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Phytoremediation potential of alimurgic plants in metal-contaminated environments

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Introduction

As soil metal contamination is rapidly increasing worldwide, mainly because of human activities, phytomanagement of polluted land is becoming an environmentally sustainable and cost-effective option that can also produce biomass and energy as secondary utilities. Some *Asteraceae* and *Polygonaceae* species growing spontaneously as invasive weeds on natural and farmed land, which are considered medical or edible alimurgic species, have been identified to accumulate high above-ground levels of toxic elements, thanks to efficient root-to-shoot translocation. Most of them combine high adaptability to marginal soils with good shoot biomass, and many are metal indicator or hyperaccumulator species.

In this study were investigated the shoot and root growth potential, metal uptake and translocation at the flowering stage of wild chicory (***Cichorium intybus*** L.), common sowthistle (***Sonchus oleraceus*** L.), salsify (***Tragopogon porrifolius*** L.), common dandelion (***Taraxacum officinale*** Web.) and garden sorrel (***Rumex acetosa*** L.) in artificially highly Cd-Co-Cu-Pb-Zn-contaminated soil.

Methodology

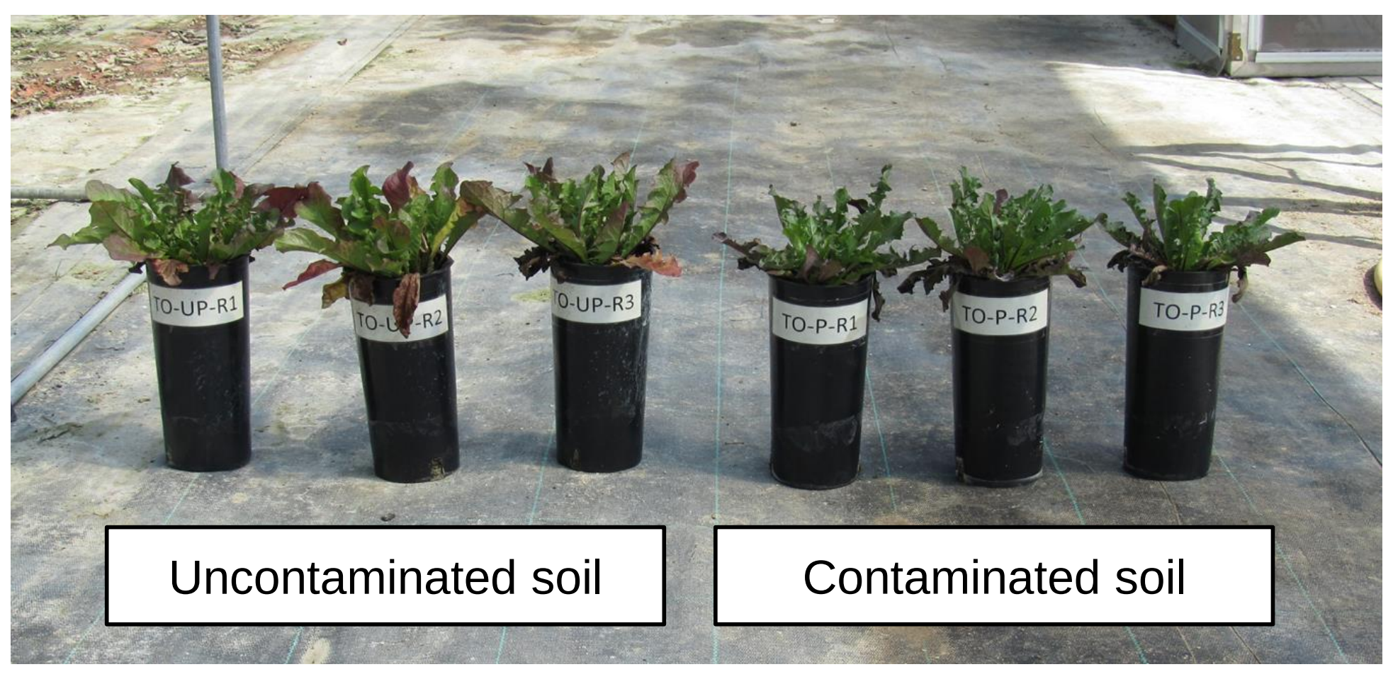

Figure 1 - *T. officinale* cultivated in the trial pots.

- Plants grown in PVC pots (n=3) (Fig. 1) filled with silty-loam soil artificially contaminated with Cd, Co, Cu, Pb and Zn, exceeding the Italian Guideline Values (IGV) for agricultural uses by ~2×, 2×, 2×, 4× and 6× respectively.
- Monitoring of the dynamics of bioavailable soil Cd, Co, Cu, Pb and Zn in uncultivated references by periodic sampling through extraction in a solution of DTPA and ICP-OES (Inductively Coupled Plasma - Optical Emission Spectroscopy) detection.
- Determination, at the end of the trial, of the metal concentrations in the total amount of percolated water from the pots.
- Separate collection of plant stems, leaves and tap-roots. Fibrous roots length was measured by automatic image analysis. Metal concentrations in plant tissues were revealed after microwave acid-digestion and ICP-OES analysis.
- *T. officinale* and *R. acetosa* growing spontaneously in potentially contaminated environments (from the soil covering a urban waste landfill, field ditch sediments and roadsides subjected to heavy traffic), together with their rhizosphere soil, were analysed for the metal concentrations.
- Statistical analysis was carried out by Statgraphics Centurion XV software. ANOVA and the Newman–Keuls test ($P \leq 0.05$) were used to evaluate differences among means.

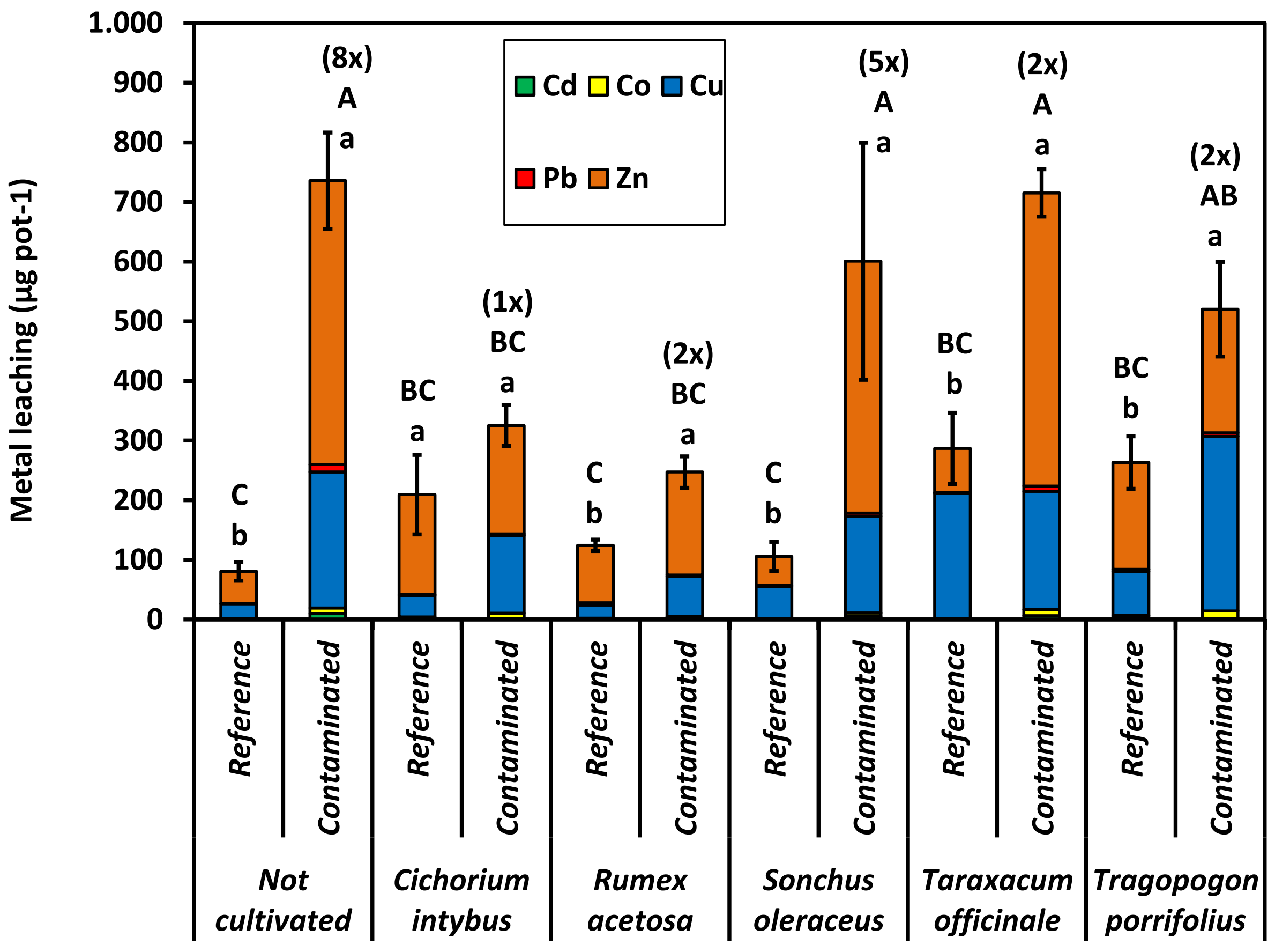

Figure 4 - Overall metal leaching in percolated water (±S.E., n=3) in pot trial. Capital letters: significance for multiple comparisons. Small letters: differences between soils within same species

Metal leaching

Concerning contamined soil data only, low metal losses were found in *C. intybus* and *R. acetosa* (Fig. 4). Zn and Cu represented almost all the leachate, on average 60% and~35%, respectively, fractions which were very stable across species and treatments. Instead, Cd, Co and Pb percolation was negligible. In contaminated soil overall leaching of Co+Cd+Cu+Pb+Zn was negatively correlated with plant biomass ($R^2 = 0.15$).

Vegetation grown at potentially polluted sites

Grew along the roadside, T. *officinale* efficiently accumulated Zn and Cu and *R. acetosa* Pb, with values generally lower than those found in the contaminated soil of the pot trial, but almost double those of the uncontaminated pots. Cd was poorly taken up and did not exceed 0.33 mg kg^{-1} plant DW.

Results

Plant growth and metal uptake

A significant lower biomass production (shoot + roots) was recorded, except for *R. acetosa* and *S. oleraceus*, which grew almost normally (Fig. 2.a).

In the contaminated environment, *Sonchus* and *Taraxacum* also showed a great reduction in fibrous root length, -59% and -73%, respectively, whereas the other species only showed small variations (Fig. 2.b).

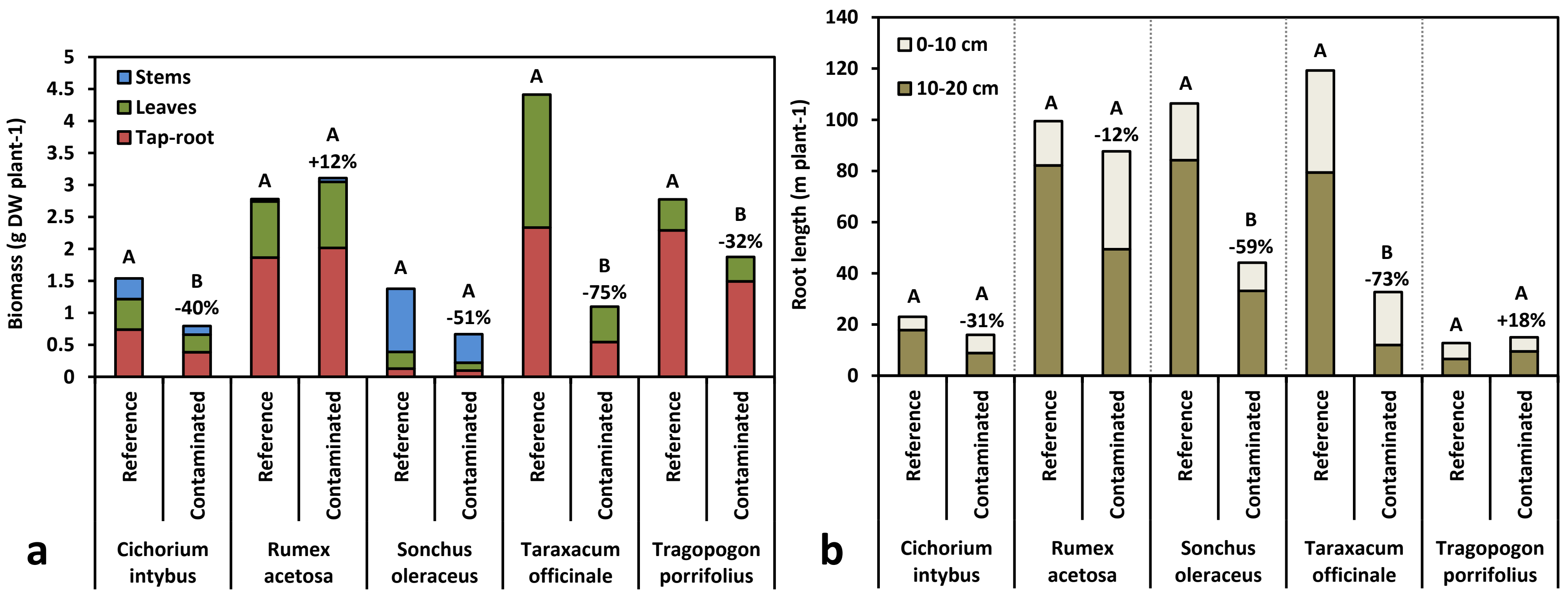

Figure 2 - Biomass (a) and root length (b) in species grown in contaminated vs. reference soil. Capital letters: differences among soils within same species (% variation with respect to reference soil).

In view of the highest biomass yield under contamination, individual plants of *R. acetosa* also reached the highest metal accumulation in both above- and below-ground plant compartments, with an overall Cd+Co+Cu+Pb+Zn stock of ~1.1 mg per plant, followed by *T. officinale* with half the *R. acetosa* value (Fig. 3). At a suitable density of 15-20 plants m^{-2} for *R. acetosa*, an uptake of ~230 g ha^{-1} of various metals was estimated, 35% of which removable by forage harvest. Despite the less efficient uptake per individual plant, similar removals were estimated for *T. porrifolius*, due to its potentially higher plant density (40-60 plants m^{-2}), with a higher fraction allocated in the harvestable above-ground biomass (~40%).

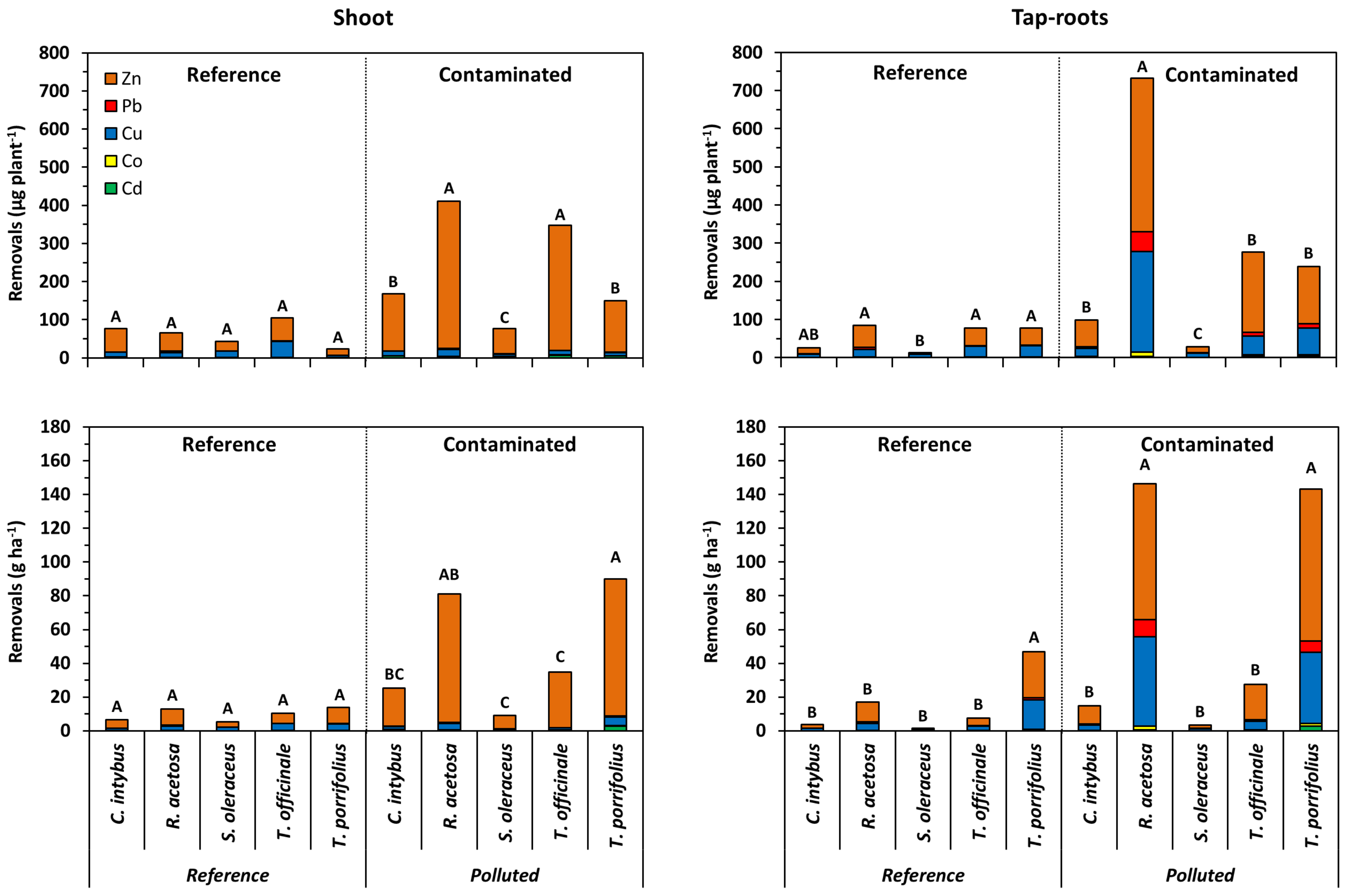

Figure 3 - Metal removals by shoots (leaves+stems) and tap-roots (n=3) per plant (top) and estimate per hectare (bottom) in pot trial. Letters: differences between species for overall removals within same soil.

Conclusions

Species choice among wild alimurgic plants creates new opportunities for phytoextraction and possibly in planta stabilisation, mainly of Zn and Cu. Stakeholders and authorities should consider the opportunity of favouring natural re-vegetation of critical environments, such as mining areas or landfills, where water drift and wind erosion facilitate metal dispersion from bare soil. However, their food use is not recommended, since leaf Cd and Pb may exceed EU safety thresholds.

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