PHYTOREMEDIATION POTENTIAL OF THE PERENNIAL CROPS GIANT REED AND SWITCHGRASS TO SOILS CONTAMINATED WITH HEAVY METALS

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ABSTRACT: Among the various impacts caused by man to the environment, soil contamination deserves attention. This gives rise to a number of environmental problems such as desertification, contamination of water resources and contamination of food crops, which can lead to serious health problems for humans directly or indirectly. To avoid these situations, it is necessary to decontaminate the soils, which can occur through various techniques (physical, chemical and biological methods). The use of plants for the decontamination of soils (phytoremediation), and specifically the use of energy crops, is an interesting alternative. Along with the decontamination action, the biomass produced may provide an additional income, when used for bioenergy or biomaterials, and the process contributes to the bioeconomy by reducing the dependence on fossil fuels. Therefore, the aim of this work was to study the effects of different heavy metals (Zn, Cr, Pb, Cd, Ni, Cu) on giant reed (*Arundo donax* L.) and switchgrass (*Panicum virgatum* L.) growth, productivity and biomass quality. The soils were artificially contaminated and the concentrations chosen were based on the limits established by the Decree Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils) - Zn: 450 mg/kg; Cr: 300 mg/kg; Pb: 450 mg/kg; Cd: 4 mg/kg; Ni: 110 mg/kg and Cu: 200 mg/kg. Results indicate that both switchgrass and giant reed are crops tolerant to Zn and Pb contamination. In contrast, for both crops, in Cr contaminated soils, a significant decrease in productivity was noted. Switchgrass was unable to grown in the Cr contaminated soils. Cadmium, nickel and copper also affected the yields of both crops, but not so significantly as chromium. In this establishment year, giant reed was three times more productive than switchgrass, and therefore showed to be more promising in heavy metals contaminated soils. Biomass is being characterized to evaluate the phytoremediation ability of both crops to the heavy metals studied.
Keywords: perennial energy crops, *Arundo donax*, *Switchgrass*, heavy metals, phytoremediation, marginal soil

1 INTRODUCTION

Switchgrass and giant reed are perennial plants, with an estimated productive lifetime of at least 10-15 years, and both the stems and leaves of the crop can be harvested annually [1]. They characterized by relatively high yields, high water and nitrogen efficiencies and an apparently low susceptibility to pests and diseases [2,3]. Both crops achieve high productivity under high summer temperatures, in the Mediterranean in case of giant reed and in the south of United States for switchgrass – and cope well with severe weather conditions such as flooding in autumn, winter or spring and dryness in summer [2,3]. Their robustness and physiological characteristics, namely their deep, dense and extensive root system, allows these crops to easily adapt to different types of soils and ecological conditions, being indicated for reducing soil erosion, minimize nutrient leaching and sequester more C in soils [1,4].

However, the increasing demand for biomass for the production of bioenergy is generating land-use conflicts which might be avoided through the establishment of dedicated energy crops on marginal land, e.g. heavy-metal contaminated land. So, the cultivation of perennial grasses in polluted soils is being presented as an approach to restore or attenuate and stabilize contaminated sites while bringing additional revenue to owners [5,6]. Simultaneously, land use conflicts with food crops are avoided [7].

In this work, the yields and some biometric characteristics of the biomass (switchgrass and giant reed) were tested is contaminated soils presenting the limits for heavy metal concentration establish thought the Decreto-Lei 279/2009 [8].

2 MATERIALS AND METHODS

The trials were established in June of 2018 with Switchgrass and with local ecotypes of giant reed. In each pot (0,06154 m^2, 12kg of soil) 2 rhizomes of giant reed were established, and in the case of switchgrass the pots were sowed (a pot for each grass with three replicates). After the establishment of the rhizomes or seeds, pots were fertilized: 3 g N/m^2 (urea, 46% N); 3 g N/m^2 (nitrolusal, mixture of NH_4NO_3+$CaCO_3$, 27% N); 17 g K_2O/m^2 (potassium sulphate, 51% K_2O); 23 g P_2O_5/m^2 (superphosphate, 18% P_2O_5). Both in the switchgrass and the giant reed pots, the concentration of zinc in contaminated soils tested was 450 mg $Zn.kg^{-1}$ (dry matter, referred as Zn_1). The concentration of lead in contaminated soil was also tested for 450 mg $Pb.kg^{-1}$ (dry matter, Pb_1), the concentration of Cr tested was 300 mg $Cr.kg^{-1}$ (dry matter, Cr_1), the concentration of Ni tested

was (110 mg Ni.kg^{-1} dry matter, Ni_1), the concentration of Cd tested was 4 mg Cd.kg^{-1} (dry matter, Cd_1) and the concentration of Cu tested was 200 mg Cu.kg^{-1} (dry matter, Cu_1). The levels tested correspond to maximum allowable for a soil with a pH above 7 [8]. Water was applied at a rate to avoid water stress. In all the experiments, control pots were also tested.

At the end of growing season (January 2019), the plants were harvested, and the aerial productivity was monitored. The following parameters were monitored: yield and height of the crop for both switchgrass and giant reed, and diameter of stem for giant reed.

3 RESULTS AND DISCUSSION

3.1 Biomass Productivity

Figure 1 presents the biomass productivity obtained in the trials at the 1st harvest year for Switchgrass.

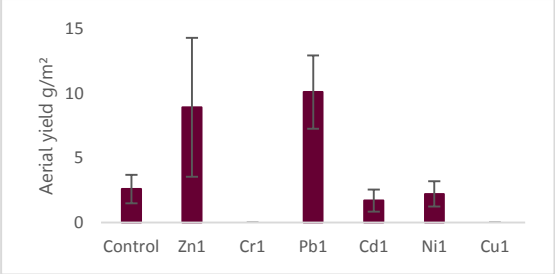

Figure 1: Switchgrass yield after cultivation in heavy metals contaminated soils.

It can be observed that for Cr and Cu contamination for Switchgrass, the yield was null. Most of the seeds were not able to germinate and the few existing germinated shoots did not resist to the contamination stress. For Ni and Cd contamination the response of biomass was a decrease in the yield. The oposite was observed for Zn an Pb contamination. Giant reed did not show a significant decrease in the yields for Zn, Pb, Cd and Ni contamination (Figure 2). Giant reed reacted to Cr and Cu contamination with a decrease in the yield (without statistical significance).

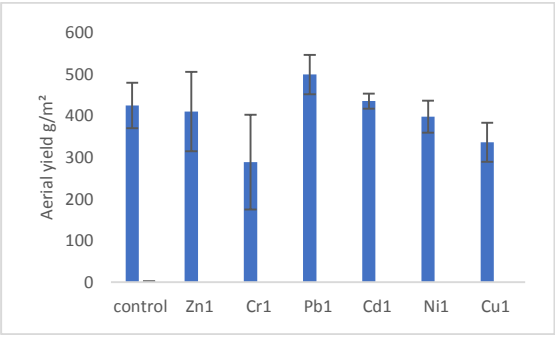

Figure 2: Giant reed yield after cultivation in heavy metals contaminated soils.

Giant reed height did not show a significant decrease for Zn, Pb, Cd and Ni contamination (Figure 3). Giant reed reacted to Cr and Cu contamination with a decrease in the height (without statistical significance).

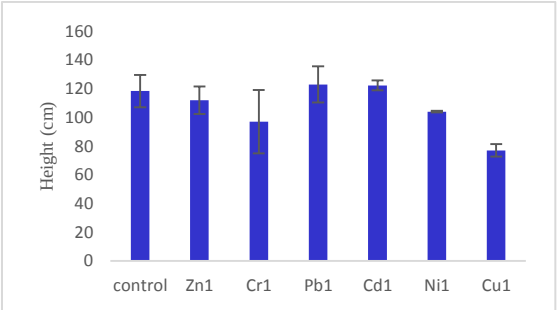

Figure 3: Giant reed height after cultivation in heavy metals contaminated soils.

Figure 4 presents the height of the crop for switchgrass under the different contaminations. No growth was observed in Cr and Cu pots and in Ni contaminated pots, a significant decrease in the height of the biomass was observed.

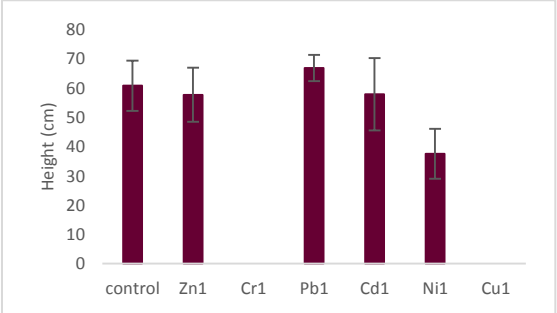

Figure 4: Switchgrass height after cultivation in heavy metals contaminated soils.

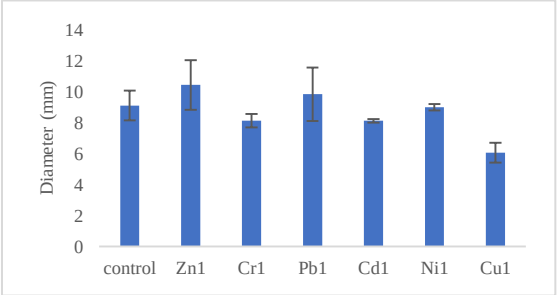

Figure 5: Switchgrass height after cultivation in heavy metals contaminated soils.

For giant reed, the diameter of the plants was measured (Figure 5), and it was observed that Cr, Cd and Cu contamination reduced the diameter of the stems. Lead and Zn contamination did not affected the diameter and Ni contamination reduced slightly the diameter.

4 CONCLUSIONS

Comparing the two chosen perennial crops, switchgrass was more affected than giant reed by the soil heavy metal contamination. Even at the limit contaminant concentrations in the soil, switchgrass was not able to grow in some contaminated pots (namely Cr and Cu contaminated pots), while giant reed appears as a promising crop to be used in contaminated land since the results showed that giant reed is not sensitive to Zn, Pb, Cd and Ni contamination. For Cr and Cu, the reduction in yield, height and diameter of stem occured but was not significant enough to compromise the production of the

biomass.

Further studies are needed to assess other parameters of the biomass quality with a view to its end use. The prospect of the valorisation of the perennial crops aerial biomass, for bioenergy or bio-products production purposes, could lessen the financial costs of soil remediation, compared to the traditional physical – chemical processes with the associated revenue of environmental benefits. Hence contributing to a more sustainable agriculture approach.

5 ACKNOWLEDGEMENTS

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