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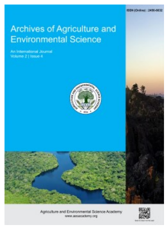

REVIEW ARTICLE

CrossMark

Sheath Blight of rice: A review of host plant interaction and disease management

Ganesh G.C. * **and Puja Roka**

Institute of Agriculture and Animal Science, Paklihawa, Rupandehi, NEPAL
*Corresponding author's E-mail: ganeshghartic@gmail.com; pujaroka96@gmail.com

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ABSTRACT

The devastating pathogen *Rhizoctonia solani*, which is responsible for significant quality and production losses worldwide, is discussed in this review article along with the symptoms, disease cycle, epidemiology which causes sheath blight disease in rice. *R. solani* Kuhn, poses a significant threat to tropical Asia's rice production, potentially reducing grain yield by 50%. The article also emphasises the numerous management techniques, such as cultural, biological, and chemical controls. It is a severe production bottleneck in high yielding rice varieties under intensive rice production techniques, monoculture methods, a dense canopy, and extensive nitrogen management. Disease propagation in fields is influenced by air temperature, moisture content, and leaf wetness, with 16-25 C temperature range and 90% humidity favoring growth. Vertical and horizontal spread are influenced by these factors. The article provides comprehensive insight on host plant interaction of pathogen *R. solani*.

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INTRODUCTION

After wheat and maize, rice (*Oryza sativa*) is the third largest and staple crop of 50% of the world's population (Rashid *et al.*, 2014). India ranks second in rice farming area after China, growing 43.9 mha across 2013-14, with productivity of 106.3 MT and 2416 kg/ha (Singh *et al.*, 2015). Rice has been domestically growing for more than 7,000 years (JB *et al.*, 2012). Rice is a leading cereal crop in terms of production and acreage in Nepal with significant role for country's agriculture and economy (Regmi *et al.*, 2023). Terai covers 73% of total area for production of rice while 24% and 4% goes for hill and high hills (Joshi *et al.*, 2020). Rice contributes 20% to Nepal's GDP and 7% to AGDP with production of approx. 5.61 million tons in area of about 1.49 million hectares (Acharya *et al.*, 2020). With nutritive value of 80% carbohydrates, 7-8% protein, 3% fat and 3% fiber, rice contributes around 80% of the nutrition for more than 2 billion people in Asia alone. (Malabadi *et al.*, 2022), describes rice as functional food as its mineral content, starch quality, glycemic index and antioxidant activity has made rice unique and its starch is completely absorbed by human body in comparison to other foods. Reduced output of rice is frequently linked to disease outbreaks, pest infestations, pesticide use, soil fertility decline, chemical input consumption, rising fertilizer and poison input prices, greenhouse gas emissions, and diminishing agricultural areas (Muhammad *et al.*, 2021; Zainol *et al.*, 2023). Low rice yields are influenced by biotic and abiotic stress conditions, including drought, flooding, and climate change-induced abiotic stress, and biotic stress, including false smut, sheath blight, and insect infestations (Akos *et al.*, 2019; Dar *et al.*, 2021). Sheath blight, a serious fungal disease caused on by *Rhizoctonia solani* Kuhn, poses a serious danger to rice in tropical Asia by reducing grain production by up to 50%. As per (Molla *et al.*, 2020), rice production throughout the world is clearly facing a serious danger from the sheath blight disease and its cause, *R. solani*. Even after 100 years since its discovery, *R. solani* has remained an "enigmatic pathogen to control" because of its adaptability and outstanding capacity to attack virtually all sorts of tissues on a wide variety of plants.

Rice sheath blight

Rice Sheath Blight is the most frequent and damaging disease caused by *R. solani* (Ramanarao *et al.*, 2011), also known as snake -skin disease because of its unique symptoms (Molla *et al.*, 2016). It is a worldwide devastating disease that leads to quality and quantity degradation (Brooks, 2007; Nagarajkumar *et al.*, 2004). *Rhizoctonia solani* is a common facultative plant parasite that lives in soil and is a necrotrophic soil-borne fungus (Anees *et al.*, 2010; Sneh *et al.*, 1998). Rhizoctonia solani, a complex species with multiple anastomosis groups;14 as per (Carling *et al.*, 2002), is a phytopathogenic species with diverse host ranges and saprotrophic growth, complicating its parasitic activity (Anees *et al.*, 2010). The disease was first discovered in Japan which significantly decreased productivity in the rice-growing region by 30–50% (Banniza & Holderness, 2001; Srivastava *et al.*, 2023). Disease later further migrated to nations that grow rice in temperate and tropical climates, such as Bangladesh, Brazil, Burma, China, Taiwan, Thailand, Nigeria, India, Iran, the UK, the USA, and Vietnam whereas tomato, barley, maize, lettuce, and sorghum are more plants that may be affected by this fungus (Chuanqing *et al.*, 2009; Sivalingam *et al.*, 2006). As per (Chuanqing *et al.*, 2009), fungi are more likely to develop resistance when one treatment is used extensively over an extended period of time, Jinggangmycin resistance was initially noted to arise occasionally in areas of Gushi county, in the province of Henan. Before spreading, fungal sclerotia can stay dormant in the soil for up to two years, especially during irrigation and crop preparation of rice (Greer & Webster, 2001). Numerous factors influence the development of diseases in rice, including monoculture practices, a large population, a dense canopy, and significant nitrogen management (Ali *et al.*, 2023).

Symptoms

The disease develops as elliptical or oval to irregular, 1-3 cm long, greenish grey patches with a brown edge at or above the water line on the leaf sheath during the tillering stage. Leaf sheath, leaf blades and emerging panicles shows symptoms, however rice crop at maximum tillering and ear head phase in must vulnerable (Rangaswami & Mahadevan, 1998). Numerous similar patches on the leaf sheath create the impression of snake skin (Singh *et al.*, 2016). As the plant approaches heading, the canopy becomes dense, creating a humid microclimate that is favorable for the rapid development of the disease. The disease may move up the plant and infect the flag leaves and panicles under severe conditions. The fungus can spread into the culms from early sheath infections and weaken the infected culms, resulting in the lodging and collapse of tillers. Additionally, the disease is known to infect panicles, causing them to produce empty or partially filled, discolored seeds with brownish black dots or patches of black to ashy grey (Figure 1).

Disease cycle

Rhizoctonia solani is a necrotrophic pathogen found in soil, causing rice fields to flood, where sclerotia germinate on rice sheaths, creating appressoria during infection (Richa *et al.*, 2016). The pathogen forms brownish black to blackish discolored lesions and is seed-borne, with infection and transmission rates ranging from 9.9% to 39.1% and 4.6-14.0% under field circumstances (Sivalingam *et al.*, 2006). Secondary infections occur when hyphae penetrate healthy plant tissues, causing new lesions and sclerotia. During blossoming, frequent contact in rice canopy tissues facilitates disease development (Ali *et al.*, 2023; Brooks, 2007). The disease affects the movement of water, minerals, and carbohydrates through xylem and phloem tissues, thus small to major yield losses can result (Wu *et al.*, 2012). The rice germplasm that is easily accessible globally lacks qualitative resistance to *R. solani*. However, several rice cultivars have been observed to have quantitative resistance to *R. solani* (Pan *et al.*, 1999; Kumar *et al.*, 2003).

Epidemiology

The increase in air temperature, moisture and leaf wetness are all major cause of disease spread in field (Biswas *et al.*, 2011; Castilla *et al.*, 2008). Singh *et al.* (2015) says the temperature range of 16 C to 25 C and relative humidity of more than 90% favors the growth of disease. Disease development occurs by vertical and horizontal spread, where temperature, humidity and physiological status of plant tissue is responsible for vertical spread while temperature, humidity and amount of inoculum is responsible for horizontal spread (Savary *et al.*, 1995). (Savary *et al.*, 1995) further stated that infectious units are used by leaf-borne diseases like rice sheath blight to propagate along mycelial threads, replicating host tissue interactions in the canopy. Rice seedlings are more susceptible to the disease at 20-30 days of age, compared to 30-40 days when artificially infected, as per pot culture experiment (Sharma & Thrimurty, 2006). Sheath blight causes lesions as a phenotypic symptom, however plant resistance to sheath blighting causes restricted infection cushion formation and lower frequency and smaller lesion size (Groth, 1992; Masajo, 1976). BPH, rice root nematode and rice tungro virus were reported to increase the severity of sheath blight as per (Singh *et al.*, 2016).

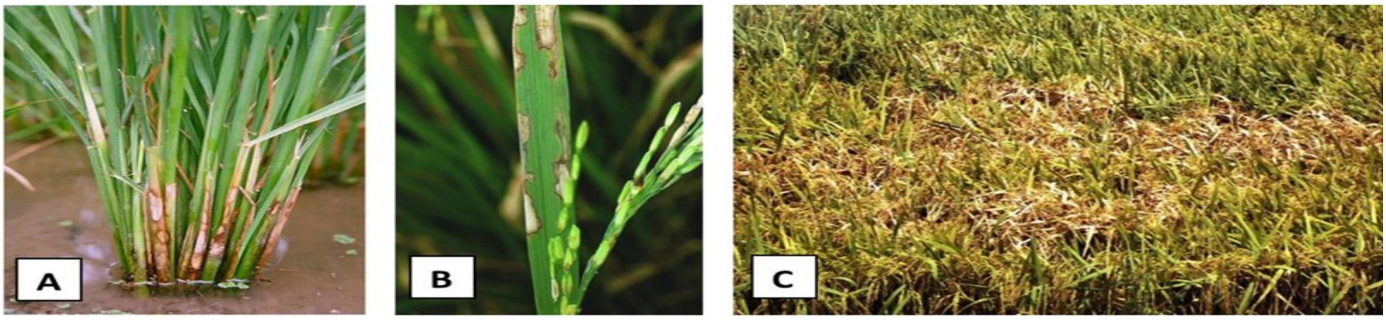

Figure 1. *Characteristic symptoms of Rice Sheath Blight Disease caused by Rhizoctonia solani A: Irregular lesions on the rice sheaths during tillering; B: Many lesions on the leafs gives the appearance of snake skin; C: Field view of sheath blight affected field. Source: https://www.ijcmas.com/special/7/Vinayak%20Turaidar,%20et%20al.pdf*

Host plant interaction

In order to successfully colonize and infect rice plants, the pathogen *R. solani* deploys a variety of processes. In response, rice plants activate several signaling pathways and create anti-crucial chemicals to fight them (Molla *et al.*, 2020). The plant host reacts to a pathogen assault by modifying its signaling pathways in a complicated manner; salicylic acid (SA), jasmonic acid (JA), and ethylene (ET) are primarily used signaling channel (Ali *et al.*, 2023; Glazebrook, 2005; Kunkel & Brooks, 2002). In the host, necrotrophic and hemi biotrophic reactions may coexist although the disease is referred as necrotrophic (González *et al.*, 2006; Kouzai *et al.*, 2017). *R. solani* utilizes a-1, 3-glucan to mask the chitin of plant's cell walls so that PRR (pattern-recognition receptor) cannot identify it (Fujikawa *et al.*, 2012). Study done by (Danson *et al.*, 2000) revealed that the glycolytic and pentose phosphate pathways' enzymes were more highly activated in response to R. solani in a resistant line than a susceptible line and also rice plants infected with R. solani show a correlation between activation of glycolytic routes, the oxidative pentose phosphate pathway (OPPP), secondary metabolism, and tricarboxylic acid cycle (TCA) cycle and decreased starch synthesis (Mutuku & Nose, 2010). The pathogen has a secretome that has been intensively studied for inhibitor I9-containing proteins. This disease can infect and spread by releasing effectors that get past plant defenses (Anderson *et al.*, 2017; Presti *et al.*, 2015). The cruciferous phytoalexin camalexin is one of the hosts phytoalexins that the virus has developed ways to decrease or detoxify. The host-specific RS toxins, which are composed of glucose, mannose, and N-acetyl galactosamine, are not produced by less virulent strains (Pedras & Ahiahonu, 2005; Vidhyasekaran *et al.*, 1997). It is unclear how resistance to sheath blight is passed down through the generations. The majority of scientists believe it to be a typical quantitative characteristic governed by polygenes and multiple loci. Sheath blight resistance is, however, regulated by a small number of major genes in a few rice cultivars, such Jasmine 85 and Teqing (Pan *et al.*, 1999).

Disease control

For cultural control wider spacing, destroying stubbles and weeds in and around rice fields, using green manuring, avoiding field irrigation, keeping the bunds and field free of weed hosts and planting rice seedlings slightly away from the bunds can all help to significantly lessen the severity of sheath blight (Singh *et al.*, 2016). The use of some chemicals as seed treatments and/or foliar sprays, such as salicylic acid, gamma-amino-butyric acid, and chitosan, has been proven to greatly decrease the severity of the sheath blight disease and to generate resistance in rice plants (Dantre & Rathi, 2007; Liu *et al.*, 2012). (Monsur *et al.*, 2023) concluded that using bio fungicide (particularly Biospark in his study) will maximize productivity however, its effectiveness for preventing the sheath blight disease of rice is somewhat lower than that of chemical fungicides. For chemical control, Topsin-M seed treatment and foliar spray have been reported to be beneficial in lowering sheath blight incidence and minimizing seed-borne *R. solani* infection, along with increased paddy grain production (Miah *et al.*, 1994) and also the seed treatment with Bavistin. In the context of integrated disease management, a mixture of synthetic chemicals, antibiotics, and biopesticides has been demonstrated to be useful in the treatment of sheath blight (Mew *et al.*, 2004; Mukhtar *et al.*, 2023). Citronella oil @ 2 ml l^{-1} was discovered to be the most effective treatment for sheath blight disease in rice by (Pal & Mandal, 2023). He further stated the best disease control was achieved with carbendazim (47.25%) than Citronella oil (36%) but Citronella was preferred considering environment point of view. Use of resistant varieties is the effective management practice against the disease (Srivastava *et al.*, 2023), apart from all the practices mentioned.

Conclusion

This review concluded that rice sheath blight is the most frequent and damaging disease caused by *R. solani.* It successfully colonizes and infect rice plants, the pathogen *R. solani* deploys a variety of processes. *R. solani* is a necrotrophic pathogen found in soil, causing rice fields to flood, where sclerotic germinate on rice sheaths, creating aspersoria during infection. The pathogen forms brownish black to blackish discolored lesions and is seed-borne, with infection and transmission under field circumstances. Disease development occurs by vertical and horizontal spread, where temperature, humidity and physiological status of plant tissue is responsible for vertical spread while temperature, humidity and amount of inoculum is responsible for horizontal spread. For cultural control wider spacing, destroying stubbles and weeds in and around rice fields, using green manuring, avoiding field irrigation, keeping the bunds and field free of weed hosts and planting rice seedlings slightly away from the bunds can all help to significantly lessen the severity of sheath blight.

DECLARATIONS

Author contribution statement

Conceptualization: G.G.C. and P.R.; Methodology: G.G.C. and P.R; Software and validation: G.G.C. and P.R; Formal analysis and investigation: G.G.C.; Resources: P.R.; Data curation: G.G.C. and P.R; Writing—original draft preparation: G.G.C.; Writing—review and editing: G.G.C. and P.R; Visualization: P.R; Supervision: P.R.; Project administration: P.R.; Funding acquisition: G.G.C. and P.R. All authors have read and agreed to the published version of the manuscript.

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