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Ascochyta leaf spot of wheat: Disease profile and management

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ABSTRACT

Wheat (*Triticum aestivum* L.), which belongs to the order Poales and Family Poaceae, is one of the most important strategic cereal crops around the world. There are many fungal diseases that may occur with this crop. *Ascochyta* leaf spot is one of the important foliar diseases of wheat. It was found that *Ascochyta tritici* (Teleomorph: Didymellaexitialis) among many pathogens, is the main causal agent of this disease. The disease becomes severe when the weather is rainy and high humidity conditions. The disease symptoms were represented by occurring oval spots, sometimes elongated, light-colored, and surrounded by a brown margin, then generated white necroses with a very dark brown-black border. Sometimes, symptoms are like those caused by *Septoria nodorum*. Symptoms are often seen on lower leaves early in the season and on upper leaves later on, so they become less distinct with time, appearing very similar to those caused by *S. nodorum*. The disease can be controlled by using healthy seeds treated with fungicides, applying crop rotation, conventional tillage, good aeration between plants, balanced fertilization, using plant extracts, and applying many foliar fungicides. Moreover, different bioagents including *Trichoderma* spp., *Pseudomonas fluorescens*, and *Bacillus* spp. have been used to control *Ascochyta* leaf spot disease biologically and reduce the disease severity significantly. This review summarizes the current knowledge of symptoms and signs, epidemiology, ecology, disease development, disease cycle, and disease management.

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Introduction

Wheat (*Triticum aestivum* L.), which belongs to Family Poaceae, ranks as one of the most consumed cereal crops worldwide. Besides, wheat and its products are rich in calories, essential amino acids, beneficial bioactive compounds, fat, dietary fiber, vitamins, minerals (Mg, Ca, P, K, etc.), and protein (Bianchi et al. 2023). In the last three seasons (2018–2021), the annual wheat production was estimated at 732.1 to 760.9 million tonnes, cultivated in an area of 213.9–219.0 million ha. Moreover, wheat cultivation spans diverse

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regions, including the tropics and subtropics, with countries like China (134.3 million tonnes), India (107.6 million tonnes), Russia (85.9 million tonnes), the USA (49.7 million tonnes), Canada (35.2 million tonnes), France (30.1 million tonnes), and Ukraine (24.9 million tonnes) being major producers (Mitura et al. 2023).

Food availability is largely dependent on food production and distribution, which are crucial for ensuring food security. Nonetheless, Wheat is susceptible to many diseases. Thus, *Ascochyta* leaf spot, rust, snow mold, root rot, powdery, and head blight are the most widespread and harmful wheat diseases worldwide. In the absence of effective plant protection management, these fungal diseases can result in significant yield losses of up to 100% of total wheat production (Rebouh et al. 2022; Kamel et al. 2023). In this review, we were interested in the specific issue of *Ascochyta* leaf spot. Moreover, the disease affects all above-ground parts of the wheat, which results in both yield and quality losses. Under favorable environmental conditions, yield losses on susceptible cultivars can sometimes reach 80% (Khaeim et al. 2022; Foresto et al. 2023).

Previously, it was believed that the causal agent was *Septoria nodurum*, but its true identity was later to be *Ascochyta tritici* (Almeida-García et al. 2022; Retman et al. 2022; Mitura et al. 2023). In Argentina, Perelló and Moreno (2003) isolated *A. hordei* var. *europaea* from the wheat infected with *Ascochyta* blight. The causal agent *A. tritici* was firstly reported in Japan and North America. Isolates of *A. tritici* can infect wheat and other cereals leading to crop damage and yield loss, especially under favorable environmental conditions such as rainy weather and humid conditions (Khaeim et al. 2022). *Ascochyta* leaf blight is now considered one of the serious diseases on cereals and its impacts on component yield appear to be highly variable. Additionally, also it affects the photosynthetic efficiency of green leaf areas (Foresto et al. 2023). The genus *Ascochyta* (Teleomoph: Didymella) which comprises about 1000 species described worldwide, is a facultative saprophyte fungus belonging to the order Sphaeropsidales, class Coelomycetes and phylum Deuteromycota. The genus causes blight and leaf spot diseases for both monocot and dicot plants 18 species which infect monocot plants from the family Poaceae including wheat leading to high yield losses (Foresto et al. 2023).

The pathogen can be carried within the seeds, and through the soil or stay on infested crop debris (Kosiada 2012). Some researchers found that *Ascochyta* leaf spot symptoms are similar to other necrotrophic foliar pathogens in wheat and barely, therefore this can lead to an underestimation of the disease incidence and the determination of the actual spread of the disease will be difficult (Kaczmarek et al. 2016; Retman et al. 2022).

The current review focused on *Ascochyta* leaf spot disease of wheat: symptoms and signs, epidemiology, ecology, disease development, disease cycle, and disease management.

1. Symptoms and signs

Ascochyta leaf spot is often overlooked in association with other leaf spot diseases. It is reported on wheat in Japan, Europe, and North America as a pathogen of minor economic importance. Nonetheless, some reports have pointed out that high humidity conditions could favor the occurrence of disease outbreaks (Perelló & Moreno 2003; Namriboi et al. 2018; Javaid et al. 2020). Its distribution and frequency may be greater than realized because most cereals and grasses throughout the world are susceptible to *Ascochyta* spp. and isolates from wheat have a broad host range among the Poaceae (Perelló & Moreno 2003; Retman et al. 2022).

This disease was the first to have been identified on wheat in Tunisia (Nasraoui et al. 1997), with more or less oval spots, sometimes elongated, light-colored, and surrounded by a brown margin. Submerged black fungal structures (pycnidia) develop within necrotic lesions; these appear as tiny black dots (Fig. 1) (Nasraoui et al. 1997). In addition, *Ascochyta* can cause leaf spots and blight turf grasses besides cereal crops (Krupinsky & Cline 2010; Foresto et al. 2023).

Fig 1. *Ascochyta* leaf spot symptoms (Retman et al. 2022).

Ascochyta leaf spot of wheat (Fig. 2a) is always overlooked in conjunction with other leaf spot diseases, these diseases can resemble *Ascochyta* leaf spot symptoms in wheat. Among these diseases:

Septoria leaf blotch: This disease is caused by the fungus *Zymoseptoria tritici*. It leads to the formation of small, dark brown to black spots with a yellow halo on wheat leaves. It can sometimes be confused with *Ascochyta* due to the similar appearance of lesions (Fig. 2b) (El Jarroudi et al. 2023).

Stagonospora leaf and glume blotch: *Stagonospora* spp. and *Parastagonospora* spp. are the fungi responsible for this disease. Symptoms include elongated, dark brown to black lesions with a yellow halo. These lesions can be mistaken for *Ascochyta* leaf spot (Fig. 2c) (Mehra et al. 2017; Bartosiak et al. 2021).

Tan Spot: Tan spot in wheat is caused by *Pyrenophora tritici-repentis*. It results in tan-colored lesions on wheat leaves with a dark brown border. These lesions may look similar to *Ascochyta* leaf spot symptoms (Fig. 2d) (Maulenbay et al. 2022).

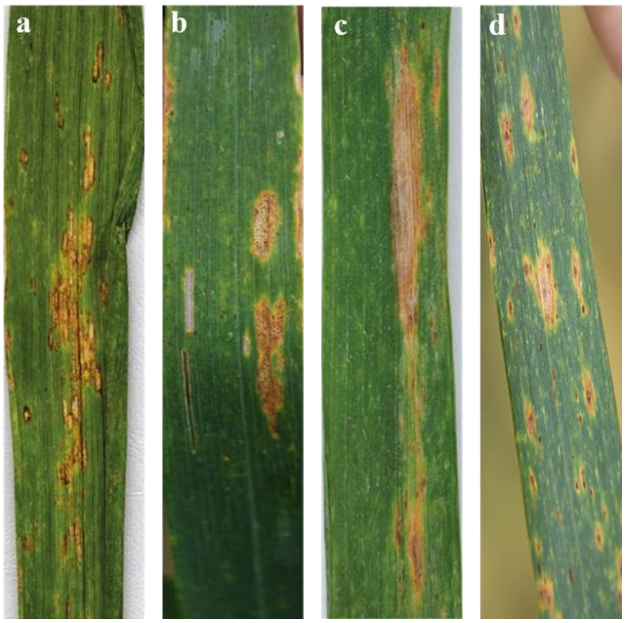

Fig 2. Symptoms of *Ascochyta* leaf spot (Retman et al. 2022) (a), *Septoria* leaf blotch (El Jarroudi et al. 2023) (b), *Stagonospora* leaf and glume blotch (Mehra et al. 2017; Bartosiak et al. 2021) (c), and tan spot (Maulenbay et al. 2022) (d) on wheat leaves.

2. Causal agents

Leaf spot diseases of wheat are caused by different pathogenic fungi. The most important are *Phaeosphaeria nodorum* (Müller) Hedjaroude (anam. *Stagonospora nodorum* (Berk.) Cast. & Germ. = *Septoria nodorum* (Berk.) Berk.), *Zymoseptoria tritici* (Roberge ex Desm.) Quaedvl. & Crous (anam. *Septoria tritici* Berkeley & Curtis), *Pyrenophora tritici-repentis* (Died.) Drechs. (anam. *Drechslera tritici-repentis* (Died.) Shoem.). Other leaf spot pathogens on wheat are *Cochliobolus sativus* (lto & Kuribayashi) Drechs. ex Dastur (anam. *Bipolaris sorokiniana* (Sacc.) Shoem.), *Fusarium* spp., *Ascochyta* spp., *Phoma* spp. (Nasraoui et al. 1997; Šárová et al. 2003; Retman et al. 2022). *Ascochyta* leaf spot disease of wheat is caused by *Ascochyta tritici* Hori & Enjoji which belongs to the family: Didymellaceae, order: Pleosporales, class: Dothideomycetes, Subclass: Pleosporomycetidae, phylum: Ascomycota, Subphylum: Pezizomycotina, kingdom: Fungi, and Domain: Eukaryota. The teleomorph of this fungus is *Didymella* which belongs to the family: Didymellaceae, order: Pleosporales, class: Dothideomycetes, Subclass: Pleosporomycetidae, phylum: Ascomycota, Subphylum: Pezizomycotina, kingdom: Fungi, and Domain: Eukaryota (Webster & Weber 2007). The genus was first described by Libert in 1830 who considered the conidia of this genus as very small asci and the content of the cells as small globose conidia (Retman et al. 2022). *Ascochyta* produces dark globose to subglobose pycnidia and hyaline straight to slightly curved, two-celled with rounded ends conidia. Pycnidia are leathery to carbonaceous, usually have a circular opening, and are easily seen at low magnification with a compound microscope. *Ascochyta* can survive as conidia in pycnidia on dead leaves. When the weather is wet, the conidia ooze from each pycnidium and disperse by irrigation, splashing rain, and other management activities.

3. Disease cycle and Epidemiology

The fungus remains as pycnidia in infected stubbles. Primary infection is caused by conidia released from these pycnidia and spread by wind and rain. Besides, this is how secondary infections occur during the growth of the wheat on which the pycnidia that release conidia develop (Fig. 3), the rainy weather and high humidity conditions are more suitable for this disease (Nasraoui et al. 1997; Foresto et al. 2023).

Ascochyta generates white necroses with a very dark brown-black border, regardless of the cereal affected. The necroses weaken the leaf blade which becomes translucent, even cracking as it ages (Nasraoui et al. 1997; Perelló & Moreno 2003; Krupinsky & Cline 2010; Jha et al. 2022). If the shape of the spots can be very varied (oval, long along the edge of the leaf, or very irregular, even forming networks) and is therefore not part of the diagnostic criteria, the key to the determination is the presence of brown to black

pycnidia within these necroses, more or less discreet depending on their degree of maturation. After the realization of an incubation chamber, iridescent white to light brown cirrhes are expelled from these pycnidia and contain the pycnidiospores (Nasraoui et al. 1997; Perelló & Moreno 2003; Krupinsky & Cline 2010; Retman et al. 2022) (Fig. 3).

If the white color of the necroses associated with very dark irregular contours makes it possible to distinguish ascochytosis from septoriosis, these symptoms can also be confused with "chemical burns" caused by a lack of selectivity of foliar herbicides such as Bifenox, or with rhynchosporiasis of barley. Nonetheless, neither of these two symptoms would show pycnidia on the necrotic surface, unlike *Ascochyta* (Nasraoui et al. 1997; Perelló & Moreno 2003; Krupinsky & Cline 2010; Foresto et al. 2023) (Fig. 3).

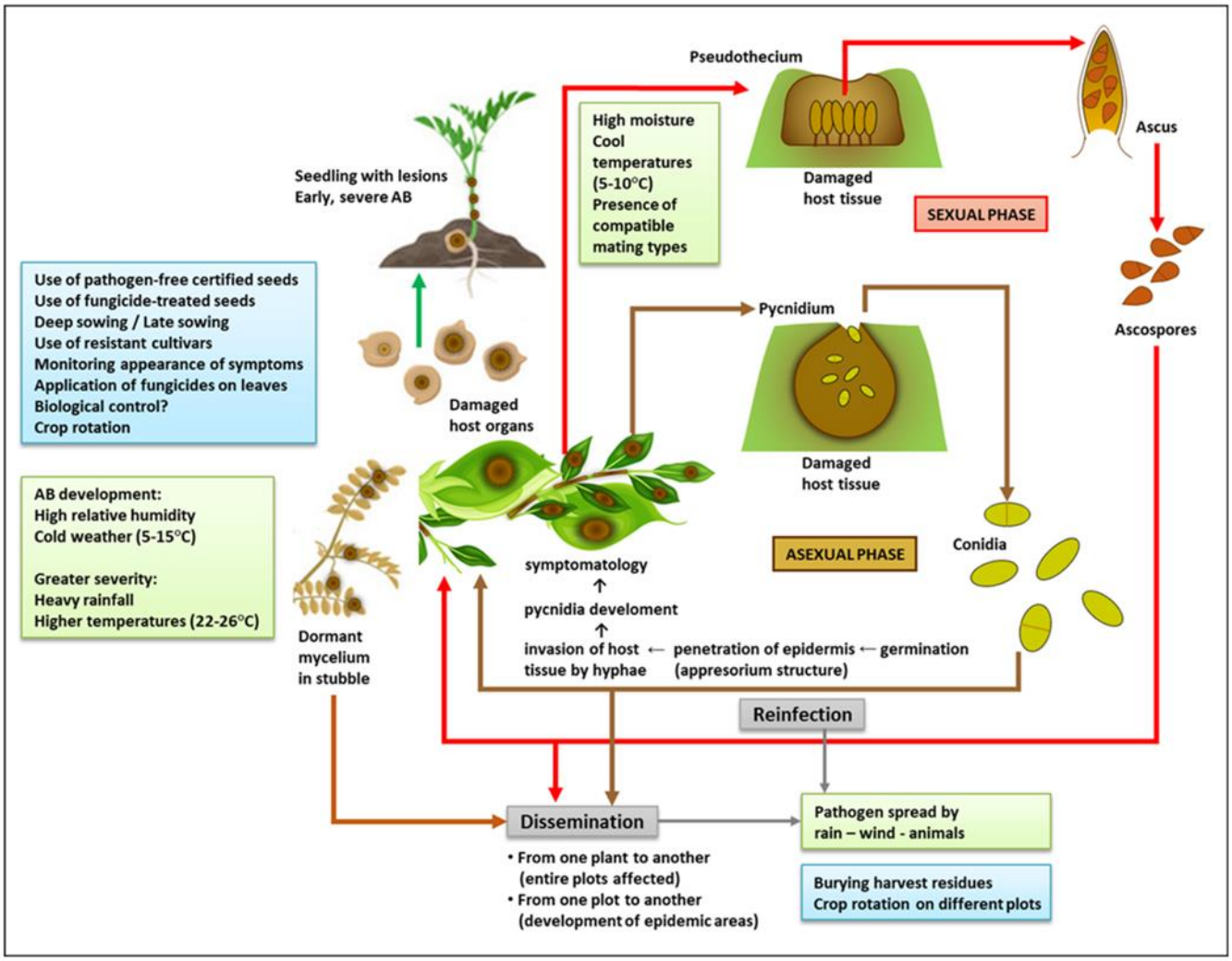

Fig 3. Integrated view of *Ascochyta* leaf spot (AB) disease: life cycle, predisposing environmental conditions (Foresto et al. 2023).

4. Disease management

To prevent *Ascochyta* development, use healthy seeds treated with fungicides, promote crop rotation (> 2 years) with non-host plants, conventional versus minimum tillage, good aeration between plants (wider rows), and balanced fertilization. Cultural practices can be clear as the methodical technique of raising crops right from land groundwork to reaping the crop. In other words, it can nasty any practice that is related to field processes, culturing/caring of the crop plants involving

land preparation/tillage, seed bed basis, deep sowing of seed, seed treatment, elimination and destruction of dead plant debris, crop rotation, retreating, gap filling/re-sowing, after/inter cultivation, weed management counting mulching, molding, irrigation, nutrient management, water organization, plant protection measures, intercropping wheat with chickpea, barley, mustard, etc. Thus, nitrogen fertilization, time of fungicide software, and sowing date affect the reduction of wheat *Ascochyta* leaf spot. Doping-specific cultural practices will help, particularly when there is group action by all the farmers of a region (Vahamidis et al. 2020; Rhouma et al. 2021a, b, c, d; Annan et al. 2023; Foresto et al. 2023).

Fungicides (protectants and systemic) are effective and should be applied at the heading. Chemically treated fields have been shown to yield 10-20% more than untreated fields (Nasraoui et al. 1997). Delayed sowing also may result in reducing disease incidence significantly depending on environmental conditions. Using foliar fungicides such as azoxystrobin, triazoles, carbendazim, boscalid, iprodione, and thiabendazole is considered an effective method to suppress and reduce the disease development, also treating seeds with fungicides like bavistin + theram, captan, rovral and hexacap considered an effective method too (Nasraoui et al. 1997; Namriboi et al. 2018).

The rapidity with which the disease spreads makes it very difficult to follow only chemical control (Liu et al. 2016) which has many risks including hazardous effects on human and animal health, effects on non-target organisms, the entrance of residual toxic compounds in the food chain and effects on microorganism biodiversity (Rhouma et al. 2021e; Hajji-Hedfi et al. 2022; Hajji-Hedfi et al. 2023). Therefore, the researchers developed many programs to control plant diseases by using eco-friendly biopesticides which contain biological control agents like arbuscular mycorrhiza, endophytic fungi (*Trichoderma* spp., *Chaetomium* spp., *Gliocladium* spp., *Paecilomyces* spp., *Acremonium* spp., *Beauveria* spp., etc.) and bacteria (*Bacillus* spp., *Pseudomonas* spp., *Streptomyces* spp., etc.) (Azizpour & Rouhrazi 2016; Hossain et al. 2016; Liu et al. 2016; Naghed et al. 2016; Garcia de Leon et al. 2020). Plant extracts (*Azadirachta indica*, *Lawsonia alba*, *Allium sativum*, *Zingiber officinale*, *Nigella sativa*, *Withania somnifera*, etc.) are effective in decreasing the severity of *Ascochyta* leaf spot of wheat (Hossain et al. 2016; Javaid et al. 2020). Moreover, compost, vermicompost, and organic manure can decrease the severity of airborne phytopathogens of wheat (Adhikari et al. 2023; Aguilar-Paredes et al. 2023; Marín-Guirao et al. 2023; Pereira et al. 2023).

Resistance is divided into two categories: qualitative resistance refers to the reaction of wheat governed by a specific gene that offers high levels of resistance at the seedling growth stage; while, quantitative resistance refers to many genes that offer partial levels of conflict at the adult plant stage (Zhan et al. 2008; Jha et al. 2022). At the seedling growth stage, qualitative resistance genes have regularly been exposed (Zhang et al. 2020; Jha et al. 2022). Furthermore, both types of confrontation are crucial, and combining these genes into new cultivars is feasible to produce more lasting disease control (Shoaib et al. 2018; Jha et al. 2022). Gene expression can touch basal defense transcripts and transcripts unique for the formation of a necrotrophic relationship with associated fungi.

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