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Integrated Management of Leaf Rust in Wheat

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Abstract: Wheat, a crucial global staple, faces significant threats from leaf rust, a disease caused by the fungus *Puccinia triticina*. Identified by orange-brown pustules on leaves, leaf rust can drastically reduce wheat yield and quality. Historically, rust has affected crops for centuries, with notable epidemics in India since the 18th century. The disease spreads from both southern and northern regions of India, with initial outbreaks in December. The fungus's adaptability and windborne spores make it a persistent challenge, necessitating a multifaceted management approach. Key strategies include developing and using resistant wheat varieties with specific resistance genes (Lr genes), continuous monitoring of pathogen populations, and employing cultural practices such as crop rotation, debris removal, and strategic planting. Chemical controls, like fungicides, are effective when applied early and rotated to prevent resistance. Biological controls using beneficial microorganisms are being researched for their potential to suppress the fungus. Integrated Disease Management (IDM) combines these methods for comprehensive protection, supported by Decision Support Systems (DSS) that use weather and disease models for timely interventions. Future advances in plant breeding and biotechnology, including CRISPR, promise faster development of resistant varieties. Collaboration among stakeholders is essential for effective disease management and sustainable wheat production.

Keywords: Epidemiology, Integrated Disease Management (IDM), Leaf rust, wheat.

Introduction

Wheat serves as a crucial staple food cultivated globally. A significant threat to wheat crops is leaf rust, a disease caused by the fungus *Puccinia triticina*. This fungus, part of the

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Puccinaceae family within the Uredinales order, is a member of the Basidiomycetes/ Teliomycetes class. The Pucciniomycotina subphylum includes over 8000 identified species that act as saprotrophs and parasites on various plants, fungi, and animals. Approximately 90% of these species belong to the Pucciniales (Uredinales) order, commonly referred to as rust fungi (Aime *et al.*, 2006).

Rust has been a significant disease affecting various crops since ancient times. In Rome, a sacred festival called "**Robigalia**" was held annually on April 25th starting around 700 B.C. to appease the god of rust. Three types of rust in wheat are Black/Stem rust (*Puccinia graminis tritici* Eriks.) occurred at higher temperature, Brown/Leaf rust (*Puccinia triticina* Eriks.) occurred at intermediate temperature and Yellow/Stripe rust (*Puccinia striiformis* West.) occurred at cooler temperature. Symptoms of leaf rust, characterized by orange-brown pustules on the leaves, can significantly reduce yield and quality if not managed properly. An integrated approach combining various strategies is essential for effective and sustainable control of leaf rust (Figueroa *et al.*, 2018).

In India, systemic investigation on wheat rust was initiated by K.C. Mehta of Agra College in the year 1922- 23. Later in 1930, rust research programme were initiated at Agra and three locations (Shimla, Almora and Murree now in Pakistan) by Imperial Council of Agricultural Research to strengthened and understand epidemiology of wheat rust in India (Nayar *et al.*, 1994). Among five stages of wheat rust, Craigie (1927) demonstrated pycnia are the sexual structure and designated as mating type (+) and (-) and determine its function and variations in the life cycle of wheat rust (Aime *et al.*, 2006).

Nagarajan and Joshi (1975) provided a historical overview of wheat rust epidemics in India. In Jabalpur, epidemics occurred in 1786, and later in 1805, 1827, 1828-29, and 1837-32. In major wheat-growing regions, rust epidemics were documented in Delhi around 1843 and in Allahabad, Banaras, and Jhansi from 1884 to 1895. Western Uttar Pradesh experienced significant losses from brown and yellow rusts between 1971 and 1973. Another severe leaf rust epidemic affected approximately 4 million hectares in Northwestern India in 1993 (Nayar *et al.*, 1994). Severe outbreaks of leaf rust were also noted in Northwestern India during 1971–1972 and 1972–1973, with estimated losses of 5.9%, 24.1%, and 2.0% for the wheat varieties Kalyansona, K-68, and Sonalika, respectively (Joshi *et al.*, 1974 and 1975).

Epidemiology and Losses Caused by Wheat Rust in India

In India leaf rust spread from both South and Northern hills. First build up of leaf rust like stem rust takes place in the last week of the month of December in the plains of Karnataka South India. At the same time period it is also established in Bihar foot Hills and Eastern part of Uttar Pradesh Mehta (1940 and 1952). The rust population from South foci moves northwards towards Madhya Pradesh and Maharashtra and another population moves from the northern foot hills towards the South. Deficiencies in pathotyping system should be addressed (Huerta *et al.*, 2011). When employing specific adult plant resistance (APR) genes, testing putative non-specific resistance genes such as Lr34, Lr46, and Lr67 is often ineffective.

Periodic surveys are essential to ensure the purity of testers. New or rare virulence for genes like Lr19, Lr21, and Lr24 should be confirmed using other known sources of these genes and molecular markers, if available.

Mains and Jackson (1926) demonstrated the physiologic specialization in *Puccinia triticina*, identifying twelve races based on infection types on eleven differential wheat hosts. Pathotype 121R63 of *P. triticina* was dominant for over 20 years, but in 2016, pathotype 121R60-1 became more prevalent (Bhardwaj *et al.*, 2019). Severe epidemics and yield losses can occur if the flag leaf is infected before anthesis (Johnston *et al.*, 1934). Leaf rust epidemics in the 1930s and 1940s significantly reduced yield, grade, and protein content of stem rust-resistant cultivars like 'Thatcher' (Peturson *et al.*, 1945 and 1948). Severe leaf rust outbreaks occur when uredinia or latent infections survive the winter at a critical level or when spring-sown wheat is infected by external inoculum early, typically before heading (Chester *et al.*, 1946).

In northwestern Mexico, leaf rust epidemics during the 1976–1977 growing season affected the bread wheat variety Jupateco 73 (Dubin and Torres, 1981), likely due to race TBD/TM (Singh, 1991; Singh *et al.*, 2004).

The Challenge of Leaf Rust

Leaf rust is notorious for its ability to adapt and overcome resistance. The pathogen's lifecycle includes windborne spores that can spread quickly over long distances. This makes it essential to employ multiple control strategies to stay ahead of the disease.

Late in the growing season, leaf rust can become extreme. This escalation can be so severe that it leads to the death of the leaves, a critical component of the plant's photosynthetic system. As the season progresses, the leaves begin to produce telia, which are structures filled with black teliospores. These telia develop underneath the leaf's epidermis, primarily on the leaf sheaths and blades, which are the main photosynthetic surfaces of the plant.

However, the formation of telia is not a guaranteed occurrence. Particularly if the infection by the brown rust fungus occurs late in the growing season, the formation of telia may not take place (Dyck and Kerber, 1985). The symptoms of this disease are not uniform across all cultivars, but rather, they depend on the level of resistance that each cultivar possesses against the rust fungus.

There are some cultivars that are completely susceptible to the disease. In these cultivars, large uredinia, which are spore-producing structures of the rust fungus, form without causing any necrosis (death of tissue) or chlorosis (yellowing of tissue) in the plant tissues. On the other hand, there are resistant varieties that exhibit a range of different responses. These responses can vary from small spots to small to medium-sized uredinia, which could be surrounded by areas showing signs of necrosis and chlorosis (Kobylanski and Soludhkina, 1996). This range of responses in resistant varieties highlights the complex interaction between the plant's defense mechanisms and the pathogen's infection strategies.

Figure 1: Succeptible Wheat Cultivar (Kharchia-65) sowing severe leaf rust epidemic

Integrated Leaf rust Management Strategies

Development and Use of Resistant Varieties: One of the most effective methods to combat leaf rust is the use of resistant wheat varieties. Plant breeders focus on incorporating resistance genes (Lr genes) into new wheat cultivars. For example, genes like *Lr34*, *Lr37*, and Lr46 are known for providing durable resistance. These genes can help slow the disease and reduce its impact.

Monitoring and Adaptation: Continuous monitoring of pathogen populations is crucial. This allows breeders to identify new virulent strains and develop new resistant varieties as needed. Recent study focused to identify foci of infection and their primary source mainly in South Indian hills. The ground survey data and information collected through rain sampler, satellite television cloud photography etc. is being utilized for developing bioclimatic models and linear prediction equations.

Cultural Practices: Crop Rotation: Rotating wheat with non-host crops such as legumes or corn can reduce the amount of fungal spores in the field. This practice breaks the disease cycle and reduces infection levels in subsequent wheat crops. Removing volunteer wheat and crop debris from the previous season can help eliminate sources of the fungus. Clean fields have fewer opportunities for the rust to overwinter and spread. Timing the planting to avoid peak periods of rust spore dispersal can help reduce infection rates. In some regions, early planting can help escape the period when rust is most active.

Chemical Control: When resistant varieties and cultural practices are not enough, fungicides can be an effective tool. Fungicides like triazoles (e.g., propiconazole) and strobilurins (e.g., azoxystrobin) are commonly used to control leaf rust. These should be applied at the first sign of infection or when conditions favor disease development. To avoid fungicide resistance, it is essential to rotate fungicides with different modes of action. This practice helps maintain their effectiveness over time.

Biological Control: Research is exploring the use of beneficial bacteria and fungi that can suppress leaf rust. These microorganisms can compete with Puccinia triticina or produce substances that inhibit its growth.

Integrated Leaf rust Management (IDM)

IDM for leaf rust involves using a combination of the above methods to manage leaf rust. By integrating resistant varieties, cultural practices, chemical applications, and biological controls, farmers can reduce the risk of severe outbreaks. Additionally, Decision Support Systems (DSS) help farmers decide when to apply fungicides or implement other control measures. DSS can use weather data, disease models, and field observations to provide timely recommendations.

Future Directions

Advancements in plant breeding and biotechnology offer new possibilities for managing leaf rust. Techniques like marker-assisted selection and genomic selection can speed up the development of resistant wheat varieties. Genetic engineering, including CRISPR, holds promise for introducing new resistance traits. Understanding the biology and epidemiology of Puccinia triticina better will also improve our ability to predict and manage disease outbreaks. Collaboration between scientists, breeders, extension agents, and farmers is essential to develop and implement effective strategies.

Conclusion

Managing leaf rust in wheat requires a multifaceted approach. By combining resistant varieties, good agricultural practices, chemical controls, and emerging technologies, we can protect wheat crops from this persistent threat. Ongoing research and adaptation are key to staying ahead of the evolving pathogen and ensuring sustainable wheat production.

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