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Arboreal Fungi in Biological Control against Soil Fungi †

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Abstract: Fungi are important components of every ecosystem. In nature, they play a significant role as decomposers, decomposing organic matter into simple compounds available for plants. They are a curious group of organisms that attracts more and more interest not only among mycologists and phytopathologists, but also geneticists, biochemists and physiologists. Metabolic products of arboreal fungi show multidirectional action, including in the field of biological protection against harmful phytopathogens. Particularly invasive and difficult to control are soil fungi, phytobacteria and phytoviruses, which are widely spread in the rhizosphere. Moreover, the variety of pathogens is constantly increasing, and new forms are rapidly emerging, often more resistant to the biological control agents used so far.

Keywords: *Macromycetes*; Basidiomycetes; polyporoid fungi; white-rot fungi; wood-decaying fungi; biological control; fungi extracts; fungal inoculants; soil-borne fungi; biological control agents

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1. Introduction

Arboreal fungi are a group of *Macromycetes*, diverse in terms of shape, size, durability and consistency [1]. Some of them have thin, leathery or delicate fruiting bodies that are spread out, outstretched–bent or fleshy, non-permanent and hat-shaped [1]. These fungi grow in the wood of trees and shrubs that are living, weakened and dying, dead-standing and lying [2]. They take up nutrients from the wood through the enzymatic degradation of the main compounds that make up the wood substance [1]. Many studies confirm that fungi contain the entire spectrum of biologically active compounds that can be used, among others in biological protection against soil fungi [3].

2. Biological Control

Plant diseases caused by plant soil pathogens are some of the most difficult to control [4]. Due to the lack of effective methods of chemical protection, interest in the biological protection of plants with the use of antagonistic microorganisms is growing [4]. One of such methods is the creation of optimal conditions for the development of plants and the protection of beneficial organisms that occur naturally in the ecosystem, or even by introducing natural antagonists and pathogens in the form of biopreparations [5]. Biological control is defined as the use of biopreparations, such as plant protection products containing a factor or factors of biological origin (BCA—biological control agents) to reduce the occurrence of pathogenic organisms [6]. Biotic microbial agents are living organisms that antagonize pathogens or induce plant defense mechanisms [7]. In order to understand the mechanisms of biological control, it is necessary to understand the different ways that organisms interact [8]. The main way of action is antibiosis, which is an antagonistic effect resulting from the production by one of the microorganisms of secondary metabolites toxic to another microorganism [4]. Therefore, secondary metabolites produced by fungi can be used for this purpose as a biopreparation in biological protection against soil fungi.

3. Antifungal Properties

Phytopathogenic fungi are spread all over the world. They cause great losses in crops, forest dieback, and due to the production of mycotoxins, they are also dangerous to humans [9]. Most of these fungi belong to the close microflora of the plant root zone. Roots are an important plant organ that provides soil anchorage and mechanical support as well as water and nutrient uptake [10]. The rhizosphere is a narrow zone of soil surrounding the roots, and it is a dynamically developing community of microorganisms that use root secretions as a source of food [11,12]. Root exudates, including volatile compounds, can attract beneficial microorganisms to increase plant growth. However, at the same time, plant pathogens are attracted, which use the volatile substances in the roots to locate the host plants [13,14]. Pathogens enter the plant and weaken its immune system, eventually causing it to die. Research indicates that arboreal fungi synthesize some of the substances produced simultaneously by plants when attacked by pathogens. Researchers showed that substances such as phenols, sterols, proteins, oligosaccharides and phenylpropanoids contribute to the induction of systemic plant resistance [15–17]. Other studies show that the arboreal fungi *Flammulina velutipes* (Curtis) Singer, *Hydnum repandum* L., *Lentinula edodes* (Berk.) and *Ganoderma lucidum* (Curtis) P. Karst. [17–24] can effectively minimize the population of harmful fungi in the soil belonging to the genus *Fusarium* [25–28]. Other studies show that strobilurins in particular, produced by the fungi *Strobilurus tenacellus* (Pers.) Singer 1962 and *Oudemansiella mucida* (Schrad.), are one of the greatest discoveries in the history of biofungicides [29,30]. Due to the unique and specific method of action of strobilurin, a number of its analogs with improved antifungal activity have been synthesized [31]. This is how very successful commercial products were created, such as Kresoxime-methyl, Pyraclostrobin and Trifloxystrobin [31]. Other scientists [32], looking for fungal origin antifungal agents, found that *Crinipellis rhizomaticola* culture filtrate has the potential to prevent plant diseases caused by *Magnaporthe oryzae* and *Colletotrichum coccodes* (Wallr.) S. Hughes. Similar results were obtained by Imtiaj and Lee [33], who examined the antifungal activity of fungi depending on the incubation time of the cultures and found that the filtrates of the cultures of *Stereum ostrea*, *Pycnoporus cinnabarinus* (Jacq.) P. Karst., *Pycnoporus coccineus*, *Oudemansiella mucida* and *Cordyceps sobolifera* also showed antifungal activity [33]. The presented research shows the great potential of using fungi in biological protection. The possibilities of using secondary metabolites of arboreal fungi for the production of biopreparations enhancing plant resistance are enormous, but they require the exploration of their mechanisms of action.

4. Conclusions

Fungi are a very important group among the five biologically separate kingdoms. The literature on biological plant protection methods provides many examples of the benefits of using arboreal fungi. Summarizing the literature data, it should be emphasized that in biological plant protection against plant diseases caused by soil fungi, preparations based on metabolites from arboreal fungi have been successfully used. The search for new fungal species with phytopathogen antagonistic properties should be continued in order to develop plant biological protection methods based on arboreal fungi as BCA. The research results presented in this review indicate great potential for the use of arboreal fungi in biological control.

Conflicts of Interest: The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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