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ORIGINAL ARTICLE

Diversity of root-endophytic *Trichoderma* from Malaysian Borneo

N. J. Cummings[1] · A. Ambrose[2] · M. Braithwaite[1] · J. Bissett[3] · H. A. Roslan[4] · J. Abdullah[2] · A. Stewart[1] · F. V. Agbayani[5] · J. Steyaert[1] · R. A. Hill[1]

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Abstract *Trichoderma* species form endophytic associations with plant roots and may provide a range of benefits to their hosts. However, few studies have systematically examined the diversity of *Trichoderma* species associated with plant roots in tropical regions. During the evaluation of *Trichoderma* isolates for use as biocontrol agents, root samples were collected from more than 58 genera in 35 plant families from a range of habitats in Malaysian Borneo. *Trichoderma* species were isolated from surface-sterilised roots and identified following analysis of partial translation elongation factor-1α (*tef1*) sequences. Species present included *Trichoderma afroharzianum*, *Trichoderma asperelloides*, *Trichoderma asperellum*, *Trichoderma guizhouense*, *Trichoderma reesei*, *Trichoderma strigosum* and *Trichoderma virens*. *Trichoderma asperellum*/*T. asperelloides*, *Trichoderma harzianum* s.l. and *T. virens* were the most frequently isolated taxa. *tef1* sequence data supported the recognition of undescribed species related to the *T. harzianum* complex. The results suggest that tropical plants may be a useful source of novel root-associated *Trichoderma* for biotechnological applications.

Keywords Root endophytes · *Trichoderma* · *Trichoderma harzianum* s.l. · Translation elongation factor-1α · Malaysian Borneo

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✉ N. J. Cummings
nicholas.cummings@lincoln.ac.nz

[1] Bio-Protection Research Centre, Lincoln University, P.O. Box 85084, Lincoln 7647, New Zealand

[2] Sarawak Forestry Corporation, Lot 218, KLCD, Jalan Tapang, Kota Sentosa, 93250 Kuching, Sarawak, Malaysia

[3] Agriculture and Agri-Food Canada, 960 Carling Ave., Ottawa, Ontario K1A 0C6, Canada

[4] Department of Molecular Biology, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

[5] Grand Perfect Sdn Bhd, Bintulu, Sarawak, Malaysia

Introduction

Members of the cosmopolitan fungal genus *Trichoderma* (Hypocreales, Ascomycota) are common inhabitants of soil, woody and herbaceous plant debris, and the rhizosphere (Kubicek et al. 2008; Harman 2000). Many species have a mycotrophic lifestyle, with the ability to feed on dead fungal tissue or directly parasitise living fungi (Druzhinina et al. 2011; Chaverri and Samuels 2013). *Trichoderma* species are now also recognised as being able to persist as plant endophytes in living sapwood, leaf tissue or roots, and may confer a range of benefits to their hosts (Bailey and Melnick 2013; Harman et al. 2004). Considerable research has consequently been directed towards the development of *Trichoderma* strains as crop protection agents to control pathogens and promote plant growth (see Benítez et al. 2004; Harman 2000; Howell 2003).

Trichoderma species are capable of forming symbiotic associations with plant roots, and have been shown to extensively colonise root surfaces and also establish as endophytes by penetrating between cells in root tissue. This interaction is restricted to cells in the first few layers of the root cortex due to plant defence responses which limit further internal growth (Harman et al. 2004; Yedidia et al. 1999). In addition to providing positive effects on plant growth, root development and nutrient uptake (Harman 2011), root colonisation with particular *Trichoderma* strains also reduces plant diseases caused by