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RESEARCH ARTICLE

Lead removal from soil by phytoremediation method

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ABSTRACT

Many control approaches are used today to prevent the contamination of soils with heavy metals and to remove pollution. One of these approaches is phytoremediation for the on-site treatment of pollutants. In phytoremediation, hyperaccumulator plants are used, which absorb heavy metals, accumulate at high levels in their tissues, and neutralize them after various processes. It was aimed to determine the effects of heavy metals on plant growth and the heavy metal accumulation capacity of plants in this study. Using the phytoremediation method, the growth process of the canola plant and its lead removal capacity from the soil were investigated. The study was carried out in 3 replicates by watering the plants only with tap water and tap water containing different concentrations of lead in greenhouse conditions. The prepared soil mixture was placed in pots as 2000 g pot^{-1}. The sown seeds were germinated using tap water in the plant growing room and the water requirement of the plants was met with tap water containing a certain concentration of lead during the next growing period. Plants were harvested at the end of the 3 month growth period. The plants irrigated with the lead solution were compared with the plants irrigated with only tap water, and the elongation amounts of root and stem lengths were determined. Plant samples with dry weights determined were burned with certain chemicals using the microwave method, and then the amount of lead in the plants was measured with the ICP-MS device.

Keywords: Canola plant, heavy metal, lead, phytoremediation, soil pollution

1. INTRODUCTION

As a result of the increase in living standards in the world and in our country, the expansion of the industrial areas, the burning of coal containing heavy metals and the increasing traffic density have caused the amount of heavy metals in the environment to reach high amount such as many pollutants. These substances can not only accumulate in organisms, but also can travel through food chains and stay in ecosystems at dangerous concentrations for a long time. As a result of this intensity, living things in nature are negatively affected and the products obtained are extremely dangerous in terms of health. The environment is an inseparable whole with soil, air and water components that are in constant interaction with each other. Soil pollution is one of the major environmental problems in this cycle, where any degradation affects the others. Humans, animals and plants need quality soils in order to maintain their life. Heavy metals such as Cu, Zn, Mn, Fe and Mo are essential nutrients for plants and naturally occur in the soil. However, the increase in the production or need of some elements in constructed and developing countries, the accumulation areas developed for the regular storage of agricultural wastes and other solid wastes can increase the metal load of the soil. Heavy metals such as Hg, Cd, Ni entering the soil in various ways are held by the soil and affect soil microorganisms. As a result of the loss of the vitality of the soil, both plants and other living things are negatively affected by this situation.

Some of the heavy metals that mix into the soil in unnatural ways and their sources can be listed as follows [1].

- Primary sources
    - Fertilizers (Cd, Pb, As, Se)

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    - Lime (As, Pb)
    - Pesticides (Pb, As, Hg)
    - Waste sludge (Cd, Pb, As)
    - Irrigation (Cd, Pb, Se)
- Secondary sources
    - Automobile aerosols (Pb)
    - Mine melting areas (Pb, Cd, Sb, As, Se, Hg)
    - Waste incineration plants (Pb, Cd)
    - Mine areas (Pb, Cd, As, Hg)
    - Outer tire (Cd)
    - Paint (Pb, Cd)
    - Sea (Se)
    - Garbage dump areas (Pb, Cd, Se)
    - Aerosols with long spreading areas (Pb, Cd, As, Se)
    - Coal burning (Pb, Cd, As, Se)
    - Alkaline batteries (Hg)

Heavy metals such as Hg, Cd and Ni usually collect in the topsoil and humus. Metals holding in the topsoil at the beginning of heavy metal pollution can penetrate deeper with the acidification of the soil in the future and mix into underground waters. For this reason, heavy metals pass into the human body both through drinking water and some plants. Besides the effects of heavy metals as ions, it is known that the toxic effects of organometal compounds are higher [2].

Until now, various remediation methods have been used to improve soil contaminated with heavy metals [3, 4]. However, these methods, besides being expensive and requiring a lot of effort, did not give definitive results in the complete removal of soil pollution. For this reason, green breeding (phytoremediation) techniques, with lower costs have been developed in recent years [5].

In phytoremediation technique, hyperaccumulator plants are used that can absorb heavy metals and accumulate them at high levels in their tissues and neutralize them after various processes [6]. Compared to different breeding methods, its most important advantages are its low cost, easy application and aesthetically beautiful appearance [7].

Phytoremediation is classified according to pollutant types. If these pollutants contain metal; phytoextraction, phytostabilization and rhizofiltration, if they contain organic matters, as phytodegradation, rhizodegradation and phytovolatization is divided into six different classes.

Phytoextraction; it is the name given to the method of taking by the root of the plants the metal compounds that cause pollution in the soil. Plants display different characteristics in absorbing harmful substances in the soil. Therefore, high amounts of contaminant resistant plants should be used.

Phytostabilization; it is generally used to prevent erosion in areas with erosion, to prevent leakage of pollutants into groundwater and their direct contact with soil. In this method, the soil surface is covered with hyperaccumulative plants suitable for the area [8]. In this method, plants fix pollutants physically and chemically by means of roots [9]. For this method, plants that can grow and develop in soils contaminated with heavy metals and that can change the physical, chemical and biological properties of the soil in order to convert toxic substances into less toxic forms are needed.

Rhizofiltration; it aims to remove heavy metals in contaminated waters rather than reclamation of the soil. In the plants to be used in this method, a well-developed root system that can act as a filter is required. Pollutants are either absorbed on the root surface of the plants or transported to the other organs of the plant by being absorbed through the roots.

The advantages and disadvantages of phytoremediation are listed below [10].

- Advantages of phytoremediation
    - It is more economical than other improvement types
    - No new plant is needed to invade the field again
    - No extra field is required for waste dumping
    - It has an aesthetic appearance and is pleasing
    - Due to on-site improvement, the pollutant is prevented from moving to another area and spreading
    - Just not a single pollutant, but many pollutants can be tackled at the same time
- Disadvantages of phytoremediation
    - Pollutants accumulated on the leaves can be mixed with the soil again in autumn
    - Pollutants may have accumulated in the plants used as firewood
    - The improvement period may take a long time
    - Pollutants can be mixed back into the soil by washing and dissolving

2. MATERIAL AND METHODS

In the study, it was used canola (*Brassica napus*) as hyperaccumulator plant and lead as a soil pollutant. The studies were carried out in the plant growth cabin and the pots and soils used were obtained from the florist.

Soils were prepared by mixing 1/3 fine-grained sand, 1/3 field soil and 1/3 fertilizer. The prepared mixture was placed weight of 2000 g pot^{-1} in 12 pots with a diameter of 20 cm and each seed was planted at 5 cm intervals. The sowing of canola seeds is shown in Fig 1.

Fig 1. Sowing of canola seeds

The experiments were carried out by giving water in different lead concentrations of 25 ppm, 50 ppm and 75 ppm to the plants under greenhouse conditions. 9 pots were used by working in 3 repetitions for each determined lead concentration. In addition, 3 different pots irrigated with tap water were used as control plants in the study. Lead solutions were added to the pots in the indicated repetitions and concentrations as use all the soil capacity. Lead solutions were obtained by dissolving $Pb(NO_3)_2$ in tap water, and the water requirement of the plants was met with prepared lead solutions. Irrigation with lead solutions was carried out after germination to prevent the plant from dying. The study was carried out for the absorption of heavy metals added to the pots by the soil in a growing cabinet with 10-12°C of night temperature, 25-30 °C of daytime temperature and 30-40% of humidity for 12 hours of illumination and 12 hours of darkness for 3 months. The germination of canola seeds is shown in Fig 2.

Fig 2. Germination of canola seeds

Plants were harvested at the end of the 3 month growing period, root and stem parts were washed with pure water, their wet weight was weighed and left to dry for 24 hours at 68°C. 3 ml H_2O_2 (hydrogen peroxide) and 2 ml HNO_3 (nitric acid) were added to the plant samples whose dry weights were determined, and they were ground by wet burning method in a microwave oven. The caps of the microwave tubes containing the samples were closed tightly and the burning process was completed and then lead analysis was performed with the Agilent 7800 ICP-MS device. The irrigation process, the harvesting process and the drying process are given respectively in Fig 3, Fig 4, and Fig 5.

Fig 3. Performing the irrigation process

Fig 4. Performing the harvesting process

Fig 5. Performing the drying process

3. RESEARCH FINDINGS AND DISCUSSION

Root and stem lengths of plants irrigated only with tap water are given in Table 1, and root and stem sizes of plants given tap water containing lead in different concentrations are given in Table 2, Table 3, and Table 4.

The results in Table 1, Table 2, Table 3, and Table 4 show that the increase in the amount of lead causes a shortening in the plant stem. On the contrary, it is seen that there is elongation in the roots. This situation has been interpreted as the above-ground part of the plant is more sensitive to lead, and lead disrupts the nutrient intake and transmission balance of the plant. As a result, plant roots react to growth and create more contact areas to increase nutrient intake. These results are shown schematically in Fig 6. The amounts of lead accumulated in the plants according to the lead analysis performed by harvesting the plants and then subjecting them to heat treatment are given in Table 5.

Table 1. Elongation in tap water plants

Pots	Root (cm)	Stem (cm)
1. Pot	13.3	5.10
2. Pot	14.4	6.05
3. Pot	12.68	5.41
Average length	13.46	5.52

Table 2. Elongation in plants fed tap water containing 25 ppm lead

Pots	Root (cm)	Stem (cm)
1. Pot	13	4.5
2. Pot	16.33	4.85
3. Pot	13.89	5.52
Average length	14.41	4.96

Table 3. Elongation in plants fed tap water containing 50 ppm lead

Pots	Root (cm)	Stem (cm)
1. Pot	15.18	3.5
2. Pot	14.44	4.2
3. Pot	20.83	5.25
Average length	16.82	4.32

Table 4. Elongation in plants fed tap water containing 75 ppm lead

Pots	Root (cm)	Stem (cm)
1. Pot	20.625	4.125
2. Pot	17.5	3.875
3. Pot	14.56	3.16
Average length	17.56	3.72

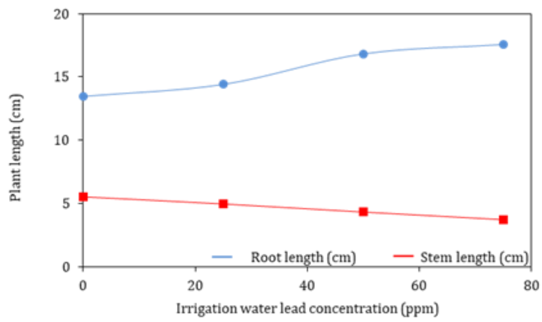

Fig 6. Schematic representation of plant root and stem sizes

Table 5 The amounts of lead found in the roots and stems of the plants according to the analysis results (mg kg^{-1})

	Without lead	25 ppm lead	50 ppm lead	75 ppm lead
1. Pot	1.05	11.01	14.45	18.32
2. Pot	1.1	14.83	16.22	20.89
3. Pot	0.95	12.02	15.50	18.35
Average	1.033	12.63	15.39	19.18

When the results are examined, the plants took an average of 12.63 ppm from 25 ppm lead. This equates to approximately 50.52% of the total lead. Likewise, an average of 15.39 ppm lead was found in the structure of plants irrigated with 50 ppm lead solution. This equals to 30.78% of the given lead. The average amount of lead in plants irrigated with tap water containing 75 ppm of lead is 19.18 ppm. In other words, 25.6% of it has passed into the plant. These values are expected to be higher in longer study time.

4. CONCLUSIONS

The data obtained as a result of this study have shown that lead removal from soil and wastewater can be done by phytoremediation in natural environments using canola plants. In the study, it was observed that the roots of canola plants irrigated with tap water containing lead lengthen as the lead concentration increased, but the stem length decreased. This situation can be explained as the mechanism by which heavy metals (lead) taken into plant tissues disrupt the nutrient absorption and mineral transmission balance in plant tissues and the plant roots respond by growing to increase the absorption of nutrient water. In addition, it turns out that canola plant roots are more resistant to lead, but the parts remaining above the soil and making photosynthesis are more sensitive. The removal of heavy metal-containing waters by phytoremediation method can be preferred because it reduces soil pollution and provides an aesthetic appearance to the environment by covering the soil surface with green tissue.

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