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Rice Blast: A Disease for Global Food Security

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Abstract

Rice blast is a serious fungal disease of rice (*Oryza sativa* L.) that is threatening global food security. It has been extensively studied due to the importance of rice production and consumption, and because of its vast distribution and destructiveness across the world. Rice blast, caused by *Pyricularia oryzae* Cavara 1892 (A), can infect aboveground tissues of rice plants at any growth stage and cause total crop failure. The pathogen produces lesions on leaves (leaf blast), leaf collars (collar blast), culms, culm nodes, panicle neck nodes (neck rot), and panicles (panicle blast), which vary in colour and shape depending on varietal resistance, environmental conditions, and age. Understanding how rice blast is affected by environmental conditions at the cellular and genetic level will provide critical insight into incidence of the disease in future climates for effective decision-making and management. Integrative strategies are required for successful control of rice blast, including chemical use, biocontrol, selection of advanced breeding lines and cultivars with resistance genes, investigating genetic diversity and virulence of the pathogen, forecasting and mapping distribution of the disease and pathogen races, and examining the role of wild rice and weeds in rice blast epidemics. These tactics should be integrated with agronomic practices including the removal of crop residues to decrease pathogen survival, crop and land rotations, avoiding broadcast planting and double cropping, water management, and removal of yield-limiting factors for rice production. Such an approach, where chemical use is based on crop injury and estimated yield and economic losses, is fundamental for the sustainable control of rice blast to improve rice production for global food security.

Keywords: Rice Blast; Rice; Food Security; Fungal Disease; Climate Change

Introduction

Impact of Population Growth on Land and Water Resources

Climate change is increasing air temperature and the frequency and intensity of extreme weather events. Meanwhile, the global human population is rapidly increasing and the availability of land and water resources for crop production continues to decline, escalating the challenge of global food security. The world's human population is anticipated to reach 9 billion by 2050 [1]. According to the Food and Agriculture Organization, food security is "when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life". For food insecurity to recede, agricultural production on currently cultivated land will need to increase by 70% globally and 100% in the developing countries by 2050, relative to 2009 levels This is challenged by a shrinking amount of prime land for rice (*Oryza sativa* L.) production, which is expected to decline by 18% to 51% in the tropics during the next century due to global warming Water scarcity, salinization, and pollution of water bodies is also increasing intensifying the challenge of global food security.

Rice Production in Food Security

Rice production is the main source of income and employment for more than 200 million households across the world Rice is the primary food for 2.5 to 3.5 billion people who are largely located in rapidly growing low-income countries In 2002, rice provided more than 500 calories person^{-1} d^{-1} for over three billion people, and a substantial amount of protein for 520 million people It is one of the most important cereals produced for food security and income by subsistence farmers In 2008 [2], 480 to 685 million tons of rice were produced on 160 million ha At the present rate of human population growth, the requirement for global rice production in 2020 is estimated at 140 million tons, representing a 50% increase compared to 2009.

Impact of Climate Change on Rice Production

On 16 December 2002, the UN General Assembly declared the year 2004 as the International Year of Rice. Decreasing hunger and poverty are key goals of the United Nations; however, the rate of improvement in rice yield has diminished over time. [Rice yield growth has declined from 2.3% per year during the 1970s and 1980s to 1.5% during the 1990s, and to <1.0% during the first decade of the present century].

Rice is produced across a wide range of agro-climatic environments around the world and its productivity is affected by biotic stresses [3]. Biotic stresses resulting from climate change can impair varietal resistance to rice blast. Climate change may change pathogen distribution and development rates, and alter the resistance, growth, and metabolism of rice. [Each stage of the rice blast disease cycle, from the germination of spores to the development of lesions, is significantly influenced by climatic factors such as temperature, precipitation, and dew, and are likely to affect pathogen distribution due to altered effectiveness of preventive approaches. Consequently, management approaches that exploit host resistance will be greatly impacted by climate change. Quantitative analyses of the effects of climate change on pathogens are lacking in field and laboratory research and in modelling-based assessments [4]. Therefore, mitigating the impact of biotic stresses on rice is key to increasing and stabilizing rice yield. Fungal diseases alone are estimated to reduce annual rice production by

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14% globally. Increased frequency and magnitude of extreme weather events combined with increased air temperature and atmospheric CO_2 concentration due to climate change are projected to spread rice diseases to new areas.

There has been limited research on rice diseases under field conditions that realistically mimic climate change, which has severely restricted the development of options for improved rice adaptation and disease control in future growing conditions. There has also been limited success in identifying traits in rice for enhanced tolerance to drought and monsoon conditions.

A crucial challenge to rice production is rice blast, caused by the fungus *Pyricularia oryzae* Cavara 1892. Rice blast is one of the most serious and recurrent difficulties affecting lowland and upland rice production around the world]. Rice blast is responsible for yield losses of about 10% to 30% annually In favorable conditions, this disease can devastate entire rice plants within 15 to 20 d and cause yield losses of up to 100%.

Rice blast has become more difficult to control because of the pathogen's ability to survive and multiply in harsh environmental conditions and easily spread to new fields [5]. Varietal resistances have declined due to the appearance of new and more virulent strains of the pathogen, making management and control more challenging. Additionally, fungicides and plant breeding have failed to provide long-lasting control of rice blast because they are too static to deal with the dynamic interactions between the pathogen and rice, which are influenced by the surrounding environment. Understanding the effects of the rice blast pathogen, the efficacy of rice defines mechanisms, and the impact of climate change on rice blast are crucial for enhancing global food security.

Strategies to mitigate the negative effects of climate change are key to increasing rice production Understanding the effects of changing air temperature, rainfall, and sea level due to climate change would enable modifications in crop management for improved rice production. Changes in duration, intensity, and frequency of rainfall would greatly impact the effectiveness of chemical control measures. Rainfall following application of fungicide may increase its coverage on foliage but a high amount or high intensity of rainfall can reduce fungicide coverage on foliage With long periods of rainy and cloudy conditions, both growth of rice and its resistance to rice blast are weakened Rice blast epidemics are favoured by extended periods of rain, lack of sunshine, and dew, which induce the release of conidia. The effect of rainfall on the dispersion of conidia is most prominent at the start of a rainy season and during heavy rains

Impact of Elevated Carbon Dioxide on Rice

Increased atmospheric CO_2 concentration enhances rice biomass production, but it can have a negative effect on grain yield if it is associated with increased air temperature, as projected with climate change Each 75-ppm increase in atmospheric CO_2 concentration is expected to increase rice yield by 0.5 tons ha^{-1}, while each 1°C increase in average air temperature during the growing season is projected to decrease rice yield by 0.6 tons ha^{-1} This is because rice is a C_3 crop, thereby having reduced photosynthetic efficiency due to photorespiration in hot conditions [Greater CO_2 levels can also reduce transpiration cooling and increase maintenance respiration when night air temperature exceeds 21°C Responses of rice to elevated CO_2 concentrations depend on nitrogen supply; greater CO_2 levels with limited nitrogen and the absence of sinks for excess carbon can limit photosynthetic capacity and growth . Increases in crop canopy and biomass with elevated CO_2 concentrations increases host size for a pathogen population A larger amount of crop residues can also increase pathogen survival and increase inoculum for subsequent crops and neighbouring fields. The impact of greater atmospheric CO_2 concentration on plant diseases is in part due to changes in host physiology and anatomy, such as reduced nutrient concentration and increased carbohydrate concentration in leaves, plant fibber content, leaf wax, layers of epidermal cells, and mesophyll cells Increased leaf blast and sheath blight severity has been associated with reduced silicon content in susceptible rice varieties under elevated CO_2 levels Additionally, increased leaf wax and epidermal thickness in rice can result in greater physical susceptibility to pathogens, along with enhanced pathogen fecundity and changes in pathogen virulence, activity, abundance, and distribution.

In high humidity environments, rice blast lesions produce spores in abundance, which are dispersed by wind and serve as inoculum for a new cycle of infection. In comparison, a lack of humidity or rainfall can reduce disease severity. Strong winds that blow soil particles can injure rice plants, creating wounds for easy penetration by pathogens. Wind also stimulates transpiration of the host and promotes solidification of leaf tissue and strengthens the resistance reaction of the host.

Impact of Warmer Air Temperature on Rice

According to the Intergovernmental Panel on Climate Change the average annual global air temperature from 1990 to 2100 could increase by 1.8 to 5.8°C, which would greatly threaten rice productivity and global food security. Optimal maximum daily air temperature during the growing season for rice grain yield is 23 to 26°C Air temperature above 33°C negatively affects anther dehiscence, pollen viability, spikelet fertility, and dry matter accumulation in grain A 2°C increase in average air temperature during grain filling can decrease rice yield by 15% to 17% Increased air temperature due to climate change is also expected to enhance growth and sporulation of the rice blast pathogen.

The temperature under which rice is cultivated affects its susceptibility to the blast disease In cold subtropical zones, an increase in air temperature is expected to cause an increase in the severity of rice blast due to increased risk of infection. Long periods of leaf dampness, high relative humidity, and temperatures of 17 to 28°C favour rice blast growth. Low humidity or dew favours the infection of rice blast When night air temperature rises above 20°C there is less spore liberation and infection is absent, but rapid growth of lesions is favoured by alternating daily minimum and maximum air temperatures of 25/32°C to 20/32°C Mild air temperature of 16 to 24°C may sustain the sporulation capacity of lesions. However, greater air temperatures that are predicted to occur as a result of climate change may reduce the incidence of rice blast in most rice growing zones. More detailed modelling research and climate monitoring that take into consideration other factors affecting rice blast would be beneficial for disease management

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Conflict of Interest

The authors declare that they are no conflict of interest

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