Preface

Fungal endophytes – biology and bioprospecting

The horizontally transmitted fungal endophytes, mostly from the Ascomycota phylum, infect living tissues of plants without expressing any disease symptoms in them. Endophytism existed even in plants of the early Devonian period and occurs in all extant plant groups, indicating that this asymptomatic association with plants is an ancient and successful survival strategy among filamentous fungi. Since it is straightforward to isolate these fungi from their plant host tissues and culture them on simple growth media, they are easily investigated in the laboratory. Endophytes have attracted much attention during the last two decades largely due to their ability to produce bioactive metabolites and a large suite of enzymes. However, knowledge regarding the evolution of endophytism as a lifestyle among fungi and the interaction of fungal endophytes with their plant hosts and other life forms in the ecosystem is only now emerging. This special section on 'Fungal Endophytes' provides a broad overview of various aspects of endophytism, spanning from its basic biology to its applications. We hope that the collection of articles in this special section will further motivate research on endophytes that will utlimately shed light on the biology of an ancient mutualism and harness the potential of endophytes for addressing key problems in health, agriculture, energy and environment.

Endophytes elaborate novel and structurally diverse metabolites including terpenoids, steroids, xanthones, chinones, phenols, isocoumarins, benzopyranones, tetralones, cytochalasines and enniatines which exhibit a variety of bioactivities including anti-bacterial, anti-viral, anti-fungal, anti-cancer and anti-malarial activities. Such an extraordinary synthetic ability of endophytes when compared to other ecological groups of fungi such as the soil-dwellers is likely a consequence of their longstanding co-evolution with the defence mechanisms of their hosts. Despite several reports on the production of such secondary metabolites by endophytes, we lack an understanding of how the host and other organisms residing in the host influence their synthetic capabilities. In this issue, Schulz *et al.* (**page 39**) hypothesize that the many different anti-bacterial and anti-fungal metabolites of endophytes are involved in maintaining a fine microbial balance *in situ*, the underpinning for a compatible multipartite symbiosis in the plant not unlike the soil microbiome. Indeed, a future challenge will be to design novel methods to unravel such complex interactions, notably the development of experimental systems that can recapitulate such interactions *in planta*.

Endophyte association enhances tolerance of host plants to abiotic and biotic stresses. The occurrence of some entomopathogenic fungi as endophytes in several plants has nurtured the hope of using them in biocontrol of phytophagous insect pests, especially since endophytes are natural residents of plants and do not cause any apparent disease. However, several aspects of biocontrol have to be addressed before the concept can be translated into practice. Vidal and Jaber (**page 46**) highlight many of the concerns which currently hinder the successful use of entomopathogenic endophytes in biocontrol. Environmental conditions, cultivar characteristics and interaction with other organisms may affect the efficacy of an endophyte vested with biocontrol potential.

The influence of endophyte symbiosis on herbivorous insects is another facet of endophyte biology that merits study. Apart from shedding light on multitrophic interactions in the ecosystem, such an investigation could aid in the biocontrol of insect pests. The article by Estrada *et al.* (**page 55**) describes how experimental manipulations could help discern basic patterns and mechanisms of interactions between endophyte communities and phytophagous insects.

Studying plants from less-studied habitats for their resident endophytes is of immediacy to get a fuller picture of endophyte diversity, and might even lead to identification of novel bioactives. Okane and Nakagiri (**page 62**) report on the endophytes of the halophilic plant *Salicornia europaea.* Ma *et al.* (**page 72**) review the methods of isolation, diversity and technological potential of orchid endophytes, while Flewelling *et al.* (**page 88**) discuss the diversity and bioactive compounds of endophytes of marine macroalgae. Similarly, following on several studies that establish the promise of endophytes as a source of novel industrial enzymes, Thirunavukkarasu *et al.* (**page 112**) demonstrate the utility of marine algae as a source of xylanses and xylosidases, an observation that is likely to stimulate further investigations of this ecological group of fungi for biofuel-related applications.

Given the life cycle of a butterfly, an incomplete picture would emerge if studies focused on only one stage in its metamorphosis from an egg to the adult fly. The same shortcoming applies to the view that endophytes, albeit their universal occurrence, are merely passive residents of plant tissues. Fungal endophytes are not casual inhabitants of plants as they influence the genetic and phenotypic expressions of their hosts. Many endophytes switch to a saprotrophic phase and continue to survive as decomposers in dead tissues such as leaf litter; specific gene regulation for these two phases in a root endophyte points to the fact that endophytism may only be a phase in the life cycle of some fungi. Though there are indications that endophytes influence litter quality and litter decomposing organisms, our knowledge on the effects of endophytes in nutrient cycling in ecosystems is far from detailed. The existing knowledge in this aspect indicates that endophytes could affect litter decomposition positively or negatively based on their interaction with their plant hosts as well as with saprotrophic degraders. Saikkonen *et al*. (**page 121**) discuss the available information in this regard, and dovetail it with the knowledge of ecology and life-history strategies of endophytic fungi, even while identifying hypotheses for future studies.

One of the most intriguing and enigmatic features of many endophytes is their ability to produce secondary metabolites of their respective host plants in culture. For example, endophytes from *Taxus brevifolia* have been reported to produce taxol, while endophytes from *Campotheca acuminata* have been shown to produce camptotheca independent of their host plants. Several theories, including the possibility of horizontal gene transfer from the plant host to the endophytes have been proposed to explain this phenomenon, but none has so far been proved conclusively. Shweta *et al*. (**page 127**) examine the diversity and distribution of endophytic fungi associated with a camptotheceine-producing plant, *Nothapodytes nimmoniana* along its entire geographical distributional range in the Western Ghats, India and ask if there is a phylogenetic basis for endophytes producing camptotheceine.

The goal of this special section is to introduce a larger fraction of life sciences researchers to the fascinating diversity and versatility of endophytes, and to attract the readers to work on the outstanding problems whose solutions will yield key insights into the biology of this cryptic guild of filamentous fungi.

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