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Rust Diseases of Wheat: A Threat to Global Food Security

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ABSTRACT

Wheat is a vital food crop globally, but its productivity is severely threatened by rust diseases caused by *Puccinia* species. The three major types are stem rust *(Puccinia. graminis tritici)*, stripe rust *(Puccinia striiformis),* and leaf rust *(P. triticina),* which affect different plant parts through a complex life cycle and develop under distinct environmental conditions. These fungal diseases reduce yield and grain quality, impacting global food security. Historical evidence and recent outbreaks highlight their persistent danger. The main approach to managing rust diseases involves breeding wheat varieties with Sr, Yr, and Lr resistance genes. However, the emergence of new pathogen races and genetic erosion pose ongoing challenges. Sustainable management requires integrating resistant varieties with agronomic practices, modern breeding, and disease monitoring.

Keywords: Wheat, Stem rust, Leaf rust, Stripe rust, *Puccinia*, Resistance genes

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Introduction

Wheat, together with rice and maize, is one of the main staple sources of calories for the global population. As a fundamental component of the world's daily meals and a key component in animal feed, the importance of wheat in global food security is undeniable [1]. Along with that, it is also the main source of plant-based protein in human diets. 735 million tons of wheat, valued at almost US$145 billion, were produced worldwide in 2015-2016 [2]. However, wheat is facing a number of diseases due to different pathogens like bacteria, protists, chromists, nematodes, and other plants. Among the plant pathogens fubgal pathogens are the largest group [3]. Accounting for the majority of plant illnesses, less than 10% of all known fungi have the ability to colonize live plants. Various fungi are engaged in a persistent symbiotic relationship with plants [4].

Ancient records suggest that diseases like mildew, blasting, and blight in wheat were, at least in part, caused by rust fungi. It is now thought that rust fungi were at least largely responsible for illnesses like blight, blasting, and mildew that infested wheat in the past. According to Aristotle. Rust emerged from "warm vapours," and he reported the harm that rust does, including years when rust outbreaks were common [5]. Wheat rust belongs to a group of rust fungi known as heteroecious rusts, which means they go through several distinct stages in their life cycle within a year. At least one of these stages occurs on a host plant that is quite different from the one where the initial or spring stage appears [6]. This article discusses the key rust diseases affecting wheat stem rust, stripe rust, and leaf rust, highlighting their causes, effects on crop production, current approaches to control and resistance, with the life cycle of Wheat Rust Fungi.

Types of rust diseases in wheat:

Leaf rust, stem rust, and stripe rust are the three primary forms of wheat rust. Each type affects discrete plant parts and is developed by a different species of *Puccinia* fungus. Moreover, their optimal setup and life cycles also differ [7].

Stem Rust (Black Rust):

The fungal pathogen *Puccinia graminis f. sp. tritici* is responsible for causing stem rust in wheat. The warm temperatures (24-30 °C), high humidity, and heavy dew are all favourable to the growth of stem rust. It mainly infects the leaves and stems of susceptible wheat varieties, but can also affect other parts of the plant, such as spikes, glumes, awns, grains, and leaf sheaths [8]. The first visible symptom is that a tiny chlorotic spot typically shows up a few days after infection. Around eight to ten days after infection,the host's epidermis ruptures as a result of the accumulation of brick-red urediniospores forming a pustule that is several millimeters long and a few millimeters wide. These pustules can grow as long as 10 mm and usually form in straight or diamond-like shapes [9]. So far, around 60 genes (referred to as "Sr genes") that grant opposition to stem rust have been recognized. Since new races of stem rust have unfolded, most of the Sr genes that have been found are no longer effective [10].

Stripe Rust (Yellow Rust)

Stripe rust, also known as yellow rust, is a wheat disease *(Triticum aestivum L.)* caused by the fungal pathogen *Puccinia striiformis.* The spores of this fungus are responsible for spreading the disease. *Triticina* is termed as "airborne disease" because it causes an infection that spreads by the wind, and yellow rust is a foliar disease of wheat [11]**.** Low temperatures are mandatory for *P.striiformis* to germinate, penetrate, grow, and sporulate. The pathogen attacks the host plants' green tissues. About a week after infection, symptoms appear, and sporulation starts a week later **[12].** Enhancing wheat's genetic resistance is a practiced technique to prevent stripe rust. For persistent resistance, research indicates that wheat breeding programs can employ slow-rusting Yr genes. The rust-resistant genes identified were Yr5, Yr9, Yr10, Yr15, Yr17, Yr18, Yr26, Yr29, Yr30, and Yr36 [13].

Leaf Rust (Brown Rust)

Puccinia triticina Eriks, a fungal pathogen, is responsible for brown rust, which primarily manifests on the leaves of affected plants. By visually examining the diseased plant's leaves, pathologists are able to detect plant diseases [14]. Rust—colored pustules on the leaves, stems, and spikes of wheat plants are one of its symptoms. Numerous rust spores are released into the environment when these pustules burst, aiding in the disease's spread [15]. There are eighty genes known to be resistant to leaf rust. Lr12, Lr13, Lr22a, Lr34, Lr35, Lr37, Lr46, Lr48, Lr49, Lr67, Lr68, Lr74, Lr75, Lr77, and Lr78 are adult plant resistant (APR) genes that are resistant to leaf rust. There is also a well-known fear of genetic erosion [16].

Life Cycle of Wheat Rust Fungi

Within the kingdom Fungi, rust fungi are members of the class Basidiomycetes, order Pucciniales. With up to five spore stages—pycniospores, aeciospores, urediniospores, teliospores, and basidiospores—they have intricate life cycles [17]. The majority of rust fungi need two unrelated hosts, usually an alternative host (such as *Berberis* spp.) and a grass host (such as wheat). On the grass host, teliospore production marks the start of the sexual cycle, during which meiosis and karyogamy take place [18]. Basidiospores, which infect the alternative host, are created when teliospores germinate. *Pycnia* grow on the alternative host, facilitating mating and the subsequent generation of aecia. After returning to infect the grass host, aeciospores produce urediniospores. During the growing season, urediniospores allow the disease to spread quickly asexually [19].

Conclusion:

Stem rust, stripe rust, and leaf rust are major wheat diseases that significantly reduce crop productivity and endanger global food security. Each of these rusts is caused by a different species of the *Puccinia* fungus. These diseases, which are induced by distinct *Puccinia* species, affect distinct plant parts and grow in varying climates, lowering grain quality and production. The enduring influence of rust fungus on wheat harvests is demonstrated by both historical documents and contemporary studies. The management of these illnesses continues to rely heavily on genetic resistance, particularly through the use of resistance genes like Sr, Yr, and Lr. However, continuous monitoring, innovative breeding, and integrated disease control are essential due to the emergence of novel pathogen races and the threat of genetic erosion. A sustainable option is to use agronomic techniques in conjunction with slow-rusting and mature plant resistance genes to strengthen wheat's resilience. To maintain consistent wheat yields in the face of changing rust threats, future efforts must integrate biotechnology, plant breeding, and disease surveillance is necessary.

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