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Rice False Smut Interaction: Understanding the Mode of Infection, Pathogenomics and Management

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Abstract

For most people worldwide, rice (*Oryza sativa*) is their main source of food security. Although false smut was once thought to have little effect, it is now being known as a serious rice disease. Rice's False Smut disease is brought on by the ascomycete's fungus *Villosiclava virens*. Both asexual and sexual stages are present, and both spores have the ability to infect the spikelet and cause the rice grain to develop into a smut ball. According to reports, 40% of output losses in rice are caused by false smut, a disease that can be managed using Early on, the pathogen causes the creation of a white fungal mass inside the spikelet, which is subsequently transformed into light-yellow smut balls. As the disease progresses, the color of the smut balls changes to orange, then green, olive-green, and greenish-black in the end. Mature smut balls covered in sclerotia contain a large number of chlamydospores in their outer layer. In addition to RFS balls, it also makes neighboring kernels sterile, which results in a significant loss in production and quality. Similar to this, RFS balls can contaminate rice grains and straws with two different forms of mycotoxins (ustiloxin and ustilaginoidin) that pose serious health risks to humans and animals. The disease's most likely stages to manifest severity are during the rice booting and heading stages.

Introduction

In addition to causing significant yield losses (up to 40% in severe years) due to RFS, *U. virens* produces a large number of mycotoxins, which are hazardous to humans and frequently contaminate rice products and creatures. Numerous investigations on the incidence, pathogen detection, mycotoxin identification, infection lifecycle, and chemical control of the disease have been conducted because of the disease's economic significance. This disease is largely uninvestigated due to a historical emphasis placed on major diseases, such as blast and bacterial blight. Moreover, the label of "minor disease" for smuts environmental variability, and length of time required to rate these intractable adult plant diseases has led to a general lack of progress towards disease control.

Classification

Kingdom: Fungi

Division: Ascomycota

Class: Sordariomycetes

Order: Hypocreales

Family: Clavicipitaceae

Genus: Villosiclava

Species: virens.

Epidemiology

Favorable conditions for the false smut development

Rice is susceptible to False Smut disease only in favorable environmental and suitable grown condition. Table 2 highlights the conditions for the False Smut development in Rice.

Fig 1- Greenish Black Smut Balls with a velvety appearance, Smut balls bursts and becomes Black in Colour

S.I.	Conditions that favor False Smut development
1	Presence of heavy rainfall and high humidity (>95%)
2	Presence of soils with high nitrogen content
3	Presence of wind for dissemination of the spores from plant to plant
4	Presence of overwintering fungus as sclerotia and chlamydospores
5	Flowering stage of the rice crop
6	Temperature ranging from 25-35 degree Celsius

Symptomatology

Rice Green smut, another name for false smut sickness, is sometimes used as a metaphor for a bumper crop. The only way to replace paddy grains is with fake smut balls, which are balls-shaped fungal mycelia. evident symptom. As the false smut ball ages, it becomes loaded with powdered chlamydospores and changes color from yellowish to green to olive green to greenish black. In the fall, sclerotia are typically developed on the fake smut balls (Schreiber *et al.*,2019). The pathogens attack rice during panicle development, but symptoms do not appear until after blooming. The fungus then covers the spikelets. When the grains mature, they all turn into a yellowish smut ball that eventually turns green and greenish black. Spores that are powdery and dark green appear.

Disease management

Reducing the severity of the disease depends on an integrated approach to disease management. It begins with the selection of seeds, taking into account appropriate culture techniques and the choice of an efficient control agent to stop and manage the disease. By lowering disease infestation, optimal consideration of preventative and control strategies at the appropriate times will assist increase yield.

Cultural approaches

Crop rotation, soil tillage, fertility rate, and a number of other alternative crop management techniques were found to provide effective control of smuts in susceptible rice cultivars, according to a study done in the United States. Previously, those same researchers discovered that in susceptible individuals, moderate nitrogen fertility rate application decreased false smut disease cultivars. Early transplanted rice had higher disease incidence when compared to late planting. To escape severe damage, sowing date and heading period could be planned in such a way that flowering should not coincide with rainy period. Use of sclerotic free seeds for sowing and cleaning of bunds may help the farmers to reduce the initial occurrence of the disease (Perez-Quintero and Szurek.,2019).

Chemical control

The growth of fungal mycelium was completely inhibited by the fungicides Triûoxystrobin 25%+, Tebuconazole 50%, and Propiconazole 25 EC when tested in vitro and in vivo. It worked well to apply prochloraz + carbendazim then chlorothalonil. in managing rice's misleading stigma. Nine modern fungicides were assessed in a 2016 kharif study for their ability to prevent false smut disease in rice. The least amount of disease severity was recorded by azoxystrobin (18.2%) SC + Difenconozole (11.4%) SC and Metiram (55%) WG + Pyraclostrobin (5%) WG @ 0.1 percent, out of the various fungicides tested. These were followed by Propiconazole 25 EC, Azoxystrobin 25% SC, Difenconazole 25% EC, Tebuconozole 250 EC, and Flusilazole (25%) SE + Carbendazim (12.5%) SE, which demonstrated better efficacy at 0.1 percent.

Biocontrol agents

In an *in vitro* study, Moscou and Bogdanove (2009) examined the antagonistic potential of nine isolates of *Trichoderma viride*, virens, harzianum, and reesei that were taken from the rice rhizosphere. They found that every strain isolate of *Trichoderma* has demonstrated antagonistic activity against *U. virens*, but *T. viride* exhibited the most antagonistic potential among them. *Antennariella placitae* has been shown to be effective against rice false smut (*Ustilaginoidea virens*) in both *in vitro* and *in vivo* conditions.

Development of resistant varieties

Numerous workers have found that a big number of rice types are resistant or tolerant depending on how they react in fields under natural conditions. 125 rice genotypes were screened using a fake smut artificial inoculation. Kaur and others (2015) found nine hybrids that shown total resistance to rice fake smut Hybrids VNR-211, GK-5025, HRI140, IRH-74, PRSH-9018, KPH-467, RH-10428, 27P64, and KRH-4.

Molecular mechanisms of *U. virens* pathogenicity

More than 1000 genes are thought to be involved in the virulence and pathogenicity of *U. virens*, according to functional genomics and transcriptome investigations. Mitogen-activated cells and these potential virulence factors are intimately connected. *U. virens* transcriptional regulation, secondary metabolism, and protein kinase (MAPK) cascade pathways. 650 proteins were found in the U. virens exudate by proteomic analysis. Exudate proteins are implicated in pathogenicity, sporulation, antioxidant effects, and fungal cell wall formation and remodeling, according to gene annotation and protein–protein interaction (PPI) network study. The identification of virulence factors is significantly accelerated by the use of a high-efficiency gene targeting approach and the publically available *U. vitrens* genome.

Many virulence factors, including autophagy, transcription factors, post-translational modification, mycotoxin production, and pathways, have been found to be associated with *U. virens* pathogenicity, mycelial proliferation, conidiation, and stress tolerance.

MAPK and Ras/cAMP signaling pathways It has been suggested that *U. virens* possesses five MAPK. The four additional MAPK signaling pathways in *U. virens* have been identified, with the exception of Smk1. Plant infection, fungicide resistance, and responses to different environmental conditions are all regulated by Hog1 homologue genes found in phytopathogenic fungi (Bogdanove *et al.*, 2010).

Molecular strategies to control false smut disease

Important virulence factors of U. virens have been identified with significant progress. Clarification of the molecular processes that underlie the pathogenicity of U. virens and pathogenicity will make it easier to create control measures for rice fake smut. The management of rice false smut has investigated the use of host-induced gene silencing (HIGS) based on the established virulence factors. The majority of sRNAs work endogenously, but some have the ability to traverse organismal boundaries between bacteria and hosts and mute genes in trans—a process known as "cross-kingdom RNAi." In order to silence genes linked to virulence during microbial infection, host plants primarily transfer sRNAs into pathogens through extracellular vesicles.

Conclusion

Up until recently, rice fake smut was thought to be one of the lesser rice diseases, but cases of the disease have been seen resurfacing in all of the main rice-growing nations. The study nearly a century of research on the illness has given us a detailed understanding of it as well as practical strategies for reducing disease infestation. The characteristic smut ball that appears on rice grains and ranges in colour from yellow to dark green makes false smut easy to identify. These smuts can seriously harm a person's health and are hazardous to humans. Research indicates that rain during flowering, increased nitrogen usage, subpar cultural practices, and susceptible varieties are related to the disease's incidence. The use of chemicals or no chemicals at all could be used to lower the incidence of disease. The selection of the resistant varieties like VNR-211, GK-5025, HRI-140 etc. followed with the cultural practices like scheduling the paddy transplant to avoid the rain during reproductive stage, optimum nitrogen application and crop rotation collectively will reduce the disease occurrence organically. Chemicals, on the other hand, can be utilized to respond quickly and are generally better known for controlling disease.

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