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Seed-Borne Fungal Pathogens: Role in Food Spoilage, Negative Impacts and Control Approaches

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Seed-borne fungal pathogens represent a critical constraint in modern agriculture, contributing to significant yield and quality losses across a wide range of crops. These fungi not only reduce germination and seedling vigor but also introduce harmful mycotoxins that threaten food safety. Their ability to persist on or within seed structures allows them to survive adverse environmental conditions and spread globally through seed trade. This review outlines the major seed-borne fungi, their mechanisms of infection, detection techniques, and management strategies, including physical, botanical, biological, and chemical methods. Emphasis is placed on integrated approaches combining eco-friendly technologies to reduce dependency on chemical fungicides while ensuring seed health and sustainable crop production.

Keywords: Seed-borne fungi, Mycotoxins, Detection, Management, Biocontrol, Seed Pathology

Introduction

Seeds are the most vital input for crop production, serving as both the foundation of agricultural productivity and a potential vector for disease dissemination. Seed-borne pathogens, particularly fungi, are capable of infecting seeds both externally and internally, leading to decreased germination, seedling mortality, and transmission of diseases to subsequent plant generations. The term 'seed pathology' was first introduced by Paul Neergaard and Mary Noble (1940), defining the scientific study of seed diseases, their detection, and management. In today's context of globalized agriculture, the movement of seed as an international commodity has amplified the risk of pathogen spread, demanding stricter quarantine and diagnostic measures to ensure biosecurity.

Food Spoilage by Seed-Borne Fungi

Fungal contamination is a major cause of seed and grain spoilage, both in the field and during storage. Field fungi such as Alternaria, Cladosporium, and Fusarium invade grains before harvest, whereas storage fungi like Aspergillus and Penicillium develop post-harvest under humid conditions. These fungi alter the physical and biochemical properties of grains, leading to reduced germination, rancidity, discoloration, and toxin accumulation. Aflatoxins (Aspergillus flavus) and ochratoxins (Penicillium viridicatum) are of particular concern due to their carcinogenic and immunosuppressive effects, posing risks to both human and animal health.

Negative Impacts of Seed-Borne Fungi

The detrimental effects of seed-borne fungi extend beyond germination failure to broader agricultural and economic impacts. They contribute to global yield losses estimated at around 9.4% annually. Seed infections cause morphological deformities, discoloration, and physiological dysfunctions such as reduced chlorophyll synthesis and enzyme inhibition.

Historical events, such as the Bengal famine (1943) due to *Helminthosporium oryzae*, highlight the severe implications of seed-borne fungal outbreaks.

Detection of Seed-Borne Fungi

Detection of fungal pathogens in seeds is a prerequisite for effective disease management. Standardized methods include the Agar Plate Method, Blotter Test, and Selective Media technique. The Agar Plate Method encourages fungal growth on nutrient-rich media, while the Blotter Test enables observation of sporulation and mycelium under moist incubation. Selective media enhance accuracy by suppressing non-target organisms, facilitating the identification of specific pathogens such as Fusarium spp. and Septoria nodorum. Organizations like ISTA and ISHI provide internationally recognized protocols for seed health testing.

Management of Seed-Borne Fungi

Physical Management

Physical treatments such as hot water and solar heat are cost-effective and efficient in eradicating fungal inoculum. Hot water treatment (around 54°C for 20 minutes) has proven effective against Alternaria spp., while solarization through controlled exposure to sunlight eliminates surface pathogens without compromising seed viability.

Botanical Management

Plant-based extracts from species like neem (Azadirachta indica), garlic (Allium sativum), tulsi (Ocimum sanctum), and ginger (Zingiber officinale) exhibit strong antifungal properties. These natural agents inhibit fungal growth and improve seed germination and vigor. Such botanical alternatives are eco-friendly and align with sustainable agricultural practices.

Biological Management

Biocontrol agents like *Trichoderma harzianum*, *T. viride*, *Bacillus subtilis*, and *Pseudomonas fluorescens* have been successfully used to suppress seed-borne fungi through competition, antibiosis, and induced systemic resistance. Seed biopriming with these agents improves plant growth, vigor, and pathogen resistance.

Chemical Management

Fungicidal seed treatments remain an integral component of disease control programs. Commonly used fungicides include carbendazim, mancozeb, captan, thiram, and hexaconazole. These agents inhibit fungal development on and within seeds. However, their use must be balanced with environmental safety and the risk of resistance development.

Integrated Disease Management

Integrated disease management approach ensures healthier seeds, higher germination rates and ultimately contributes to global food security. It combines physical, botanical, biological, and chemical methods to manage seed-borne fungi effectively. By using multiple approaches together, we can reduce pathogen load, improve seed germination, and protect seedlings better than any single method.

Conclusion

Seed-borne fungi are a persistent threat to global food security due to their ability to spread, persist, and adapt. A combination of preventive measures, early detection, and integrated management approaches—encompassing physical, botanical, biological, and chemical methods—offers the most sustainable solution. Future research should emphasize eco-friendly alternatives and resistant crop varieties to minimize dependency on chemical fungicides while ensuring seed health and agricultural sustainability.

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