PRODUCTION OF OIL CROPS UNDER HEAVY METALS CONTAMINATED SOILS

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ABSTRACT: Cultivation of energy crops in heavy metals contaminated soils is an option once it contributes to reduce land use competition with food crops and the development of a vegetative cover contributes to reduce soil loss and degradation by erosion processes and water surface runoff. Therefore, the aim of this work was to study the effects of different heavy metals (Ni, Pb, Zn and Cd) on growth and yield of different energy crops, namely the oil crops *Camelina sativa*, *Brassica carinata* and *Thlaspi arvense*. 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; Pb: 450 mg/kg; Cd: 4 mg/kg and Ni: 110 mg/kg. Preliminary screening of the different crops studied indicate that *Brassica carinata* and *Camelina sativa* growth was not significantly affected by heavy metals contamination. By opposition, all the heavy metals affected the growth of *Thlaspy arvense*. Yet, contamination reduced significantly the number of siliquae, especially Ni and Cd contamination, which may hinder the economical viability of oil crops cultivation in heavy metals contaminated soils. Biomass is being characterized to evaluate the effects of the contamination on the oil characteristics and the phytoremediation capacity of these oil crops to the heavy metals contaminated soils studied.

Keywords: Oil crops; contaminated soils; heavy metals; phytoremediation;.polluted soil; land use.

1 INTRODUCTION

Anthropogenic activity, whether intentional or accidental, is responsible for most of the heavy metals accumulation in soils, especially in the geographical vicinity of polluting industrial activities. Soils contaminated with heavy metals might show signals of marginality through the degradation of their quality, inducing the reduction of crop yields and the quality of agricultural products, desertification, and the loss of ecosystem services, posing a significant threat to human health if those heavy metals enter the food chain [1].

Cultivation of energy crops in heavy metals contaminated soils is an option once the development of a vegetative cover contributes to reduce soil loss and degradation by erosion processes and water surface runoff [2]. Moreover, their physiological characteristics, allows these crops to easily adapt and tolerate different types of contamination [3, 4, 5]. Additionally, energy crops may contribute to the remediation of heavy metals contaminated soils through phytoextraction processes and the biomass being produced may provide an additional income to owners, when used for bioenergy or biomaterials [6, 7]. Oil crops, as sources for medium-chain fatty acids and medium-chain polymer building blocks, can be used for the production of plastics, surfactants, detergents, lubricants, plasticizers and other products, replacing fossil feedstocks [8]. As oil crops production competes directly with the food products supply both by soil usage and grains diversion for biofuels production, limiting oil crops production to heavy metals contaminated soils avoid land use conflicts with food crops [9, 10]. Therefore, the aim of this work was to do a preliminary study on the effects of different heavy metals (Ni, Pb, Zn and Cd) on growth and yield of different energy crops, namely the oil crops *Camelina sativa*, *Brassica carinata* and *Thlaspi arvense*.

2 MATERIALS AND METHODS

The trials were established in November 2018 in pots, with three different oil crops: *Brassica carinata*, *Camelina sativa* and *Thlaspi arvense*. The crops were sowed in each pot containing 12 kg of soil. After the establishment of the plants, 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); 26 g P_2O_5/m^2 (superphosphate, 18% P_2O_5). Each pot was artificially contaminated with the following heavy metals: Zn, Pb, Cd and Ni. 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; Pb: 450 mg/kg; Cd: 4 mg/kg and Ni: 110 mg/kg [11]. Each crop was also sowed in pots without contamination, used as control. Three replicates were set for each heavy metal concentration and control. Water was applied to avoid water stress.

At the end of the growing season (May 2019), the plants were harvested and both the aerial productivity and the number of siliquae were monitored.

3 RESULTS AND DISCUSSION

3.1 Biomass Productivity

Figure 1 presents the effect of the different heavy metals on the average aboveground biomass productivity of the different oil crop studied.

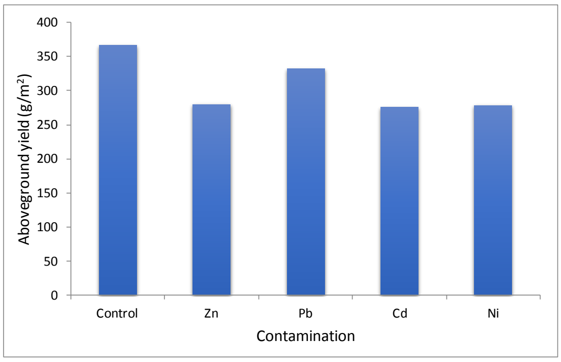

Figure 1: Oils crops aboveground productivity (average of the different oil crops studied) in different contamination levels. Control corresponds to pots without contamination; contamination level tested corresponds to maximum allowable, according to [11].

Although it was observed a small reduction in the aboveground productivity in the contaminated trials when compared to the control, the presence of heavy metal did not affect significantly the oil crop yields. Lead was the metal that affected least the yields and Zn, Cd and Ni presented a similar pattern. Concerning *Brassica carinata* yields, Zn contamination reduced by 20% de yields, but the remaining metals reduced less than 10% the productivity. *Camelina sativa* was not affected by the presence of the heavy metals, except with Cd, that presented a reduction in yields of 30%. Of all the species under study, *Thlaspi arvense* was the one that presented a more pronounced decrease in the aboveground productivity for all heavy metals. In Zn, Pb and Ni soils, the loss was of *circa* 60% and in the Cd contaminated pots the loss was 90%.

Figure 2 presents the differences observed among the different oil crops tested in terms of the aboveground biomass productivity, in the control pots and in the contaminated pots.

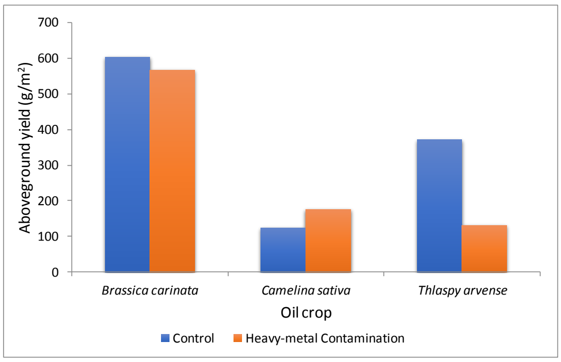

Figure 2: Oils crops aboveground productivity in the control and in the contaminated pots (average results obtained in the different tested pots with heavy metals).

Results indicate that *Brassica carinata* and *Camelina sativa* were not significantly affected by heavy metal contamination. *Thlaspy arvense* yield was significantly afected by heavy metal contamination. *Brassica carinata* was the oil crop with the highest yield, followed by *T. arvense. Camelina sativa* showed the lowest yield.

3.2 Siliquae Productivity

Figure 3 presents the effect of the different heavy metals on the average siliquae productivity of the different oil crop studied.

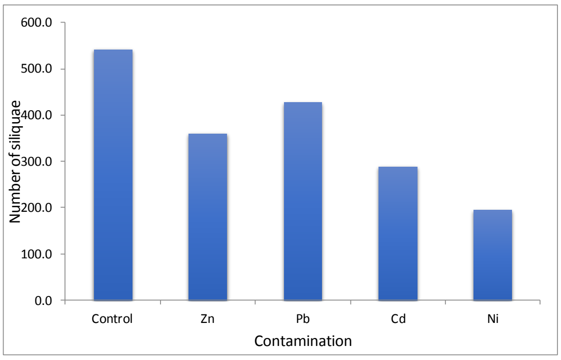

Figure 3: Oils crops silique productivity (average of the different oil crops studied, per m²) in different contamination levels. Control corresponds to pots without contamination; contamination level tested corresponds to maximum allowable, according to [11].

Results presented indicate that all the heavy metals affected the number of siliquae found in oil crops. As observed in Figure 1, lead was the metal that affected least the siliquae productivity, followed by Zn and Cd. Nickel was the heavy metal that most inhibits the production of siliquae. Siliquae productivity of *Brassica carinata* was not significantly affected by the heavy metal contamination, except for Ni, resulting in a productivity loss of around 60%. In this case, the effects of metals in the siliquae production did not followed the pattern of the aboveground yields. Siliquae productivity of *Camelina sativa* was not affected by the heavy metal contamination, except in the pots contaminated with Cd, following the same trend observed with the aerial yields. In the Cd pots, an extremely significant loss of 90% was reported. Siliquae productivity of *Thlaspi arvense* was significantly affected by all the heavy metal contaminations tested, with losses ranging from 60% to 95%. In Zn, Pb and Ni soils, the loss was of *circa* 60% and in the Cd contaminated pots the loss was 90%. Again, this followed the same trend of the aerial yields.

Figure 4 presents the differences observed among the different oil crops tested in terms of the siliquae productivity, in the control pots and in the contaminated pots.

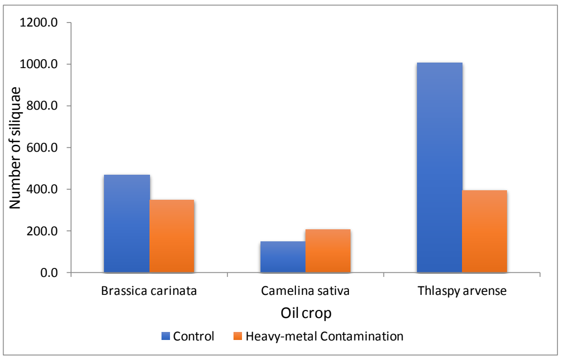

Figure 4: Oils crops siliquae productivity in the control and in the contaminated pots (average results obtained in the different tested pots with heavy metals, per m²).

Results indicate that *Brassica carinata* and *Camelina sativa* were not significantly affected by heavy metal contamination. *Thlaspy arvense* yield was significantly afected by heavy metal contamination. *Thlaspy arvense* was the oil crop with the highest yield, followed by *Brassica carinata*. *Camelina sativa* showed the lowest yield. Comparing solely the yields in contaminated soils, *T. arvense* and *B. carinata* presented similar results.

4 CONCLUSIONS

Three oil crops were subjected to different heavy metals. In general Zn, Cd and Ni are the heavy metals that most affect the aboveground productivity of the cultures but Pb doesn't significantly affect the aboveground productivity.

When comparing the productivity of each crop it is possible to verify that *Brassica carinata* and *Camelina sativa* are not significantly affected by heavy metals contamination but *Thlaspy arvense* aboveground productivity significantly decrease in the presence of the tested heavy metals suggesting that this oil crop is very sensible to the presence of heavy metals in soils.

In general, some heavy metals affect the average number of siliquae found in oil crops. Ni is the heavy metal that most inhibits the number of siliquae in *Brassica carinata* but Cd is the heavy metal that most inhibits number of siliquae in *Camelina sativa* and in *Thlaspi arvense*.

5 ACKNOWLEDGEMENTS

This work was supported by the MEtRICs unit which is financed by national funds from FCT/MCTES (UID/EMS/04077/2019).

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