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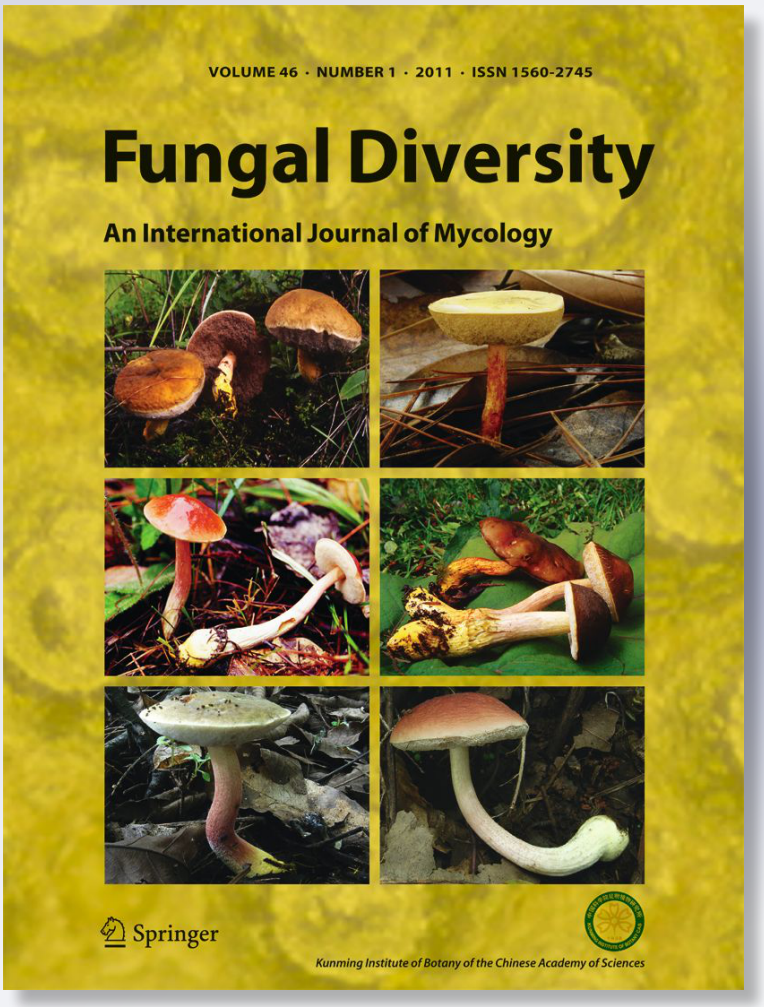

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REVIEW

Fungal endophytes: an untapped source of biocatalysts

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Abstract Horizontally transmitted endophytes are an ecological group of fungi that infect living plant tissues and survive in them without causing any disease symptoms. Even as facets of the endophyte-plant symbiotic relationship are being uncovered, there is an increasing appreciation of the different growth substrates exploited by endophytes and the vast repertoire of secreted enzymes of these fungi. These attributes exemplify the striking biodiversity of fungal endophytes and should motivate bioprospecting these organisms to identify novel biocatalysts that might help address challenges in medicine, food security, energy production and environmental quality.

Keywords Fungal enzymes · Microbial bioprospecting · Biodiversity

Introduction

The absorptive mode of nutrition in fungi has resulted in the evolution and secretion of a battery of enzymes that catabolize complex organic polymers (e.g., cellulose, chitin, protein) in the environment to smaller constituents, which are then absorbed by their cells for metabolism. That these polymers need not be broken down to monomeric units is borne out by the expression in some ascomycete and basidiomycete fungi of an oligosaccharide transporter that might play a role in uptake of sucrose (a disaccharide) and raffinose (a trisaccharide) (Fang and Leger 2010). This mode of nutrition and the diverse nature of substrates that the different ecological groups of fungi exploit for growth help rationalize their ability to employ a diverse array of extracellular enzymes (e.g., amylases, cellulases, chitinases, lipases, and proteases). It is therefore not surprising that around 60 % of the currently used industrial enzymes are of fungal origin (Østergaard and Olsen 2010); applications include baking, fermenting coffee beans, processing meat, manufacturing corn syrup, hydrolyzing milk protein, removing stains, dehairing hides, separating racemic mixtures of amino acids, biosensing and bioremediation (Table 1).

Although fungi are extraordinarily species rich with about 1.5 million estimated members (Hawksworth 1991), merely five genera (*Aspergillus, Humicola, Penicillium, Rhizopus* and *Trichoderma*) account for three quarters of the 60 % fungal enzymes used in industrial processes (Østergaard and Olsen 2010) lending immediacy to screening fungi of different ecological groups for novel and more efficient biocatalysts (Peterson et al. 2011). It is in this context that we focus here on the need to study endophytes.

Bioprospecting fungal endophytes for novel catalysts: rationale

Fungal endophytes, an integral part of the plant microbiome, infect and reside in plants (algae, bryophytes, pteridophytes, gymnosperms and angiosperms) without initiating any visible disease symptoms (Hyde and Soytong 2008). Although not universal, infection by endophytes could confer fitness

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