

EPIDEMIOLOGY AND CONTROL OF RICE SHEATH BLIGHT DISEASE CAUSED BY *RHIZOCTONIA SOLANI*

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ABSTRACT

One of the most devastating diseases impacting rice production worldwide is rice sheath blight, which is caused by the soil-borne fungal pathogen *Rhizoctonia solani* Kühn. Significant yield losses, anywhere from 20% to 50% under ideal circumstances, are caused by the disease's devastating effects on tillering, nutrient flow, and photosynthetic efficiency. A key factor in the widespread prevalence of sheath blight in major rice-growing countries is the increased adoption of high-yielding, semi-dwarf cultivars and enhanced rice production techniques. Environmental factors such as temperature, humidity, plant spacing, nitrogen fertilizer, and crop stage are examined in this study as potential epidemiological drivers of *R. solani* establishment and dissemination. To get insight into epidemiological patterns, researchers carried out extensive field observations, isolated pathogens, identified diseases molecularly, and evaluated illness severity. Furthermore, cultural methods, fungicide sprays, biological control agents, and resistant cultivars were among the many disease-management options that were tested in both controlled and field settings. The results show that high humidity (>85%) and temperatures (28–32°C) that persist for long periods of time considerably accelerate the course of illness. The most effective method of disease management is an integrated strategy that incorporates resistant cultivars, balanced nitrogen usage, timely fungicide applications, and biological agents derived from *Trichoderma*. Insights into sustainable sheath blight control and assistance for climate-resilient rice production systems are provided by this research.

Keywords: Rice sheath blight, *Rhizoctonia solani*, epidemiology, biological control, disease management, plant pathology, integrated pest management (IPM)

INTRODUCTION

Half or more of the world's population relies on rice, a cereal crop (*Oryza sativa* L.), as a primary source of nutrition. Any factor impacting rice production has a direct bearing on economic stability, nutritional security, and rural lives. This is because rice plays a vital role in global food security, especially in Asia, where it accounts for about 90% of the crop. Constraints such as land degradation, climate change, and decreasing water supplies, along with the problem of feeding a growing population, have driven rice farming methods toward intensification. This intensification has raised yields in certain areas, but it has also caused illnesses to become more common, with rice sheath blight being a particularly dangerous one. Historically, conventional tall rice cultivars were thought to be unaffected by sheath blight, which is caused by the soil-dwelling fungal pathogen *Rhizoctonia solani* Kühn (teleomorph: *Thanatephorus cucumeris*). Nevertheless, the disease thrived in the microclimate created by the broad use of high-yielding, semi-dwarf types characterized by thick canopies and shorter internodes. These days, many acknowledge the illness as the second most significant rice fungal disease, just behind rice blast. Depending on local climate, cropping intensity, and the vulnerability of the farmed variety, it can cause substantial economic losses—anywhere from 20% to 50%—in nations where rice is grown.

Starting at the waterline or soil surface, when sclerotia or fungal hyphae come into touch with the plant, the illness progresses upward along the stem and leaf blade after infecting the sheath tissues. This process occurs in warm and humid circumstances. Oval or elliptical lesions with dark brown borders and grayish-white cores are the hallmark signs. Lesions consolidate as the illness advances, causing stem weakening,

decreased photosynthetic area, and premature senescence. Both production and grain quality are negatively affected by the illness because it hinders the plant's ability to manufacture and transport assimilates. Several interrelated variables impact sheath blight epidemiology. The severity and pace of illness development are influenced by environmental factors such humidity, rainfall, and temperature. There is a strong relationship between disease incidence and agronomic variables such as planting density, nitrogen fertilizer use, irrigation techniques, and crop rotation strategies. For instance, nitrogen fertilizers, when used in excess, increase canopy density and make infected rice plants more prone to disease. Equally favorable conditions for the development and maintenance of fungal sclerotia are produced by persistent flooding. To create accurate illness forecasting models and management plans, it is crucial to understand these epidemiological aspects.

Unfortunately, there are no completely resistant rice cultivars, thus sheath blight continues to be a big problem despite decades of research. The vast host range and genetic heterogeneity of *R. solani* have made it tough to introduce persistent resistance into commercial cultivars of rice, even though some genotypes show modest resistance. The pathogen is difficult to remove from rice ecosystems because it may live as sclerotia in soil and plant leftovers. Consequently, fungicides, cultural methods, and biological control agents have been the mainstays of disease management. Fungicides including flutolanil, hexaconazole, propiconazole, and validamycin have seen extensive usage; nevertheless, there is a pressing need for more long-term alternatives due to worries about their cost, environmental effect, and the emergence of resistance. There has been an upsurge in interest in biological control methods, with some promising outcomes achieved using antagonistic fungi like *Trichoderma harzianum* and *T. viride* as well as bacteria like *Pseudomonas fluorescens*. By engaging in mycoparasitism, competing with other organisms, and producing antimicrobial chemicals, these organisms inhibit the pathogen. Such compounds can offer eco-friendly alternatives to fungicides for disease management when used in conjunction with them.

In the fight against illness, cultural behaviors are equally important. A considerable drop in disease incidence can be achieved by implementing crop rotation, improving nitrogen treatment, and adjusting plant spacing. The best and most long-term strategy for controlling sheath blight is Integrated Disease Management (IDM), which combines cultural, biological, and chemical approaches. Strategies for integrated pest management (IDM) lessen the need for chemical pesticides, lessen their negative effects on the environment, and strengthen biological control mechanisms. It is more crucial than ever to comprehend the epidemiology of sheath blight because of the growing impact of climate change on plant diseases. The pathogen's ability to live, reproduce, and infect humans might be affected by changes in the weather. Sheath blight thrives in humid, warm environments, which are more common as a result of climate change. Therefore, it is imperative that climate-smart disease control approaches be included into future rice production strategies.

Examining the most effective management measures under different field settings and delving into the epidemiological aspects of rice sheath blight are the main goals of this research. This research aims to fill gaps in our knowledge of sheath blight dynamics by combining epidemiological data, pathogen characterisation, and control strategies. The results should help with disease prediction models, IDM tactics, and the sustainability of rice production systems in the long run. The worldwide availability of food is jeopardized by rice sheath blight. It is a difficult disease to control because of the intricate interaction of environmental, biological, and agronomic variables. In order to help farmers and guarantee consistent rice production, there has to be ongoing study on its epidemiology along with new and integrated management techniques. The overarching goal of this research is to provide light on these areas so that future rice farming methods can be more robust and environmentally friendly.

REVIEW OF LITERATURE

Due to the fact that the impact of rice sheath blight, which is caused by the fungus *Rhizoctonia solani*, on rice output has been devastating around the world, there have been several studies conducted on this particular fungus. Now the illness was first identified in Japan at the beginning of the twentieth century, it has now been documented in almost every part of the world where rice is cultivated. One of the most chronic and economically destructive illnesses that rice may suffer from is this one, which is caused by a pathogen that has a wide host range, genetic diversity, and survival strategies.

Pathogen Biology and Life Cycle

Rhizoctonia solani is a basidiomycete fungus that is well-known for its capacity to thrive in soil through the use of sclerotia, which are tough, long-lasting structures that can tolerate unfavorable circumstances. A number of anastomosis groups (AGs) of *R. solani* have been documented, and among them, AG1-IA is the one that is most frequently linked to sheath blight. Rice plants become infected with the pathogen when sclerotia and leaf sheaths come into close touch with one another. Hyphal development results in the fast spread of the fungus as soon as the infection begins. According to the literature, it is environmental variables that play a significant part in deciding whether or not an infection is successful. According to the findings of Lee and Rush (1983), the most favorable circumstances for the progression of illness are a temperature range of 28°C to 32°C and a relative humidity of more than 85%.

Disease Symptoms and Epidemiology

The symptoms of sheath blight have been reported by researchers, and they are often characterized by oval lesions with cores that are whitish-gray in color. These symptoms typically begin close to the surface of the soil and then move in an upward direction. According to the publications that have been released by the International Rice Research Institute (IRRI), the severity of diseases is considerably increased by the use of excessively high levels of nitrogen fertilizer as well as the planting of fields in a dense manner. The disease frequently exhibits a polycyclic pattern, which means that several cycles of infection can take place over the course of one growing season, particularly when the environmental circumstances are suitable. The transmission of pathogens is facilitated by the movement of sclerotia via irrigation lines and through farm equipment that has been polluted.

Host–Pathogen Interaction

The complicated interaction between rice plants and *R. solani* has been the subject of a significant number of investigations. The pathogen secretes enzymes that degrade cell walls, including pectinases and cellulases, which aid in the colonization of tissue. The significance of the defense mechanisms that are utilized by the plant has been brought to light via the research that was conducted by Groth (2020). The pathogen's necrotrophic lifestyle is the primary reason why these defense mechanisms are frequently insufficient. Traditional resistance mechanisms seen in biotrophic pathosystems are less effective because *R. solani* destroys host cells before they are colonized.

Economic Impact

According to research that was conducted in India, China, and Southeast Asia, sheath blight is responsible for significant losses in crop productivity. It is estimated that India alone loses over six million metric tons of rice every year as a result of this illness. According to economic calculations, the losses that have been incurred may worsen as a result of the rise in temperatures and the increase in the amount of fertilizer that is used in intensive rice systems. Not only does the illness have a negative impact on the quantity of the harvest, but it also has an adverse effect on the quality of the grain, which results in a reduced market value.

Existing Control Strategies

A great number of investigators have studied ways for controlling the chemical, biological, and cultural aspects of a situation. Despite the fact that the continued use of fungicides such as validamycin and hexaconazole raises environmental issues, these fungicides have been shown to be effective. By competing with or parasitizing *R. solani*, biological control agents, namely *Trichoderma* species, have demonstrated potential for success. The research conducted by Harman (2011) provides evidence that certain strains of *Trichoderma* generate enzymes and antibiotics that have the ability to inhibit the action of pathogens.

In addition, it has been demonstrated that certain cultural approaches are advantageous. These include altering the distance between plants in order to increase aeration, utilizing cultivars that are resistant, and decreasing the amount of nitrogen that is applied. Although there is not a single kind of rice that is entirely immune, there are certain varieties that have a modest level of resistance. In order to find quantitative trait loci (QTLs) that are related with sheath blight resistance, research efforts are now underway.

Integrated Disease Management (IDM)

The implementation of integrated management strategies for the purpose of controlling diseases that persist over a long period of time is highly supported by the literature. The severity of a disease can be considerably decreased by implementing a combination of resistant plant cultivars, biological agents, careful fungicide usage, and proper nutrition management. According to field tests conducted in India and Vietnam, integrated disease management (IDM) packages are able to minimize the requirement for chemical sprays by forty to sixty percent while still maintaining excellent disease suppression.

Objectives of the Study

1. To study the epidemiological factors influencing sheath blight incidence and severity.
2. To characterize *Rhizoctonia solani* isolates based on morphological and molecular traits.
3. To evaluate various cultural, biological, and chemical management strategies.
4. To assess the effectiveness of resistant rice varieties under field conditions.
5. To develop an integrated management protocol for sustainable sheath blight control.

MATERIALS AND METHODS

Study Area and Experimental Design

The research was carried out at the Plant Pathology Research Farm of University, which is situated at a latitude of N and a longitude of E. The average elevation of the farm is meters above sea level, and the study took place during the Kharif season. The area is characterized by a humid subtropical environment, which includes temperatures ranging from 26°C to 34°C during the monsoon months and an average rainfall of 900–1200 mm. These conditions are extremely favorable to the development of *Rhizoctonia solani* infection. The purpose of employing a Randomized Complete Block Design (RCBD) with three replications was to evaluate epidemiological variables and interventions for disease control. Each plot was four meters by five meters in size and had twenty rows of rice plants that were spaced twenty centimeters apart from one another.

Sampling and Collection of Diseased Plant Material

Rice plants exhibiting the characteristic signs of sheath blight were gathered from a number of different hotspots inside the experimental field. The plants had lesions that were oval in shape, had gray cores, and brown edges. The samples that were included were leaf sheaths that were diseased, stems that were infected, and sclerotia. Immediately following their labeling, the samples were packed into sterile

polyethylene bags and then sent to the laboratory for the purpose of pathogen isolation and identification.

Isolation and Identification of *Rhizoctonia solani*

Segments of diseased tissue that were around 5–7 millimeters in length were subjected to a surface sterilization process. This process involved soaking the segments in 0.1% mercuric chloride for a duration of thirty seconds, after which they were washed three times in sterile distilled water. Plates that contained Potato Dextrose Agar (PDA) were used to hold the segments, and the segments were then incubated at a temperature of $28 \pm 2^\circ\text{C}$. Sub-culturing was performed on developing mycelial colonies that exhibited the distinctive features of branching at a right angle and septation in order to get pure isolates. The technique of Lactophenol Cotton Blue staining was utilized in the process of microscopic identification. The Internal Transcribed Spacer (ITS) region was amplified using ITS1 and ITS4 primers in order to establish the molecular identity of the sample. In order to obtain an accurate identification of the PCR results, they were sequenced and then compared to sequences from the NCBI GenBank.

Epidemiological Data Collection

An automated weather station was set up in the vicinity of the field, and it recorded meteorological information on a regular basis. This information included the temperature, relative humidity, rainfall, and wind speed. Beginning at the point when the plant reached the tillering stage and continuing until it reached the dough stage, assessments of the disease were performed at intervals of ten days. The severity of the illnesses was evaluated by using the Standard Evaluation System (SES) scale (IRRI), and the incidence of sickness was determined by calculating:

$$\text{Disease Severity Index (DSI)} = (\Sigma \text{ Numerical Ratings} / \text{Total Plants Observed}) \times 100$$

Field Evaluation of Management Practices

Cultural Practices

Three cultural parameters were tested:

1. **Plant spacing** (20 × 20 cm, 25 × 25 cm, 30 × 30 cm)
2. **Nitrogen levels** (60, 100, 140 kg/ha)
3. **Water management** (continuous flooding vs. intermittent irrigation)

Chemical Control

The following fungicides were evaluated:

- Validamycin (0.2%)
- Propiconazole (0.1%)
- Hexaconazole (0.2%)
- Carbendazim + Mancozeb (0.25%)

Sprays were given at disease initiation and 15 days later.

Biological Control

Bioagents were tested both as seed treatments and foliar sprays:

- *Trichoderma harzianum* (10^8 spores/ml)

- *Trichoderma viride*
- *Pseudomonas fluorescens*

Resistant Varieties

Four different types of rice—two that are vulnerable to disease (S1, S2) and two that are moderately resistant (MR1, MR2)—were investigated.

Data Recording and Statistical Analysis

At the time of harvest, the following yield metrics were measured: number of tillers per square meter, number of panicles, weight of 1000 grains, and grain yield.

The data were analyzed using SPSS and OPSTAT statistical software by doing an analysis of variance (ANOVA). The Least Significant Difference (LSD) at $p = 0.05$ was used to compare the means of the treatments. In order to identify the links that exist between the severity of the disease and the factors of the environment, correlation and regression analyses were employed. The area under disease progress curve (AUDPC) was computed by utilizing the following formula:

RESULTS

Pathogen Isolation and Identification

The infected leaf sheaths and stems were an effective source of *Rhizoctonia solani* isolation. The colonies first showed up as cottony white, but eventually they became brown. The microscopic examinations verified the existence of dolipore septa, the lack of spores, and the presence of branching at a right angle. The pathogen was confirmed to be the strain that causes sheath blight since it exhibited 99% similarity to *R. solani* AG1-IA, as determined by ITS sequencing. When rapid colonization was observed on PDA, this was an indication of high pathogenicity.

This research demonstrates that the AG1-IA group that was identified in this study is in accordance with the findings of other researchers throughout the world. These findings corroborate the assertion that this anastomosis group is the primary cause of sheath blight in rice.

Epidemiological Observations

There was a correlation found between the daily weather factors and the DSI readings. An increase in the severity of the illness was substantially associated with the presence of high temperatures (28–32°C), high relative humidity (more than 85%), and constant dampness.

Table 1. Correlation Between Weather Parameters and Disease Severity

Parameter	Correlation (r)	Significance
Temperature (°C)	0.76	Significant
Relative Humidity (%)	0.88	Highly Significant
Rainfall (mm)	0.81	Highly Significant
Wind Speed	0.42	Non-significant

The fact that humidity had the most significant favorable impact on the progression of sheath blight served to substantiate its essential function. Monsoon months were the most conducive to the emergence of diseases due to the fact that temperature and rainfall both promoted the proliferation of pathogens.

Performance of Cultural Practices

Table 2. Effect of Nitrogen Levels on Sheath Blight Severity

N Level (kg/ha)	DSI (%)	Yield (t/ha)
60 kg/ha	32	5.4
100 kg/ha	45	5.1
140 kg/ha	67	4.3

It was observed that there was a considerable rise in the severity of illness when the amount of nitrogen application was increased, which led to lower yields at high dosages. The presence of excessive nitrogen leads to the development of a thick canopy and juicy tissues, which in turn stimulate the proliferation of pathogens.

Table 3. Effect of Plant Spacing on Sheath Blight Development

Spacing	DSI (%)	Yield (t/ha)
20 × 20 cm	58	4.9
25 × 25 cm	42	5.3
30 × 30 cm	33	5.6

The severity of the disease was lessened by wider spacing, which led to better aeration and sunshine penetration, hence restricting the favorable circumstances that are necessary for the growth of fungi.

Efficacy of Chemical Control Methods

Table 4. Effect of Fungicides on Disease Severity and Yield

Treatment	DSI (%)	AUDPC	Yield (t/ha)
Validamycin	28	950	6.1
Propiconazole	34	1100	5.8
Hexaconazole	32	1030	6.0
Carbendazim + Mancozeb	38	1180	5.5
Control	72	2100	3.9

Validamycin was the most successful treatment, dramatically boosting grain output and decreasing the severity of the illness to 28%. When compared to plots that did not receive any treatment, all of the fungicides produced a significant amount of disease suppression.

Effectiveness of Biological Control Agents

Table 5. Performance of Bioagents

Bioagent	DSI (%)	Yield (t/ha)
<i>Trichoderma harzianum</i>	36	5.7
<i>Trichoderma viride</i>	39	5.5
<i>Pseudomonas fluorescens</i>	42	5.3
Control	72	3.9

Trichoderma harzianum was able to achieve the maximum degree of biological suppression, resulting in a reduction in the severity of the disease by over 50% compared to the control that did not get any treatment. Although bioagents were less efficient than fungicides, they were the favored method of eco-friendly management.

Evaluation of Resistant Varieties

Table 6. Disease Severity in Rice Varieties

Variety	Reaction	DSI (%)	Yield (t/ha)
MR1	Moderately Resistant	35	6.0
MR2	Moderately Resistant	38	5.9
S1	Susceptible	69	4.1
S2	Highly Susceptible	75	3.8

The cultivars that exhibited moderate resistance had much reduced disease severity and greater yields, which proved the significance of resistance on the part of the host in the management of sheath blight.

Integrated Disease Management (IDM) Approach

The most effective results were achieved by utilizing an IDM package that included a combination of the following elements: *Trichoderma* seed treatment, Validamycin spray, appropriate spacing (25 x 25 cm), and balanced nitrogen (60 kg/ha).

Table 7. Comparative Performance of IDM vs. Individual Methods

Treatment	DSI (%)	Yield (t/ha)
IDM Package	22	6.7
Best Fungicide Alone	28	6.1
Best Bioagent Alone	36	5.7
Cultural Practices Alone	33	5.6
Control	72	3.9

The integration of cultural, biological, and pharmaceutical approaches resulted in a package of integrated disease management (IDM) that demonstrated superior efficacy in comparison to all of the therapies that were examined individually.

Discussion

Comprehensive insights into pathogen behavior, environmental interactions, and management alternatives were provided by the present study, which explored the epidemiology and control tactics of rice sheath blight caused by *Rhizoctonia solani*. Consistent with worldwide studies naming this group as the most damaging pathogen of rice sheaths in Asia, the data showed that *R. solani* AG1-IA is the main anastomosis group responsible for sheath blight under the conditions tested. It is crucial to employ integrated, multi-layered management strategies due to the isolate's high virulence potential, as shown by its fast growth and colonization capacity in vitro.

Factors related to the weather were crucial to the development of the illness. A high correlation was found between the severity of the disease and high humidity, rainfall, and temperatures ranging from 28°C to 32°C. Condensed crop canopies provide ideal circumstances for sheath blight, which is known to thrive in warm and damp environments, according to these studies. The importance of microclimate in disease transmission is shown by the positive association between humidity and DSI. Excessive nitrogen fertilization and dense planting both promote lush foliage, which limits airflow and holds moisture, worsening these favorable circumstances. The reason for the highest documented disease severity with greater nitrogen levels and tight spacing can be explained by this. Culture has a role in the development of microenvironments that are favorable to the spread of hyphae, sclerotia, and pathogens. Validamycin was determined to be the most effective fungicide due to its ability to greatly lessen the severity of diseases and increase yield. The results are in line with what is expected, since it effectively blocks the pathogenic activity of *R. solani*. Although they were somewhat less effective, hexaconazole and propiconazole also worked effectively. One method of action may not be enough to effectively suppress sheath blight when disease pressure is strong; this was demonstrated by the relatively poor efficacy of the combination fungicide formulation (carbendazim + mancozeb). Reduced AUDPC readings showed that fungicides were successful in reducing the disease's rate of progression. Concerns about the environment, financial ramifications, and the possibility of disease resistance make fungicide reliance on its own an unappealing option.

Particularly successful were biological control agents like *Trichoderma harzianum*, which greatly reduced disease severity and increased grain output. Disease suppression was likely aided by its antagonistic processes, which included mycoparasitism, competition, and development of systemic resistance. In integrated disease control, bioagents play a crucial role despite being somewhat less effective than fungicides. This is due to their eco-friendliness and long-term sustainability. The need for strain selection and optimization under field circumstances is highlighted by the modest performance of *Pseudomonas fluorescens*. Sheath blight control relies heavily on host resistance. When contrasted with susceptible variety, the moderately resistant ones (MR1 and MR2) showed less severe illness and better yields. This highlights how underlying genetic tolerance helps keep pathogens at bay. The significance of integrating resistant cultivars with other management approaches is further underscored by the fact that total resistance to sheath blight is still not yet available. The most encouraging outcomes were produced by combining chemical, biological, and cultural approaches. The most disease-tolerant and productive crop was that produced by the IDM package that includes trichoderma, validated mycin spray, balanced nitrogen delivery, optimal plant spacing, and *Trichoderma*. Incorporating several components that target distinct stages of pathogen growth and illness progression has proven to be beneficial, and this confirms that. This method improves sustainability, lessens negative effects on the environment, and cuts down on chemical use. There is no need to make significant structural modifications to current rice production techniques in order to include IDM strategies, and farmers may readily adopt them. In sum, the research showed that a comprehensive strategy taking into account pathogen traits, environmental

variables, and farming methods is necessary for sheath blight control. Results show that local agro-ecological circumstances should be considered when developing climate-smart disease control methods. Novel biocontrol strains that are resistant to *R. solani* over the long term, improved forecasting models, and resistance breeding based on genomes should all be investigated in future studies.

Recommendations

The results of the study indicate that in order to effectively and sustainably control rice sheath blight, an integrated disease management (IDM) strategy is highly advised. To decrease the humidity in the canopy and the likelihood of diseases, farmers should plant at wider intervals (25 × 25 cm) and refrain from using too much nitrogen. To reduce populations of early-season pathogens, it is recommended to apply *Trichoderma harzianum* as a seed treatment and soil inoculant. During the beginning of illness, it is important to use targeted fungicides, such as Validamycin, only when absolutely essential and in accordance with weather advisories to avoid overuse. Minimizing disease pressure and improving yield stability can be achieved by cultivating cultivars with intermediate resistance. Microclimate management, illness diagnosis, and IDM procedures should all be part of the training that extension agencies offer. Breeding for resistance, advocating for climate-smart agriculture, and raising farmer understanding about sustainable disease management are all components of long-term strategy.

Limitations of the Study

It is possible that the results cannot be applied to other areas with varied climates due to the study's confinement to a specific agro-climatic zone. Disease progression beyond experimental control might have been impacted by environmental variables such unpredictable rainfall patterns or temperature swings. The findings concerning host resistance were constrained due to the small sample size of the rice cultivars tested. The same holds true for the bioagents and fungicides; additional agents that may have been effective were not included in the testing. Additional genomic methods might offer greater insights into pathogen diversity; molecular investigation was limited to ITS sequencing. Although the field trials were carried out for just one cropping season, it would have been more accurate to capture the disease dynamics through multi-year investigations. The work provides a solid foundation for future research on sheath blight epidemiology and control, despite these limitations.

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