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Rice Blast Disease[1]

Nalleli Garcia, Rachel Kalicharan, and Jessie Fernandez Garcia[2]

Introduction

Rice blast disease is one of the most devastating fungal diseases that can impact more than 50 species of grasses, including rice, barley, wheat, oat, and millet (Zhang et al. 2022). Found in over 85 countries, rice blast poses a serious threat to global food security, annually destroying approximately 10% to 30% of harvested rice (Nalley et al. 2016). This amount would otherwise be enough to feed 60 million people (Pennisi 2010). As the global human population is projected to surpass 9.7 billion by 2050, affordable high-calorie foods such as rice will become pivotal to keep up with food demands. However, with a projected 30% increase in global rice production required by 2035 to meet these growing demands, it is important to implement effective agricultural practices for sustaining and enhancing rice production (Prasad et al. 2017). The purpose of this document is to increase awareness of one of the most highly destructive plant pathogens by describing its lifestyle, symptoms, and current disease mitigation practices. Given that the Everglades Agricultural Area (EAA) plays a vital role in rice cultivation, this publication is also intended for Florida rice growers to be used as a diagnostic field guide in the identification and management of rice blast disease.

Pathogen

Magnaporthe oryzae (synonym *Pyricularia oryzae*) is the causal agent responsible for rice blast disease. *M. oryzae* is a branching, filamentous fungus that belongs to the Ascomycota phylum and the Pyriculariaceae family. This fungus is a hemibiotrophic fungus, meaning it has two distinct phases of living during the infection process (Figure 1). Initially, *M. oryzae* enters a more friendly, biotrophic phase, where the fungus invades and lives inside the host cells without causing immediate damage. During this phase, it avoids triggering the plant's immune response, allowing the fungus to spread undetected. After a few days, *M. oryzae* switches to a harmful necrotrophic phase, where it starts killing and feeding on host cells, leading to the formation of visible necrotic lesions on the surface of the leaf (Fernandez and Orth 2018). These necrotic lesions are the sites of cell death on the leaf, appearing as brown, darkened spots. On these necrotic lesions, *M. oryzae* produces thousands of asexual, self-replicating spores known as conidia that are instrumental in continuing the fungal life cycle. *M. oryzae* conidia are three-celled and have an elongated shape (Figure 2). They are often seen as a dark-brown color and are approximately 20–30 micrometers long — this is roughly half the thickness of a human hair. *M. oryzae* conidia can produce a sticky substance, called mucilage, that helps with the adherence to the surface of the leaf (Hamer et al. 1988).

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2. Nalleli Garcia, biological scientist II, Department of Microbiology and Cell Science; Rachel Kalicharan, graduate student, Department of Microbiology and Cell Science; and Jessie Fernandez Garcia, assistant professor, Ph.D., Department of Microbiology and Cell Science; UF/IFAS Extension, Gainesville, FL 32611.

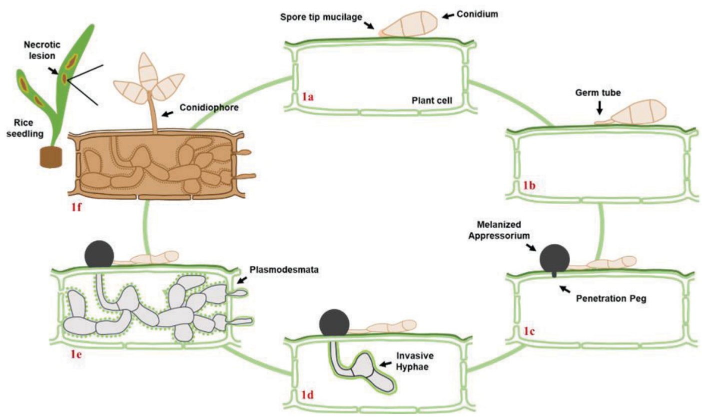

Figure 1. The life cycle of the hemibiotrophic *M. oryzae*. Rice blast begins when a three-celled spore called a conidium (1a) lands on the surface of the leaf. This is the start of the biotrophic phase. Following environmental conditions that favor disease development, a germ tube is formed (1b) which later differentiates into a melanized appressorium (darkly pigmented penetration structure) (1c). Turgor pressure is generated within the appressorium and directed towards the leaf cuticle via the penetration peg (1c). Once inside the plant cell, *M. oryzae* differentiates into invasive hyphae (1d) which move from cell to cell via plant cell connections known as plasmodesmata (1e). After 4–5 days, *M. oryzae* switches to a necrotrophic growth (1f), characterized by plant cell death and the formation of necrotic lesions on the surface of the leaf that contain thousands of spores that are able to spread and begin the infection cycle again.
Credits: J. Fernandez, UF/IFAS

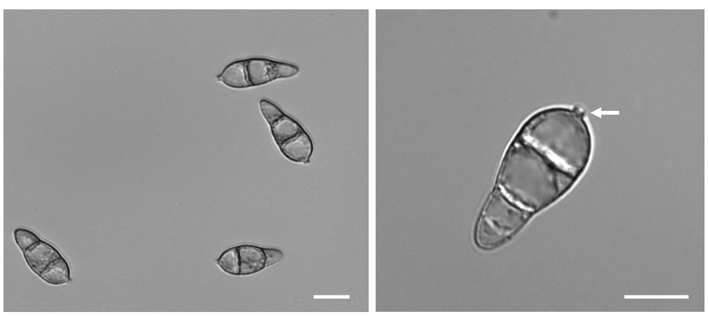

Figure 2. Illustration of the morphology of conidia (the plural of "conidium") from *M. oryzae*. Each conidium consists of three cells, with a white arrow indicating the scar where the conidium separated from the conidia-producing structure in the fungus, known as conidiophore. The scale bar represents 10 µm.
Credits: R. Kalicharan, UF/IFAS

Disease Cycle

Rice blast disease begins when the conidium lands on the leaf's surface, attaches itself to the leaf cuticle, and germinates (Figure 1) (Cruz-Mireles et al. 2021). Day temperatures of 25°C–28°C (77°F–82°F), night temperatures of 17°C–23°C (63°F–73°F), and humidity exceeding 90% are optimal for spore germination. Proper germination leads to the production of a penetration structure known as an appressorium. The appressorium is a dome-shaped structure that generates massive amounts of turgor pressure, caused by an accumulation of the compound glycerol, to allow for mechanical penetration of the leaf cuticle (outermost leaf surface). The appressorium is surrounded by a thick layer of dark pigmentation known as melanin that prevents the movement of water outside the cell and helps build enough turgor pressure (Wang et al. 2005). *M. oryzae* utilizes a structure known as a penetration peg generated at the bottom of the appressorium to direct the mechanical force through the plant cuticle (Wilson and Talbot 2009). Once inside the initial plant cell, *M. oryzae* produces long branching filaments known as invasive hyphae (fungal cells) that allow the fungus to disperse within a plant cell and move to neighboring cells via plant connections known as plasmodesmata (Kankanala et al. 2007). During this initial biotrophic stage of infection, the fungus is able to colonize plant cells in a way that the natural plant cell defense response is not activated (Fernandez 2023). This makes it difficult to identify the initial stages of the rice blast disease in the field. After 4–5 days, the fungus switches to its necrotrophic phase, where it begins killing the cells it has colonized and produces visible necrotic lesions on the leaf surface (Perfect and Green 2001).

Symptoms

M. oryzae can infect plants of all ages, from seedlings to mature plants. Rice blast can also infect various parts of a plant including leaves, sheath, neck, and panicle (Puri et al. 2009). Most notably, rice blast disease presents distinct physical symptoms, including lesions that appear on the surface of the leaf. These lesions initially begin as small spots and progress into diamond-shaped formations, featuring a dark-brown color with lighter-colored, yellowish leaf tissue around the margins (Figure 3). Rice cultivars more resistant to rice blast will produce smaller and darker lesion types compared to more susceptible cultivars. While less common, symptoms on the sheath also produce the same type of necrotic lesions.

One of the most severe symptoms of rice blast is infection to the neck. When *M. oryzae* sporulates at the stem of the plant, the stem becomes weak and likely to break; this is known as neck rot. Neck rot symptoms can prevent nutrient and water flow to the panicle, a specialized plant structure that eventually produces rice grains (Bonman 1989). This may prevent adequate maturation of the grains, which begins to turn the panicle white, or may prevent the development of the panicle entirely. Rice blast can also infect the panicles, producing symptoms such as necrotic lesions. Infected panicles can turn white and be unable to produce viable seeds, further contributing to overall yield loss (Hayashi et al. 2019).

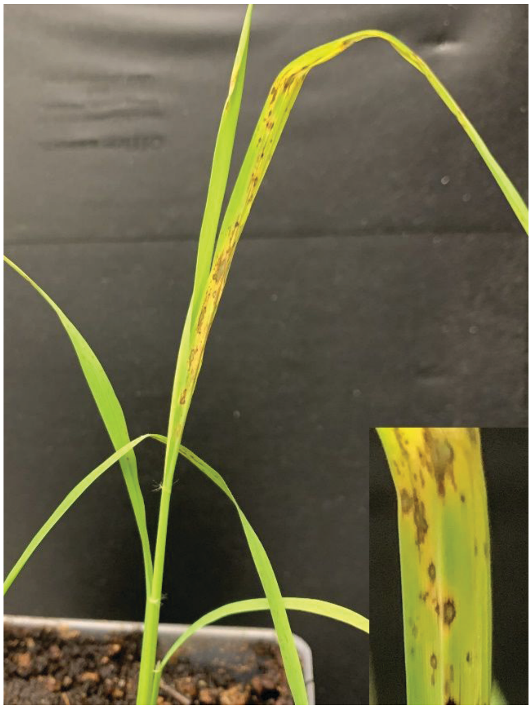

Figure 3. Rice blast necrotic lesions on susceptible rice plants.
Credits: N. Garcia, UF/IFAS

Dissemination and Spread

The necrotic lesions become sites where the fungus will produce a specialized filamentous cell known as a conidiophore that will produce thousands of spores that can remain viable for up to a week on the leaf surface (Figure 1). These spores can be dispersed through wind and rain to uninfected neighboring plants, allowing the disease cycle to continue (Zhang et al. 2014). Continued disease cycles create a buildup of disease-causing inoculum (the material, such as fungal spores, that can cause infection) in the crop area, making the management of rice blast difficult. In addition, *M. oryzae* can survive between growing seasons within infected crop residues in the field and/or in contaminated seeds that can introduce the disease to new areas (Raveloson et al. 2018). Environmental conditions such as high humidity, wet weather, and excessive fertilization contribute to the dissemination of *M. oryzae* spores (Younas et al. 2023). In Florida, typical environmental conditions that prevail during the rice growing season are characterized by high humidity and wet conditions, which promote the germination and dissemination of *M. oryzae* spores. Unfortunately, regional geographical and climatic conditions amplify the risk of rice blast disease outbreaks.

Cultural Practices

Providing around 20% of the calories consumed worldwide, rice is the most common staple food in the world. In Florida, the Everglades Agricultural Area (EAA) commercially grows thousands of acres of cultivated rice every year (Bhadha et al. 2023). The successful growth of rice crops is tied to several factors including adequate soil structure, crop rotations, and the practice of flooding fields. The soils of the EAA contain about 85% organic matter and are rich in nutrients, providing crops with a suitable environment for efficient nutrient absorption. Crop rotations between rice and sugarcane allow for the retention of soil nutrients throughout growing seasons. In addition, the practice of flooding fields, where large amounts of water are added to inundate entire fields, also reduces nutrient depletion and aids in controlling pests and weeds. In the EAA, flooding is done continuously, from 14–21 days before harvest. Water levels in the field always remain 3–4 inches deep (Bhadha et al. 2018). While many practices are implemented in the EAA to prevent disease progression, Florida rice growers face the persistent threat of rice blast disease negatively impacting rice crop production.

Disease Management

Given that rice blast disease outbreaks have been found in over 80 countries where rice is cultivated, crop rotation is an effective strategy to break the disease cycle, as planting non-host crops in between rice cultivation seasons disrupts the pathogen's continuity (Kato 2001). While not an essential nutrient for rice crops, silicon treatment has been known to reduce rice blast disease in rice by strengthening the plant cell wall, and to aid in plant growth by helping curb abiotic, environmental stresses such as metal toxicity (Datnoff et al. 1997). In Florida, silicon supplementation in areas where silicon content is low has been applied for decades to increase rice yields.

In addition, fungicides are also a key component of chemical control strategies against rice blast disease. Timely application of fungicides, particularly during periods of high disease pressure, helps prevent and manage outbreaks. Synthetic fungicides such as carpropamid, tricyclazole, pyroquilon, and phthalide have been found to be effective against rice blast disease (Arif Khan et al. 2022). However, prolonged use of one fungicide leads to resistance by *M. oryzae*.

Beyond chemical control strategies, selecting resistant rice varieties is crucial for disease management because it is the most effective way to mitigate rice blast (Miah et al. 2013). Breeding programs that develop rice varieties with inherent resistance to specific races (genetic variants) of *M. oryzae* contribute significantly to sustainable disease control (Tian et al. 2022). However, through time, the effectiveness of resistant cultivars diminishes due to the evolution of *M. oryzae* (Syauqi et al. 2022). There is a continual effort to identify and deploy new rice varieties with durable resistance to multiple races of rice blast that can be adapted to local conditions in Florida. Every year, the EAA performs rice variety trials that have allowed for the implementation of rice varieties from different parts of the United States. As such, rice variety diversity has increased from three varieties to eleven from 2008–2021. While this publication does not extensively cover rice production and varieties in Florida, more information can be found in Ask IFAS publication SL439 (https://edis.ifas.ufl.edu/publication/SS653). By incorporating more durable resistant cultivars, farmers can reduce the reliance on chemical inputs and enhance overall field resilience. However, it is essential to regularly assess and update resistance breeding programs to stay ahead of evolving *M. oryzae* strains.

Diagnosis

The accurate diagnosis of rice blast disease depends heavily on identifying the specific fungal pathogen involved. Initial identification is typically done by direct examination of fungal spores observed on plant tissues under a microscope. Alternatively, inducing sporulation by incubating infected tissue in a moist chamber can aid in identification. Moreover, the pathogen can be isolated and cultured on artificial media, facilitating further examination through the formation and characterization of spores.

As an additional resource, the Florida Extension Plant Diagnostic Clinic (FEPDC) network is available for assistance with pathogen identification. To learn more about sample submission procedures and laboratory diagnosis costs, reach out to your local UF/IFAS Extension office or contact FEPDC directly.

Summary

Rice blast disease, a serious threat to global agriculture, is caused by the filamentous fungus *Magnaporthe oryzae*. Infection begins when a three-celled, tear-shaped spore lands on the surface of a rice leaf and germinates. For 4–5 days, *M. oryzae* infects rice cells without causing visible symptoms (the biotrophic phase). Once the rice blast fungus switches to the necrotrophic growth phase, cell death begins, and lesions are visible on the leaf surface. Spores produced on these lesions can be spread via wind or rain and can infect surrounding plants. As rice blast can infect all parts of a plant, it is crucial that measures be taken to try to prevent the spread of *M. oryzae,* namely through resistant cultivars. Currently, a cultivar that can resist all genetic variants (strains) of *M. oryzae* does not exist. However, to ensure the sustainability of Florida rice cultivation, an integrated and adaptive approach that combines cultural practices, chemical control, deployment of resistant cultivars, and vigilant monitoring is essential. By implementing these strategies, we can better mitigate rice blast while promoting sustainable and resilient rice cultivation in Florida.

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