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Inoculation of soil native cyanobacteria to restore arid degraded soils

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Restoration projects in semiarid lands often yield poor results. Water scarcity, low soil fertility, and poor soil structure strongly limit the survival and growth of planted seedlings in these areas. Under these conditions, a previous stage that improves edaphic conditions would turn out to a successful plant restoration. By successfully colonizing arid soils, cyanobacteria naturally provide suitable edaphic conditions, enhancing water availability, soil fertility and soil stability. Furthermore, cyanobacteria can be easily isolated and cultured ex-situ to produce high quantities of biomass, representing a potential tool to restore large areas efficiently.

The objective of this study was to test the effect of inoculated cyanobacteria on degraded soils at three different semiarid areas from southeast Spain: Tabernas badlands, a limestone quarry located in Gádor, and grazed grassland in Las Amoladeras (Cabo de Gata). Soil native cyanobacteria belonging to three representative N-fixing genera (*Nostoc*, *Scytonema* and *Tolypothrix*) were isolated from such soils and cultured in $BG11_0$ medium. Each strain was inoculated (6 g m^{-2}), separately and mixed (all in the same proportion), on Petri dishes with 80 g of each soil. Biocrust development was monitored during 3 months in these soils under laboratory conditions, at a constant temperature of 25^{o}C. During the experiment, two irrigation treatments were applied simulating a dry (180 mm) and a wet (360 mm) rainfall year (average recorded in the study sites). After 3 months, net CO_2 flux, spectral response and soil surface microtopography (1 mm spatial resolution) of inoculated and control soils was measured under wet conditions, all of them as a surrogate of biocrust development. Samples of the surface crust were collected in order to determine total soil organic carbon (SOC) content.

The inoculated soils showed positive values of net CO_2 flux, thus indicating a net CO_2 uptake, whereas control soils showed CO_2 fluxes closed to zero. This higher CO_2 fixation in the inoculated soils was reflected in the higher SOC content found in these soils with respect to the non-inoculated soils. Soil surface roughness increased with biocrust development in the inoculated soils as compared to control soils. From the different treatments, soil inoculation with the mixture of the three strains promoted the highest SOC contents and absorbance at 680 nm (indicative of higher chlorophyll a content) on the three soil types. Therefore, using a consortium of cyanobacteria to inoculate degraded soils seems to be a more promising strategy to restore soils than inoculating individual species. Finally, differences between irrigation treatments were no significant, suggesting that water availability was not a key driver for cyanobacteria development under control laboratory conditions.

Our results underline the viability of cyanobacteria inoculation to form an artificial developed biocrust that contribute to CO_2 uptake and increase soil fertility which could facilitate further plant cover establishment. However, more studies are necessaries to test the effectiveness of inoculated crust development under field conditions.