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BEHAVIOUR OF MUSTARD PLANTS GROWN IN CONTAMINATED SOIL

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Abstract: The purpose of this study was to monitor a mustard crop and to measure plant parameters (mass, height, moisture, chlorophyll content) grown in soil contaminated with heavy metals (Cu, Zn, Pb) and mixture of heavy metals (Cu + Zn + Pb). The contaminated soils, after planting the mustard in the form of seedlings in pots, were treated with a chelating agent (EDTA) in three concentrations in order to decontaminate the soils. The plants from this study were harvested 30 days after planting the seedling and 80 days, so at the end of the vegetation, during this time they were watered weekly with 20 ml EDTA / pot for each concentration, respectively: EDTA 1 (0.5 m), EDTA 2 (1.0 m), EDTA 3 (2.0 m). The experimental results obtained show us how to grow mustard in different contaminated soils and the possibility of its use in soil decontamination.
Keywords: heavy metal, mustard, contaminated soil

INTRODUCTION

Agricultural soils contaminated with heavy metals have posed a major threat to environment and human health due to various anthropogenic activities. The situation demands immediate attention of scientists and technologists to remove heavy metals from contaminated soil. Phytoremediation of heavy metals refers to the use of pollutant–accumulating plants to extract and accumulate contaminants to the harvestable parts and is increasingly being considered as an environmentally friendly, easy and cost–effective solution to clean up soils contaminated by heavy metals [4].

For effective phytoremediation, heavy metals must be translocated and accumulated in the easily harvested part of the plants. The research on phytoextraction has been mainly focused on plants known as hyperaccumulators. However, phytoremediation potential may be limited by these plants due to the slow growth rate, low biomass production and a reasonable time frame by remediation with little known agronomic characteristics [15]. In addition, the efficiency of phytoextraction depends on the characteristics of the soil and the contaminants. Phytoextraction is applicable only to sites that contain low to moderate levels of metal pollution as plant growth is not sustained in heavily polluted soils. Soil metals should also be bioavailable.

Therefore, many plants with higher biomass, such as maize [13], Salix spp. [5,10] and sunflower [3] have been also tested for their phytoextraction potential. Together with the application of chemical amendments, including chelators such as EDTA [8, 14], soil acidifiers, organic acid, ammonium, these high biomass plants could partially eliminate these limiting steps. It has been recognized that selection of appropriate plant materials and appropriate chemical amendments is still very important even today for promoting phytoremediation efficiency [15].

There are many studies on phytoremediation of metal contaminated soils with special reference to Indian mustard (*Brassica Juncea*) [4,7,11,15], alfalfa (*Medicago sativa*) [4], marigold (*Calendula officinalis*) [2,9], pea (*Pisum sativum*) [6], white sweetclover (*Melilotus alba L.*), red clover (*Trifolium pratense L.*), curled mallow (*Malva verticillata L.*), safflower (*Carthamus tinctorius L.*) and hemp (*Cannabis sativa L.*) [12].

The use of plants to monitor heavy metal pollution in the terrestrial environment must be based on a cognizance of the complicated, integrated effects of pollutant source and soil–plant variables. The major factor governing metal availability to plants in soils is the solubility of the metal associated with the solid phase, since in order for root uptake to occur, soluble species must exist adjacent to the root membrane for some rinlte period. The release rate and form of this soluble species will have a strong influence on the rate and extent of uptake and, perhaps, mobility and toxicity in the plant and consuming animals.

The factors influencing solubility and form of available metal species in soil vary widely geographically and include the concentration and chemical form of the element entering soil, soil properties (endogenous metal concentration, mineralogy, particle size distribution), and soil processes (e.g., mineral weathering, microbial activity), as these influence the kinetics of sorption reactions, metal concentration in solution and the form of soluble and insoluble chemical species.

The plant root represents the first barrier to the selective accumulation of ions present in soil solution. Uptake and kinetic data for nutrient ions and chemically related non nutrient analogs suggest that metabolic processes associated with root absorption of nutrients regulate both the affinity and rate of absorption of specific non nutrient ions [1].

The present study was conducted in order to monitor some important parameters for a mustard culture, which grew in a controlled environment, in pots with soil contaminated with copper, zinc and lead and treated with EDTA chelating agent. The results show how grows/ adapts the plant in certain conditions and possible uses of the plant in soil decontamination.

MATERIAL AND METHOD

For conducting experimental researches 4 mustard crops were established, with soil contaminated with copper, zinc, lead and mixtures of the three metals. In march 4 mustard seedlings were planted in pots (controlled) for the three metals, corresponding to a soil content of 1019 mg / kg Cu, 654 mg / kg Zn, 511 mg / kg Pb, and the mixture: 264 mg / kg Cu, 296 mg / kg Zn, 661 mg / kg Pb. The plants were watered every week with water without EDTA (EDTA 0) and water in which 20 ml EDTA / week was added in three concentrations (EDTA 1 – 0.5 m, EDTA 2 – 1.0 m and EDTA 3 – 2.0 m). One month after planting, from each pot a mustard seed was harvested, which was measured and weighed, to monitor the evolution of the plant one month after planting.

The physical–chemical properties of the soil contaminated with heavy metals were: pH 5.5; total nitrogen 1.26 %, total phosphorus 0.62%, total potassium 0.76 %, electrical conductibility 1.0, particle elements of over 20 mm maximum 4 %, moisture 67.2 %.

The measurement of height of each mustard plant was done with the ruler, the height was measured from the tip of the root to the end of the last leaf. The mass of the samples was determined by weighing at the electronic scale KERN of precision 0.001 g.

The moisture of the soil and the plant was made using the oven in which the soil / plant was dried at 105^0 C to evaporate the water related to the soil / plant. The chlorophyll content was determined with the chlorophyllometer (Figure 1).

Figure 1. Chlorophyllometer

Aspects during the experimental research, one month after planting, and at the end of the harvest, about 80 days, can be seen in the images in figure 2 and 3:

Figure 2. Mustard grown in contaminated soil – harvesting 30 days of vegetation

Figure 3. Mustard grown in contaminated soil – harvesting 80 days of vegetation

RESULTS

In table 1 it presents the mass, the height, the moisture and the chlorophyll of the mustard plant at harvesting after a month of vegetation.

Table 1. Parameters monitored one month after mustard planting

Heavy metal	EDTA concentration, %	Mass of the plant, g	Height of the plant, mm	Moisture, %	Chlorophyll
Cu	0	0.8474	187	84.40	11.40
	1	2.0099	221	87.53	9.77
	2	0.6691	136	84.76	7.99
	3	1.8532	181	80.01	10.70
Zn	0	2.4304	188	88.96	10.30
	1	2.1334	195	91.90	7.26
	2	2.2468	185	86.98	10.30
	3	4.0288	261	90.58	6.20
Pb	0	1.3627	157	87.47	7.10
	1	0.2262	85	87.45	5.78
	2	1.8343	196	89.15	7.06
	3	1.3322	150	80.97	8.31
Cu+ Zn+ Pb	0	2.5130	268	87.06	8.81
	1	0.6291	102	73.30	4.95
	2	5.7449	254	84.39	10.2
	3	1.3027	154	81.38	15.2

Regarding the mass of the plant, a maximum of about 4.0 g is observed in 2 cases, namely: for mustard growed in soil contaminated with Zn and treated with EDTA 3 in high concentration (2.0 m) and for mustard growed in soil contaminated with mixture of Cu Zn Pb and treated with EDTA 1 at a concentration of 0.05 m. The minimum mass of 0.2 g was recorded in the plant grown on soil contaminated with Pb and treated with EDTA 1 (0.5 m).

Plant heights ranged from 85 mm for plants grown in soil contaminated with Pb and treated with EDTA 1 (0.5 m), to 268 mm for plants grown in soil infested with a mixture of Cu + Zn + Pb and not treated with EDTA 0.

Plant moisture ranged from 73.3–91.9%.

Chlorophyll content was decreased in plants grown in soil contaminated with EDTA addition in concentrations of 0.05 and 1.0 m, compared to the control sample, without addition of EDTA. Chlorophyll values ranged from 4.95 (Cu + Zn + Pb, EDTA 1) to 11.4 (Cu, EDTA 0). Chlorophyll values for mustard obtained in the experiment are lower than those obtained by the authors of the paper [4], in which mustard has a higher chlorophyll content.

From parameters monitored one month after planting the mustard, at the end of the vegetation, about 80 days, only part of them were recorded, namely the mass and humidity of the plant. These are shown in the figures 4 and 5.

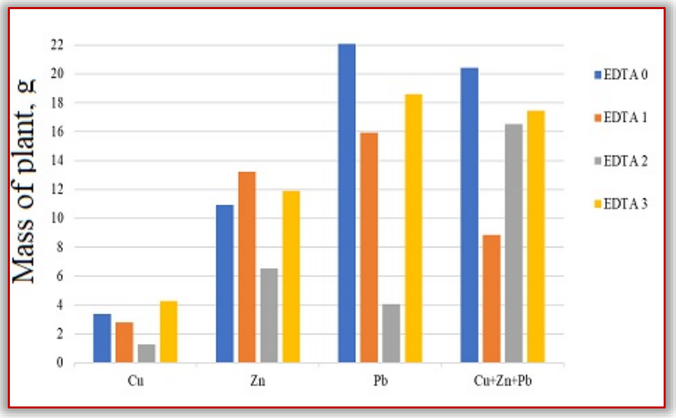

Figure 4. Mass of mustard plant

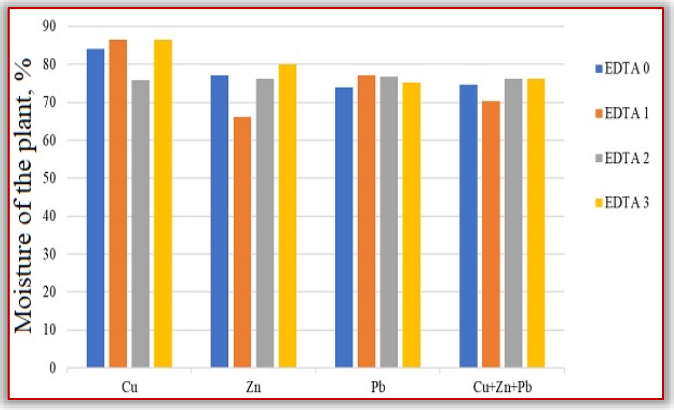

Figure 5. Moisture of mustard plant

The masses of plants grown in pots with contaminated soil, at the end of the vegetation increased, as was naturally the case, less those developed in the soil contaminated with Cu, because at the middle of the vegetation period (40 days), the plants wilted. Plants grown in soil with Pb and metal mixture without addition of EDTA recorded the highest values of the masses: 22.08 g (Pb) and 20.42 (mixture).

The plants reached the end of the vegetation period, had flowers, some also made seeds. These were weighed and the mass and humidity of each were determined, the values can be found in the table 2.

Table 2. The masses and moistures of the mustard seeds have reached maturity

Heavy metal	EDTA concentration, %	Mass of seeds of a plant, g	Moisture, %
Zn	EDTA 0	1.1950	80.41
	EDTA 1 (0.5m)	2.4482	81.46
Pb	EDTA 0	2.0560	81.10
	EDTA 1 (0.5m)	2.2740	80.52
Mixture (Cu+Zn+Pb)	EDTA 0	1.5034	78.93
	EDTA 1 (0.5m)	2.1427	78.74
	EDTA 2 (1.0 m)	1.6262	82.64

It can be seen from the table 2 that the seeds of plants grown in soil without the addition of EDTA 0, have lower values than those grown in soil with EDTA 1, so the addition of the chelating agent is beneficial in the development of mustard fruits. From metals, beneficial action for the plant was in the case of lead, where it is observed that the mass of seeds is maximum (2,274 g) and zinc with the mass of seeds (2.4482 g).

Seed moisture ranges from 78.74 % (Cu+Zn+Pb, EDTA 1) to 82.64% (Cu+Zn+Pb, EDTA 2).

The characteristics of the soil at the final harvest (80 days) of the mustard, can be seen in the figures 6 and 7.

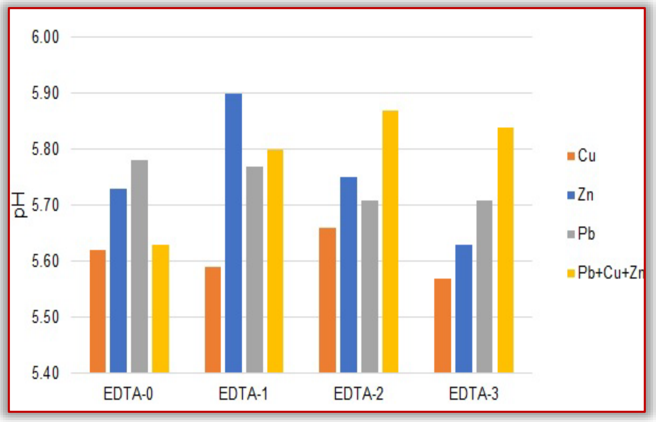

Figure 6 – pH of soil after mustard harvesting

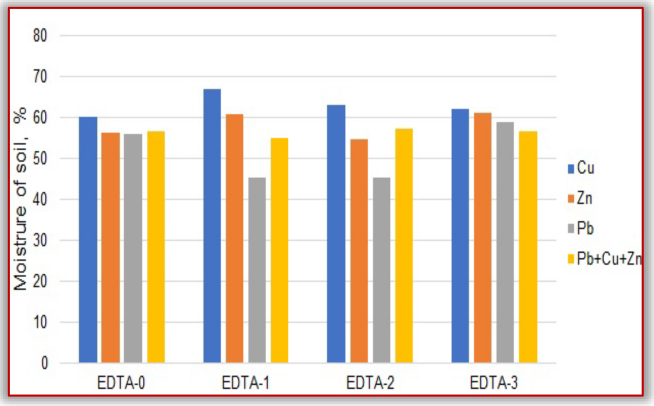

Figure 7 – Moisture of soil after mustard harvesting

The pH of the soil where the chelating agent was not added has lower values than the soils where the chelating agent was added, with the exception of copper. The pH of the soil contaminated with Zn and Pb, respectively, decreases as EDTA is added. In the case of soil contaminated with a mixture of Cu Zn Pb and treated with the three concentrations of EDTA the values were close to 5.8 compared to the one without adding EDTA with value 5.6. Soil moisture ranged from 45.4% (Pb) to 67.1% (Cu).

CONCLUSIONS

From the experimental results obtained after monitoring the cultivation of mustard grown in soil contaminated with heavy metals and treated with EDTA, the following conclusions can be drawn:

- in the case of copper, no plant has reached maturity, has not flowered;
- the plants grew well in soil infested with Zn, with Pb, without the addition of EDTA and with the addition of EDTA in very low concentration EDTA 1 (0.5 m), the proof that they reached maturity by developing fruit (siliceous) with seeds in them;
- in addition, plants grown in soil infested with a mixture of the three metals (Cu + Zn + Pb), have grown up to the seed stage at a higher concentration of EDTA 2 (1.0 m) added to the soil.
- the masses of mustard seeds grown in soil contaminated with Zn, Pb and mixture of Cu + Zn + Pb were higher for seeds grown in soil treated with EDTA compared to the untreated soil;
- the order of the four types of mustard crop, for the height is less clear, but we observe from table 1 that the flowering plants had heights of over 1 meter;
- the moistures of the plants ranged between 73.3% (Cu + Zn + Pb) and 91.9% (Zn);
- the pH of the soil varied in the range 5.6 – 5.9, in soil with Pb (5.7), that with Cu (5.6), with Zn (5.6–5.9), mixture of metals (5.6–5.8);
- soil moisture ranged from 45.4% (Pb) to 67.1% (Cu);
- until the repetition of the experiences, in which to vary the influence factors of the evolution of plants: pH, luminosity, temperature, moisture, nutrients, etc., the minimums and maximums which disrupts the monotony of the experimental data obtained, can be attributed to the underlined influence factors.

The data suggests that the mustard has been developed on soils contaminated with metals and therefore can be grown on these soils, and can be used in the phytoremediation process.

Note:
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