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Biotic Stress Tolerance and Implications for Breeding and Disease Management of Major Foliar Diseases of Durum Wheat (*Triticum durum* Desf.) in Tunisia

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Abstract

Durum wheat (*Triticum durum* Desf.) is a strategic cereal crop in Tunisia, where its productivity is strongly constrained by biotic stresses, particularly foliar fungal diseases. This review focuses exclusively on the three most widespread and economically important foliar diseases affecting durum wheat in Tunisia: *septoria tritici* blotch, rust diseases (stripe rust and leaf rust), and tan spot. The epidemiology of these diseases, their estimated yield losses, and their interaction with agronomic practices and climatic conditions are synthesized. Special emphasis is placed on host tolerance and resistance as sustainable management strategies, and the implications for breeding programs and integrated disease management are discussed.

Keywords: Durum Wheat; Foliar Diseases; Biotic Stress; Septoria Tritici Blotch; Rusts; Tan Spot; Disease Tolerance; Breeding; Disease Management; Tunisia

1. Introduction

Durum wheat (*Triticum durum* Desf.) plays a crucial role in food security and agricultural systems in Tunisia and across the Mediterranean region. Despite its importance, grain yield remains highly variable and frequently below its potential due to the combined effects of abiotic and biotic stresses [1,2]. Among biotic constraints, foliar fungal diseases are recognized as the most recurrent and economically damaging factors limiting durum wheat production. The Mediterranean climate of Tunisia—characterized by irregular rainfall, mild winters, and increasing climatic variability—creates favorable conditions for the development and spread of several wheat diseases. Long-term surveys and epidemiological studies have consistently identified three foliar fungal diseases as the most widespread and economically important on durum wheat: *septoria tritici* blotch (STB), rust diseases (stripe rust and leaf rust), and tan spot [3–5]. These diseases primarily affect leaf tissues, reducing photosynthetic capacity, accelerating senescence, and consequently impairing grain filling. The combined effect of simultaneous infections often results in significant reductions in both yield quantity and grain quality, including protein content and test weight.

Chemical control is commonly used to manage wheat diseases; however, its effectiveness is limited by economic costs, environmental concerns, and the rapid evolution of pathogen populations. Consequently, genetic tolerance and resistance, together with integrated management strategies, represent the most sustainable approaches for maintaining yield stability.

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Accordingly, this review emphasizes the implications of foliar disease epidemiology for breeding programs and disease management strategies, highlighting opportunities to exploit genetic sources of tolerance and resistance in Tunisian durum wheat germplasm.

2. Major foliar diseases of durum wheat in Tunisia

2.1. Septoria tritici blotch (STB)

STB, caused by *Zymoseptoria tritici*, is the most prevalent foliar disease of durum wheat in Tunisia. The pathogen is well adapted to local agro-climatic conditions and exhibits high genetic variability [6,7]. Disease development is favored by moderate temperatures and prolonged leaf wetness, with rainfall playing a key role in spore dispersal. Yield losses can range from 15% to 50% depending on disease severity, cultivar susceptibility, and seasonal climatic conditions [5,6]. Partial resistance and tolerance have been identified as more durable breeding targets than complete resistance [9].

2.2. Rust diseases

Rust diseases, primarily stripe rust (*Puccinia striiformis* f. sp. tritici) and leaf rust (*Puccinia triticina*), are recurrent threats in Tunisia. Stripe rust develops under cool and humid conditions, while leaf rust prefers warmer temperatures. Airborne urediniospores and rapid emergence of virulent races enable sudden epidemics. Yield losses range from 10% to 40% for leaf rust and may exceed 50% for stripe rust [5,10,11]. Adult plant resistance and quantitative resistance are prioritized in breeding for durable tolerance [11,12].

2.3. Tan spot

Tan spot, caused by *Pyrenophora tritici-repentis*, is increasingly important in Tunisia, especially in areas with residue retention and reduced tillage. The pathogen survives on crop residues, enabling early infection. Yield losses typically range from 10% to 30%, higher under favorable environmental conditions [5,8]. Moderate tolerance observed in several durum wheat genotypes offers opportunities for genetic improvement [9].

3. Epidemiology, Environmental Drivers, and Agronomic Interactions of Major Foliar Diseases

The epidemiology of major foliar diseases of durum wheat in Tunisia is strongly influenced by environmental conditions, cropping systems, and pathogen survival strategies. The Mediterranean climate, characterized by mild and wet winters followed by warm springs, creates favorable conditions for the development and spread of foliar fungal pathogens, particularly septoria tritici blotch (STB), rust diseases (leaf rust and stripe rust), and tan spot [3,5]. These diseases are predominantly polycyclic, with multiple infection cycles occurring during the growing season, leading to rapid disease escalation under conducive conditions.

Septoria tritici blotch, caused by *Zymoseptoria tritici*, is highly dependent on rainfall and leaf wetness for spore dispersal and infection. Frequent precipitation events during tillering and stem elongation stages promote splash dispersal of pycnidiospores from lower to upper leaves, which are critical for grain filling [4,6]. Similarly, rust diseases caused by *Puccinia triticina* and *Puccinia striiformis f. sp. tritici* are favored by moderate temperatures and high relative humidity, with stripe rust showing greater adaptation to cooler conditions typical of northern and central Tunisia [7,8]. Tan spot, caused by *Pyrenophora tritici-repentis*, survives on infected crop residues and initiates primary infections early in the season, particularly under conservation agriculture systems where residues are retained on the soil surface [10].

Agronomic practices play an important role in modulating disease pressure and epidemic development. Crop rotation with non-host species reduces primary inoculum levels, whereas continuous cereal cultivation and residue retention favor pathogen survival and increase disease incidence [18]. Sowing date is another critical factor influencing disease dynamics; early sowing often exposes crops to prolonged periods of favorable conditions for infection, while late sowing may reduce disease severity but increase vulnerability to abiotic stresses such as drought and heat [11]. Plant density and nitrogen fertilization also affect canopy structure and microclimate, indirectly influencing humidity levels and disease development.

Foliar diseases exert their detrimental effects primarily through the reduction of green leaf area and photosynthetic efficiency. Infected leaves exhibit premature senescence, decreased chlorophyll content, and impaired assimilate translocation, ultimately limiting grain filling duration and grain weight [12]. Yield losses associated with these diseases vary depending on genotype susceptibility, disease severity, and environmental conditions, but combined infections of STB, rusts, and tan spot may result in yield reductions exceeding 40% in favorable epidemic years [5,6].

Climate change is expected to further modify disease epidemiology and spatial distribution in Tunisia. Rising temperatures, altered rainfall patterns, and increased climatic variability may enhance the frequency and intensity of disease outbreaks, particularly by extending the periods conducive to pathogen reproduction and dispersal [19]. Moreover, climate-induced stress on host plants may increase susceptibility to foliar infections, while shifts in pathogen populations could lead to the emergence of more aggressive races. These evolving dynamics underscore the need for adaptive disease management strategies and for breeding programs focused on durable, quantitative resistance that remains effective across a wide range of environments.

4. Implications for Breeding and Disease Management

Effective management of major foliar diseases in durum wheat in Tunisia requires a comprehensive approach integrating genetic, agronomic, and environmental strategies. Exploiting the genetic diversity present in local germplasm, including landraces and regionally adapted cultivars, provides valuable opportunities for enhancing disease tolerance and resistance. Several studies have reported moderate to high levels of partial resistance to septoria tritici blotch, rusts, and tan spot in Tunisian wheat germplasm, highlighting the potential for breeding programs to select and combine these traits for durable protection [9,12]. Quantitative resistance, which is polygenic and generally non-race-specific, reduces pathogen reproduction, slows epidemic progression, and provides more stable protection across environments compared to single major gene resistance [11]. The integration of such genetic strategies with optimized agronomic practices—including crop rotation, residue management, optimal sowing dates, and cultivar selection—can substantially reduce disease pressure and delay epidemics. Additionally, predictive modeling and monitoring of disease outbreaks under changing climatic scenarios can guide cultivar deployment and fungicide application, ensuring efficient resource use and minimizing environmental impact. Overall, a holistic strategy combining genetic improvement, agronomic management, and climate-informed decision-making is essential for achieving sustainable durum wheat production in Tunisia.

5. Conclusion

Septoria tritici blotch, rust diseases, and tan spot constitute the most significant foliar fungal diseases constraining durum wheat production in Tunisia. Their severity is influenced by environmental conditions, agronomic practices, and pathogen evolution. Genetic tolerance and resistance, when combined with integrated management strategies, are essential for sustainable production. Breeding programs should emphasize quantitative resistance, exploit local germplasm, and ensure adaptability under changing climatic conditions. Integrated strategies that combine resistant cultivars, cultural practices, and predictive disease management can stabilize yields, maintain grain quality, and reduce reliance on chemical control, thereby supporting both economic and environmental sustainability.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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