Natasha Tajuddin, Mohammed Rizman-Idid, Peter Convey and Siti Aisyah Alias*

Thermal adaptation in a marine-derived tropical strain of *Fusarium equiseti* and polar strains of *Pseudogymnoascus* spp. under different nutrient sources

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Abstract: We documented relative growth rates (RGRs) and activities of extracellular hydrolytic enzymes (EHEs) of one marine-derived tropical strain of *Fusarium equiseti* originally isolated from Malaysia and two polar strains of *Pseudogymnoascus* spp. from the Arctic and Antarctic under various temperatures and different nutrient conditions. RGRs and relative enzyme activities (RAs) of protease, amylase and cellulase were screened in seawater nutrient assay plates augmented with either skim milk, soluble starch or carboxymethylcellulose with trypan blue, respectively, across culture temperatures between 5°C and 40°C. Measures of RGR were fitted into third-degree polynomial and Brière-2 temperature-dependent models to estimate optimum temperatures for growth (T_{opt}) and maximum growth rates (RGR_{max}), and were used to calculate temperature coefficients (Q_{10}) and activation energies (E_a) for growth. All studied strains showed highest RGR and RA when grown using a skim milk nutrient assay. T_{opt} for growth was 25°C in *F. equiseti* and 20°C in *Pseudogymnoascus* spp. Only *F. equiseti* showed cellulase activity. These data suggest a preference for protein-based substrates over plant-derived substrates for metabolism in these fungal strains. The tropical *F. equiseti* could utilise higher levels of thermal energy for growth than the polar strains of *Pseudogymnoascus* spp., implying adaptation of these fungi to different bioclimatic regions.

***Corresponding author: Siti Aisyah Alias,** Institute of Ocean and Earth Sciences, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia; and National Antarctic Research Centre, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia, e-mail: saa@um.edu.my
Natasha Tajuddin: Institute of Ocean and Earth Sciences, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia; and Institute of Graduate Studies, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia
Mohammed Rizman-Idid: Institute of Ocean and Earth Sciences, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia
Peter Convey: British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, UK; and National Antarctic Research Centre, University of Malaya, Lembah Pantai, Federal Territory of Kuala Lumpur, Malaysia

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Introduction

Fungi are present on various substrates in the marine environment, from coastal to deep-sea ecosystems. Some fungi are of terrestrial and/or freshwater origin, particularly those occurring in seawater and sediment in coastal areas, and therefore these fungi are generally called "marine-derived" fungi (Pang et al. 2016). They play an important role as decomposers in marine environments, transforming dissolved or particulate organic matter (DOM and POM) into simpler chemical compounds that can be utilised by themselves or other consumers in the marine food web (Bianchi 2011). Eighty-percent of the organic matter, largely composed of proteins, followed by carbohydrates, lipids and nucleic acids, present in marine ecosystems is preserved in deltaic and coastal deposits (Hedges 1992, Fabiano and Danovaro 1998, Kujawinski 2011). Marine fungi mainly occur in coastal environments, which are typified by high organic matter content and productivity (Pang and Jones 2017).

Fusarium Link and *Pseudogymnoascus* Raillo are fungal genera that are common in environmental samples originating from the lower (tropical) and higher (temperate and polar) latitudes, respectively. Representatives of the two genera are clearly halotolerant (Kochkina et al. 2007, Summerell et al. 2010). Some species are pathogenic to other living organisms. A majority of the well-characterised members of *Fusarium* [e.g. *Fusarium oxysporum* Schltdl., *Fusarium graminearum* Schwabe, *Fusarium solani* (Mart.) Saccardo, *Fusarium equiseti* (Corda) Saccardo] are cosmopolitan plant pathogens colonising aerial and root structures in plants and sediments/soils in which their hosts occur (Summerell et al. 2010). Several *Fusarium* species have been reported to grow differentially in response to specific environmental triggers such as changes in temperature and nutrient sources, and some are dimorphic, growing as yeasts at temperatures higher than 30°C (Szécsi and Magyar 2011). In comparison to *Fusarium*, there are currently fewer described *Pseudogymnoascus* species. However, *Pseudogymnoascus* spp. are often the most common fungal group in both temperate and polar