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Fusarium Stalk Rot of Maize –Impact on Maize Production

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Abstract

Fusarium stalk rot is one of the most devastating soil-borne diseases of maize, occurring in all continents of the world including India. Post-flowering stalk rots of maize is attacked by more than fifteen species of Fusarium. Water stress and high soil temperature at flowering are the predisposing factors for this disease at post flowering stage. In general, potassium fertilizers reduces, but, that of nitrogen if in excess, increase the severity of the stalk rot disease. In this article, the distribution, symptoms, epidemiology, disease cycle, genetics of resistance, impact of the disease and integrated disease management approaches are discussed.

1. Introduction

Maize is one of the leading cereal crops grown in all agro-climatic regions around the world. In India, it is the third most important cereal crop grown after rice and wheat, accounting for 9% of total food grain production. It is grown in an area of 9.7 M ha, with production of 28.60 MT and productivity of 3.03 t ha^{-1} (Economic Survey, 2020-21). It is known to be affected by various biotic and abiotic stresses. Among the biotic stresses, fungal diseases of which most importantly the post flowering stalk rots (PFSR) pose a great threat to the productivity of maize. Fusarium stalk rot (*Fusarium verticillioides*), charcoal rot (*Macrophomina phaseolina*), late wilt (*Cephalosporium maydis*) are most prevalent and destructive diseases in India. Stalk rot is the most devastating soil-borne fungal disease mostly prevalent in rainfed areas. This disease complex occurs in wide geographic regions both in tropical and subtropical environments. Though, several species of *Fusarium* (*F.verticilloides, F. moniliformae, F. graminareum, F. subglutinans, F. proliferatum, F. equiseti, F. oxysporum, F. redolense, F. chlamydosporum, F. sulphurcum, F. roseum, F. merismoides, F. nivale, F. solani, F. avenaceum, F. acuminatum)* have been reported to cause stalk rots, the fungal species *F. verticilloides* is the major cause of stalk rot in maize (Gopi et al., 2019).

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2. Distribution of Fusarium Stalk Rot of Maize

Fusarium stalk rot of maize is caused by *F. verticillioides* (Saccardo) and was first reported from the United States of America by Pammel in 1914 as a serious root and stalk diseases. Later, it was found that *F. moniliformae* was a primary cause of root rot and stalk rot in maize. In India, Fusarium stalk rot was reported first from Mount Abu, Rajasthan. It is one of the most devastating soil-borne diseases of maize, occurring in all continents of the world, including USA , Europe, Africa, Asia, and Australia. In India, the disease is prevalent in most of the maize growing areas where water stress occurs after the flowering stage of the crop, particularly in rainfed areas of Jammu & Kashmir, Punjab, Haryana, Delhi, Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal, Andhra Pradesh, Tamil Nadu and Karnataka.

3. Disease Cycle

The fungi overwinter in the soil and in the plant residues as mycelia, hard-wall developed chlamydospore or sexual body in some species. Therefore, it is vital to avoid cultivation without crop rotation. The fungus attacks the stalk as mycelia by spores developed sexually or asexually. Loose tissues and injuries are the best gates to this infection. The pathogens feed the internal parts of the internodes, and the stem will be empty. In the plant tissue, the mycelia develop chlamydospores when the feeding material is at its end. Asexual spores develop outside, at the nodes in rings. Sexual bodies and spores develop at some species on the basal part of the stalk. The genetic material of these fungi varies a lot by sexual multiplication and anastomosis between mycelia and asexual spores. Disease-inflicting species have several strains and isolates, which are difficult to distinguish. Their multiplication rate, toxin and pigment developing disposition is also varied (Figure 1).

4. Biology of Fusarium Stalk Rot

The fungus overwinters as mycelium in corn residue, other dead plant residue, and in corn seed. This fungus is often found growing in healthy stalks and may cause rot only under certain conditions. Spores are spread by wind and splashing water; infection takes place through the roots, wounds in the stalk, or leaf scars.

5. Disease Symptoms

The stalk rot symptoms are observed during post flowering and pre-harvest stage. The rotting extends

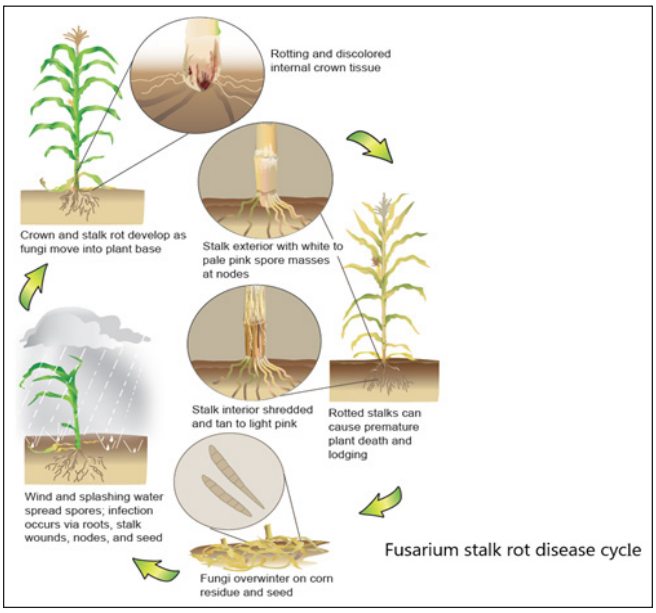

Figure 1: Disease cycle of Fusarium stalk rot in maize

from infected roots to the stalk and causes premature drying, stalk breakage and ear dropping, thus significantly reducing maize yields (Figure 2). The disease causes internal decay and discoloration of stalk tissues, directly reducing yield by blocking translocation of water and nutrients, thus resulting in death and lodging of the plant. Symptom development depends on several stress factors including an excess or lack of moisture, heavy and continuous cloudiness, high plant density, foliar diseases, and corn borer infestation.

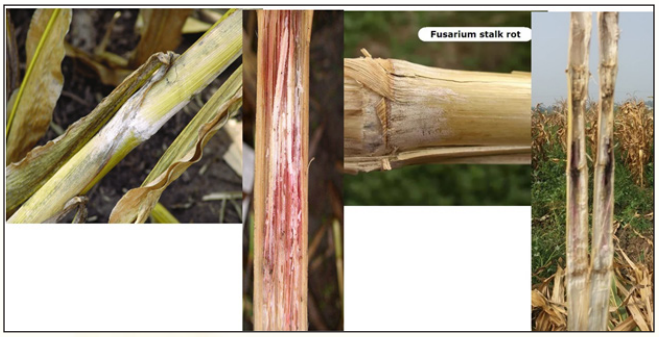

Figure 2: Symptoms of Fusarium stalk rot (From left to right): White fungal growth visible at the node; Pink to salmon discoloration inside the stalk; Growth of mycelium at the nodes; Split open stem showing pink to brown discoloration

6. Epidemiology of Fusarium Stalk Rot

The temperature may be one factor that determines the extent of invasion of the stalk rot fungi of maize (Williams and Munkvold, 2008). *F. verticillioides* is more

common in regions with hot and dry growing conditions, especially before or during pollination. These conditions, especially at maize silking stage predispose the plants to infection by *F. moniliforme* and *F. proliferatum*. Williams and Munkvold (2008) have reported the role of high temperatures in promoting systemic disease of maize by *F. verticillioides*.

The water stress at flowering and high soil temperature help in increasing the magnitude of stalk rot symptom at post-flowering stage of the crop. The PFSR is more severe under moisture stress conditions after flowering (Khokhar et al., 2014). Pre-tasselling moisture stage resulted in higher stalk rot incidence than moisture stress at post pollination and grain filling stages. Soil texture affected the incidence of *F. verticillioides* on maize when grown alone or intercropped with cowpeas and soybeans. Disease incidence was greater in sandy soil than in loam or clay soils.

In general, stalk rot incidence and severity increase with increased fertility. There is evidence that potassium fertilizers reduce the severity of stalk rot and that nitrogen one, especially if in excess compared with potash, increase stalk rot's severity. Cultural practices such as crop rotation and tillage have been reported to influence the disease incidence and severity of Fusarium infection in maize. Residues of previous crops serve as a source of inoculum for subsequent infection, which may further enhance the risk of infection with *Fusarium spp* (Khokar et al., 2014)

7. Factors Associated with Stalk Rot Incidence

Stalk rotting pathogens are often considered weak parasites, since they are capable of invading host and causing a disease only when environmental conditions are favorable for disease development. External abiotic factors and overall crop management are recognized as elements linked with development and spread of stalk rot diseases. These stresses, especially when encountered during later stages of growth, create favorable conditions for disease spread (Annette et al., 2020)

• Water deficit: Especially after flowering helps in increasing the incidence of the stalk rot at post flowering stage

• High temperature: *F. verticilloides* is more common in regions with hot and dry weather conditions especially before or during pollination

• Unbalanced mineral nutrition

• Residues of previous crop: serve as a source of inoculum for subsequent infection

8. Host Plant Resistance

Resistance to post flowering stalk rot disease involves several physiological, morphological and functional traits. Maize stalk strength is determined by two main factors, the mechanical structure of the stalk and abiotic stress factor. The degree of stalk rot infection depends greatly on environmental factors, the genotype and environment interaction (GxE) and the resistance of the given maize genotype to the pathogens. Inbreds and hybrids differed significantly in resistance and infection types and disease scores of hybrids were generally lower than that of inbreds. Discovery and utilization of resistance genes to improve maize tolerance to stalk rot is a cost effective and environment friendly approach to reduce the grain yield loss. A large body of efforts is being diverted toward development of biotechnological tools for identification and tagging of genes conferring resistance to PFSR. The identification of quantitative trait loci (QTL) for resistance to PFSR is considered as an efficient tool in development of disease resistant maize hybrids. A major gene for Fusarium stalk rot resistance has been reported on chromosome 6. Studies have also indicated that resistance to stalk rot is quantitatively inherited and controlled by multiple genes with additive effects.

9. Disease Management

Since the stalk rot of maize is a complex disease involving more than one organism, it is very difficult to manage the disease with single control measure. Hence, efforts are needed to explore the feasibility of combination of various control measures for integrated management of stalk rots.

• Field sanitation by complete destruction of previous crop debris and deep summer ploughing in the months of April and May for two to three times

• Crop rotation with non-cereal crops

• Application of balanced dose of fertilizers

• Adoption of resistant/tolerant hybrids

• Avoid water stress condition of soil at flowering stage by providing irrigation

• Incubate FYM 100 kg + *Trichoderma* 2.5 kg under slightly wet conditions for 15-20 days and mix it with FYM 500 kg + vermicompost 100 kg + dung ash 10 kg. Prophylactic application of the mixture at the time of sowing.

• Seed treatment using *T. harzianum* 4 g kg^{-1} seed along with soil application of with soil application of castor or neem cake 250 kg ha^{-1}, 15 days prior to sowing

• Foliar spray after 40 and 55 days after sowing (DAS) or immediately after symptom appearance using 2 gl^{-1} carbendazim 12%+mancozeb 62.7% thoroughly covering entire foliage

• If disease severity is more at 50 DAS, application of second spray of tebuconazole 2 g l^{-1} at 55 DAS

10. Impact on Yield

The stalk rot usually occurs after the flowering stage and before physiological maturity, which reduces yields in two ways: i) affected plants die prematurely, thereby, producing lightweight ears having poorly filled kernels and ii) plants with stalk rot easily lodge, which makes harvesting difficult, and ears are left in the field during harvesting. Stalk rot reduces maize yield directly by affecting the physiological activity of the plants and finally results in lodging, which is the main cause of economic losses. The annual loss due to maize diseases in India was estimated to be 13.2 to 39.5% (Costa et al., 2019) The disease was reported to cause a reduction of 18.7% in cob weight and 11.2% in 1000-grain weight in the infected plants. Estimated the reduction in grain weight by 5-20%, whereas the estimated loss due to Fusarium stalk rot has been reported as 38% in total yield (AICRP, 2014).

11. Conclusion and Future Perspective

Though significant strides have been made in disease management of Fusarium stalk rot, the disease continues to be a serious problem in maize. There is a need to develop an effective, economically feasible and environment-friendly method to manage the disease. It is important to understand the host-pathogen-environment interactions with emphasis on abiotic factors. Early detection using molecular diagnostic tools is the need of the hour. Development of reliable field-screening techniques are imperative to complement Fusarium stalk rot resistance breeding. Inheritance pattern of Fusarium stalk rot needs to be confirmed so as to develop resistant maize varieties/hybrids through conventional as well as biotechnological approaches.

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