

Integrated Study on the Etiology and *In-Vitro* Fungicidal Management of False Smut Disease in Rice

Mehrab Khan¹, Zubair Ahmed Nizamani^{1*}, Gul Bahar Pussio², Hamal Rahim¹

¹Department of Plant Pathology, Sindh Agriculture university, Tandojam, Sindh Pakistan

²Plant Disease Research Institute

Tandojam

Corresponding Author Email: zahmednizamani@sau.edu.pk

Article Received 15-03-2025, Article Revised 23-04-2025, Article Accepted 20-05-2025

ABSTRACT

Rice is the second most valuable food grain and cash crop in Pakistan after wheat and cotton, serving as a vital source of food and income across Asia. Despite its importance, Pakistan's per-acre rice yield is significantly lower than global averages, primarily due to biotic stresses such as plant diseases. Among the nearly 50 diseases affecting rice globally, false smut, caused by *Ustilaginoidea virens*, poses a serious threat to rice production and farmer livelihoods. To assess the incidence and management of false smut in southern Pakistan, a survey was conducted in key rice-growing areas including Khorwah, Kario Ganhwar, and the surroundings of Badin city. Disease incidence ranged from 24.00% to 46.00%, with the highest incidence observed in Khorwah (46.00%) and the lowest in Badin (24.00%). Diseased samples were collected for pathogen isolation using tissue culture techniques, and fungal identification was based on morphological features. Four fungal species were identified: *Ustilaginoidea virens* (45.12% frequency), *Penicillium* (28.31%), *Pyricularia oryzae* (18.57%), and *Aspergillus* (8%). *U. virens* emerged as the predominant pathogen based on frequency and colony characteristics. For disease management, six fungicides were evaluated using the food poisoning method at concentrations of 500, 1000, and 1500 ppm. Among them, Topsin-M and Nativo demonstrated complete inhibition of pathogen growth at 1500 ppm, making them the most effective. Aliette and Romeo showed moderate effectiveness, while Melody duo and Copper oxychloride were less effective across all concentrations. The study concludes that Topsin-M and Nativo are highly effective in controlling false smut in rice and should be recommended for integrated disease management strategies in affected regions. These findings provide a practical approach to mitigating yield losses caused by this destructive pathogen.

KEYWORDS: Integrated Study, Etiology, *In-Vitro*, Fungicidal, False Smut, Rice

INTRODUCTION

In Pakistan rice is the second most valuable food grain and cash crop after wheat and cotton. It provides food for over half of the world's population and is regarded as a cash crop in developing world. It is ranked in third highest production position worldwide after sugarcane and maize (FAOSTAT, 2022). Rice is the most important grain when it comes to human nutrition since it supplies over 25% of the calories that humans consume daily. According to models that are used to estimate the amount of rice that populations will produce and consume grain's necessity production is anticipated to increase by a factor of two by the year 2050 (FAOSTAT, 2017). Ninety percent of the globally produced rice farmed and ingested worldwide is in Asia. However, Pakistan's average paddy production is lower than that of other primarily rice producing countries such as Indonesia, China, Bangladesh, Vietnam, Japan etc. Pakistan ranks as the world's 12th largest rice producer and 4th largest rice exporter. The factors that lead to low yield include limited availability to high yielding rice varieties,

inadequate water during rice sowing and transplanting and a lack of high-quality seed (Khaliq *et al.*, 2019).

Rice is not only a nutritious food option, but it can also be a successful cash crop. It is the second main staple crop for human sustenance following wheat. It holds the second most significant crop for exports after cotton. Rice production is responsible for 3.5 percent of the enhanced value to agricultural products and One-half of the country's gross domestic product. Rice production is essential to Pakistan's economy for several reasons including the generation of export earnings, the creation of domestic jobs, the expansion of rural areas and the reduction of poverty. In Pakistan, rice is a food staple that is also grown commercially for its economic value. According to the statistics, the crop was sown at 3,537 thousand hectares in the year 2021-22, which is a 6.1% rise over the total number of hectares that were planted the year before, which was 3,335 thousand hectares. The overall amount of rice harvested in 2022 was 9.323 million tonnes, which is 10.7 percent more than the amount harvested in 2021, which was 8.420 million tonnes. Over the course of the last several years, there has been a growth in the

total land area that is allocated to rice growing. Rice production in Pakistan often surpasses annual demand resulting in a surplus that may be sold on the international market. Because of the disastrous floods and monsoon downpours in Pakistan, particularly in the Sindh and Balochistan provinces, hundreds of thousands of houses, schools, and hospitals have been devastated along with wide swathes of agricultural land. Additionally, around 1,700 individuals have lost their lives because of these natural disasters. Most summer crops have been destroyed but happily the cash crop of rice has survived the floods and is expected to bring in a significant amount of money from export profits (GoP, 2022). By the end of the year 2022, a total of around 515 million metric tonnes of rice will have been farmed on a worldwide scale. This results in a 0.23 percent increase in global production. India is still the greatest exporter of rice in the globe even though Sub-Saharan Africa is the largest buyer of rice worldwide. There are ten countries that are responsible for more than 80 percent of the world's rice output. Rice will continue to play an essential role as a staple meal since it is a source of significant amounts of both calories and nutrients. Pakistan cultivates three unique varieties of rice, all of them are harvested and used locally as well as exported. Among them are the fragrant Basmati variety, the IRRI type with medium to long grains and the bold grain which can withstand low temperatures. The aromatic and flavorful Basmati rice that is so simple to cook has helped it garner acclaim all around the world. In compared to basmati the medium long grain rice varieties that Sindh produces have a greater yield, Sindh is famous to produce these rice varieties (FAOSTAT, 2022).

This complex carbohydrate meets the daily energy requirements of the global population, over half of whom make it a very important food source. Rice in its many forms may, depending on the kind, be an excellent source of several vitamins and minerals. This suggests that it has significant promise as a tool for combating malnutrition in the world. Rice may be prepared for cooking by either being steamed or ground into flour. It is a basic ingredient in many different types of cuisine including Asian, Middle Eastern and it may be found in a broad variety of soups, sides, and main dishes. Rice may be found in a broad range of various products including breakfast cereals, noodles, and even alcoholic beverages like Japanese sake (Rohman *et al.*, 2014).

Over fifty different diseases consisting of six bacterial, twenty-one fungal, four parasitic nematodes, and twelve viral strains have been recognized as potential dangers to the rice crop. The degree of food security in a nation may be used as a proxy for the nation's overall social and political stability (Kabir *et al.*, 2015). In the case of false smut large masses of spores that range in color from greenish to olive grow within rice panicles and these spores end up taking the place of the rice grains. When conditions are favorable

false smut has the potential to rapidly spread and become a significant problem in rice varieties that provide high yields. To design effective counter measures, Gaining a thorough comprehension of the elements that lead to the formation of smut is crucial. It is essential to determine the infectious agents that cause the disease, acquire knowledge on the life cycle of the pathogen and comprehend how the disease is transmitted. In regions where rice production is experiencing difficulties, diseases such as rice false smut (RFS) are becoming an increasingly serious issue. Rice false smut was formerly regarded to be a relatively minor disease; however, its rising prevalence across major rice producing nations like China, India, and the United States has aroused the interest of many agricultural specialists. This is due to the reality that the disease is spreading more widely across these countries (Fan *et al.*, 2020; Alase *et al.* 2024; Jatoi *et al.*, 2016a; Jatoi *et al.*, 2016b).

The management of these diseases often relies on the use of fungicides. The effectively combat fungal pathogens it is essential to assess the efficacy of various fungicides under controlled in-vitro conditions. The purpose of this study was to examine the effects of various fungicides on the growth of the causal fungus's mycelial colony, which is an essential step in diagnosing and treating fungal diseases. Effective disease control techniques can be developed with the use of fungicides' ability to effectively suppress mycelial growth. These strategies may include optimizing fungicide application methods, doses, and timing to minimize crop losses and reduce the environmental impact of chemical control methods. By providing valuable insights into the effectiveness of various fungicides this study contributes to the broader goal of sustainable and efficient disease management in agriculture (Villa *et al.*, 2017; Jatoi *et al.*, 2016c; Jatoi *et al.*, 2015). But due to the continues variations in physiological factors and the pathogens sensitivity, it varies over time. Therefore, this research study was planned to investigate etiology and in-vitro management of false smut of rice.

MATERIALS AND METHODS

Record the disease incidence of false smut of rice:

Different locations in district Badin of Sindh were surveyed to record the disease incidence of false smut of rice and to collect infected rice disease panicles. In order to isolate and identify the pathogenic fungus, the recovered specimens were brought to the mycological laboratory at the Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture University Tandojam. The following relationship was used to determine the disease incidence of infected paddy fields.

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected rice panicle} \times 100}{\text{Total number of rice panicle observed}}$$

Isolation and identification of the causal fungus:

Disease specimens showing the symptoms of disease were brought to the mycology laboratory at Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture university Tandojam. The infected portion was divided into tiny three-to-four-millimeter pieces and surface sterilized for two minutes using 5% commercial bleach (sodium hypochlorite). The sterilized pieces were placed on Petri plates containing Potato Dextrose Agar (PDA) medium after being twice cleaned with sterile water and moved to sterilized filter paper for drying. Each plate typically contained five pieces of the infected samples. In order to monitor fungal sporulation, all petri plates were maintained in an incubator at $26\pm^{\circ}\text{C}$ for seven days. Different fungal colonies started to emerge in the meantime, and they were refined using the hyphal tip method and single spore isolation technique.

The colony growth of the most frequently isolated fungus was recognized on the basis of its morphological characteristics.

Pure culture of the causal fungus: After identification of targeted fungus, the pure culture of isolated fungus was made and maintained for future use. Evaluation of different fungicides on the mycelial colony growth of the causal fungus: The efficacy of different fungicides such as, Nativo, Topsin-M, Aliette, Romeo, Copper Oxychloride and Melody Duo were examined with different doses 500, 1000 and 1500 ppm with three replications in *in-vitro* conditions against the causal fungus by food poisoning method. Using a sterile cork borer (5 mm), the pathogen was removed from an 8–10-day old culture plate, put in the center of a PDA plate, and incubated at 26°C . Petri plates that were left untreated served as the control. On the back of the petri plates, two lines that were mutually perpendicular and intersected in the middle

of the plate were used to record the growth of the fungus's radial colony. Following each 24-hour period, the colony growth data was noted in millimeters beside these lines until the plates were fully filled in each treatment.

Date analysis: The Statistix v. 8.1 software (Analytical Software) was used, the mean and all gathered data were compared for significant differences analysis among variance using the LSD test = 0.005 of a completely randomized design.

RESULTS

Survey and sampling of false smut disease of rice:

During the present study, the surveyed and sampling of false smut disease of rice was conducted at different locations of district Badin such as Khorwah, Kario Ganhwar and surrounding of Badin city. The rice plants showing the diseased symptoms were collected in paper envelope for the isolation purpose (Figure. 1) During the survey, rice false smut disease symptoms were observed after the grain filling stage of the crop. At the initial stage of the false smut, the pathogen produced snowball like projection between the spikelets. After that, outer white color mycelial epidermal cells broke down which turn into yellowish orange color of chlamydospore were released into the air currents. In the later stage, the smut ball turned greenish black, and the size of the smut balls varied.

Disease incidence of the false smut of rice at different localities: The disease was found in all surveyed locations with different intensities. Among the surveyed locations, the highest disease incidence % was recorded at Khorwah 46.00% followed by Kario Ganhwar 30.00% and minimum disease incidence % was recorded in surrounding of Badin city with 24.00% (Figure 2).



Figure.1. Samples showing infected panicle of rice

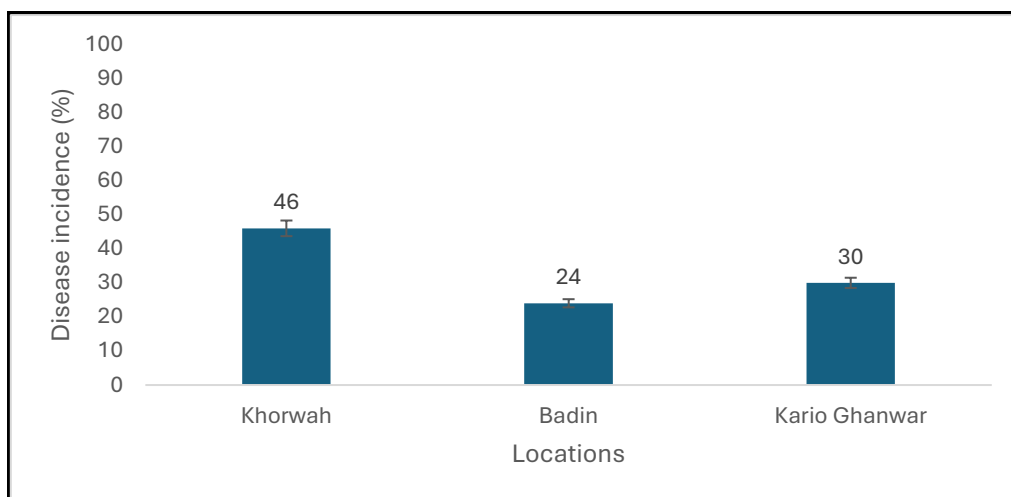


Figure 2. Disease incidence of the false smut of rice at different localities

Frequency isolation of pathogens from infected panicles of rice: During isolation, four different fungi, such as *Ustilaginoidea virens*, *Pyricularia oryzae*, *Aspergillus*, and *Penicillium*, were isolated with different frequencies. *Ustilaginoidea virens* was isolated with the highest frequency at 45.12%, followed by *Penicillium* at 28.31% and *Pyricularia oryzae* at 18.57%. The lowest frequency of 8% was

observed by *Aspergillus* (Fig. 3) based on their highest fungal frequency, the pre-dominant fungus identified was *Ustilaginoidea virens*, determined by its morphological colony characteristics (Figure. 4). It produced slow-growing colonies. Conidia are elliptical (measuring 3-5 μm in diameter) which on maturation or under unfavorable condition, develop into round spinulate chlamydospores

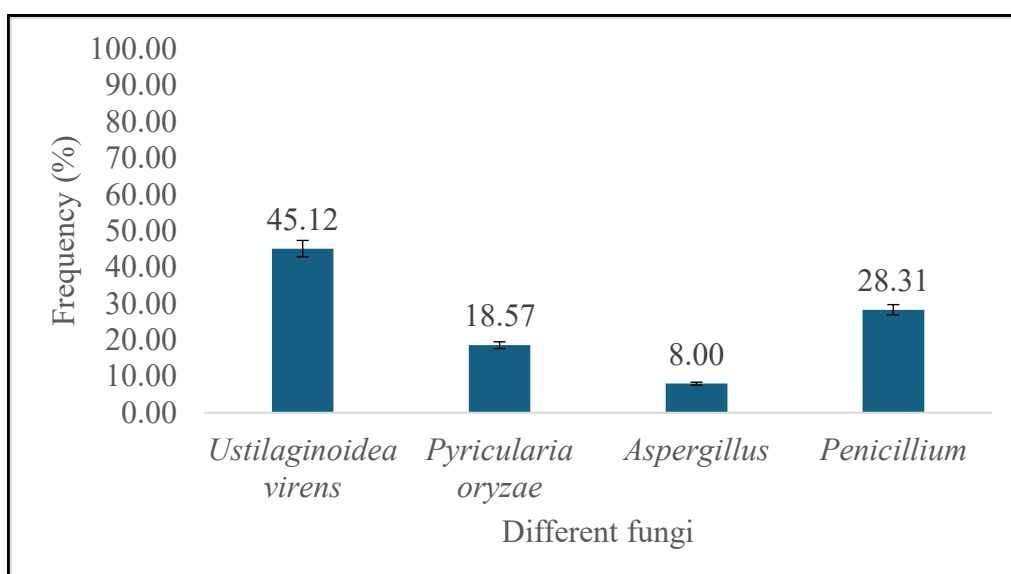


Figure 3. Frequency % of different fungi isolated from infected panicles of rice

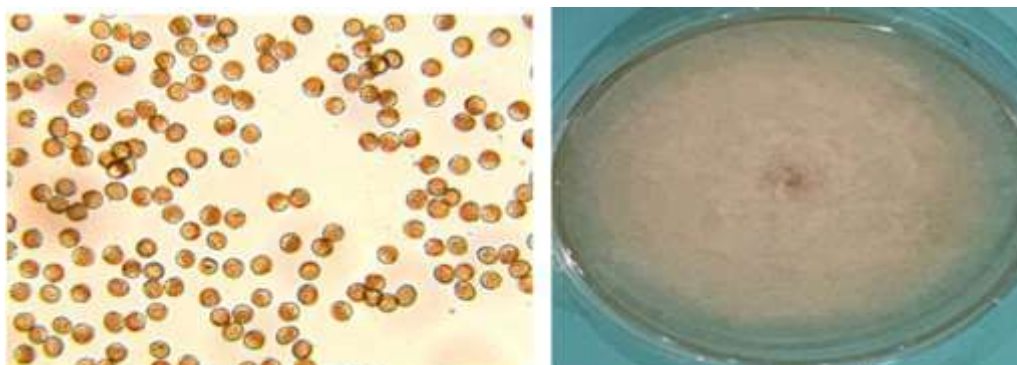


Figure .4. Isolated conidia and pure culture of *Ustilaginoidea virens*

Effect of different fungicides on linear colony growth of *Ustilaginoidea virens* under *in-vitro* conditions:

The results shows that all tested fungicides reduced the linear colony growth of *Ustilaginoidea virens* under *in-vitro* conditions. As the dose of the fungicides increases the growth of the test fungus decreases. Among all tested fungicides the Topsin-M and Nativo were found highly effective fungicides as compare to other fungicides. The lowest linear colony growth of the test fungus was recorded by Topsin-M fungicide (0, 6.5 and 11.55 mm) at 1500, 1000 and 500 ppm doses followed by Nativo (6.5, 9.5 and 14.55 mm), Aliette (10.55, 15.55 mm) at 1500, 1000 and 500 ppm doses. The highest mycelial colony growth of the test fungus was recorded by Melodey duo (74 mm) followed by Copper oxychloride (70 mm) and Romeo (66.33 mm) at 500 ppm. Among the tested fungicides Melodey duo and copper oxychloride were found less effective as compare to other fungicides (Figure 5).

Effect of different fungicides on growth inhibition % of *Ustilaginoidea virens* under *in-vitro*

conditions: The results shows that all tested fungicides inhibited the linear colony growth of *Ustilaginoidea virens* under *in-vitro* conditions. As the dose of the fungicides increases the growth of the test fungus decreases. Among all six tested fungicides the Topsin-M recorded the highest growth inhibition % (100) followed by Nativo (94.04) and Aliette (89.26) at 1500 ppm. All fungicides inhibited the growth of test fungus at all used doses. The lowest inhibition % was noted by Melodey duo (17.78) and Copper oxychloride (22.22) at 500 ppm. The highest dose 1500 ppm of all tested fungicides inhibited the maximum inhibition of test fungus as compare to lowest dose 500 ppm. The Aliette and Romeo were found moderately effective against the test pathogen. The Topsin-M fungicide completely inhibited the linear colony growth of the test pathogen at 1500 ppm. It was also noted that the 1500 ppm doses of all tested fungicides were also found effective against the test fungus (Figure 6).

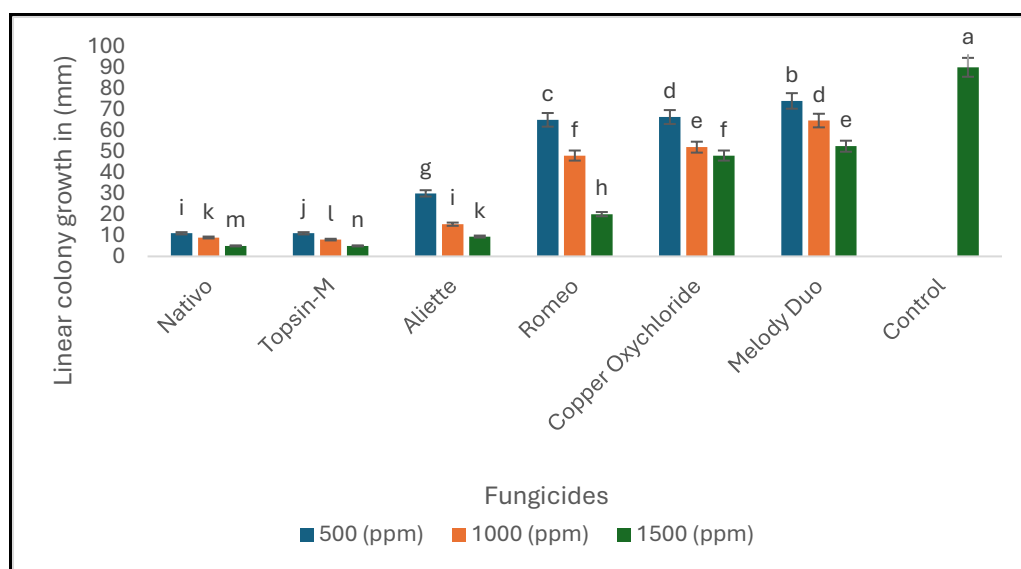
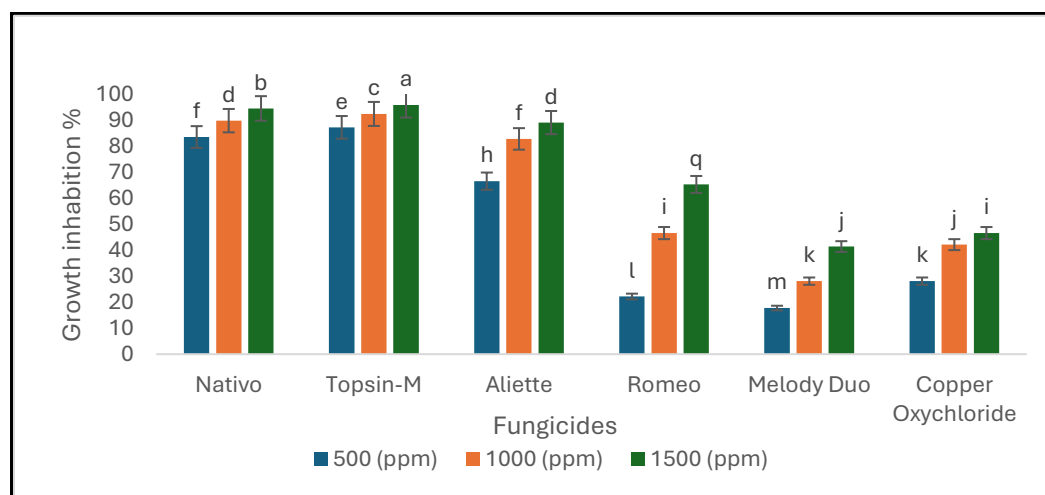


Figure 5. Effect of different fungicides on linear colony growth of *Ustilaginoidea virens* under *in-vitro* condition



Figure, 6. Effect of different fungicides on growth inhibition % of *Ustilaginoidea virens* under *in-vitro* condition

DISCUSSION

Rice (*Oryza sativa* L.) is one of the world's most crucial staple crops, providing sustenance to over half of the global population. However, its cultivation faces numerous challenges, among which plant diseases pose a significant threat to crop yields and global food security (Prasad *et al.*, 2017). Rice is susceptible to several diseases, including rice blast, bacterial leaf blight, false smut, rice bunt, and stem rot. Among these, false smut of rice caused by the fungus *Ustilaginoidea virens* (teleomorph: *Villosiclava virens*) is emerging as a major concern for rice growers worldwide (Fan *et al.*, 2020; Jatoi *et al.*, 2018; Jatoi *et al.*, 2019). False smut not only reduces yield but also deteriorates grain quality and poses potential health hazards due to mycotoxin production. Therefore, understanding the etiology of false smut and developing effective in-vitro management strategies is essential to ensure sustainable rice production and food security.

In the present study, surveys and sample collection were conducted at multiple locations in the Badin district. Disease incidence of false smut was recorded in Khorwah, Kario Ganhwar, and surrounding areas of Badin. The highest incidence (46%) was observed in Khorwah, followed by Kario Ganhwar (30%), and the lowest incidence (24%) in Badin. These findings align with those of Baite *et al.* (2017), who recorded a 33.33% incidence in the Pooja variety during the Kharif season in Odisha. Similarly, Navarasu *et al.* (2022) reported incidence ranging from 1.36% to 36.36% in Tamil Nadu, while Soodamani *et al.* (2023) found the highest incidence (40%) in Erode during a 2023 survey in the Cauvery Delta and Western zones of Tamil Nadu.

The isolated fungus was sub-cultured for identification and further investigation. Isolation and morphological analysis confirmed the presence of four fungal species: *U. virens*, *Pyricularia oryzae*, *Aspergillus*, and *Penicillium*. Among these, *U. virens* was dominant, characterized by slow-growing colonies and elliptical conidia (3–5 µm) that developed into circular, spinulate chlamydospores under favorable conditions (Wang *et al.*, 2019; Zhou *et al.* 2024). Similar morphological diversity among isolates was observed by Sunkad *et al.* (2023), who identified 15 *U. virens* isolates during their survey, with isolate Uv-2 noted for its high virulence.

To manage *U. virens*, six fungicides were evaluated using the food poisoning method. Topsin-M and Nativo were found to be the most effective, showing complete inhibition of mycelial growth at 1500 ppm. Aliette and Romeo demonstrated moderate effectiveness, while Melody Duo and Copper Oxychloride were the least effective across all tested concentrations (500, 1000, and 1500 ppm). The statistical analysis revealed a significant difference in fungal growth inhibition among fungicides at varying concentrations. These findings are supported by

Banasode and Hosagoudar (2020), who tested systemic and combi-fungicides at 100, 200, and 500 ppm. Their results showed that Propiconazole 25% EC, Tebuconazole 250 EC, and Azoxystrobin + Difenconazole combinations achieved up to 100% suppression of mycelial growth.

Our results are also consistent with those of Kumar *et al.* (2020), who evaluated six fungicide formulations against *U. virens*, including Flusilazole + Carbendazim, Trifloxystrobin + Tebuconazole, and Copper Hydroxide. Their in-vitro assays demonstrated that Trifloxystrobin + Tebuconazole exhibited the highest inhibition (86.66%) at 100 ppm, while Copper Hydroxide showed the least (65.07%). All fungicides significantly reduced fungal growth across concentrations of 10 to 100 ppm after 21 days of incubation.

CONCLUSIONS

Based on the present study, it is concluded that the incidence of false smut disease in rice varies significantly across different locations. The highest disease incidence was recorded in Khorwah (46%), followed by Kario Ganhwar (30%), while the lowest incidence (24%) was observed in the areas surrounding Badin city. Four fungal species were isolated from infected samples, each with varying frequencies. *Ustilaginoidea virens* was the most frequently isolated fungus (45.12%), followed by *Penicillium* (28.31%) and *Pyricularia oryzae* (18.57%), whereas *Aspergillus* showed the lowest frequency (8%). Among the tested fungicides, Nativo and Topsin-M were found to be highly effective in suppressing the mycelial growth of *Ustilaginoidea virens*. Aliette and Romeo exhibited moderate effectiveness, while Copper Oxychloride and Melody Duo were the least effective across all tested concentrations (500, 1000, and 1500 ppm).

CONFLICTS OF INTEREST

We declare no competing interests affecting the work reported in this study.

AUTHORS' CONTRIBUTION

MK conceptualized, designed, investigated and wrote original draft. Mk and ZAN formatted the figures, validated data and formal analysis. MK and GBP reviewed and edited manuscript draft. ZAN

RECOMMENDATIONS

As a conclusion, it is recommended to consider Topsin-M and Nativo as the preferred fungicides for controlling *Ustilaginoidea virens*, as they exhibited the lowest linear colony growth at higher concentrations. However, fungicide selection should also account for cost-effectiveness and local environmental conditions. Regular monitoring of rice fields is essential to assess disease prevalence, particularly in regions with a history of high incidence, as early detection enables timely intervention. Additionally, efforts should be made to explore and promote rice varieties with natural resistance to *U. virens*, as this represents a sustainable

long-term strategy for disease management. Continuous monitoring of fungicide resistance among fungal populations is also crucial, and a proactive approach should be implemented to manage and delay resistance development..

REFERENCES

- Alase, S., Pramesh, D., Prasanna Kumar, M. K., Sridhara, S., Elansary, H. O., Rashwan, M. A., ... & Nagaraja, A. (2024). Field-scale efficacy of bioformulations, bioagents, and fungicides for controlling rice false smut disease: an integrated approach. *Cogent Food & Agriculture*, 10(1), 2371934.
- Baite, M. S., Raghu, S., Lenka, S., Mukherjee, A. K., Prabhukarthikeyan, S. R., & Jena, M. (2017). Survey of rice false smut caused by *Ustilagoidea virens* in Odisha. *Journal of Bioscience*, 12(4), 2081–2085.
- Banasode, M., & Hosagoudar, G. N. (2020). In-vitro & in-vivo evaluation of fungicides against false smut disease of rice in hilly zone of Karnataka, India. *International Journal of Current Microbiology & Applied Sciences*, 9(9), 3598–3609.
- Fan, J., Yang, J., Wang, Y. Q., Li, G. B., Bag, M. K., Lenka, S., & Jena, M. (2020). Yield loss assessment in rice (*Oryza sativa*) due to false smut disease. *Indian Journal of Agricultural Sciences*, 90(2), 361–364.
- FAOSTAT, (2017). Food and Agriculture Organization of the United Nations, FAOSTAT. Rome Italy.
- FAOSTAT, (2022). Food and Agriculture Organization of the United Nations. FAOSTAT Statistical Database (2022). Available online: <http://www.fao.org/faostat/en/#data/QC> (accessed on 1 November 2022).
- GoP, (2022). Economic survey of Pakistan.2021-2022. Government of Pakistan, Ministry of Food, Agriculture & Livestock, Agriculture & Livestock Division (Economic Wing), Islamabad.
- Jatoi, G. H., Keerio, A. U., Abdulle, Y. A., & Qiu, D. (2019). Effect of selected fungicides and Bio-Pesticides on the mycelial colony growth of the *Helminthosporium oryzae*. brown spot of rice. *Acta Ecologica Sinica*, 39(6), 456-460.
- Bhutto, S. H., Tariq, J. A., Syed, R. N., & Jatoi, G. H. (2018). Isolation and characterization of bacteria isolated from the rice crop in lower Sindh. *Pak. J. Biotechnol*, 15(1), 151-154.
- Jatoi, G. H., Abro, M. A., Tariq, J. A., Memon, S., Mangi, N., Kerio, A. U. D., ... & Menga, A. S. (2016a). Efficacy of selected fungicides on the linear colony growth of the *Helminthosporium oryzae* caused by brown spot disease of rice. *Pakistan Journal of Biotechnology*, 13(1), 13-17.
- Jatoi, G. H., Bhatti, A. G., Hidayatullah, S. M., Bhatti, M. U., Abro, M. A., & Memon, S. (2016b). Rhizobacteria associated from rhizospheric soil and there antifungal activity against Brown spot fungus (*Helminthosporium oryzae*). *Sci. Int-(Lahore)*, 28(4), 4119-4122.
- Jatoi, G. H., Abro, M. A., Tariq, J. A., Memon, S., Mangi, N., Keerio, A. U. D., ... & Qiu, D. (2016c). Screening of potential bacterial bio-control agents against the *Helminthosporium oryzae* in-vitro conditions. caused by brown spot of rice. *Pakistan Journal of Biotechnology*, 13(2), 95-100.
- Jatoi, G. H., Abro, M. A., Memon, S. H., Hussain, S., Mangi, N., & Maari, S. A. (2015). Efficacy of different Botanical extracts on the linear colony growth of the *Helminthosporium oryzae*. *European Academic Research*, III, 7, 8383-8397.
- Kabir, M. S., Salam, M. U., Chowdhury, A., Rahman, N. M. F., Iftikharuddaula, K. M., Rahman, M. S., & Biswas, J. K. (2015). Rice vision for Bangladesh: 2050 & beyond. *Bangladesh Rice Journal*, 19(2), 1–18.
- Khaliq, T., Gaydon, D. S., Cheema, M. J. M., & Gull, U. (2019). Analyzing crop yield gaps & their causes using cropping systems modelling–A case study of the Punjab rice-wheat system, Pakistan. *Field Crops Research*, 232, 119–130.
- Kumar, U. C., Azad, C. S., Shekhar, S., Kumari, J., Kumar, S., & Kumar, A. (2020). Evaluation of fungicides against *Ustilagoidea virens* pathogen causing false smut disease of rice. *Current Journal of Applied Science & Technology*, 39(12), 7–15.
- Navarasu, S., E.G. Ebenezer, K.E.A. Aiyathan, & B. Jeberlin. (2022). Survey for the incidence of false smut disease of rice in Tamil Nadu. *The Pharma Innovation*, 11 (7), 4461-4465.
- Prasad, R., Shivay, Y. S., & Kumar, D. (2017). Current status, challenges, & opportunities in rice production. *Rice production worldwide*, 1-32.
- Rohman, A., Helmiyati, S., Hapsari, M., & Larasati Setyaningrum, D. (2014). Rice in health & nutrition. *International Journal of Food Research*, 21(1), 13.
- Villa, F., Cappitelli, F., Cortesi, P., & Kunova, A. (2017). Fungal biofilms: Targets for the development of novel strategies in plant disease management. *Frontiers in microbiology*, 8, 654
- Wang, W. M., Fan, J., & Jeyakumar, J. M. J. (2019). Rice false smut: an increasing threat to grain yield & quality. *Protecting rice grains in the post-genomic era*, 89-108
- Zhou, L., Mubeen, M., Iftikhar, Y., Zheng, H., Zhang, Z., Wen, J., ... & Chen, L. (2024). Rice false smut pathogen: implications for mycotoxin contamination, current status, and future perspectives. *Frontiers in Microbiology*, 15, 1344831....

Publisher's note: JOARPS remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. To

view a copy of this license, visit [Creative Commons Attribution 4.0 International License \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)