Phytoremediation abilities of maize (*Zea mays* L.) inoculated with plant growth promoting rhizobacteria in Zinc and Cadmium contaminated soils

Helena Moreira, Ana P. G. C. Marques , António O. S. S. Rangel , Paula M. L. Castro

CBQF – Centro de Biotecnologia e Química Fina, Escola Superior de Biotecnologia, Centro Regional do Porto da Universidade Católica Portuguesa, Rua D. António Bernardino de Almeida, 4200-072 Porto, Portugal

hgmoreira@porto.ucp.pt

CATÓLICA PORTO

BIOTECNOLOGIA

Introduction

Heavy metal contaminated soils are a worldwide problem. Efforts to reduce their high impact by using sustainable and low-cost strategies such as phytoremediation may be a promising path in remediation techniques. **Maize** (*Zea mays* L.) is a crop that grows widely throughout the world with important attributes to be considered a plant suitable for this purpose such as:

- high biomass yield per hectare;
- quick, vigorous and tall (2-3 m) growing cereal capable of continuous phytoextraction of metals from contaminated soils;
- accumulator and tolerant for Cd and Zn..

Plant stress associated with phytoremediation strategies can be reduced by plant growth promoting rhizobacteria (PGPR). The use of these bacteria may increase the maize performance concerning its overall economical aspects, such as an increase of biomass production, that can be used for the generation of energy.

Ralstonia eutropha (B1) and *Cryseobacterium humi* (B2) are PGPR and metal resistant rhizobacteria isolated from a metal contaminated site and showed to be able to enhance biomass and growth production in maize by up 360 and 47 % respectively, in previous experiments.

The aim of the present work was to assess the influence of the inoculation with selected PGPR on the biomass production and metal accumulation by *Zea mays* in Zn and Cd contaminated soils.

Methodology

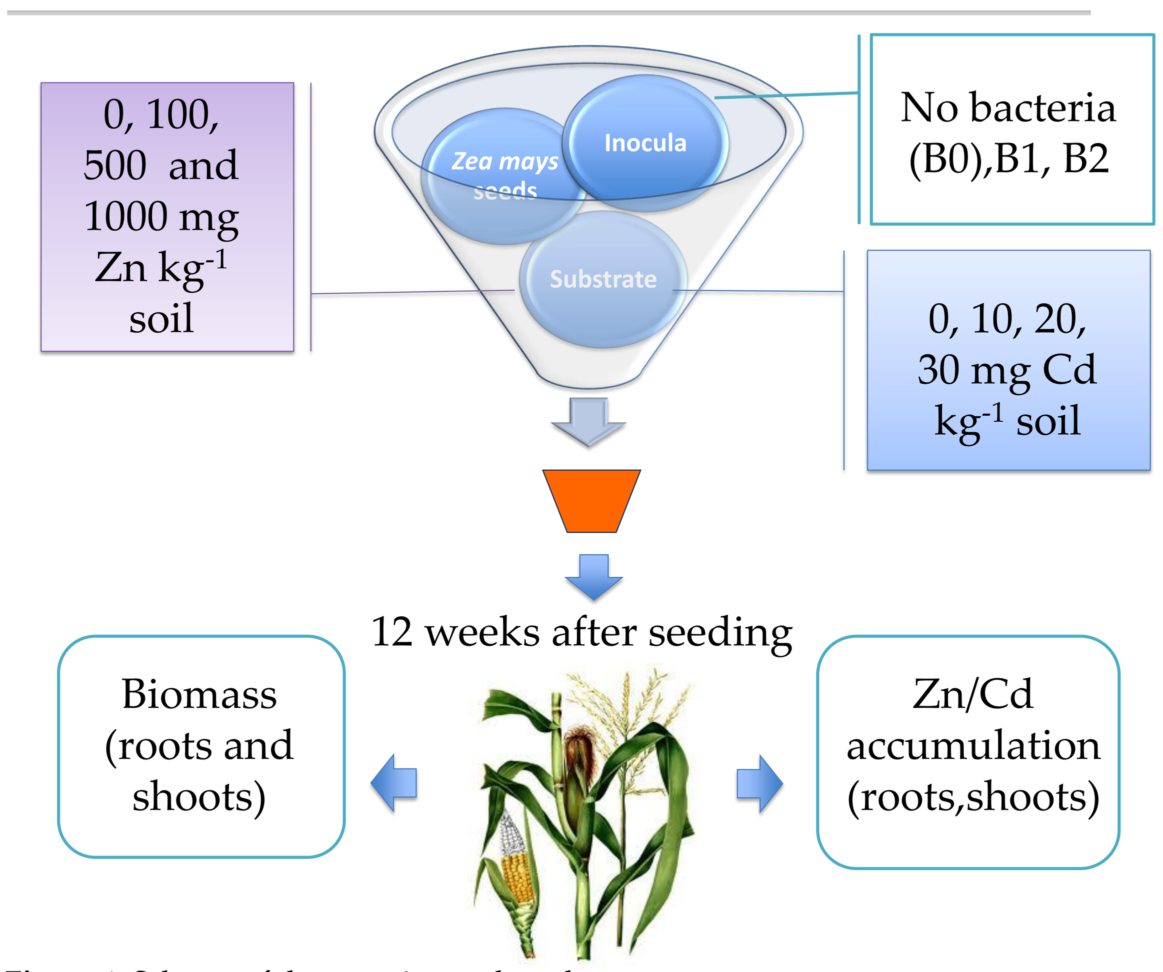

Figure 1: Scheme of the experimental work

Results and Conclusions

Zn and Cd accumulation in plant tissues – shown in tables 1 and 2 - and dry biomass - shown in figures 2 to 5 - were determined in order to infere on the influence of the bacterial inoculation and degree of metal contamination on plant development and remediation capacities.

Cd

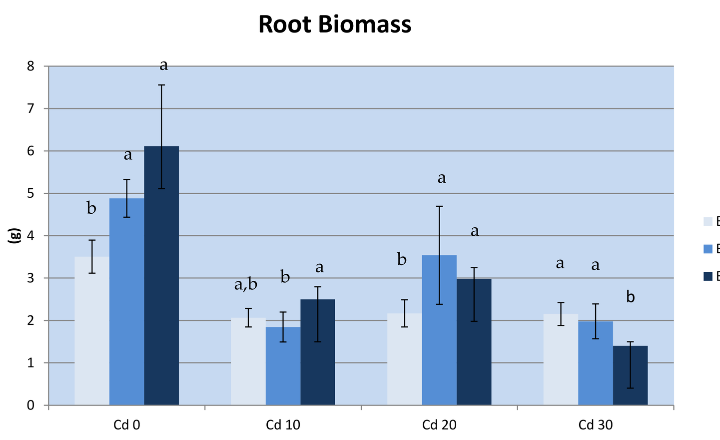

Figure 2: Root biomass in plants exposed to Cd; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test.

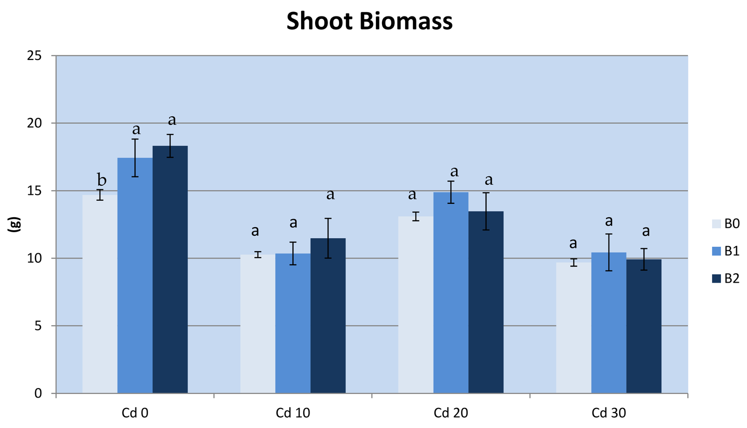

Figure 3: Shoot biomass in plants exposed to Cd; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test.

Table 1: Cd accumulation in roots and shoots of *Zea mays*

Cd (mg kg-1)	Treatment					
	Roots			Shoots		
	No bacteria	B1	B2	No bacteria	B1	B2
10	52 ± 2[a]	25 ± 6[b]	71 ± 23[a]	21 ± 4[a]	6 ± 2[b]	4 ± 1[b]
20	80 ± 6[a]	82 ± 6[a]	82 ± 7[a]	32 ± 3[a]	30 ± 3[a]	21 ± 2[b]
30	122 ± 11[a]	131 ± 13[a]	134 ± 11[a]	88 ± 5[a]	81 ± 5[b]	82 ± 1[a,b]

Cd was not detected in plants grown in control soil, therefore treatment was omited from the table. Results are shown as means ±S.D (n=4). Means with different letters in each plant line are significantly different from each other (P < 0.05) according to the Duncan test.

-**Roots**: bacteria generally increased roots biomass, but had no influence on Cd accumulation ;
- **Shoots:** in general bacteria decreased Cd accumulation in **shoots** and had no influence on its biomass.

Zn

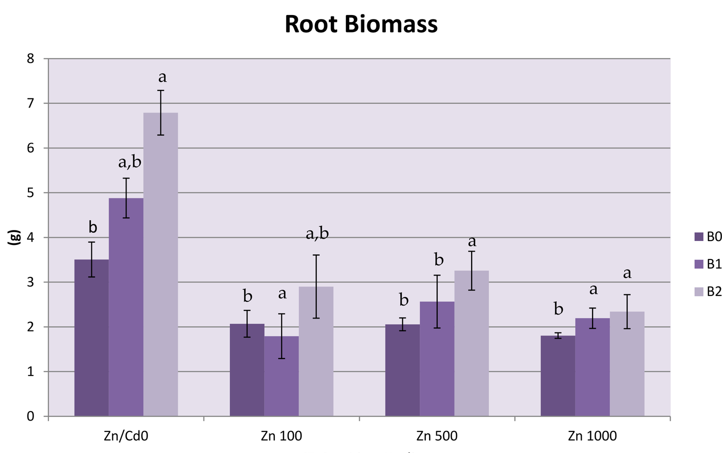

Figure 4: Root biomass in plants exposed to Zn; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

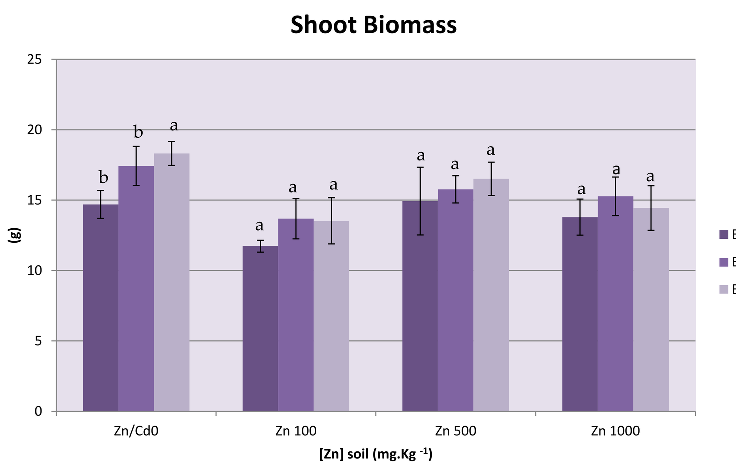

Figure 5: Shoot biomass in plants exposed to Zn; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test.

Table 2: Zn accumulation in roots and shoots of *Zea mays*

Zn (mg kg-1)	Treatment					
	Roots			Shoots		
	No bacteria	B1	B2	No bacteria	B1	B2
0	87 ± 11[a]	35 ± 4[b]	75 ± 5[b]	18 ± 1b	24 ± 2[a]	18 ± 1[a]
100	260 ± 17[b]	336 ± 45[a]	338 ± 41[b]	695 ± 82[b]	836 ± 59[b]	968 ± 102[a]
500	809 ± 55[a]	805 ± 92[a]	820 ±113[a]	430 ± 47[a]	415 ± 43[b]	422 ± 52[b]
1000	2225 ± 304[a]	1653 ± 127[b]	2143 ± 159[a]	640 ± 61[a,b]	565 ±61[b]	681 ± 39[a]

Results are shown as means ±S.D (n=4). Means with different letters in each plant line are significantly different from each other (P < 0.05) according to the Duncan test.

- **Roots:** in general bacteria increased root biomass, however this was not always significant;
- **Shoots:** Bacteria generally had do influence on shoot biomass production;
- There was no trend for bacterial influence on Zn accumulation at the roots and shoots.

Bioconcentration and Translocation Factors (BCF/TF)

Cd

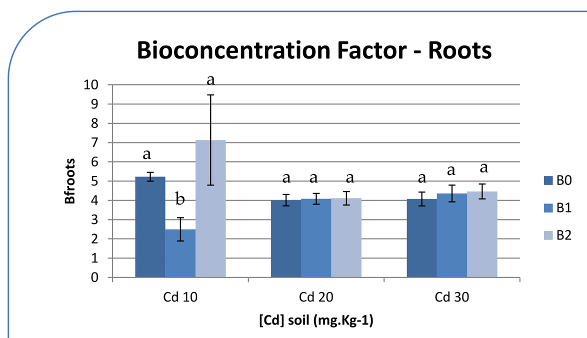

Figure 6: Bionconcentration factors (BF) of roots; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test.

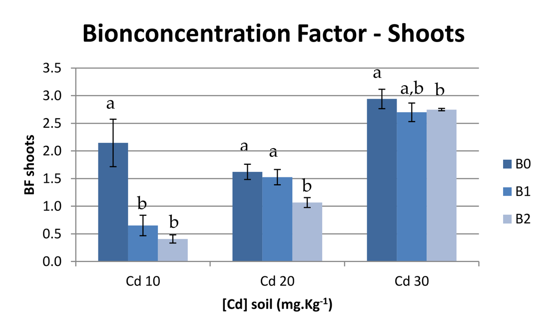

Figure 7: Bionconcentration factors (BF) of roots; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

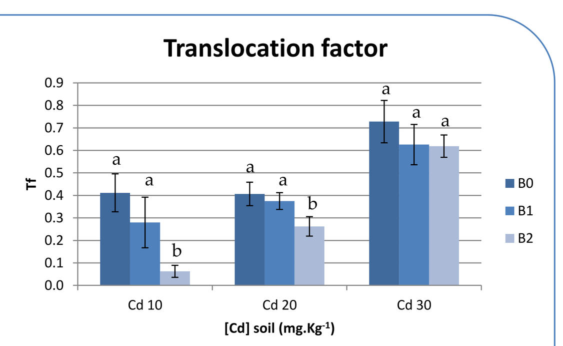

Figure 8: Translocation factors (TF); results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

Zn

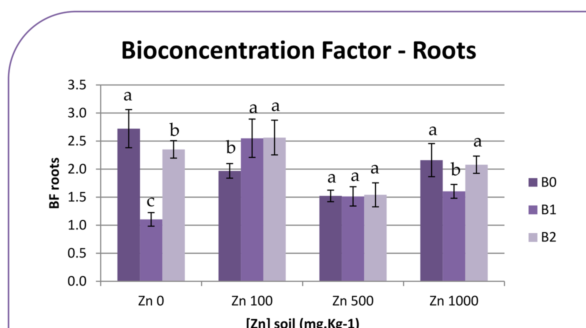

Figure 9: Bionconcentration factors (BF) of shoots; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

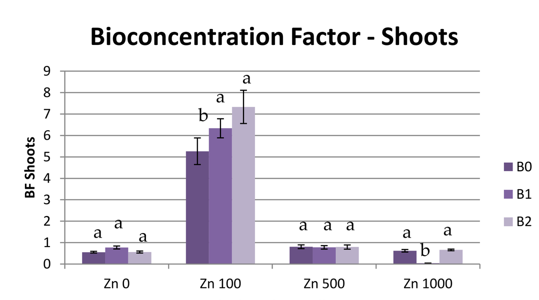

Figure 10: Bionconcentration factors (BF) of roots; results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

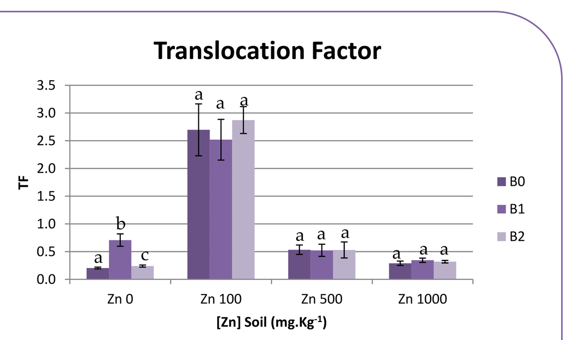

Figure 11: Translocation Factor (TF) results are shown as means ±S.D (n=4). Means with different letters in concentration are significantly different from each other (P < 0.05) according to the Duncan test..

- At low concentration (10 mg.kg^{-1}) BF on roots was decreased by strain B1 and was increased significantly by B2. However these bacteria had no influence on it at higher concentrations;
- Bacterial inocula decreased significantly BCF on shoots to values below 1 but had no significant influence at higher concentrations;
- TF<1 at all concentrations, but at 10 mg.kg^{-1}, B2 decreased it significantly.

- Bacterial inocula increased significantly BCF on roots and shoots at a soil concentration of 100 mg Zn Kg^{-1} but generally had no influence at higher concentrations;
- B1 had influence in TF only in plants grown in non spiked soil.

Acknowledgements

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