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Major Fungal Diseases of Maize and their Integrated Management Strategies

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ABSTRACT

In this study generation mean analysis (GMA) approach was used to Maize (*Zea mays* L.) is one of the most extensively cultivated cereal crops, serving as a staple food and a major source of income for millions of farmers worldwide. In India, it is the third most important cereal crop grown after rice and wheat, contributing significantly to food and nutritional security, feed for livestock, and used as raw material in several industries. However, its production and productivity are drastically reduced by several diseases caused by fungi, bacteria, viruses, and nematodes. Among the various biotic agents, fungal diseases significantly affect maize yield. Major fungal diseases affecting maize are Turcicum Leaf Blight (*Exserohilum turcicum*), Maydis Leaf Blight (*Bipolaris maydis*), Common Rust (*Puccinia sorghi*), Downy Mildew (*Peronosclerospora sorghi*), and Banded Leaf and Sheath Blight (*Rhizoctonia solani*) in India. These diseases not only decrease the yield but also reduce the quality of grain, resulting in food insecurity and economic losses. Integrated Disease Management (IDM) provides a sustainable measure for mitigating these challenges by integrating multiple strategies such as cultural, biological and chemical control methods. Advances in pathogen diagnostics, molecular breeding, and precision agriculture tools further enhance the efficacy of these strategies. This study explores the major fungal diseases of maize, their pathogen, symptoms, epidemiology, and the modern integrated management approaches, while emphasizing the importance of collaborative efforts between scientist, farmers, and policymakers to safeguard sustainable maize production and national food security.

Key words : *Zea mays*, Fungal diseases, IDM, Turcicum leaf blight, Banded leaf and sheath blight.

Introduction

Maize is a multifaceted crop with several uses, *viz.* for food, feed, industrial applications, energy, and pharmaceuticals. As a food source, maize is consumed in numerous ways such as sweet corn, cornmeal, and flour. Besides this, it is used as an essential ingredient in animal feed,

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mainly for livestock and poultry. Its industrial uses are diverse, with maize oil, starch, and other derivatives being used to produce food, textiles, paper, biodegradable plastics, and pharmaceuticals. It is also used to produce a biofuel (ethanol) blended with petrol. In 2022, about 1.17 billion metric tons (MT) of maize were produced, which was 33.8% higher than that of rice (0.78 billion MT) and 30.9% higher than that of wheat (0.81 billion MT). Worldwide maize production has increased from 0.89 billion MT in 2012 to 1.17 billion MT in 2022, growing at a decadal CAGR of 2.9%. The USA was the major producer of maize contributing around 30% of global production followed by China (24%) and Brazil (9%) in 2022. Worldwide maize consumption has increased from 988.6 million MT in 2013 to 1236.8 million MT in 2023 growing at a decadal CAGR of 2.3%. Global exports rose at a decadal CAGR (2013-2023) of 5.1%, increasing from 122.8 million MT in 2013 to 202.1 million MT in 2023. India ranked 4th in maize acreage and 5th in production contributing to around 4.9% of the acreage and 2.9% of production respectively worldwide in 2022. In India, about 22% of maize is directly consumed as food whereas a major share of production is used for industrial usage mostly for animal feed and starch. Maize is predominantly grown in two seasons: *kharif* (75% area) and *rabi* (20% area), with the average productivity of *kharif* maize being 2.94 MT/ha and *rabi* maize 5.36 MT/ha respectively (https://ficci.in/api/press_release_details/4944). It is cultivated in diverse agro-climatic zones, ranging from tropical to temperate regions, and supports the livelihood of millions of farmers. Despite advancements in production techniques, maize yields are often compromised by several biotic and abiotic constraints, among which fungal diseases are prominent. The major fungal diseases affecting maize in India, include Turcicum Leaf Blight (*Exserohilum turcicum*), Banded Leaf and Sheath Blight (*Rhizoctonia solani*), Maydis Leaf Blight (*Bipolaris maydis*), Common Rust (*Puccinia sorghi*), and Downy Mildew (*Peronosclerospora sorghi*). These diseases reduce not only the crop yield but also the quality of the grain, posing a serious threat to the food and nutritional security and income of the farmer. The effective management of fungal diseases requires an integrated approach that combines cultural, biological, chemical, and genetic strategies. For each disease, we discuss the pathogen, symptoms, disease cycle, predisposing conditions, and recent integrated management strategies.

1. Turcicum leaf blight

Introduction

Turcicum leaf blight of maize is caused by the fungus *Exserohilum turcicum* (Pass.) teleomorph, *Setosphaeria turcica* (Luttrell) K. J. Leonard and E. G. Suggs (Singh *et al.*, 2019). The disease has a worldwide distribution particularly in areas where high humidity (75-90 %) and moderate temperature (22-25°C) prevails during the cropping season (Chung *et al.*, 2010; Sibiya *et al.*, 2013). The epidemic of the disease is increasing every year in all maize-growing areas because of intensive maize cultivation (Tirtha *et.al.*, 2016). The loss in grain yield ranges from 24 to 91 % (Pant *et al.*, 2000; Nwanosike *et al.*, 2015).

Turcicum leaf blight (TLB) disease of maize is of worldwide importance. The first time TLB was reported from New Jersey, USA, in 1878 and a serious epidemic happened in Connecticut, USA in 1889. In India, too, severe losses of 25–90% in grain yield due to TLB epiphytotic have been reported (Chennulu, 1962; Jha, 1993 and Harlapur, 2005). Recently, there has been an increase in the TLB disease incidence in the maize-producing regions. Vivek *et al.* 2010 reported that the incidence and severity of TLB had increased, especially in Southern Africa, in the past 3–5 years. It is predominantly prevalent in hilly states like Uttarakhand, Himachal Pradesh, North-Eastern States, West Bengal, Bihar, Karnataka, and the union territories of Jammu & Kashmir (Aggarwal *et al.*, 2021).

Symptoms

The disease arises from the seedling stages to maturity in maize. If the disease develops before silk emergence, the damage is maximized. Severe incidence at an early stage causes premature death of the plant and blighted leaves thereby economically affecting the fodder quality which is of great value when, it is used as a fodder crop during the lean season (Patil, 2000). Besides yield loss, it causes qualitative changes in the seed as a result the germination capacity and sugar content decrease, and highly infected plants are susceptible to stalk rot (Cardwell *et al.*, 1997, Reddy *et al.*, 2013).

The disease starts as elongated, spindle-shaped, greyish-green to tan lesions on leaves. Lesions may coalesce, leading to extensive blighting and premature leaf senescence (Hooda *et al.*, 2016). The symptom of the disease in maize is a severe defoliation especially during grain-filling period (Sibiya *et al.*, 2013).

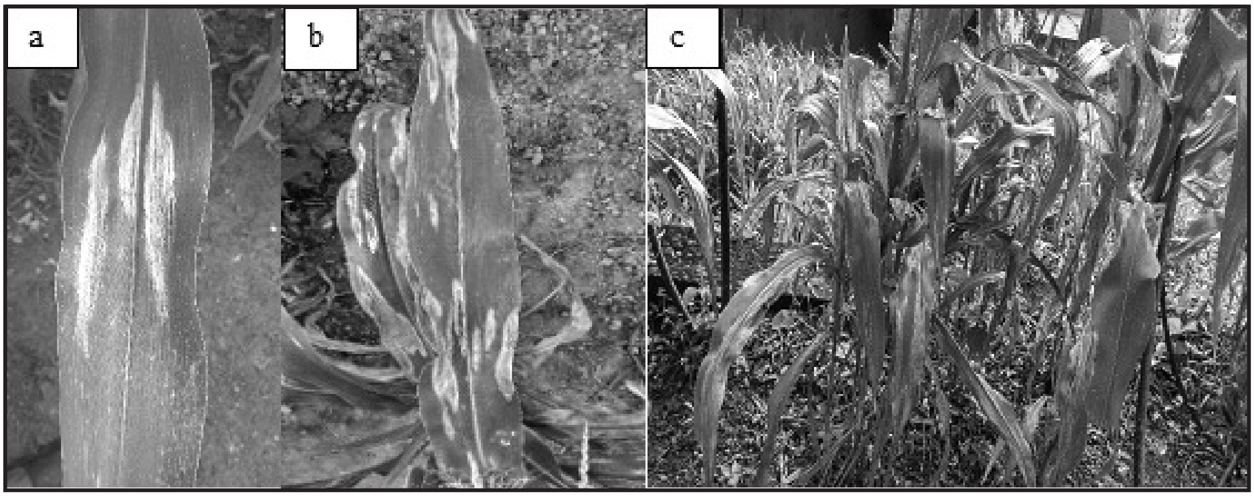

Figure 1 : TLB disease symptom on leaves (a, b) and TLB infected field (c) Pathogen

Turcicum leaf blight is caused by the fungus *Exserohilum turcicum* (Pass.) teleomorph, *Setosphaeria turcica* (Luttrell) K. J. Leonard, and E. G. Suggs.

Nature of the Pathogen :

Setosphaeria turcica is classified as a hemi biotrophic ascomycete fungus. The pathogen initially establishes itself as a biotroph, feeding on the living tissues of the maize plant. At this stage, it causes minimal damage and ensures continued nutrient extraction. Over time, the fungus transitions into a necrotrophic phase, killing plant tissue to derive nutrition from the dead or decaying material. This dual nature allows the pathogen to maximize its survival and spread across maize fields, making it particularly challenging to manage (Hooda *et al.*, 2016).

Predisposing Conditions

The development and spread of Turcicum Leaf Blight are strongly influenced by specific environmental factors :

Temperature : Moderate temperatures in the range of 20°C to 28°C are highly conducive to disease progression. These conditions favour the germination of fungal spores and the growth of mycelia.

Humidity : High relative humidity, particularly above 90%, promotes the development of the disease by facilitating spore germination and infection.

Moisture : Prolonged periods of leaf wetness due to rain, dew, or overhead irrigation create an ideal environment for conidial infection and fungal proliferation.

Dense Canopy : Overcrowding of maize plants reduces air circulation, thereby increasing humidity levels within the crop canopy and encouraging disease establishment.

Disease Cycle

The life cycle of *Exserohilum turcicum* involves multiple stages of survival, dispersal, and infection, which ensure the pathogen's persistence across cropping seasons:

Survival Phase

The pathogen primarily overwinters as mycelia and conidia on infected crop residues such as leaves, husks, and plant debris left in the field. These structures serve as primary inoculum sources for initiating infection in the subsequent cropping season.

Dispersal Phase

The fungal conidia (asexual spores) are dispersed through wind over long distances and by splashing rainwater during wet weather. This enables the pathogen to spread rapidly within and between fields.

Infection Phase

Under favourable conditions (warm temperatures, high humidity, and leaf wetness), the conidia land on susceptible maize plants and germinate. The germinated spores penetrate the leaf surface, establishing the pathogen and leading to the formation of lesions.

Secondary Spread

Once the initial infection develops, secondary conidia are produced on the lesions. These conidia serve as the source for secondary infections, further spreading the disease within the crop. This continuous cycle of infection and conidial production allows the disease to escalate rapidly, particularly under prolonged favourable conditions.

Management Strategies

- Several management strategies can be employed to manage TLB Disease :

- Use of varieties or hybrids which are resistant or tolerant to TLB.
- Practice crop rotation with non-host crops like legumes.
- Removal of crop residues to reduce the inoculum.
- Application of fungicides like Indofil M-45(mancozeb) @2.5 ml/lit of water or azoxystrobin 18.2% + difenoconazole 11.4 SC w/w @1 ml/lit of water. The initial spray should be immediately after the appearance of the symptom followed by a second spray at 10 to 15 days intervals.

2. Banded Leaf and Sheath Blight (BLSB)

Introduction

The disease was first reported in Sri Lanka (Bertus 1927) and in India it was first reported in the Tarai region of Uttar Pradesh (Payak and Renfro, 1966). It causes a yield loss from 11 to 40% depending on the environmental condition. The causal organism is *Rhizoctonia solani* Kuhn and the perfect stage is *Thanatephorous cucumeris* (Frank) Donk. In India, it affects most maize-growing states such as Himachal Pradesh, Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, West Bengal, Odisha Telangana, Delhi, and Northeast India (Aggarwal *et al.*,2021).

Symptoms

Generally, the symptoms appear on 42-50-day-old maize plants. At first water-soaked straw-coloured necrotic lesion alternating with dark brown bands developed on basal leaf sheaths. Later on, lesions enlarge and coalesce with each other and spread upwards. In later stages, dark brown sclerotia developed on diseases husk, sheaths, and maize cob. In case of severe infestation developing cops are completely damaged and dried.

Figure 2 : BLSB disease symptom on Maize on sheaths (a), cob b), sclerotia developed on leaf sheath and cob (c, d)

Pathogen

Banded Leaf and Sheath Blight is caused by the fungus *Rhizoctonia solani* Kuhn, with its sexual or perfect stage identified as *Thanatephorus cucumeris* (Frank) Donk.

Nature of the Pathogen

Rhizoctonia solani is a soil-borne fungal pathogen with an exceptionally wide host range, infecting 263 plant species across 43 families (Di *et al.*, 2023). This broad adaptability allows the fungus to survive and thrive under diverse agro-ecological conditions, making it one of the most challenging pathogens to control. The pathogen primarily produces sclerotia (hard, resting fungal structures) and mycelium, which serve as primary sources of infection and ensure long-term survival in the soil.

Predisposing Conditions

The occurrence and severity of BLSB are influenced by specific environmental and agronomic conditions that favour pathogen proliferation and infection:

Temperature : Optimal temperatures ranging between 25°C and 30°C create ideal conditions for the germination of sclerotia and growth of the pathogen.

Humidity : High levels of relative humidity, often associated with rainy weather or irrigation, provide the moisture required for infection and disease development.

Dense Planting : Overcrowding of maize plants reduces airflow within the canopy, leading to increased humidity levels and prolonged leaf wetness, which facilitate pathogen spread.

Excessive Nitrogen Application

High nitrogen levels promote lush vegetative growth, making plants more susceptible to fungal attack by creating a dense canopy and nutrient-rich tissue favourable for infection.

Disease Cycle

The life cycle of *Rhizoctonia solani* involves multiple stages of survival, dissemination, and infection, enabling it to persist in the soil and spread efficiently within maize fields :

1. **Survival Phase**
   - o The pathogen survives in the soil and crop residues primarily as **mycelium** or **sclerotia**.
   - o **Sclerotia**, which are hard, compact resting structures, can remain viable in the soil for **several years**, making it difficult to eradicate the pathogen from infested fields.
2. **Primary Inoculum Sources**
   - o The primary sources of inoculum include **sclerotia in the soil** and **alternate grass hosts**, which act as reservoirs for the pathogen during the off-season.
   - o The pathogen can also survive on plant debris left in the field after harvest.
3. **Dispersal Phase**
   - o The spread of the pathogen occurs through **irrigation water**, **flooding**, and the movement of **contaminated soil** or infected plant debris.
   - o Sclerotia and mycelium are dispersed across fields during

farming operations, such as ploughing and irrigation, enabling the pathogen to infect new plants.

4. **Infection Phase**
   - o Under favorable conditions (high humidity and warm temperatures), the sclerotia germinate, and the fungal mycelium infects the plant tissues, starting from the lower leaf sheaths.
   - o The pathogen spreads upward, infecting adjoining tissues, including leaves and cobs, through direct contact with diseased plant parts.

5. **Secondary Spread**
   - o Once infection is established, the disease spreads rapidly within the crop canopy through **contact between infected and healthy tissues**.
   - o This secondary transmission ensures that the pathogen can affect a significant portion of the crop under favorable environmental conditions.

Management

- Use good-quality seed and tolerant or resistant varieties or hybrids.
- Apply balanced fertilizer to avoid excessive nitrogen application.
- Timely weeding and removal of infected plant debris.
- Stripping of two to three lower leaves with their sheaths in contact with the soil so that it reduces the chance of pathogen spread from the infected plant debris to the healthy plant.
- Spray Azoxystrobin 18.2% + Difenconazole 11.4% w/w SC (Amistar Top 325 SC) @ 1ml/lit. of water just after symptoms are seen and if required again spray at 10-day interval.

3. Common rust

Introduction

The disease was appeared in the American continent for long back. In India, it is reported for the first time by Mishra in 1963. It causes up to 61% yield loss under severe infestation. In India, it is prevalent in maize-growing states such as Himachal Pradesh, Haryana, Maharashtra, Tamil Nadu, Karnataka, Northeast India, and the union territories of Jammu & Kashmir (Aggarwal *et al.*, 2021).

Symptoms

The symptoms are characterized by round to oval, elongated cinnamon-brown pustules scattered over both leaf surfaces. The postulates of this rust are large circular elongated brown to cinnamon. In case of severe infestation, the leaf tissue becomes necrotic, affecting photosynthesis and grain filling. These pustules rupture and expose dusty red urediniospores which are spread through wind and can infect other maize leaves directly. The pustules are frequently seen on leaves, but these may appear on any maize plant part *viz.* stalk and sheath etc. The rusting symptoms generally appear on 35 to 40 days old maize plant later on these symptoms may be found at any crop growth stage.

Pathogen

The causal organism of common rust is the fungus *Puccinia sorghi* Schw.

Nature of the Pathogen

Puccinia sorghi is an obligate parasite that relies on living host plants for survival and reproduction. It primarily produces urediniospores, which play a key role in spreading the disease through wind dispersal.

Predisposing Conditions

The development and spread of common rust are influenced by specific environmental factors:

Temperature : Moderate temperatures in the range of 16°C to 23°C provide optimal conditions for pathogen development and spore germination.

Relative Humidity : High relative humidity creates a favourable environment for rust infection, particularly during periods of cool and moist weather.

Disease Cycle

The life cycle of Puccinia sorghi involves both survival and dissemination stages, ensuring the continuity of the disease:

Primary Inoculum Sources (PSI)

The primary inoculum consists of uredospores that survive on infected plant residues and alternate hosts. Alternate hosts of the pathogen include plants such as *Oxalis corniculata* and *Euchlaena mexicana*, which act as reservoirs for the fungus during unfavourable conditions.

Infection Phase

Infection begins when urediniospores land on susceptible maize plants under cool, moist conditions. The spores germinate and penetrate the plant tissues, initiating the formation of pustules on leaves and other plant parts.

Dispersal

Urediniospores produced in the ruptured pustules are dispersed by wind, enabling the pathogen to spread rapidly across fields and cause subsequent infections.

Survival

The fungus survives through spores on alternate hosts, ensuring its persistence across cropping seasons.

Management

- Manage the residue through sanitation (cleaning up debris or infected plant)
- Practice crop rotation with non-cereal crops
- Cultivation of rust-resistant or tolerant varieties/hybrids and farmers are advised to choose a specific tolerant or resistant hybrid of their location.
- Early sowing (May to June) is recommended to avoid peak infection periods.
- Plough down the crop debris which may reduce initial infection.
- Spray of mancozeb (Indofil M-45) fungicide @ 2.5-4g per liter of water at the initial appearance of pustules. If the incidence of the disease is higher, 3 sprays at 10 days intervals are recommended. Spraying of propiconazole 25% EC (Tilt) at the rate of 1ml per liter of water (Aggarwal *et al.*,2021).

Figure 3 : common rust disease symptom on maize leaves

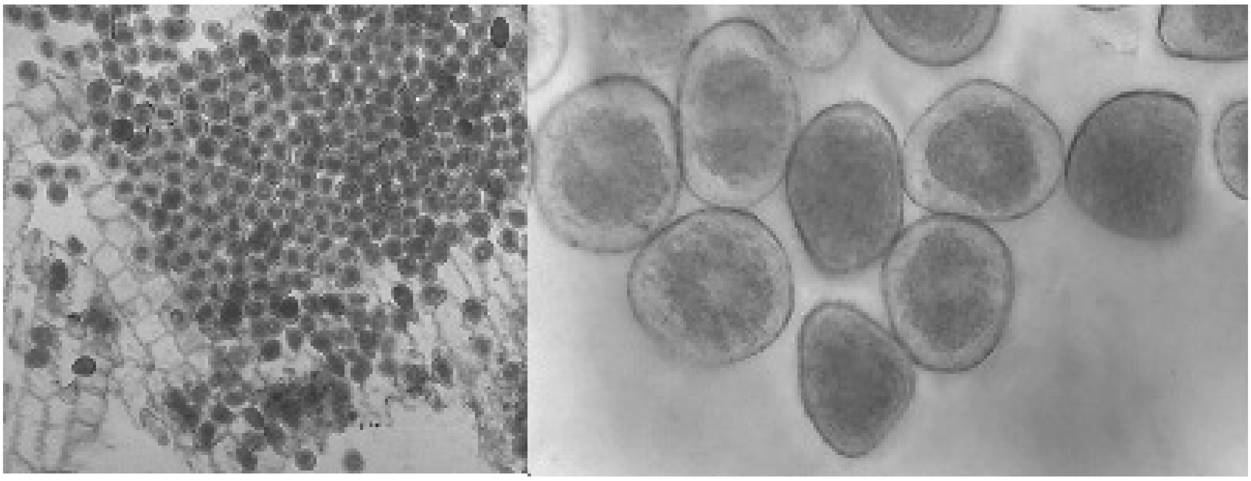

Figure 4 : Urediniospores of *Puccinia sorghi* Schw. seen on maize leaves under the microscope

4. Maydis Leaf Blight (MLB)

Introduction

The incidence of Maydis leaf blight disease was the first time reported by Drechsler as *Helminthosporium maydis* in 1925 from the USA. In India, it was reported for the first time from Maldah, West Bengal by Munjal and Kapoor in the year 1960. The disease may cause losses of up to 70% or even more under favorable conditions. The disease is common across the country.

Symptoms

The disease infects the crop from the seedling to the harvesting stage. The disease can be recognized by the presence of almost rectangular-shaped brown to necrotic lesion either on the upper or lower leaves. Lesions are initially small, round to oval, diamond-shaped, and later they merge to form large irregular patches. Under severe disease incidence, generally when infection arises before silking, lesions may coalesce, blighting the whole leaf. The disease epidemics occurring in the initial stage leads to premature drying of the blighted leaves and loss their fodder value (Aggarwal *et al.*,2021).

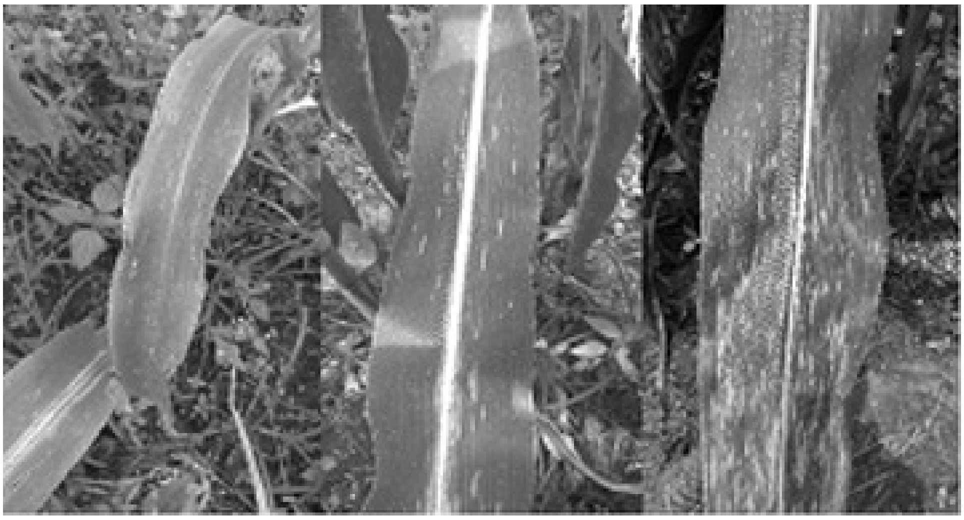

Figure 5 : MLB disease symptom on maize leaves

Pathogen

The causal organism responsible for Maydis Leaf Blight is *Bipolaris maydis*.

Nature of the Pathogen

Bipolaris maydis is a seed-borne fungus capable of infecting a wide range of crops and grasses in addition to maize. It produces conidia, which act as the primary inoculum for initiating the disease cycle.

Predisposing Conditions

The development and spread of Maydis Leaf Blight are favoured by the specific climatic conditions:

Temperature: The optimal temperature for conidial germination ranges from 8°C to 27°C.

Humidity : A warm and humid climate is most conducive to disease development, especially when free water is present on the leaf surface.

Wet Season : Infection is more prevalent during the early phase of the wet season when prolonged leaf wetness occurs.

Disease Cycle

The life cycle of *Bipolaris maydis* involves multiple sources of inoculum and modes of survival, ensuring its persistence across seasons:

Primary Source of Inoculum

The fungus primarily survives as a seed-borne pathogen, infecting maize seeds and enabling the disease to initiate at an early crop stage.

Alternate Hosts

Bipolaris maydis also infects other crops such as wheat, barley, sorghum, oats, and sugarcane, which serve as alternative hosts. The pathogen's spores have been found associated with seeds of plants like cowpea, Johnson grass, Sudan grass, and Teosinte, further contributing to its spread.

Disease Spread

Conidia produced on infected plants are dispersed by wind, rain, and contaminated soil, facilitating secondary infections during favourable weather conditions.

Survival

The pathogen can persist on infected crop debris and seeds, ensuring its carryover to the next cropping season.

Management

- Treat the seeds with Thiram or Captan @ 4 g/kg of seed.
- Collect the infected crop residue from the field after harvesting and destroy it.
- Use resistant or tolerant hybrids and hence farmers are advised to choose particular resistant or tolerant hybrid for their location.
- Spray Indofil M-45(mancozeb) @2.5 ml/lit of water or Azoxystrobin 18.2% + Difenconazole 11.4% w/w SC (Amistar Top 325 SC) @ 1ml/lit. of water just after symptoms are seen and if required again 2 sprays at 10-15 days interval.

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