An Introduction to Rice Diseases

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Abstract

Rice (*Oryza sativa*) represents the major food, feeding more than half of the world population every day. The dependence of such a large population to meet their daily dietary requirements on this tropical crop causes large-scale production in different parts of the world. Since the crop thrives comfortably in humid climates, the areas differing in such environmental conditions require the application of agrochemicals and require an extensive crop management programme to efficiently manage the diseases that hamper the crop's growth. The rice diseases, mainly caused by bacteria, fungi, and viruses, lead to significant damage and loss in the crop yield. The fungal diseases mainly attack stems, roots, grains, and foliage. The level of plant damage caused by these diseases depends on the innate capacity of the crop species to withstand the disease, severe environmental conditions, soil fertility and composition, the effect of agrochemicals, and the stage of plant growth. This chapter provides a concise discussion of the various diseases caused by bacteria, fungi, and viruses that impede rice crop growth.

Keywords

Oryza sativa · Diseases · Crop yield · Foot rot · Blast · Bacterial diseases · Fungal diseases

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1.1 Introduction

Disease is an abnormal condition of the plant species that deters the optimal functioning of its cells, tissues, enzymes, and biological and biochemical pathways (Nazarov et al. 2020). Disease in plants occurs via biotic factors or pathogens such as nematodes, bacteria, fungi, viruses, and mycoplasma. In addition, the abiotic or physical factors such as temperature, soil pH, nutrient deficiency, moisture content, presence of toxic elements in soil, water stress, heavy metal stress, and amount of light readily influence the plant's growth and development or the progression of diseased conditions (Hasan et al. 2020; Pautasso et al. 2012; Elad and Pertot 2014). The rice diseases cause an approximate 10% loss in annual production, with main diseases as 'blast' and 'helminthosporium' caused by *Pyricularia oryzae* Cav. and *Cochliobolus miyabeanus*, respectively (Asibi et al. 2019), while 'stem rot' and 'foot rot' diseases caused by *Leptosphaeria salvinii* Catt. and *Gibberella fujikuroi*, respectively, deter the production of rice adversely. The incidence of blast epidemic reportedly claims 60–70% loss in the rice production or even 100% crop loss in the individual fields (Nalley et al. 2016; Kihoro et al. 2013; Kirtphaiboon et al. 2021). Blast disease causes severe leaf infection, especially in the post-transplanting stage, causing total destruction of the foliage. Due to this disease, the half-filled rice earheads that form tend to break and fall off. The treatment of "foot rot" includes application of the seedlings with organo-mercurial fungicides (Kongcharoen et al. 2020), whereas the "blast" disease is much more widespread and requires immediate attention to prevent its spread. The popularisation of the breeding of resistant varieties of rice seedlings represents another desirable approach to prevent the outburst of diseases and to obtain a good yield (Laha et al. 2017; Miah et al. 2013; Dubina et al. 2020). Figure 1.1 illustrates the major diseases in rice. This chapter deals with a succinct discussion of the various diseases of rice and their causal pathogens.

1.2 Fungal Diseases in Rice

Nearly 20,000 fungal species reportedly cause plant diseases globally. These fungal species remain active or dormant on both living and dead tissues of the plants depending on the conditions favouring their growth and proliferation. Pathogenic fungi produce spores that, when dispersed by air, water, soil, invertebrates, and insects, may affect the whole crop. Certain fungi, such as mycorrhizae, provide significant benefits to plants by forming mutualistic relationships with their roots (Iqbal et al. 2021). Majority of the fungal species cause plant diseases, including rust, wily, blight, canker, leaf spot, anthracnose, mildew, and root rot. Fungal diseases such as rice blast serve as an alarming threat to global food security owing to their widespread distribution and destruction of the rice crop. *Magnaporthe oryzae* causes rice blast disease, which is the most devastating fungal disease, infecting the plant

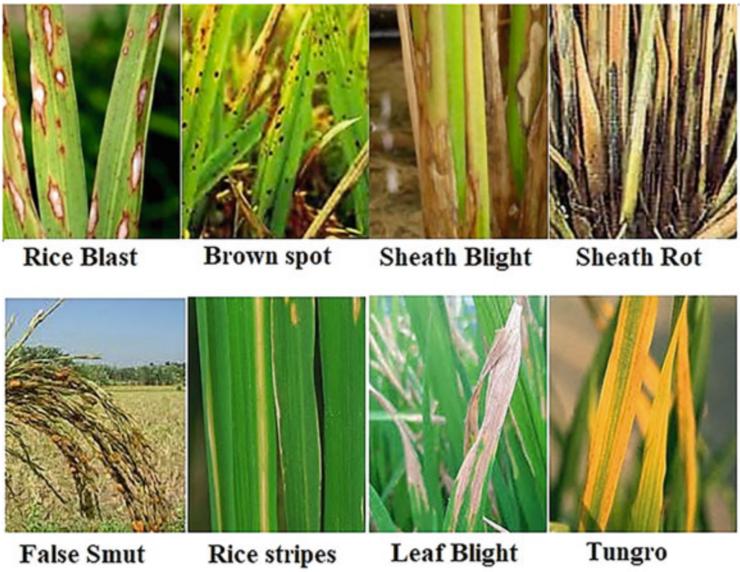

Fig. 1.1 Various diseases in rice crop that affect its yield

during all the growth stages and hampering the crop yield by 10–35%. Countering this pathogen encompasses cultural, biological, and molecular approaches that lead to the development of tolerant and resistant rice varieties by adopting effective breeding programs (Hirooka and Ishii 2013; O'Brien 2017; Sabri et al. 2020). Identification, isolation, and characterisation of several blast-resistant genes resulted in the emergence of allelic variants via molecular breeding and transgenic approaches such as miRNA and genome editing (Tabassum et al. 2021). Similarly, in the management of fungal resistance in rice, breeding techniques such as gene rotation, pyramiding, and multiline varieties proved highly profitable (Ramalingam et al. 2020). However, the co-evolution of the pathogens and their variable nature necessitate consistent research aimed at the advancement of sustainable, resistant cultivators. Table 1.1 presents the various fungal diseases in rice, their causal organisms, symptoms, and the affected plant parts.

1.3 Bacterial Diseases in Rice

Bacterial blight caused by gram-negative bacteria *Xanthomonas oryzae* pv. *oryzae* and bacterial leaf streak disease caused by the gram-negative bacteria *Xanthomonas oryzae* pv. *oryzicola* represent the deadliest bacterial disease in rice that affect the overall rice production worldwide (Yugander et al. 2017; Pradhan et al. 2020). Nevertheless, the rice plant too has adopted innate potency to counter the bacterial

Table 1.1 Symptoms and causal organism for the various fungal diseases in rice

Disease	Symptoms	Causing organism	Ref.
Rice blast	• Above ground parts of rice get effected • Elliptical or spindle-shaped legions occur on leaf blade • Lesions enlarge and coalesce eventually killing the leaf • Stem node turns blackish and becomes fragile • Brown lesions appear on branches of panicles and spikelets	*Pyricularia grisea*	Greer et al. (1997)
Sheath blight	• Ellipsoid or ovoid lesions appear on leaf sheath • Lesions coalesce and become bigger thereby causing leaf death • Waterline in the low land fields serve as favourable condition for fungal growth	*Rhizoctonia solani*	Li et al. (2021)
Brown spot	• Small, circular, brown coloured lesions on seedlings • Black discoloration of root occurs • Fungus causes dark brown to black oval spots on glumes • Black discoloration of grain occurs • Affected seedlings show stunted growth	*Bipolaris oryzae*	Shabana et al. (2008)
Leaf scald	• Zonate lesions, alternating light tan and dark brown spots starting from leaf edges • Enlargement and coalescing of lesions causes blight of leaf blade • Scalded appearance of leaf occurs	*Microdochium oryzae*	Manandhar (1999)
Narrow brown spot	• Short, linear, and brown lesions on leaf sheath, pedicels, and glumes • Net blotch-like pattern appears on leaf sheath as the cell wall turns dark brown, while intercellular areas turn tan to yellow • Diseases mainly appear in the mature stages of the rice crop	*Cercospora janseana*	Simanjuntak et al. (2020)
Stem rot	• Disease symptoms appear in the field after mild tillering stage • Small, blackish, irregular lesion appears on outer leaf sheath near water line • Fungus penetrates into the inner leaf sheath and causes partial/entire rotting • Fungus penetrates and rots the culm • Infection of the culm causes lodging, chalky grains, unfilled panicles, and death of the tiller • Infected stem contains dark greyish mycelium • Tiny, black sclerotia embed the diseased leaf sheath tissue	*Sclerotium oryzae*	Ghosh et al. (2020)

(continued)

Table 1.1 (continued)

Disease	Symptoms	Causing organism	Ref.
Sheath rot	• Leaf sheath containing young panicles gets rotted • Whitish powdery growth occurs inside affected sheath • Panicle fails to emerge as they remain inside the sheath • Grains become sterile, shriveled, and discoloured • Panicles that fail to emerge become rot • Florets turn red brown to dark brown	*Sarocladium oryzae*	Ayyadurai et al. (2005)
Bakanae	• Hypertrophic effect or abnormal elongation of plant occurs • Affected plants produce adventitious roots at the lower nodes of the culm • Affected plants contain very few tillers, and leaves dry quickly • Diseased tillers die quickly even before reaching maturity • Surviving infected plants bear empty panicles	*Fusarium fujikuroi*	Singh et al. (2019)
False smut	• Individual grains of the panicle turn into greenish spore balls with velvety appearance • Membrane around the spore balls eventually bursts as the spore grows while being enclosed in the floral parts • The outermost layer of the ball contains mature spores and the remaining fragments of the mycelium	*Ustilaginoidea virens*	Fan et al. (2020)

attack. The plant's immune response consists of dual mechanisms to counter the bacterial attack. Cell surface-localized pattern recognition receptors play a central role in the detection of pathogen-associated molecular patterns, including the highly conservative flagella of bacteria essential for sustaining the life of the pathogen (Mendes et al. 2018; Yuan et al. 2021a, b; Kim et al. 2020). These microbial components cause a variety of responses, including reactive oxygen species (ROS) generation, increased calcium ion concentrations, callose aggregation in the cell wall, activation of mitogen-activated protein kinases (MAPKs), and production of antimicrobial components such as phytoalexins (Jeandet 2015). Mainly, the broad-spectrum resistance shown by plants overcomes the intruding pathogens. It comprises a defence mechanism chiefly localised within the plant cell based on polymorphic resistance proteins that identify the specific virulence effectors secreted by the pathogens within the host cells, thereby prompting effector-triggered immunity (ETI) (Meng et al. 2020; Wang et al. 2016). ETI represents a robust resistance mechanism associated with cellular senescence at the infection site (Liu et al. 2013;

Table 1.2 Symptoms and causal organism for the various bacterial diseases in rice

Disease	Symptoms	Causing organism	Ref.
Bacterial blight	• Water-soaked lesions appear at the leaf margin • Increase in the size of affected region • Yellowish border appears between dead and green areas of the leaf • Withering of leaves or entire young plant occurs • Leaves become pale yellow at later stage of growth	*Xanthomonas oryzae*	He et al. (2010)
Bacterial leaf streak	• Water-soaked streaks appear between the leaf veins • Later, these become longer and translucent and become light brown coloured • Large areas of leaf become dry due to numerous streaks	*Xanthomonas oryzae*	Jiang et al. (2020)
Foot rot	• Infected plants become taller • Plants become thin, with yellowish green leaves • Seedlings dry at an early tillering • Partially filled grains	*Dickeya zeae*	Pu et al. (2012)
Grain rot	• Wilting and rotting of leaves • Discoloration of panicle • Shrivelled leaves • Lesions on seeds • Lesions on glumes	*Burkholderia glumae*	Zhou et al. (2016)
Sheath brown rot	• Appearance of necrotic areas on leaves • Discolouration of seeds occurs • Leaves show abnormal colours • Spikelets of emerging panicles become discoloured	*Pseudomonas fuscovaginae*	Razak et al. (2009)

Yuan et al. 2021a, b). This hypersensitive response serves as the strongest immune retort against the invading pathogen. Nonetheless, the approaches to mitigating the bacterial blight of rice present only trivial effectiveness. Chemical disease control is generally discouraged due to its environmental and human toxicity (Zhai et al. 2002; Amoghavarsha et al. 2021). The development of resistance among the pathogenic bacterial strains further questions the chemical methods of disease control (Ellur et al. 2016). Breeding of rice varieties with sturdy genes against the bacterial infection presents a viable option to ensure a healthy crop (Tao et al. 2021; Kumar et al. 2020a, b). The introduction of these genes to the genomes of commercial rice strains presents a highly desirable strategy to counter bacterial infection in the tropical countries that produce huge yields of rice every year (Wang et al. 2020; Oliva et al. 2019). Table 1.2 presents the various bacterial diseases in rice, their causal organisms, symptoms, and the affected plant parts.

1.4 Virus Diseases in Rice

In India, four virus types primarily affect the rice crop, with tungro being the most widespread virus disease affecting the rice crop in more than ten Indian states (Sharma et al. 2017; Nguyen et al. 2021). The virus diseases such as grassy stunt and strains such as GCV4 are confined to the southern part of the country (Ta et al. 2013; Zhao et al. 2021). Virus diseases like ragged stunt and necrotic mosaic are among the most damaging to rice production in India (Ghosh 1980; Bhattacharya et al. 2020). The majority of rice disease-causing viruses thrive in Asian and American continents, but rice stripe necrosis furovirus, maize streak germivirus, African cereal streak virus, rice yellow mottle sobemivirus, and rice crinkle disease persist in Africa and neighbouring countries (Awodero 1991; Liu et al. 2020). Intensified rice cultivation and the application of high-yield varieties, mechanical contamination, unregulated use of pesticides, fertilizers, and practise of crop monoculture serve as the determining factors for the evolution of virus diseases in rice (Ichiki et al. 2013; Rybicki 2015; Chen et al. 2020). The japonica rice varieties in the Americas and the Asian continents show vulnerability to the virus diseases, while the indica rice varieties show susceptibility to the virus-borne diseases (Cho et al. 2013; Orasen et al. 2020). Breeding and screening resistant rice varieties, plant quarantine, integrated pest management strategies, and the development of genetically engineered resistant rice varieties are all important approaches for effective disease management in rice (Savary et al. 2012; Chatterjee et al. 2021). Table 1.3 presents the various virus diseases in rice, their causal organisms, symptoms, and the affected plant parts.

1.5 Nematode Diseases in Rice

Nematodes predominantly cause a huge economic loss, mainly to two crops, maize and rice. The nematodes cause significant cellular changes inside the root-knot nematode-induced feeding sites upon interaction with the rice crop (Kyndt et al. 2014). The transcriptome analyses, exogenous hormone application, and mutant analyses suggested comprehensive models depicting the interactions of plant hormone pathways, such as jasmonate, in response to the innate defence adopted by rice against nematodes (Zhou et al. 2020; Gheysen and Mitchum 2019; Wang et al. 2014a, b). The nematodes represent soil-borne pathogens that pose a threatening loss to rice cultivators due to the emergence of new cultivation practises that include less water usage for growing the rice crop (Khan and Ahamad 2020). Reportedly, the nematode pathogens cause an alarming 10–25% loss to the rice crop worldwide (Kumar et al. 2020a, b). The havoc of pathogenic nematodes is mainly confined to tropical and subtropical regions with a large variety of species (Porazinska et al. 2012; Reddy 2021). In addition, the lack of proper resources for effective crop management and control and the ideal conditions for the thriving of nematode populations serve as determining factors for the nematode diseases in the rice crop grown in these areas (Prasad et al. 1987; Khan et al. 2021). Table 1.4 presents the

Table 1.3 Symptoms and causal organism for the various virus diseases in rice

Disease	Symptoms	Causing organism	Ref.
Tungro	• Affected areas exhibit stunted growth and reduced tillering • Leaves become orange-yellow coloured and develop rust-coloured spots • Leaf become discoloured starting from the tip that extends till the lower part of leaf blade • Young leaves display mottled appearance • Old leaves show rust-coloured specks of various sizes • Affected plants show a delayed flowering • Panicles bear partially filled grains covered with dark brown specks • Transmitted by green leafhoppers	*Rice tungro bacilliform virus* and spherical virus	Zarreen et al. (2018)
Grassy stunt	• Plant show severe stunting • Plants show excessive tillering • Leaves may be mottled or striped • Transmitted by brown plant hopper	Rice grassy stunt virus	Satoh et al. (2013)
Ragged stunt	• Plant show severe stunting • Plants show reduced tillering • Leaves show ragged appearance • Leaf blades twist to form a spiral • Vein swelling appear on leaf sheath, leaf blade, and culm • Transmitted by brown plant hopper	*Rice ragged stunt virus*	Wang et al. (2014a, b)

Table 1.4 Symptoms and causal organism for the various nematode diseases in rice

Disease	Symptoms	Causing organism	Ref.
Ufra or stem nematode	• Affected seedlings and plant show chlorosis • Stunted plant growth • Deformation and twisting of leaves occur • Exserted panicles, with unfilled grains	*Ditylenchus angustus*	Ali and Ishibashi (1996)
White tip	• Chlorosis of leaf occurs • Infected leaf dries up and shreds • Flag leaf becomes twisted • Panicles do not emerge • If panicles emerge, they display high sterility, distorted kernels, and distorted glumes	*Aphelenchoides besseyi*	Ou et al. (2014)
Root knot	• Infected plants display stunted growth and become yellow • Infected plants show reduced tillering • Infected plants show the appearance of root galls • Disease mostly occurs in upland, as compared to the lowland rice	*Meloidogyne graminicola*	Tian et al. (2018)

various virus diseases in rice, their causal organisms, symptoms, and the affected plant parts.

1.6 Conclusion

Oryza sativa, grown mainly as an annual plant, survives as a perennial crop in tropical areas. The rice crop in these areas faces vulnerability to a variety of diseases caused by bacteria, fungus, and nematodes, mainly due to the climatic conditions. Excessive use of fertilizers and chemicals to increase crop production and yield in order to feed the world's population exacerbates the crop's susceptibility to disease. The overuse of chemicals increases the incidence of microbial resistance and causes biomagnification in the higher trophic levels. However, plant breeding techniques, integrated pest management, biological methods of crop management, genome culturing, and the cultivation of resistant varieties of rice have contributed towards the effective management of rice disease. The production of flood-resistant rice, drought-resistant rice, and salt-tolerant rice also made sure there was enough of the crop to go around.

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