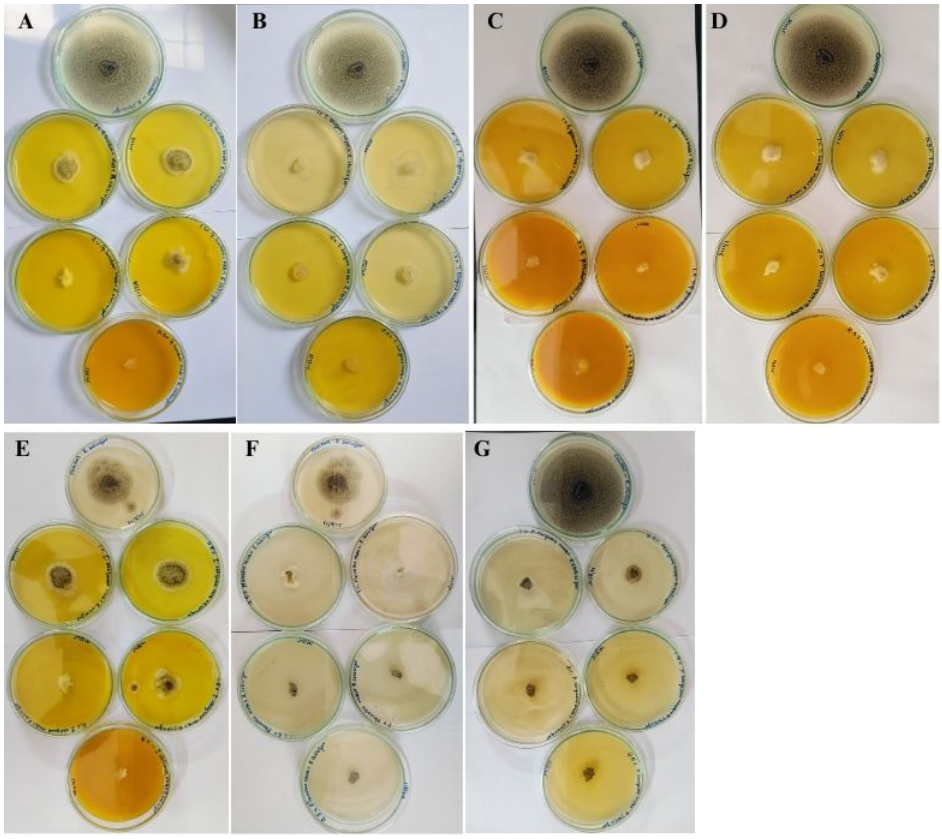


Figure 4. Poison Food Test: Inhibition of WRF methanol extract of **(A)** - *G. lucidum*,**(B)**- *T. elegans*,**(C)** - *G. gibbosum*,**(D)** - *T. linteus*,**(E)** - *I. obliquus*,**(F)** - *L. sajor-caju*,**(G)** - *P. sanguineus* against the pathogenic fungi of *R. stolonifer.*

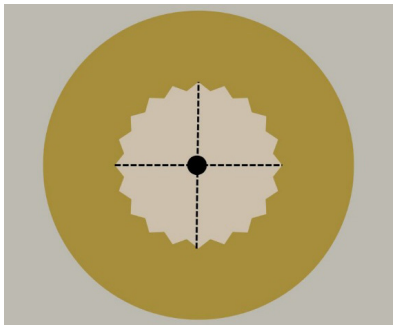


Figure 5. Efficacy test: Inhibition zone.

evaluated for their antagonistic activity against *Rhizopus artocarpi*, the causative agent of jackfruit fruit rot, using the dual culture technique. Of the two, *T. viride* proved to be more effective, inhibiting the pathogen by 72.63% in sensitive isolates and 78.55% in resistant isolates (Dalavi *et al.*, 2017). In this study, WRF of *G. lucidum, G. gibbosum, T. elegans, P. sanguineus, L. sajor-caju, T. linteus,* and *I. obliquus* were evaluated against the fruit rot fungus. At a 5% concentration exhibited strong antifungal activity, inhibiting fungal growth by 95%-100%. Pruning and training are effective management techniques for insect pests and diseases of stem and fruit rot,

bacterial death, pink disease, leaf spot, fruit bronzing, and Gummosis. This technique provides good ventilation and reduces relative humidity at tree canopy levels (Khan *et al.*, 2021). In this present study, WRF were used as biocontrol for Fruit rot in Jackfruit.

CONCLUSION

This study reports the first occurrence of soft rot caused by *R. stolonifer* affecting jackfruit flowers and fruit in and around Bengaluru, India. The disease, prevalent during the flowering and fruiting seasons (February-April), leads to significant fruit loss, with young fruits exhibiting soft, watery, brown spots that progress to black, shrivelled, and mummified stages. The rapid spread of the pathogen, facilitated by wind, rain, and insect vectors, contributes to successive infection cycles and widespread disease outbreaks. The antifungal efficacy assessment of methanolic extracts from wood rot fungi (WRF) revealed significant inhibitory activity against *R. stolonifer*. Among the tested fungi, *T. linteus*, *G. gibbosum*, *T. elegans*, and *P. sanguineus* demonstrated the highest antifungal potential, achieving complete inhibition at 3% concentration. *L. sajor-caju* and *G. lucidum* showed moderate efficacy, requiring 4% for full inhibition, whereas *I. obliquus* exhibited the lowest activity, necessitating a 5% concentration.

In India, WRF extracts aside from been identified for the first time as biocontrol agents against *R. stolonifer*, which causes jackfruit rot. These results demonstrate the potential of wood rot fungal extracts as efficient biocontrol agents, providing a viable, environmentally responsible substitute for conventional fungicides in the management of jackfruit rot. To commercialise these WRF extracts as biocontrol agents against fungal plant diseases, more studies are required, with an emphasis on formulation, field use, and large-scale viability.

ACKNOWLEDGEMENT

The authors are grateful to the management, particularly Rev. Fr. Swebert D' Silva SJ, Pro-Chancellor, Rev. Fr. Dr. Victor Lobo SJ, Vice Chancellor, Rev. Dr. Roshan Castelino SJ, Research Director, St. Joseph's University, Bengaluru, Dr. Neelam Mishra, Head of the Department of Botany, St. Joseph's University, Bengaluru, Dr. Fr. Melwyn D' Cunha SJ. Associate Professor, Department of Botany, St Aloysius (Deemed to be University), Mangalore.

REFERENCES

Dalavi, R. B., Kamble, S. S., and Kavle, T. R. 2017. Biocontrol of jackfruit rot using *Trichoderma* spp. *Int J Res Biosci Agric Technol,* **5**(Special Issue 3).

Duvvi. N. B, Nagadesi, P. K., Suneetha, N. N., and Kumar, A. 2018. Soft rot of jackfruit (*Artocarpus heterophyllus*) by *Rhizopus artocarpi* (*Berk. & Broome*) Boedijn, in Andhra Pradesh, India. *Acta PhytopatholEntomol Hung,* **7**(11): 2451-2455. https://doi.org/10.21746/aps.2018.7.11.2

Fukasawa, Y., Osono, T., and Takeda, H. 2011. Wood decomposing abilities of diverse lignicolous fungi on nondecayed and decayed beech wood. *Mycologia,* **103**(3): 474-482. https://doi.org/10.3852/10-206

Ghosh, R., Barman, S., Mukhopadhyay, A., and Mandal, N. C. 2015. Biological control of fruit rot of jackfruit by rhizobacteria and food-grade lactic acid bacteria. *Biol Control,* **83**: 29-36. https://doi.org/10.1016/j.biocontrol.2014.12.020

Gomez, K. A., and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research (2nd ed.). New York: John Wiley and Sons.

Nagadesi P. K, and Arya A. (2016). Biocontrol of Timber Decaying Fungi by Botanical Pesticides an Ecofreindly Technology. World Scientific News, 44:206-223.

Nelson, S. 2005. Rhizopus rot of jackfruit (PD-29). University of Hawaii, College of Tropical Agriculture and Human Resources (UH-CTAHR).

Pointing, S. B. 2001. Feasibility of bioremediation by white-rot fungi. *Appl MicrobiolBiotechnol,* **57**(1-2): 20-33. https://doi.org/10.1007/s002530100745

Poonia, S., Meena, M., and Kumar, A. 2022. Evaluation of antifungal activity of plant extracts using poison food technique against phytopathogenic fungi. *J PharmacognPhytochem,* **11**(2): 156-160.

Rayner, A. D. M., and Boddy, L. 1988. Fungal decomposition of wood: Its biology and ecology. John Wiley and Sons, Chichester.

Schilling, J. S., Kaffenberger, J. T., Held, B. W., Ortiz, R., and Blanchette, R. A. 2020. Using wood rot phenotypes to illuminate the "gray" among decomposer fungi. *Front Microbiol,* **11:**Article1282. https://doi.org/10.3389/fmicb.2020.01282

Zheng, R. Y., Chen,G. Q., Huang,H., and Liu, X. Y. 2007. A monograph of Rhizopus. Sydowia. 59.2. p. 273-372.