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Crop molds and mycotoxins: Alternative management using biocontrol

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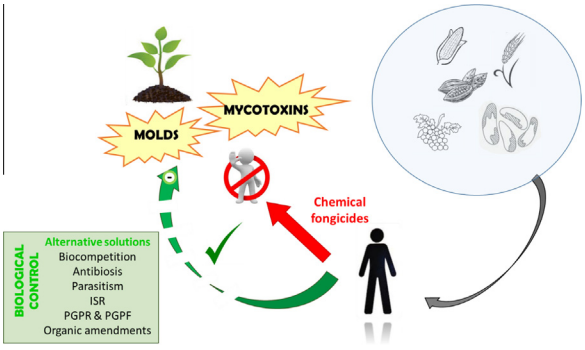
HIGHLIGHTS

- Fungi take an important part in the microorganism world.
- Mycotoxins are mainly associated to 3 fungal genus.
- Biocontrol of these strains involves multiple mechanisms.
- Organic amendments are promising tools for sustainable agriculture.

GRAPHICAL ABSTRACT



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ABSTRACT

Phytopathogenic and/or mycotoxigenic filamentous fungi are involved in a great number of plant diseases that cause yield and quality losses of crops. Besides the economic damages, these fungi produce mycotoxins that present health risks for humans and animals who consume contaminated foods. The most dangerous mycotoxins in the agriculture and the food industry that are regulated in European Union (trichothecenes especially deoxynivalenol, fumonisins, aflatoxins and ochratoxin A) are produced by three main fungal genera (*Fusarium, Aspergillus* and *Penicillium*). Many approaches have been applied to prevent and manage the phytopathogenic and/or mycotoxigenic fungi. However, these methods involve the use of chemical inputs that are harmful for humans, animals and environment. In a concern of sustainable development, the application of biocontrol has been considered for addressing this problem in a more environmentally friendly way. This review considered the incidence of the three fungal genera and their mycotoxins in crops and in foodstuff. The impacts of the fungal contamination and the toxin accumulation were reported. Besides, the biological control means against these pathogens were reviewed. Among them, organic amendments showed to be effective in both producing antifungal activities and reinforcing plant health.

Contents

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1. Introduction

Fungi take an important part in the microorganism world. They might have benefices in sciences, industries and technology. Nevertheless, filamentous fungi appear to be a potential harm for humans, animals and crops. In fact, many of them are phytopathogenic and/or mycotoxigenic. Their occurrence leads to many soil-borne diseases for plants, thereby causing various food and feed-borne mycotoxicoses for humans and animals through the consumption of contaminated products. Thus, these filamentous fungi damaged not only human and animal health but also the international economy.

The main targets of molds are cereals, grains, fruits and vegetables. The major toxins that are associated with the contamination are deoxynivalenol (DON) (or nivalenol in some areas), fumonisins, zearalenone, aflatoxins and ochratoxin A (OTA) (Miller, 2008). These are the most important mycotoxins (Pitt, 2000) produced mainly by species of *Aspergillus, Fusarium* and *Penicillium*. Cereals constitute a staple food for all over the world as well as the main source of animal feed (Von Braun, 2007). So, research for protecting crops from molds and their mycotoxins has become indispensable.

For decades, various agricultural practices have been applied. However, the current approaches dealing with the fungal phytopathogens were based on the use of chemical agents that are reported to be acutely and chronically hazardous to humans, animals and ecosystems. Within the context of the "organic farming" and the sustainable development concern, alternative practices have to be developed, notably the biological solutions that maintain the quality and the abundance of crops with respecting the ecosystems and human and animal health.

In this context, this review describes: i) the main phytopathogenic and mycotoxigenic filamentous fungi and their mycotoxins, ii) the main strategies of biological control applied to these molds with emphasis to the application of organic amendments.

2. Phytopathogenic and mycotoxigenic fungi

2.1. The genus Fusarium

2.1.1. Phytopathogenesis

Fusarium is a large group of ascomycete fungi that belongs to the class of *Sordariomycetes* and to the family of *Nectriaceae*. *Fusarium* is one of the most important phytopathogenic group (Booth, 1971).

The occurrence of *Fusarium* can be found in all types of plant tissues, soil debris and soils in many cereal crops. The most affected cereal by the pathogenic *Fusarium* are corn (Aboul-Nasr and Obied-Allah, 2013; Sreenivasa et al., 2013; Becker et al., 2014; Liu et al., 2014), wheat (Cui et al., 2013; Lindblad et al., 2013; Tittlemier et al., 2013), barley (Oliveira et al., 2012; Běláková et al., 2014), sorghum (Sreenivasa et al., 2013; Divakara et al., 2014; Kange et al., 2015) and oat (Kiecana et al., 2012, 2014; Fredlund et al., 2013). The *Fusarium* species responsible for these contaminations are *Fusarium graminearum, F. sporotrichioides, F. poae, F. avenaceum, F. culmorum, F. accuminatum, F. langsethiae, F. verticillioides, F. proliferatum, F. oxysporum, F. anthophilum* and *F. paranaense*. *Fusarium graminearum* is the most common species in the infections.

The *Fusarium* pathogens were also found in various vegetables and fruits, i.e. soybeans (Arias et al., 2013; Chang et al., 2015; Costa et al., 2016), chili (Sundaramoorthy et al., 2012; Jalaluldeen et al., 2014) and tomato (Bharat and Sharma, 2014; Loganathan et al., 2014).

Fusarium spp. are the major soil-borne and seed-borne pathogens causing damage to a wide range of crops and they are responsible for various diseases. The most frequent diseases in cereal crops is Fusarium Head Blight – FHB that can lead to enormous loss of yield and low quality of crops (Zhang et al., 2013). *Fusarium* spp. are causative agents for rot disease in many plants: root rot in soybean (Arias et al., 2013; Chang et al., 2015), stalk rot in maize (Kaur et al., 2014), root and steam rots in cucumber (Pavlou and Vakalounakis, 2005). *Fusarium oxysporum* f. sp. *cucumerum* J.H. Owen caused the Fusarium wilt that has been reported as one of the most severe diseases in cucumber (Qiu et al., 2012). *Fusarium oxysporum* caused also the wilt in banana (Ploetz, 2006) and melon (Ma et al., 2014; Cohen et al., 2015). A newly soil-borne pathogen strain of *F. oxysporum*, which was identified as *F. oxysporum* f. sp. *citri*, caused diseases on seedling of citrus trees (Hannachi et al., 2015). The loss of yield and the severity of diseases is linked to the extent of the *Fusarium* infection (Chang et al., 2015). *Fusarium* infections are also reported in both humans and animals (Zhang et al., 2006; Antonissen et al., 2014).

2.1.2. Toxinogenesis

The majority of the *Fusarium* species are able to produce mycotoxins and are involved in the accumulation of toxins in food and