Strategy for Farmers to Combat Climate Induced Plant Disease

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ABSTRACT

Climate change significantly influences plant disease dynamics, increasing the frequency and intensity of outbreaks. Historical events, such as the Irish Potato Famine and Bengal Famine, highlight the devastating impacts of plant diseases under conducive environmental conditions. Modern climate variability, including rising temperatures, erratic rainfall, and increased atmospheric CO_2 levels, alters host-pathogen interactions and exacerbates disease severity. This article discusses these challenges and their impact on plant diseases dynamics. It also explains ways to manage these challenges using chemical, biotechnological, biological, technological, and cultural methods. By integrating forecasting tools and sustainable practices, these methods aim to strengthen resilience against climate-induced plant diseases and support farmers in mitigating their impact effectively.

INTRODUCTION

Climate change poses significant challenges to global agriculture, particularly by exacerbating plant diseases. Historical instances such as the Irish Potato Famine (1845) and the Bengal Famine (1943) highlight the devastating impacts of plant diseases under favourable environmental conditions. Both events illustrate the synergy of a virulent pathogen, a susceptible host, and a conducive environment—a triad crucial for disease proliferation. With the industrial-era rise in CO_2 levels, global temperatures have increased by 0.2°C per decade over the past 30 years, creating more favourable conditions for pathogens.

Shifts in weather patterns due to climate change influence cultivation zones, introducing new diseases in some areas while diminishing their economic impact elsewere. For instance, Bangladesh experienced an outbreak of *Magnaporthe oryzae tritici* in 2015 due to unusually warm and humid pre-harvest conditions. Annual crop losses from biotic stresses cost India ₹2.25 lakh crores, while global damages amount to $290 billion (Sahu *et al*., 2023). These trends underscore the urgency of developing strategies to combat climate-induced plant diseases.

1. Impact of climate change on plant diseases:

Environmental factors have profound effect on climate change. Some of the factors influencing Disease development has been mentioned below (Fig. 1):

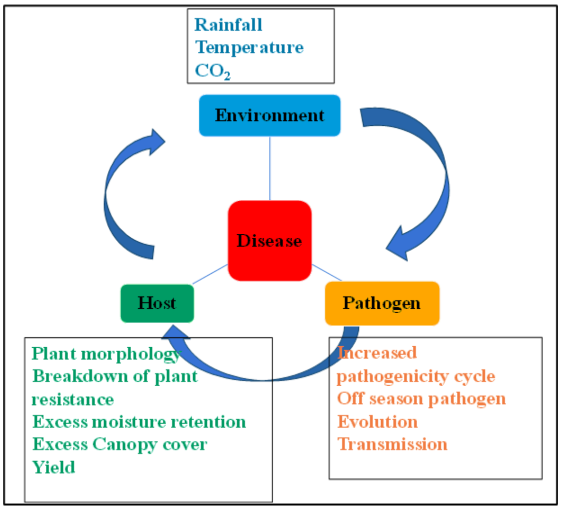

Fig. 1: Relationship between host-pathogen and environment

1.1. Temperature: Climate change significantly impacts plant disease dynamics. Rising temperatures increase disease severity by accelerating pathogen cycles of diseases (late blight in potatoes and stem canker in rapeseed), and promoting more virulent pathogen strains (Fusarium head blight and wheat stripe rust). Warmer conditions may also prolong the infection period by extending the overwintering of pathogen (wheat stem rust), and reduce the efficacy of temperature-sensitive plant resistance genes, like Lr217 and Lr210 in wheat against wheat leaf rust (Burdon and Zhan, 2020).

1.2. Rainfall and Moisture: Changes in rainfall patterns further affect disease dynamics. Higher temperatures increase humidity, promoting dew formation, which supports pathogens. Erratic rainfall facilitates water retention on leaves, encouraging diseases like late blight and powdery mildew. Conversely, drought conditions weaken forest trees and facilitate fungal diseases such as *Ganoderma*. Reduced rainfall has been linked to the intensification of rice blast and chickpea dry root rot.

1.3. Atmospheric CO_2: Atmospheric CO_2 is projected to rise to 710 ppm by 2050, benefiting C_3 plants through enhanced RUBISCO efficiency, leading to faster growth, higher photosynthesis, increased canopy cover, water use efficiency and nitrogen uptake. However, these benefits come at a cost: denser canopies create microclimates favourable for pathogens like rust and powdery mildew. Faster plant growth also benefits necrotrophic pathogens, while reduced respiration weakens plant defence. Rice blast and wheat's *Fusarium graminarium* are expected to worsen under elevated CO_2 due to nutrient imbalances and weaker resistance mechanisms (Maurya et.al. 2022).

2. Disease control under climate change scenario:

2.1. Chemical control: Chemical fungicides remain a primary tool for managing plant diseases, with usage growing annually by 2.65% in India. However, climate change impacts fungicide efficacy. Elevated CO_2 and changing weather conditions alter plant physiology, reducing fungicide penetration and increasing the need for higher doses. High temperatures degrade fungicides and reduce uptake efficiency, while erratic rainfall washes away contact fungicides. Modern fungicides like strobilurins and imidazoles offer promise with low-dose and environmentally safer formulations.

2.2. Biotechnological control: Climate change significantly influences host-pathogen interactions, requiring advancements in biotechnology for disease resistance. Techniques like PCR and ELISA enable early pathogen detection, aiding timely interventions. Marker-assisted selection (MAS) has successfully introduced resistant genes, such as Xa-13 and Xa-21, into into Pusa Basmati-1 for BLB resistance. Transgenic approaches, RNA interference (RNAi), and RNA silencing effectively enhance resistance to pathogens and pests. For instance, RNA silencing has shown success against the cotton bollworm, while transgenic tobacco demonstrates resistance to multiple pathogens.

2.3. Biological control: Biological control offers a sustainable alternative to chemical fungicides, leveraging antagonistic microorganisms like *Trichoderma* and *Pseudomonas*. These biocontrol agents suppress pathogens through enzymatic action and metabolite production. For example, rice seeds treated with fluorescent pseudomonads resist sheath blight. However, challenges such as short shelf life and environmental sensitivity hinder their widespread adoption. Advances in biotechnology could enhance the resilience and commercial viability of these agents.

2.4. Cultural control: Traditional agricultural practices remain effective in mitigating plant diseases under changing climates. Techniques like crop rotation prevent soil-borne pathogens, while planting resistant varieties and adjusting planting times reduce risks. Practices such as drip irrigation minimize leaf wetness, and proper spacing limits disease spread. Sanitation measures, including the removal of infected debris, disrupt pathogen life cycles. Additionally, intercropping and polyculture diversify ecosystems, making them less susceptible to disease outbreaks.

2.4. Technological advancement: Modern technologies like simulation models, ecological niche models, and Geographic Information Systems (GIS) enhance disease forecasting and management (Fenu and Malloci, 2021). Tools like IBSNAT and CROPSYST, tailored for crops like wheat and rice, provide predictions based on environmental data. GIS integrates pathogen and climate information for targeted interventions, as demonstrated in monitoring chickpea blight in India. Disease forecasting models such as BLASTM and EPIRICE support rice farmers in mitigating risks posed by climate-induced disease outbreaks.

CONCLUSION

Climate-induced plant diseases represent a critical threat to global agriculture, aggravating crop losses through rising temperatures, erratic rainfall, and elevated CO_2 levels. Addressing these challenges requires an integrated approach that combines cultural, chemical, biotechnological, biological, and technological measures. Sustainable practices like crop rotation, alongside advancements in forecasting tools, are pivotal in mitigating disease impacts. Collaboration among policymakers, researchers, and farmers is essential to safeguard global food security in an era of climate change.

This holistic strategy is vital not only for managing current threats but also for building resilience against future climate-induced agricultural challenges.

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