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Endophytic *Acremonium zeae* and *Xylaria adscendens* in Crops: A Review

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KeyWords

Acremonium zeae, Biological control, Endophytes, Fungi, *Xylaria adscendens*

Abstract

Fungal endophytes have been shown to increase the survival and persistence of their host plants in a diverse range of environments and may also protect them from pathogens. Acremonium zeae and Xylaria adscendens have both been reported as endophytes of many important crops plants with the potential to serve as biocontrol agents against some important pathogenic fungi. This review paper focus on the use of fungal endophytes; such as Acremonium zeae and Xylaria adscendens to protect some economic crops against important pathogens.

Introduction

A lot of plants contain endophytes that Wilson (1995) defined as "fungi or bacteria which, for all or part of their life cycle, invade the tissues of living plants and cause unapparent and asymptomatic infections entirely within plant tissues but cause no symptoms of disease". Fungal endophytes are known to produce antibacterial substances (Radić and Štrukelj, 2012) and have been shown to improve the tolerance of host plants to a variety of biotic and abiotic stresses (Bacon *et al*., 1997; Rodriguez *et* al., 2004). The presence of fungal endophytes has been shown to increase the survival and persistence of their host plants in a diverse range of environments and may also protect them from insects, pathogens, and herbivores (Martin and Dombrowski, 2015). *Acremonium zeae* has been the subject of recent investigations because of its production of pyrrocidine antibiotics and its potential to serve as a biocontrol agent against mycotoxin producing fungi (Wicklow *et al*., 2005). *Xylaria* species are common in virtually every study that has ever been done on endophytes, especially in tropical ecosystems (Davis *et al*., 2003). This work review fungal endophytes *Acremonium zeae* and *Xylaria adscendens* and their endophytic relationships with some economically important crop plants.

I. Endophytic Microbes

Microorganisms such as fungi, bacteria, cyanobacteria, and actinomycetes belonging to a class of plant symbionts residing within plant tissue are referred to as "endophytes" (De Bary 1866). From the germination of seeds to the development of fruits, endophytic microorganisms are associated with different parts of the plant, such as the spermosphere (in seeds), rhizosphere (roots), caulosphere (in stems), phylloplane (in leaves), anthosphere (in flowers), and laimosphere and carposphere (in fruits) (Clay and Holah 1999). To adapt to abiotic and biotic stress factors, endophytic microbes produce bioactive substances (Guo *et al*., 2008). The associations of endophytic microbes with plants, and in many cases their tolerance to biotic stress factors, have correlated with fungal natural products or biologically active metabolites, such as enzymes, phytohormones, nutrients, and minerals, and also enhance the resistance of the host against herbivores, insects, disease, drought, phytopathogens, and variations in temperature and salinity (Breen 1994; Brem and Leuchtmann 2001; Schulz *et al*., 2002). Endophytic microbes enhance the resistance of plants to abiotic stress factors such as increasing drought tolerance, high temperature, low temperature, low pH, high salinity, and the presence of heavy metals in the soil (Jalgaonwala *et al*., 2017). On the other hand, plants provide a protective environment for the growth and multiplication of endophytic microbes, protection from aridness, and longevity via seed transmission to the next generation of the host (Khan *et al*., 2015).

II. Endophytic Fungi Diversity

Fungal endophytes are defined functionally, as those fungi found within living, healthy plant tissues; they make their living by not harming their host enough to induce a defensive reaction (Clay 1990, Rudgers *et al*. 2009). Since their discovery, they have been found to be both ubiquitous and incredibly diverse in plants of all ecosystems (Arnold & Lutzoni 2007, Porras-Alfaro & Bayman 2011). Although numerous benefits to fitness for host-plant partners in the endophytic symbiosis have been observed, and many more proposed (Rodriguez et al. 2009). From reported works on endophytic fungi diversity, it can be concluded that reported fungi belong to diverse phyla including Ascomycota, Basidiomycota, and Mucoromycota. Reported works show biodiversity and abundance of endophytic fungi from chickpea, common pea, maize, pigeon pea, rice, soybean, tomato, and wheat (Rana *at al*., 2019.

Despite all the benefits of fungal endophytes to plants highlighted above, it is however still worthy to note that some endophytes have still yet been observed to be latent pathogens or saprotrophs, waiting for host-plant weakness or death to be the first to colonize and digest host tissues (Chapela & Boddy 1988, Osono 2006, Promputtha et al. 2007, 2010).

III. The Use of *Acremonium* and *Xylaria* species as Endophytes

Acremonium zeae is one of the most prevalent fungal colonists of preharvest corn and produces symptomless infections of corn seeds and has been isolated from the stalks of mature plants (Fisher *et al*., 1992; King, 1981; Reddy and Holbert, 1924; Sumner, 1968). A positive aspect concerning the use of *Acremonium* spp. lies in the fact that they produce chlamydospores. These give them a greater competitive and adaptive advantage to the environment, thus surviving longer under field conditions (Vivas *et al*., 2017). *Acremonium zeae* produces two lactam-containing antibiotics, named pyrrocidine A (PA) and B (PB), with PA exhibiting greater inhibitory activity against *Fusarium verticillioides* and other fungi (Gao *et al*., 2016). *Acremonium zeae* has been characterized as a protective endophyte of maize and displays antifungal activity against other fungi. Pyrrocidines A and B were discovered to be the metabolites accounting for this activity. Pyrrocidine A also showed potent activity against major stalk and ear rot pathogens of maize, including *Fusarium graminearum*, *Nigrospora oryzae*, *Stenocarpella* (*Diplodia*) *maydis*, and *Rhizoctonia zeae* while also exhibiting potent activity against *Clavibacter michiganense* subsp. Nebraskense, the causal agent of Goss's bacterial wilt of maize(Poling *et al*., 2008).

Acremonium zeae is not recognized as causing ear, kernel or storage rots of maize (White, 1999) and there have been no reports that *A. zeae* isolates from maize produce any metabolites toxic to animals or plants (Dillon *et al*., 2018)**.** *Acremonium zeae* was found to be antagonistic to kernel-rotting and mycotoxin-producing fungi *Aspergillus flavus* Link and *Fusarium verticillioides* (Sacc.) Nirenb. in cultural tests for antagonism (Wicklow *et al*., 1980, 2005). The fungus also limited *Aspergillus flavus* colonization and aflatoxin contamination of intact grains removed from ears produced in an environmental chamber and wound-inoculated in the milk stage with both *Aspergillus flavus* and *A. zeae* (Wicklow *et al*., 1988). Chemical studies of the organic extract from maize kernel fermentations of *A. zeae*, which displayed significant antifungal activity against *Aspergillus flavus* and *F. verticillioides* in conventional paper disc assays, revealed that the metabolites accounting for this activity were two polyketide – amino acid derived antibiotics pyrrocidines A and B (Wicklow *et al*., 2005). Pyrrocidine A also exhibits potent in vitro activity against major stalk and ear rot pathogens of maize including *Stenocarpella maydis* (Berk.) B. Sutton and *Fusarium graminearum* Schwabe (Wicklow and Poling 2006). *Acremonium zeae* was characterized as a "protective endophyte" of maize that might best defend against pathogen attack at the more vulnerable seed and seedling stage (Wicklow *et al*. 2005).

Some species of *Xylaria* have been discovered to be endophytes of many tree species (Whalley 1996; Læssøe, 1999; Crozier *et al*. 2006; Thomas *et al*. 2008; U'Ren *et al*. 2009; Vega *et al*. 2010). Members of this genus are important saprotrophs, found primarily on decomposing dead wood—and, rarely, on leaves and fruits—on the forest floor (Whalley 1996, Lodge, 1997, Rogers, 2000). Xylaria species are visible during sexual sporulation, forming relatively large, macroscopic stromata, or 'fruiting' structures (Bayman *et al*. 1998, Davis & Shaw 2008). Xylaria species are common in virtually every study that has ever been done on endophytes, especially in tropical ecosystems (Davis *et al*., 2003).

Conclusion

A ot of progress has been made in fungal endophytic research. Fungal endophytes have been found to colonize land plants everywhere on earth. They have been isolated from boreal forests, tropical climates, diverse xeric environments, extreme arctic environments, ferns, gymnosperms, and angiosperms (Mohali *et al*. 2005; Selim *et al*. 2017; Šraj-Kržič *et al*. 2006; Suryanarayanan *et al*. 2000). Endophytic fungi play an important role in protecting their host from attack by phytopathogens and also facilitate the solubilization of the macronutrients phosphorus, potassium, and zinc; the fixation of atmospheric nitrogen; and the production of various hydrolytic enzymes, ammonia, siderophore, and hydrogen cyanide (HCN) (Maheshwari 2011; Rana *et al*. 2016a, b, 2017; Verma *et al*. 2015b, c, 2016a, b).

Climate change and the expansion of agricultural production to marginal lands will also require innovative ways to increase abiotic and biotic stress tolerance and improve nutrient uptake efficiency in crop plants to meet future global food demands. Many plants contain endophytic organisms that Wilson (1995) defined as "fungi or bacteria which, for all or part of their life cycle, invade the tissues of living plants and cause unapparent and asymptomatic infections entirely within plant tissues but cause no symptoms of disease" (Wilson, 1995). Fungal endophytes are known to produce antibacterial substances (Radić and Štrukelj, 2012) and have been shown to improve the tolerance of host plants to a variety of biotic and abiotic stresses (Bacon, *et* al., 1997; Malinowski and Belesky 2000; Rodriguez *et al*., 2004). The presence of fungal endophytes has been shown to increase the survival and persistence of their host plants in a diverse range of environments and may also protect them from insects, pathogens, and herbivores (Martin and Dombrowski, 2015). There is therefore need to sponsor more fungal endophytic researches such as the use of *Acremonium zeae* and *Xylaria adscendens* endophytes, especially in the poor/developing countries, inorder to identify more efficient biocontrol agents for incorporation into sustainable plant pathogen control packages. This has become imperative, since the use of current popular control measures such as cultural or chemical disease control method is no longer adequate nor sustainable in most of these poor countries.

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