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Article

Cymodocea nodosa, a native candidate for phytoremediation of potentially toxic elements and restoration of Mediterranean soils

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Abstract

Seagrass ecosystems provide ideal for industrial activities often leads to high concentrations of potentially toxic elements (PTE) discussing with depth. This study investigated the potential of the native seagrass Cymodocea nodosa for phytoremediation of PTE-polluted coastal sediments. Rhizosphere soil, roots, rhizomes, sheaths of both seawater and other contaminated bioenergetics, and Cymodocea nodosa. Cymodocea nodosa's field of fertilizer and the. Cymodocea nodosa's field of fertilizer

Plant and root nodule analyses

Roots were separated from soil samples, washed under tap water to remove soil particles, then carefully rinsed with deionized water and dried using paper towel. For each root sample, the total number of nodules has been reported. Root and aerial parts of *C. juncea* were weighted within few hours of the return from the field to obtain the fresh biomass. The plant samples were dried at 60 °C for at least 72 h and weighed again to obtain the dry biomass. To analyze the plant PTE concentration, the dry samples were ground at 0.5 mm: the aerial parts using tungsten carbide blades (Foss Tecator Cyclotec 1093) and the root parts using a mixer mill (Retsch MM400). About 0.5 g dry matter of each plant sample (triplicate) was digested in microwave mineralizer system (Milestone Start D) with an acidic mixture (2/3 HNO_3 + 1/3 HCl). After a filtration using a 0.45 μm mesh, the solutions were analyzed by ICP-AES as previously described for soil samples. Standard plant reference material (DC 73349 from NCS, China) was analyzed as a part of the quality assurance-quality control protocol (accuracies within 100 ± 10%).

Data processing and statistical analyzes

In order to estimate the variation of soil PTE pseudo-total concentrations, we calculated differences of concentration (delta values) between samples of 0–10 cm and 10–20 cm depth within a plot ($\delta = [PTE]_{0-10} - [PTE]_{10-20}$). For comparing among sites, we chose to use delta values rather than directly soil pseudo-total concentrations per plot, because they showed a high intra-site variability.

Root bioconcentration factors (BCF) were calculated, for the root and root PTE pseudo-total concentrations as following[60]: $BCF_{root} = [PTE]_{root}$ / $_{parts}[PTE]_{soil}$ where [PTE] is the PTE pseudo-total concentration. The translocation factor (TF) was estimated as following: $TF = [PTE]_{aerial\ parts}/[PTE]_{root\ parts}$.

We tested for normality using a Shapiro–Wilk test in R 3.0.2 software[78] and stats and ade4 packages[79]. When data were not normally distributed, we used Wilcoxon tests to analyze the differences between samples from different sites and/or depths (soil and root samples). We also used Spearman rank correlation tests to analyze the correlations between variables.

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Author contributions

A.H., P.F., H.F., J.R. and S.L. contributed to the study conception and design. Material preparation, data collection and analysis were performed by A.H., P.P., H.F., J.R., S.C., M.D.S., L.V. and I.L.S. The first draft of the manuscript was written by A.H. and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. Funding acquisition was achieved by A.H., H.F. and I.L.S.

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Data availability

All data generated or analysed during this study are included in the published article available on request. More information is available from the corresponding author on reasonable request. Collection of plant material was done in agreement with the PNCal regulation number 02015-046 available at http://www.calanques-parcnational.fr/fr/download/file/fid/1095.

Competing interests The authors declare no competing interests.

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