Endophytic bacteria of the rock-dwelling cactus *Mammillaria fraileana* affect plant growth and mobilization of elements from rocks

Blanca R. Lopeza, Clara Tinoco-Ojangurenb, Macario Bacilio a, Alberto Mendozac, Yoav Bashana,d,∗

a Environmental Microbiology Group, Northwestern Center for Biological Research (CIBNOR), Mar Bermejo 195, Col. Playa Palo de Santa Rita, La Paz, B.C.S. 23090, Mexico
b Insituto de Ecologia, Universidad Nacional Autonoma de Mexico, Apdo. Postal 1354, Hermosillo, Sonora 83000, Mexico
c Centro de Biotecnologia Genomica-IPN, Blvd. Del Maestro s/n, Col. N. Mendoza, Reynosa, Tamaulipas 88710, Mexico
d The Bashan Foundation, 3740 NW Harrison Blvd., Corvallis, OR 97330, USA

A b s t r a c t

Mammillaria fraileana is a major pioneer, small cactus that harbors endophytic bacteria that have plant growth-promoting traits, including rock-weathering capacity. Our working hypothesis was that this functional group of endophytic bacteria assists in establishing pioneer plants on rocks. When these endophytic bacteria were inoculated on seedlings grown in rock substrate, mobilization of elements from the substrate increased at variable levels across combinations of substrates and inoculants. In plants grown in the rhyodacite substrate, where these cacti naturally grow, increased mobilization occurred in plants inoculated with several strains. Promotion of plant growth, manifested as an increase in dry weight, was greater in cacti inoculated with *Enterobacter sakazakii* M2PFe. Accumulation of nocturnal acids, indicating photosynthesis by crassulacean acid metabolism, was superior in plants inoculated with the endophytes *Azotobacter vinelandii* M2Per and *Pseudomonas putida M5TSA*. Inoculation with endophytes can stimulate plant growth of *M. fraileana* by mobilizing elements from rock, which can lead to higher photosynthetic activity and accumulation of biomass. Inoculation with *P. putida M5TSA* also led to accumulation of more total nitrogen than plants inoculated with a control nitrogen-fixing bacteria. Evidence of endophytic colonization is provided after initial inoculation of seedlings and re-isolation and sequencing of 16S DNA of recovered bacteria from developing disinfected plants. The associative interaction between pioneer cacti and their bacterial endophytes enable the host plants to grow in places where plants do not normally grow. Through colonization and establishment of pioneer plants, soil is created, which facilitates colonization by other desert species and contributes to the diversity of dry lands.