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Antarctic *Pseudomonas* spp. promote wheat germination and growth at low temperatures

Luis Andrés Yarzábal[1,2] · Lorena Monserrate[3] · Lenys Buela[1,4] · Eduardo Chica[5]

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Abstract

The development of cold-active biofertilizers and biopesticides could help improve sustainable agriculture in mountainous regions. With this aim, both psychrophilic and psychrotolerant microorganisms have been prospected in cold regions around the world and tested for their plant-growth promoting (PGP) effects. Interestingly, very little is known about the PGP effects of polar microorganisms in commercial crops. This study aimed at isolating cold-active plant-growth promoting *Pseudomonas* spp. from Antarctic soils and testing their PGP effects, both in vitro and on wheat (*Triticum aestivum*). Twenty-five *Pseudomonas* spp. strains isolated from Antarctic soils at Greenwich Island (South Shetland Islands, Antarctic Peninsula) were tested. The isolates grew well at temperatures ranging from 4 to 30 °C and were therefore considered as eury-psychrophiles. The isolates solubilized tri-calcium phosphate at 8 and 16 °C in the presence of different sugars as sole carbon sources. Besides producing indole-acetic acid, siderophores and hydrogen cyanide, several isolates inhibited growth of three plant pathogenic fungi (*Fusarium oxysporum*, *Pythium ultimum* and *Phytophtora infestans*) by means of both soluble- and volatile-secondary metabolites. Bacterization of *T. aestivum* seeds with selected isolates significantly enhanced root elongation. Moreover, when grown in sterile soil and in a temperature-controlled growth chamber at 14 ± 1 °C, inoculated *T. aestivum* seedlings showed a significant increase in their root- and shoot-lengths compared to untreated controls. Overall, the results suggest that some of these Antarctic *Pseudomonas* spp. isolates could act as cold-active biofertilizers.

Keywords Biofertilizers · Plant-growth promoting bacteria · *Pseudomonas* · Psychrotolerant · Antarctica

Introduction

Pseudomonas is a genus of diverse and ecologically versatile bacteria able to colonize terrestrial, freshwater and marine habitats (Spiers et al. 2000; Silby et al. 2011; Wu et al. 2011). Among the various traits exhibited by *Pseudomonas* species, some strains successfully colonize the rhizosphere of many plants playing widely diverging roles such as plant-growth promoters (PGP), as biocontrol agents and even as pathogens (Lugtenberg et al. 2001; Raaijmakers et al. 2002). Another remarkable trait of *Pseudomonas* species is that they can withstand different kinds of stress. Numerous psychrotolerant and psychrophilic *Pseudomonas* have been isolated from cold environments all around the world (Shivaji et al. 1989; Meyer et al. 2004; Reddy et al. 2004; Bozal et al. 2007; Mishra et al. 2009; Canion et al. 2013; Kosina et al. 2013; Da Silva et al. 2017). Many of these cold-adapted *Pseudomonas* have shown PGP effects both in vitro, and in vivo under greenhouse and field conditions, generating interest in their potential use in agriculture

✉ Luis Andrés Yarzábal
yluis@ula.ve

1 Universidad Católica de Cuenca, Unidad de Salud y Bienestar, Av. Las Américas, Cuenca, Azuay, Ecuador

2 Laboratorio de Microbiología Molecular y Biotecnología, Facultad de Ciencias, Universidad de Los Andes, Av. Alberto Carnevalli, Mérida, Estado Mérida, Venezuela

3 ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, ESPOL, Biotechnological Research Center of Ecuador, Campus Gustavo Galindo, Guayaquil, Ecuador

4 Facultad de Farmacia y Bioanálisis, Universidad de Los Andes, Av. 16 de Septiembre, Mérida, Estado Mérida, Venezuela

5 Carrera de Ingeniería Agronómica, Facultad de Ciencias Agropecuarias, Universidad de Cuenca, Avenida 12 de Octubre y Diego de Tapia, Cuenca, Azuay, Ecuador

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