Microbiological Research 168 (2013) 183–191

Contents lists available at SciVerse ScienceDirect

Microbiological Research

journal homepage: www.elsevier.com/locate/micres

Screening of Brazilian cacti rhizobacteria for plant growth promotion under drought

Vanessa Nessner Kavamura[a,b,*], Suikinai Nobre Santos[a,b], João Luiz da Silva[a], Márcia Maria Parma[a], Luciana Aparecida Ávila[a], Alexandre Visconti[a], Tiago Domingues Zucchi[a], Rodrigo Gouvêa Taketani[a], Fernando Dini Andreote[b], Itamar Soares de Melo[a]

[a] Laboratory of Environmental Microbiology, Embrapa Environment, P.O. Box 69, Jaguariúna, SP 13820-000, Brazil
[b] Department of Soil Science, "Luiz de Queiroz" College of Agriculture, University of São Paulo, P.O. Box 83, Piracicaba, SP 13400-970, Brazil

ARTICLE INFO

Article history:
Received 2 October 2012
Received in revised form
27 November 2012
Accepted 1 December 2012
Available online 29 December 2012

Keywords:
Cacti
PGPR
Zea mays L.
Water stress
Semi-arid

ABSTRACT

Drought is one of the major problems worldwide. The search for new and efficient microorganisms, from unexplored environments, to be used in association with plants to alleviate the negative effects imposed by water stress, is an interesting alternative. Thus, cacti-associated bacteria from the Brazilian semi-arid region were isolated based on their ability to grow in medium with reduced water availability. Strains were tested for the production of exopolysaccharides (EPS), as well as *in vitro* plant growth promotion traits. A great proportion of the isolates belong to the genus *Bacillus*. From a total of forty-eight bacteria, 65% were able to grow in medium with reduced water availability (0.919A_w), exopolysaccharide production was observed for 65% of the strains. The production of indole acetic acid (IAA) exceeding 51 $\mu g\,mL^{-1}$ was observed for 4% and the high solubilization of Ca–P was verified for 6% of the isolates. No strain was able to produce hydrogen cyanide (HCN), 71% produced ammonia and 79% showed a halo of carboxymethyl cellulose (CMC) degradation. *Zea mays* L. growth promotion under water stress (30% of field capacity) was achieved by two strains of *Bacillus* spp. This is the first report to describe cacti-associated bacteria from Brazilian semi-arid with plant growth-promoting abilities.

Introduction

Water is one of the most limiting factors for plant development, as well as for all life forms. Drought is a natural and complex phenomenon that affects several parts of the world, causing social, economic and environmental negative impacts (Macedo et al. 2010). Agricultural losses due to drought are quite substantial. One alternative for growing plants under dry conditions is the use of xerotolerant microorganisms associated to crops. These microorganisms can be found in environments where they are constantly submitted to water stress, as the scenario found in the Brazilian northeast. It has a semi-arid climate, which is considered to have an aridity index of 0.2–0.5 and rainfall ranging from 200 to 800 mm (*United Nations Environmental Programme*, UNEP 2007). There are two well defined seasons: rainy and dry, with the predominance of a dry and hot weather. It comprehends a unique biome called Caatinga, a poorly explored environment so far. This biome is characterized by typical vegetation with the presence of a relatively low tree layer (up to 5 m high), with thin spiny trees and shrubs, deciduous in the dry season (Queiroz 2006). The vegetation is also characterized by the presence of plants belonging to the Cactaceae family, whose members remain green even during the summer. These cacti had been modified throughout evolution, with some unusual evolutionary features such as changes in vegetative structures (loss or reduction of leaves); the cortex and the medulla are transformed into a tissue suitable for water storage; side branches are transformed into clusters of spines (Anderson 2001). One cactus widely distributed in the Caatinga is *Cereus jamacaru*, known as "mandacaru" (Fig. 1A). It has an arboreal appearance, with a cylindrical trunk with four to six ribs and innumerous spiny branches. Two other cacti, *Melocactus* sp. (Fig. 1B), known as "cabeça-de-frade" and *Pilosocereus gounellei* (Fig. 1C), known as "xique-xique" also have a wide distribution. The first possesses a cone-shaped shoot and can reach up to 22 cm high. It has ten edges with areolas of spines arranged in groups of five to seven, the flowers are red and the fruit is pink (Barbosa 1998). The second one is usually found in rocky and stony soils, more specifically in "Caatinga de lajedo" (Fig. 1D) (Taylor and Zappi 2004). It is a species with a columnar shape, forming a set of branches like a chandelier. Its height can vary from short stature, up to small tress with 3–4 m high (Gorelick 2009).

* Corresponding author at: Laboratory of Environmental Microbiology, Embrapa Environment, P.O. Box 69, Jaguariúna, SP 13820-000, Brazil. Tel.: +55 11 979544265.
E-mail address: van_nessner@yahoo.com.br (V.N. Kavamura).

0944-5013/$ – see front matter © 2012 Elsevier GmbH. All rights reserved.
http://dx.doi.org/10.1016/j.micres.2012.12.002

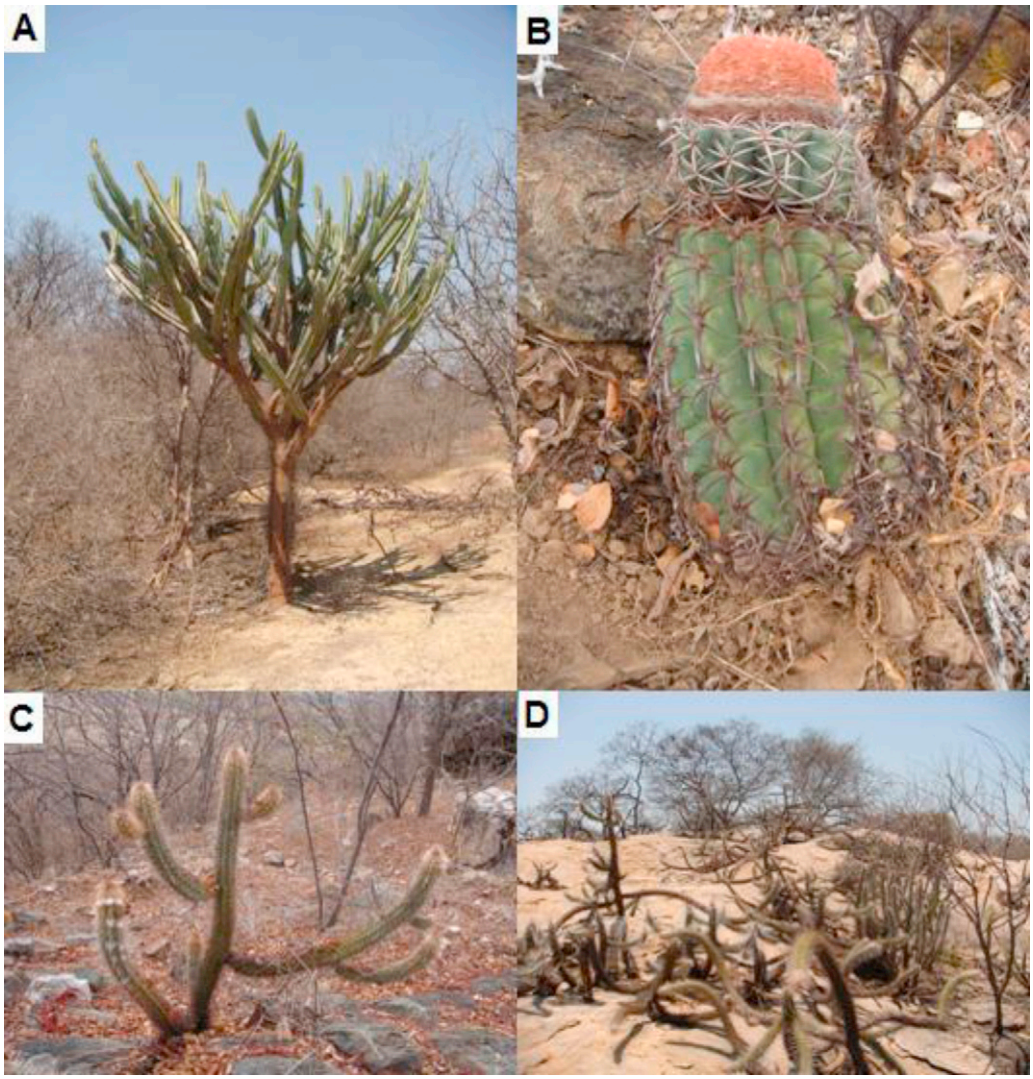

Fig. 1. Cacti found in the Caatinga biome of the Brazilian semi-arid region. A – *Cereus jamacaru*; B – *Melocactus* sp.; C – *Pilosocereus gounellei*; D – *P. gounellei* commonly found in rocky and stony soils ("Caatinga de lajedo").

Due to the high biodiversity potential, this biome possibly harbors novel microorganisms with interesting and desirable characteristics like the ability to tolerate some environmental stressful conditions, *e.g.* drought, as well as to promote plant growth. Microorganisms can survive under drought conditions through several mechanisms such as the production of exopolysaccharides (EPS) (Nocker et al. 2012), biofilm formation (Chang et al. 2007) and osmolytes production in order to avoid cell water loss (McNeil et al. 1999). Besides, microorganisms can also offer plant protection against desiccation through the maintenance of a moist environment and conducive to root development, supply of nutrients, hormones, also acting as plant growth-promoters.

The mechanisms by which plant growth-promoting rhizobacteria (PGPR) act, can be whether direct or indirect (Saraf et al. 2011). Phytohormone production like indole acetic acid (IAA), gibberellin, cytokinin and ethylene; phosphate solubilization; nitrogen fixation and siderophore production are all considered direct mechanisms. The main auxin produced by plants is IAA that can also be produced by soil inhabiting bacteria. It stimulates root proliferation that increases nutrient uptake, thus promoting plant growth (Lambrecht et al. 2000). Phosphorus is a highly distributed nutrient in soils; however, it can bind easily to other elements, like Fe, Al and Ca, depending on soil pH, being inaccessible for plant absorption (Lindsay et al. 1989). Phosphate solubilization can be performed by some fungi and bacteria through the production of organic acids that dissolve phosphate by anion exchange or binding to Fe or Al, turning phosphorus available (Omar 1998). Among the indirect mechanisms, it is possible to consider antibiosis by volatile production, such as hydrogen cyanide (HCN) and ammonia; competition; parasitism, with the production of enzymes such as chitinases, glucanases and cellulases (Kai et al. 2009; Minaxi et al. 2012; Sindhu and Dadarwal 2001).

Therefore, due to their multiple traits, the search for new PGPR becomes interesting, once they can be used as inoculants for biofertilization, phytostimulation and biocontrol purposes (Bloemberg and Lugtenberg 2001) in agriculture, forestry and environmental recovery (Lucy et al. 2004).

In this way, the aim of this work was to identify and characterize novel rhizobacteria from three Brazilian cacti, *C. jamacaru*, *P. gounellei* and *Melocactus* sp. able to grow at reduced water content, exhibiting plant growth-promotion traits for future application in agricultural improvements under drought conditions.