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Vegetation-induced soil water repellency as a strategy in arid ecosystems. A geochemical approach in Banksia woodlands (SW Australia)

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Introduction

Banksia woodlands (BW) are iconic ecosystems of Western Australia (WA) composed by an overstorey dominated by Proteaceae, e.g. Banksia menziesii and Banksia attenuata, in combination with other species, such as Eucalyptus spp., Verticordia spp. or Melaleuca spp. Although located in very poor dune soils, BW provide numerous ecosystem services and sustain a high biodiversity. In this area, annual rainfall is relatively high (about 800 mm) but permeability of the sandy substrate leads to a functionally arid ecosystem. Currently, BW are threatened by sand mining activities and urban expansion; therefore conservation and restoration of these woodlands are critical. Despite numerous efforts, the success of restoration plans is usually poor mostly due to the high sensitivity to drought stress and poor seedling survival rates (5-30%) (Benigno et al., 2014). A characteristic feature of BW is their root architecture, formed by a proteoid (cluster) system that spreads to form thick mats below the soil surface, favouring the uptake of nutrients (especially, P), and preventing soil erosion. Root exudates are related to numerous plant functions, as they facilitate penetration of roots in soil and enhance the extraction of scarce mineral nutrients and its further assimilation. Exudates may also interact directly with soil or indirectly through microbial mediated events being also related to soil water repellency (SWR; Lozano et al, 2014). Knowledge about the specific compounds able to induce SWR is limited (Doerr et al., 2000), but it is generally accepted that is caused by organic molecules coating the surface of soil mineral particles and aggregates (Jordán et al., 2013). Proteaceae release short-chained organic acids to enhance phosphate acquisition, which have been also reported to be related with SWR (Jiménez-Morillo et al., 2014).

It is hypothesized that disruption of water dynamics in mature BW soils is underlying the failure of restoration plans. This research aims to study SWR and its impact on water economy in relation with soil functioning and plant strategies for water uptake in pristine BW. Results are expected to shed light on the origin and implications of SWR in the area and provide useful information for improving ongoing restoration plans.

Materials and methods

The study was conducted in natural BW of WA. Soil samples were collected at different soil depths (0-1, 1-10, 20-30 and 40-50 cm). Rationale for sampling depths was based on the different severities of SWR at each layer under field conditions. Soil water repellency was assessed under laboratory conditions in oven-dry samples (48 h, 105 ºC) and the chemical organic assemblage of bulked soil subsamples from each layer was analysed by direct analytical pyrolysis (Py-GC/MS).

Results and discussion

Soil water repellency distributed discontinuously through the soil profile. The first thin layer (0-1 cm) composed of coarse sand and litter, located immediately above Banksia root clusters, showed wettable conditions. In contrast, the relatively well aggregated soil layer where the Banksia cluster root system is located (1-10 cm) was severely water-repellent. The 20-30 and 40-50 cm deep layers rendered wettable or subcritically water-repellent. After Py-GC/MS analysis, major compounds were identified and grouped according to their probable biogenic origin (lignin, polysaccharides, peptides, etc.). Among other soil organic compounds, well resolved bimodal alkane/akene (C8-C31, maxima at C13 and C26) and fatty acids series (short-chained, C5-C9, and long-chained even-numbered C12-C18) were associated to the root cluster soil layer (1-10 cm). Also, a relatively high contribution of fire-derived polycyclic aromatic hydrocarbons (PAHs) was observed (7%), which is consistent with frequent fires occurring in BW.

These results point to possible indirect links between organic substances released by roots and soil wettability involving soil microorganisms. Further discussion should shed light on possible ecological plant strategies and specific adaptations for water uptake in such arid ecosystems of WA.

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