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STANDARDIZATION OF INDIGENOUS TECHNICAL KNOWLEDGES (ITKS) BASED BIO FORMULATIONS FOR THE MANAGEMENT OF MAJOR RICE DISEASES IN THE CAUVERY DELTA REGION OF TAMIL NADU

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ABSTRACT

Over-reliance on synthetic chemical fungicides for managing fungal diseases in rice (*Oryza sativa* L.) compromises agroecosystem dynamics, induces pathogen resistance and poses persistent environmental risks. Indigenous Technical Knowledges (ITKs) based bio formulations represent an ecologically sound and economically sustainable alternative. In this investigation, ten traditional farmer derived bio inputs from the Cauvery Delta region of Tamil Nadu and Puducherry U.T., India, were systematically documented and benchmarked against three major phytopathogenic fungi: *Bipolaris oryzae* (brown spot), *Pyricularia oryzae* (rice blast) and *Rhizoctonia solani* (sheath blight). Amplification and sequencing of the ribosomal DNA internal transcribed spacer (rDNA-ITS) locus confirmed the identity of three regional hyper virulent isolates: *B. oryzae* Bo₈ (558 bp; GenBank ON556554), *P. oryzae* Pg₇ (541 bp; GenBank ON556555), and *R. solani* Rs₆ (514 bp; GenBank ON556551). *In-vitro* screening via the poisoned food bioassay demonstrated that Panchagavya achieved superior radial growth inhibition across all three pathogens (60.65% - 70.75%), followed by Five-leaf extract (55.05% - 66.20%), Mint leaf extract (53.20% - 62.35%), and Fish Amino Acid (51.75% - 57.42%). Concentration standardization assays (5%, 10%, and 15% v/v) indicated that escalating the concentration from 5% to 10% significantly increased mycelial growth suppression, whereas a further increase to 15% yielded statistically equivalent inhibition. Consequently, a 10% (v/v) working concentration was established as the optimum operational dose, providing maximum fungal suppression while optimizing input material usage and reducing costs by 33%. Integrating these molecularly validated, standardized ITK preparations into Integrated Disease Management (IDM) frameworks provides a scalable, eco-friendly approach for sustainable rice crop protection.

Key words: ITKs, Panchagavya, Fish Amino Acid, Five-leaf extract, Mint leaf extract, Cauvery Delta.

Introduction

Asian rice (*Oryza sativa* L.) represents an irreplaceable agronomic staple fundamental to global dietary sustenance, supplying daily caloric requirements for over 65% of the human population (Mohapatra *et al.*, 2025). On a global scale, paddy cultivation extends across approximately 162 million hectares of arable land, yielding an estimated aggregate harvest of 755 million metric tonnes per year (English *et al.*, 2025). Within this

international production ecosystem, India occupies a key position, with rice accounting for roughly 40% to 42% of the country's total agricultural food grain yield (Guru *et al.*, 2025). In the southern state of Tamil Nadu, the Cauvery Delta region comprising administrative districts such as Thanjavur, Thiruvarur, Nagapattinam, Mayiladuthurai, Cuddalore, and Karaikal within Puducherry Union Territory, functions as the primary agricultural granary (Kumaraswamy *et al.*, 2025;

Balamurugan *et al.*, 2025a). This region's high productivity is driven by favorable alluvial soil deposits, a conducive tropical environment, and an extensive network of canal based irrigation systems (Galkate *et al.*, 2026).

Despite the substantial productivity potential of the Cauvery Delta, sustainable harvest security is chronically challenged by a destructive complex of phytopathogenic fungi. A key contributor to these yield reductions is *Bipolaris oryzae* (Breda de Haan) Shoemaker, the seed and air borne fungal agent responsible for brown spot disease. Infection by *B. oryzae* results in widespread foliar necrosis, severe panicle damage, and marked grain discoloration, leading to documented crop losses ranging from 6% to as much as 90% (Chhabra *et al.*, 2023). Simultaneously, *Pyricularia oryzae* Cavara, the causal organism of rice blast, targets vulnerable foliar surfaces, nodal junctions and panicle necks. By obstructing essential vascular transport during sensitive reproductive and grain filling stages, blast infections frequently trigger severe physiological decline and grain degradation (Chaiharn *et al.*, 2020). Furthermore, *Rhizoctonia solani* Kuhn, a soil borne necrotrophic fungus responsible for sheath blight, survives across seasonal breaks via persistent sclerotia resting in field soil and post-harvest plant detritus. Encouraged by elevated microclimatic temperatures, high humidity levels and dense crop canopy foliage, *R. solani* produces rapidly coalescing lesions on basal leaf sheaths, causing structural lodging, canopy collapse, and harvest losses reaching up to 58.6% (Goswami *et al.*, 2019).

Traditional management strategies designed to mitigate these fungal diseases rely extensively on recurring applications of synthetic chemical fungicides. However, persistent chemical dependency creates critical agro ecological problems (Adkar-Purushothama *et al.*, 2026). Unregulated or continuous applications create strong selection pressures that accelerate the development of fungicide resistant pathogen populations, disrupt non-target microbiomes within the phyllosphere and rhizosphere, increase operational expenses for smallholder farmers, and leave persistent pesticide residues throughout the food chain (Vincent and Devlin 2026).

Indigenous Technical Knowledges (ITKs) offers a sustainable alternative framework built upon generations of empirical agricultural observations and traditional farming practices (Tripura *et al.*, 2024). Farmers across the Cauvery Delta frequently prepare and apply traditional bio-formulations, including fermented bovine byproduct mixtures such as Panchagavya, fermented fish waste hydrolysates like Fish Amino Acid (FAA), and poly-botanical preparations such as Five-leaf extract, to protect

crops and stimulate plant vigor (Parvathi and Ushakumari 2020). Nonetheless, despite widespread local use, the systematic integration of these bio-inputs into formal Integrated Disease Management (IDM) frameworks remains constrained by a lack of rigorous scientific documentation, precise species-level molecular confirmation of targeted pathogens, and standardized application dosages (de Souza *et al.*, 2026).

To address these empirical and practical knowledge gaps, the present investigation was conducted with four interconnected objectives. First, a comprehensive field survey was undertaken to record traditional ITK preparations and application methods utilized by smallholder growers across six districts in the Cauvery Delta. Second, hyper-virulent regional strains of *B. oryzae*, *P. oryzae*, and *R. solani* were isolated from symptomatic crop tissues and definitively confirmed using ribosomal DNA internal transcribed spacer (rDNA-ITS) region sequencing. Third, the *in-vitro* antifungal efficacy of ten documented ITK formulations was systematically benchmarked against the molecularly validated isolates using poisoned food assays. Finally, multi-concentration dose-response trials and statistical equivalence testing were performed to determine optimal, cost-effective working concentrations that maximize fungal suppression while preventing unnecessary input expenditures.

Material and Methods

Survey and Documentation of Indigenous Technical Knowledge (ITK)

A comprehensive field survey was conducted across primary rice cultivating tracts within the Cauvery Delta region, targeting the districts of Thanjavur, Thiruvarur, Nagapattinam, Mayiladuthurai, Cuddalore and Karaikal within Puducherry Union Territory. The primary objective was to systematically record traditional and locally adopted plant protection practices utilized by smallholder growers for managing insect pests and phytopathogenic diseases. Detailed empirical information concerning raw ingredient composition, methodological preparation protocols, field application regimens and regional acceptability was collected through structured farmer interactions, participatory rural appraisals, and direct field observations.

Isolation and Molecular Identification of fungal Pathogens

Fungal pathogens were isolated from symptomatic rice leaves and leaf sheaths collected from rice growing areas of the Cauvery Delta. Brown spot (*B. oryzae*) and Blast (*P. oryzae*) were purified by single spore isolation, while sheath blight (*R. solani*) was obtained through hyphal tip isolation. Genomic DNA was extracted

Table 1: Survey and documentation of Indigenous Technical Knowledges (ITKs) formulations in the Cauvery Delta region.

S. No.	Target District	ITK Formulation	Targeted Diseases
1	Thiruvarur	3G Solution	Brown spot, Blast
2	Karaikal	Panchagavya	Broad-spectrum foliar pathogens
3	Mayiladuthurai	Fish Amino Acid (FAA)	Foliar fungal diseases
4	Thiruvarur	Ponneem	Brown spot
5	Thiruvarur	Five-leaf Extract	Brown spot, Blast, Sheath blight
6	Thiruvarur	Mint Leaf Extract	Brown spot
7	Mayiladuthurai	Mooligai Viratti	Major rice fungal diseases
8	Cuddalore	Tulsi Leaf Extract	Brown spot, Blast
9	Thanjavur	Fruit Mixture	Foliar fungal diseases
10	Mayiladuthurai	Fermented Buttermilk Mix	Brown spot

from pure cultures, and the rDNA-ITS region was amplified using ITS1 (52 -TCCGTAGGTGAACC TGCGG-32) and ITS4 (52 -TCCTCCGCTTATTGA TATMP-32) primers. The PCR products were sequenced, and the obtained sequences were compared with NCBI database entries using BLASTn for molecular identification.

***In-Vitro* Bio Efficacy Bioassays**

The antifungal efficacy of the selected ITK formulations was assessed using the poisoned food technique. PDA was amended with 10% (v/v) of each ITK supernatant after cooling the autoclaved medium to 45°C. The amended medium was poured into Petri plates (15 mL plate⁻¹) and allowed to solidify. A 9 mm mycelial disc from 10 days old actively growing cultures was placed at the center of each plate. Unamended PDA served as the control. The plates were incubated at 28 ± 2°C for 10 days, and radial growth was measured along two perpendicular axes. Parallel assays in PDB were performed to determine the reduction in fungal mycelial dry weight.

Concentration Standardization Protocol

The four most effective ITK formulations identified through the poisoned food technique were selected for concentration standardization. Each formulation was tested at 5, 10, and 15% (v/v) concentrations in PDA. The required quantity of each formulation was incorporated into molten PDA cooled to approximately 45°C, mixed thoroughly, and poured into sterile Petri plates. After solidification, a 9 mm mycelial disc from a 10 days old actively growing fungal culture was placed at the center of each plate. Unamended PDA served as the control. Plates were incubated at 28 ± 2°C, and radial mycelial growth was recorded after incubation. The concentration providing maximum fungal growth inhibition was selected as the optimum concentration for subsequent studies.

The percentage inhibition was calculated using Schmitz (1930) formula:

$$\text{Antifungal activity (\%)} = [(D_c - D_s) / D_c] \times 100$$

where D_c and D_s represent fungal growth in the control and treatment, respectively. Data were analyzed using ANOVA under a CRD with five replications, and treatment means were compared using C.D. at $p \leq 0.05$.

Results

Survey and Documentation of Indigenous Technical Knowledges (ITKs)

The field survey documented 10 indigenous technical knowledges (ITKs) formulations traditionally used by rice farmers across the surveyed districts of the Cauvery Delta region. The formulations comprised plant extracts, fermented preparations, animal derived products, and botanical mixtures. Their major ingredients, locations of traditional use, and targeted rice diseases are presented in Table 1.

Preparation of Indigenous Technical Knowledge (ITK) Formulations

The selected ITK formulations were prepared using farmer-practiced procedures, with the quantities and processing conditions standardized for experimental evaluation.

3G Solution (Agni Asthiram)

Green chilli (1 kg) was processed into a paste using a small quantity of water. Separately, 500 g each of garlic and ginger were ground to obtain smooth pastes. The three preparations were combined and diluted with 6 L of water, followed by thorough mixing. The resulting preparation, locally referred to as Agni Asthiram, was filtered through khadi cloth, and the clarified liquid was stored in a clean glass bottle until required.

Panchagavya

Panchagavya was formulated from five cow-derived materials, namely cow dung, cow urine, milk, ghee, and

curd, maintained at a proportion of 5:3:2:1:2, respectively. Initially, cow dung and ghee were blended thoroughly in a wide-mouthed earthen vessel and allowed to remain for three days, with the mixture being agitated once daily. On the fourth day, cow urine, milk, and curd were incorporated and mixed uniformly. The vessel was protected with a nylon mesh and maintained under shade to permit fermentation while preventing insect entry. The preparation was mixed periodically throughout a 30-day fermentation period. Subsequently, the fermented liquid was filtered through khadi cloth and collected for further experimentation (Plate 1).

Fish Amino Acid (FAA)

Fish-processing waste was obtained locally and combined with jaggery at a 1:1 ratio by weight. The mixture was placed in an airtight container and maintained under cool, shaded conditions for 10 days to allow fermentation. Following fermentation, the liquid fraction was separated using muslin cloth and transferred to a sterilized glass container. Before experimentation, the filtrate was diluted with water to obtain a 10% (v/v) preparation (Plate 2).

Ponneem

Ponneem was prepared from neem oil and Pungam oil using 10% Kaadi soap solution as a wetting agent. The resulting formulation was diluted at a rate of 30 mL in 10 L of water before application. The diluted preparation was maintained for use in the experimental treatments.

Five-Leaf Extract

Equal quantities (1 kg each) of fresh Neem (*Azadirachta indica*), Pungam (*Pongamia pinnata*), Calotropis (*Calotropis gigantea*), Adathoda (*Justicia adhatoda*) and Notchi (*Vitex negundo*) leaves were

collected and washed first with tap water and subsequently with sterile distilled water. The cleaned leaves were chopped and immersed in 5 L of water, followed by the addition of 5 L of cow urine. The mixture was maintained in darkness for 20 days and agitated once every two days. At the end of the fermentation period, the liquid fraction was separated by filtration through khadi cloth and designated as the 100% stock extract.

Mint Leaf Extract

Fresh mint leaves obtained from the local market were washed thoroughly with sterile distilled water. One kilogram of the leaves was macerated with 1 L of distilled water to obtain the crude extract. The preparation was passed twice through Whatman No. 1 filter paper to remove plant residues. The clarified filtrate was collected in a clean glass bottle and used for subsequent experiments.

Mooligai Viratti

Fresh leaves of neem, pungam, Calotropis, Adathoda, and Neyveli kattamani (*Ipomoea carnea*) were collected at 1 kg each and processed into a fine paste. A separate mixture was prepared using 2 kg cow dung, 1 L cow urine, and 2 L water. The leaf paste was incorporated into this mixture along with 500 g jaggery and homogenized thoroughly. The container was kept in a shaded location and covered with a gunny cloth. The preparation was stirred three times daily during fermentation. After seven days, the liquid portion was filtered through khadi cloth and collected for experimental use.

Tulsi Leaf Extract

Tulsi (*Ocimum sanctum*) leaves were detached from the stems, washed, and dried under suitable conditions



Plate 1: Preparation of Panchagavya.

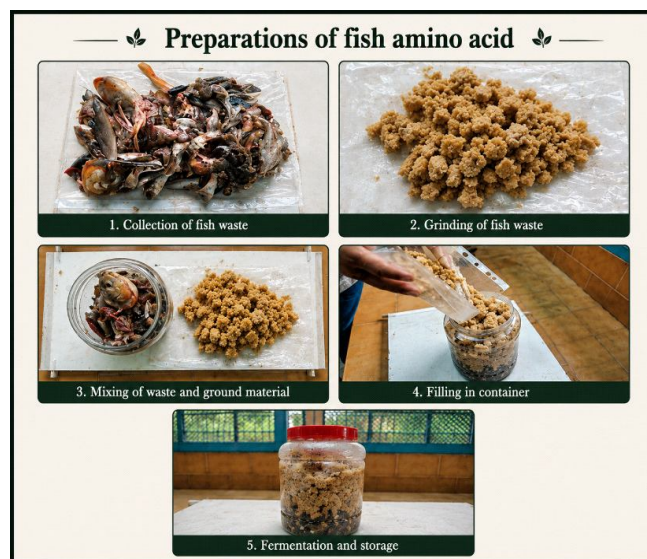


Plate 2: Preparation of Fish amino acid.

Table 2: Comparative *in-vitro* efficacy of ITK formulations at 10% concentration against major rice fungal pathogens.

Formulation	<i>B. oryzae</i>		<i>P. oryzae</i>		<i>R. solani</i>	
	Growth (mm)	Inhibition (%)	Growth (mm)	Inhibition (%)	Growth (mm)	Inhibition (%)
Panchagavya	31.14(33.91)	65.40	35.41(36.51)	60.65	26.32(30.86)	70.75
Five-leaf Extract	33.78(35.53)	62.46	40.45(39.49)	55.05	30.42(33.47)	66.20
Mint Leaf Extract	34.90(36.21)	61.22	42.12(40.46)	53.20	33.88(35.59)	62.35
Fish Amino Acid	38.38(38.28)	57.35	43.42(41.21)	51.75	38.32(38.24)	57.42
Ponneem	45.12(42.19)	49.86	48.30(44.02)	46.33	42.15(40.48)	53.16
Mooligai Viratti	48.25(43.99)	46.38	52.14(46.22)	42.06	45.30(42.30)	49.66
Tulsi Leaf Extract	52.10(46.20)	42.11	55.60(48.21)	38.22	50.12(45.06)	44.31
Fruit Mixture	55.40(48.10)	38.44	58.22(49.73)	35.31	53.45(46.97)	40.61
Fermented Buttermilk Mix	58.12(49.67)	35.42	62.15(52.03)	30.94	56.80(48.90)	36.88
3G Solution	63.19(52.64)	29.78	69.23(56.30)	23.07	60.95(51.32)	32.27
Unamended Control	90.00	0.00	90.00	0.00	90.00	0.00
C.D.	1.21	—	1.48	—	1.10	—
Se(m)	0.40	—	0.49	—	0.36	—

for approximately seven days. The dried leaves were subsequently pulverized using an electric grinder to obtain a uniform powder. The powder was dispersed in water to prepare a 10% concentration, which was used for subsequent experimental studies.

Fruit Mixture

Banana, pumpkin, and papaya (3 kg each) were used along with 2 kg brown sugar and two country chicken eggs. The fruits were cleaned thoroughly and cut into small pieces. The prepared fruit material was placed in an airtight plastic container together with the eggs and brown sugar and mixed thoroughly. The container was maintained in a cool, dry location protected from direct sunlight. After 10 days of fermentation, the liquid fraction was recovered by filtration through khadi cloth and collected for further experimental use.

Fermented Buttermilk - Cow Urine Formulation

Buttermilk was allowed to undergo fermentation in an earthen vessel for 3-4 weeks. The fermented buttermilk was subsequently combined with cow urine and diluted with water to obtain the working preparation. The resulting formulation was used for experimental evaluation as a foliar application.

Molecular Identification of Virulent Isolates

Molecular characterization based on rDNA-ITS amplification and sequencing confirmed the identity of the selected virulent fungal isolates. The *Bipolaris oryzae* isolate Bo8 produced an ITS amplicon of 558 bp and was deposited in NCBI GenBank under accession number ON556554. Similarly, *Pyricularia oryzae* isolate Pg7 yielded a 541 bp ITS sequence with accession number ON556555, while *Rhizoctonia solani* isolate Rs6 produced a 514 bp amplicon and was assigned GenBank accession number ON556551. These sequence data

confirmed the molecular identity of the three virulent rice pathogens used in subsequent bio-efficacy experiments.

Comparative Screening of ITK Formulations

All ten ITK formulations significantly suppressed the radial mycelial growth of *B. oryzae*, *P. oryzae* and *R. solani* compared to the unamended control. Panchagavya demonstrated the highest overall antifungal activity, achieving mycelial inhibition of 65.40% (*B. oryzae*), 60.65% (*P. oryzae*), and 70.75% (*R. solani*). Five-leaf extract ranked second (62.46%, 55.05%, and 66.20% inhibition), followed closely by Mint leaf extract (61.22%, 53.20%, and 62.35%) and Fish Amino Acid (57.35%, 51.75%, and 57.42%). Moderate to lower inhibition was observed for Ponneem (49.86% - 53.16%) and Mooligai Viratti (42.06% - 49.66%), while Tulsi leaf extract, Fruit mixture, Fermented buttermilk mix, and 3G solution showed progressively weaker activity. The unamended control exhibited maximum radial growth (90.00 mm) across all three pathogens, with critical difference values recorded at 1.21 mm (*B. oryzae*), 1.48 mm (*P. oryzae*), and 1.10 mm (*R. solani*). Complete radial growth and inhibition metrics are summarized in Table 2.

Concentration Standardization and Dose Optimization

Dose-response evaluations across 5%, 10%, and 15% concentrations established 10% as the optimum working dose for the top four ITK bio-inputs (Panchagavya, Five-leaf extract, Mint leaf extract, and Fish Amino Acid). Escalating the concentration from 5% to 10% produced a statistically significant reduction in mycelial growth across all three pathogens. However, increasing the concentration further from 10% to 15% yielded only marginal numerical reductions. Across all pathogens, radial growth was markedly reduced between 5% and 10% concentrations for Panchagavya (from 35.60-42.10

Table 3: Concentration-dependent response of selected ITK formulations against major rice fungal pathogens.

Formulation	Concentration	<i>B. oryzae</i> Growth (mm)	<i>P. oryzae</i> Growth (mm)	<i>R. solani</i> Growth (mm)
Panchagavya	5%	38.52(38.36)	42.10(40.45)	35.60(36.63)
	10%	30.08(33.26)	35.19(36.38)	28.14(32.03)
	15%	29.92(33.16)	34.80(36.15)	27.78(31.80)
Five-leaf Extract	5%	41.20(39.93)	46.50(42.99)	38.20(38.17)
	10%	34.12(35.74)	40.08(39.27)	31.43(34.09)
	15%	33.86(35.58)	39.58(38.98)	30.67(33.62)
Mint Leaf Extract	5%	43.10(41.03)	49.20(44.54)	41.50(40.10)
	10%	35.17(36.37)	43.18(41.08)	34.13(35.74)
	15%	35.03(36.28)	42.77(40.84)	33.94(35.63)
Fish Amino Acid	5%	51.20(45.68)	56.40(48.67)	48.10(43.91)
	10%	45.00(42.13)	49.16(44.51)	40.19(39.34)
	15%	44.75(41.98)	48.89(44.36)	39.78(39.10)
Control	-	90.00	90.00	90.00

mm to 28.14–35.19 mm), Five-leaf extract (from 41.20–46.50 mm to 31.43–40.08 mm), Mint leaf extract (from 41.50–49.20 mm to 34.13–43.18 mm), and Fish Amino Acid (from 48.10–56.40 mm to 40.19–49.16 mm). Because the 10% and 15% treatments were statistically on par, 10% was standardized as the optimum operational concentration, maximizing bio-efficacy while optimizing raw material efficiency. Dose-response metrics and statistical groupings are detailed in Table 3.

Discussion

The continuous and non-judicious reliance on synthetic chemical fungicides in rice agroecosystems poses severe ecological risks, accelerates the selection of resistant fungal strains, disrupts beneficial phyllosphere and rhizosphere microbiomes, and raises production costs for resource limited growers (Adkar-Purushothama *et al.*, 2026). Indigenous Technical Knowledges (ITKs) based bio formulations offer an ecologically sound, cost effective and circular alternative that bridges traditional farming wisdom with formal plant pathology (Prasad *et al.*, 2025; Balamurugan *et al.*, 2025b). Systematically surveying and documenting farmer practices across the Cauvery Delta region revealed diverse bio inputs comprising fermented bovine preparations, fish waste hydrolysates, poly botanical extracts, and organic mixtures developed through empirical adaptation (Habanyati *et al.*, 2024). Standardizing their preparation protocols utilizes key biochemical pathways, including anaerobic fermentation, enzymatic protein hydrolysis, and alkaline maceration, which generate low molecular weight organic acids, secondary alkaloids, phenolic compounds, and volatile monoterpenes (Boudalia *et al.*, 2026).

Ribosomal DNA internal transcribed spacer (rDNA-ITS) region sequencing definitively confirmed the species identities and taxonomic fidelity of the target hyper-

virulent isolates: *B. oryzae* (Bo8), *P. oryzae* (Pg7), and *R. solani* (Rs6) (ABE *et al.*, 2003). *In vitro* bio efficacy screening via the poisoned food technique demonstrated that the evaluated ITK formulations significantly suppressed fungal growth compared to unamended controls (Tripura *et al.*, 2024). Among these, Panchagavya achieved the highest overall antifungal activity, operating through a multi-target mode of action that combines direct chemical toxicity, microbial antagonism from beneficial lytic organisms (*Lactobacillus* and *Bacillus* spp.), and host defense elicitation (Dhiman *et al.*, 2021). Five-leaf extract demonstrated strong secondary efficacy, driven by synergistic phytochemicals such as azadirachtins, furanocoumarins, and secondary glycosides (Hussain *et al.*, 2023). Mint leaf extract and Fish Amino Acid (FAA) also produced marked mycelial suppression through volatile monoterpenes and organic fatty acids, respectively (Patel 2015).

Dose-response evaluations across multiple concentrations revealed a non-linear saturation curve typical of biological extracts. While initial dose increases significantly enhanced fungal suppression, escalating the concentration further yielded statistically equivalent inhibition, placing both higher treatments in the same significance group (Iqbal *et al.*, 2024). Standardizing application rates at the 10% operational concentration provides maximum disease control while reducing raw material usage by 33% compared to higher doses (Barbu *et al.*, 2025). Integrating these molecularly validated, standardized ITK formulations into Integrated Disease Management (IDM) frameworks provides a scalable, eco-friendly, and economically viable strategy for sustainable rice crop protection (Raghuvanshi *et al.*, 2025).

Conclusion

This study provides scientific validation and standardization for Indigenous Technical Knowledge (ITK)-based bio-formulations traditionally utilized by rice growers across the Cauvery Delta region. Ribosomal DNA internal transcribed spacer (rDNA-ITS) region sequencing successfully established the taxonomic identity of regional hyper-virulent fungal isolates: *B. oryzae* strain Bo8 (GenBank ON556554), *P. oryzae* strain Pg7 (GenBank ON556555), and *R. solani* strain Rs6 (GenBank ON556551). Among the ten evaluated farmer-derived inputs, Panchagavya demonstrated superior broad-spectrum antifungal activity against all three pathogens, followed by Five-leaf extract, Mint leaf extract, and Fish Amino Acid (FAA). Multi-concentration dose-response evaluations proved that a 10% (v/v) working concentration represents the optimum operational dosage, achieving statistically equivalent pathogen suppression to higher concentrations (15%) while optimizing input efficiency and reducing material costs by 33%. Overall, integrating these molecularly validated, standardized ITK preparations into formal Integrated Disease Management (IDM) frameworks offers a scalable, ecologically sound, and cost-effective alternative to synthetic fungicides, promoting sustainable rice disease control and supporting agroecosystem stability.

Disclaimer

(Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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References

- Abe, A., Sone T., Sujaya I.N., Saito K., Oda Y., Asano K. and Tomita F. (2003). rDNA ITS Sequence of *Rhizopus oryzae*: Its Application to Classification and Identification of Lactic Acid Producers. *Bioscience, Biotechnology, and Biochemistry*, **67**, 1725–1731. <https://doi.org/10.1271/bbb.67.1725>.
- Adkar-Purushothama, C.R., Chettimada A., Murali T.S., Muthusamy A., Bouarab K. and Perreault J.P. (2026). Non-chemical control of fungal pathogens in crops: a one-health perspective on strategies, mechanisms, and future directions. *Front Plant Sci.*, **16**. <https://doi.org/10.3389/fpls.2025.1746521>
- Balamurugan, K., Christopher D.J. and Jaiganesh V. (2025a). Molecular characterization and cross-pathogenicity analysis of *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. associated with Mango anthracnose. *Ann Phytomed*, **14**. <https://doi.org/10.54085/ap.2025.14.1.114>
- Balamurugan, K., Christopher D.J. and Jaiganesh V. (2025b). Exploring *Streptomyces albobacillus* for the Sustainable Management of Mango Anthracnose. *J. Adv. Biol. Biotechnol.*, **28**, 636–645. <https://doi.org/10.9734/jabb/2025/v28i82737>
- Barbu, C.A., Fierascu I., Semenescu A. and Cotrut C.M. (2025). Critical Review Regarding the Application of Plant Extracts as Eco-Friendly Corrosion Inhibitors—A Sustainable Interdisciplinary Approach. *Molecules*, **30**, 3722. <https://doi.org/10.3390/molecules30183722>
- Boudalia, S., Symeon G.K., Dots V., Gueboudji Z., Kouadri I., Sehili B., Terfa M.T., Smeti S., Gueroui Y. and Bousbia A. (2026). The Valorization of Agrifood Byproducts and Waste to Advance the Sustainable Development Goals: Current State and New Perspectives. *Sustainability*, **18**, 2165. <https://doi.org/10.3390/su18052165>
- Chaihar, M., Theantana T. and Pathom-aree W. (2020). Evaluation of Biocontrol Activities of *Streptomyces* spp. against Rice Blast Disease Fungi. *Pathogens*, **9**. <https://doi.org/10.3390/pathogens9020126>
- Chhabra, R., Sharma R., Hunjan M.S., Sharma V.K., Sharma P. and Chauhan S.K. (2023). Microstructural and metabolic variations induced by *Bipolaris oryzae* inciting brown spot disease of rice. *CEREAL RESEARCH COMMUNICATIONS*, **51**, 953–968. <https://doi.org/10.1007/s42976-023-00351-z>
- de Souza, T.A.F., Martins L.M.V., Hungria M. and Fernandes-Júnior P.I. (2026). Survey of scientific production on bio-inputs in Northern and Northeastern Brazil (2010–2025): A focus on plant growth-promoting microorganisms in legumes and grasses. *Braz J. Microbiol.*, **57**, 117. <https://doi.org/10.1007/s42770-026-01949-1>
- Dhiman, M., Singh V. and Kaushal R. (2021). Role of Indigenous Microbes for the Control of Major Fungal Pathogens of Turmeric. In: Kaushal M, Prasad R (eds) *Microbial Biotechnology in Crop Protection*. Springer, Singapore, 313–334.
- English, B.C., Menard R.J., de la Torre Ugarte D.G., Lambert L.H., Hellwinckel C.M. and Langholtz M.H. (2025). Agriculture's Potential Regional Economic Contributions to the United States Economy When Supplying Feedstock to the Bio-Economy. *Energies*, **18**, 2081. <https://doi.org/10.3390/en18082081>
- Galkate, R.V., Yadav V.S., Yadav S., Jaiswal R.K. and Yadava R.N. (2026). Delta Regions of India, Their Role and Significance in Water and Land Resources. In: Yadav S, Galkate R, Yadava RN (eds) *Water Resources in Delta Region in India: Water Management, Quality Assessment and Modeling*. Springer Nature Switzerland, Cham, 27–52.
- Goswami, S.K., Singh V., Kashyap P.L. and Singh P.K. (2019). Morphological characterization and screening for sheath blight resistance using Indian isolates of *Rhizoctonia solani* AG11A. *Indian Phytopathology*, **72**, 107–124.

- <https://doi.org/10.1007/s42360-018-0103-2>
- Guru, P.K., Sahu P., Shukla P., Diwan P., Panwar G., Tiwari P., Nagori A., Carpenter G., Sanodiya R., Meena B.S., Kumar M., Rani A., Rath I., Dey D., Verma N., Gangil S., Khandai S. and Yahaya R. (2025). A critical review on rice cultivation and mechanization level in Indian perspective. *Results in Engineering*, **26**, 105632. <https://doi.org/10.1016/j.rineng.2025.105632>
- Habanyati, E.J., Paramasivam S., Seethapathy P. and Manalil S. (2024). Assessing Organic Farming Adoption in Selected Districts of Tamil Nadu: Challenges, Practices, and Pathways for Growth. *Agronomy*, **14**, 2537. <https://doi.org/10.3390/agronomy14112537>
- Hussain, S., Javed W., Tajammal A., Khalid M., Rasool N., Riaz M., Shahid M., Ahmad I., Muhammad R. and Shah S.A.A. (2023) Synergistic Antibacterial Screening of *Cymbopogon citratus* and *Azadirachta indica*: Phytochemical Profiling and Antioxidant and Hemolytic Activities. *ACS Omega*, **8**, 16600–16611. <https://doi.org/10.1021/acsomega.2c06785>
- Iqbal, N., Shoaib A., Fatima Q., Farah M.A. and Raja V. (2024). Synthesis and antifungal efficacy of chitosan nanoparticles against notorious mycotoxigenic phytopathogens. *Plant Stress*, **14**, 100614. <https://doi.org/10.1016/j.stress.2024.100614>
- Kumaraswamy, K., Balasubramani K., Ramkumar M., George S.L. and Prasad K.A. (2025). Regional Geomorphology of the Tamil Nadu Coast. In: Chattopadhyay S (ed) Marine and Coastal Resources of India: Selected Case Studies. Springer Nature Switzerland, Cham, 199–211.
- Mohapatra, P.K., Sarkar R.K., Panda D. and Kariali E. (2025). Origin and Evolution of Rice as Domesticated Staple Food Crop. In: Mohapatra PK, Sarkar RK, Panda D, Kariali E (eds) Tillering Behavior of Rice Plant. Springer Nature, Singapore, 1–17.
- Parvathi, S.U. and Ushakumari K. (2020). Influence of on-farm liquid organic manures on soil health and crop production. *AJSS*, **15**, 11–21. <https://doi.org/10.15740/HAS/AJSS/15.1/11-21>.
- Patel, S. (2015). Plant essential oils and allied volatile fractions as multifunctional additives in meat and fish-based food products: a review. *Food Additives & Contaminants: Part A*, **32**, 1049–1064. <https://doi.org/10.1080/19440049.2015.1040081>
- Prasad, M., Kumar S., Kumar A., Khan N. and Shukla S.K. (2025). Blending Traditional Knowledge of Farmers in Agriculture with Modern Scientific Technologies in Central Uttar Pradesh. In: Acharya CL, Chaudhary RS, Gurumurthy P, Rao AS (eds) Blending Indian Farmers' Traditional Knowledge in Agriculture with Modern Scientific Technologies: A Way Forward. Springer Nature, Singapore, 353–374.
- Raghuvanshi, R.S., Milan A., Sharma B., Raghuvanshi S., Bag D., Nigam R., Babu S. and Dhiman S. (2025). A Review on Sustainable Plant Disease Management through Integrated Approaches. *J. Exp. Agric. Int.*, **47**, 719–739. <https://doi.org/10.9734/jeai/2025/v47i123972>
- Schmitz, H. (1930). A Suggested Toximetric Method for Wood Preservatives. *Ind Eng Chem Anal Ed.*, **2**, 361–363. <https://doi.org/10.1021/ac50072a004>
- Tripura, P., Devi C.A., Manzoor U. and Kapri A. (2024). Chapter 18 - Indigenous technical knowledge integration in organic farming. In: Meena VS, Rakshit A, Meena MD, Baslam M, Fattah IR, Lam SS, Kaba JS (eds) Waste Management for Sustainable and Restored Agricultural Soil. *Academic Press*, 371–386.
- Vincent, S.A. and Devlin P.F. (2026). Fungicides disrupt total and endophytic phyllosphere bacterial communities but a salicylic acid hyperimmune mutant shows microbiome resilience. *ISME Commun*, **6**, ycag102. <https://doi.org/10.1093/ismeco/ycag102>