Journal of Soil Sciences and Agricultural Engineering

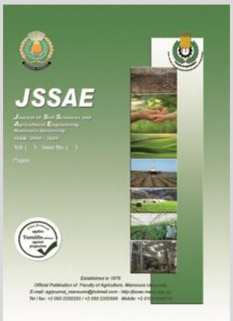
Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Bioaccumulation and Translocation Factors of Lead in Mustard and Maize Plants in Soil Kurdistan Region _ Akre City

Cross Mark

Nizar Ali Mohammed [1] * and Abdulrahman Sammo Hussein[2]

[1]Akre technical college, Duhok Polytechnic University, Kurdistan Region,-Iraq
[2]Shingal technical Institute, Duhok Polytechnic University, Kurdistan Region, Iraq



ABSTRACT

The aim of this study is to determine the Pb bioaccumulation and translocation factors in mustard (*Brassica juncea*) and maize (*Zea mays L*). growing in the pot experiment in Akre horticulture nursery soil. In present paper, about 1gm of root and shoot portions of the selected plant species that were growing in the site were separately collected. Besides, 10gm of soil samples were also collected from the pots at each sampling where the plants were previously sampled. The soil and plants were analyzed for Pb by atomic absorption spectrophotometer (AASP), type GBC 932AA. Bioaccumulation factor (BAF) was measured in the plant species and obtained from the ratio of Pb content in the plant root to that of extracted Pb content in the soil. And, Translocation factor (TF) was obtained from the ratio of Pb content in the plant shoots to that in the plant roots, from the results obtained, the two plant species had BAF and TF>1, suggesting their applicability in extraction of Pb polluted soil at the study site. Since Pb accumulation and translocation, factors in the two plants species were more than one so they regard as accumulator plants and suggest that the plants species having phytoextraction ability and could be used in restoring soil contaminated with Pb.

Keywords: *bioaccumulation, translocation factor, Lead, accumulation, phytoextraction.*

INTRODUCTION

Phytoremediation is a biological, low-cost, and environmentally sustainable soil remediation technique that employs plants to degrade, kill, or remediate pollutants. (Pilon-Smits, 2005) and (Mahar *et al.*, 2016). Both the bioaccumulation factor (BAF) and the translocation factor (TF) were used to evaluate the phytoremediation capacity of mustard and corn plants (TF) (Malik *et al.*, 2010).

Lead has become a significant anthropogenic contaminant that has been released in to the environment since the industrial revolution. As a result, Pb has built up in various terrestrial and aquatic habitats (Verma and Dubey, 2003). In addition, Pb is an extremely toxic metal whose effects on human health (Juberg *et al.*, 1997). Pb has been shown to accumulate in plants from a variety of sources, including soil, but studies on Pb accumulation in plants are inconsistent (Al-Salman and Abdul-Aziz, 2002). Pb is often present in the cytoplasm of cells, often in the form of electron-dense precipitates in membranous inclusions, vesicles, or organelles (Sinha *et al.*, 2006). Phytoremediation opens up new possibilities for the use of this method to clean up lead-contaminated soils.

Mustard as a Plant for Phytoremediation There are approximately 400 plant species in the Asteraceae, Brassicaceae, Caryophyllaceae, Poaceae, Violaceae, and Fabaceae families that can tolerate extremely high levels of heavy metals in the soil (Rathore *et al.*, 2013) (Hall, 2002) (Baikhamurova *et al.*, 2020).

maize is one of the world's most important cereal crops, and Pakistan's third most important cash crop (Long *et al.*, 2006). (Abdul, 2010) found that some corn varieties were found to be resistant to lead toxicity and can be used as suitable species for phytoextraction in lead-contaminated soils. Another advantage of corn is its ability to produce energy. As a result of a field experiment by (Meers *et al.*, 2010). The toxicity of lead causes root growth to stop, as well as growth at the root tips to be inhibited (Eun *et al.*, 2000). The interactions of mixed contaminants could decide the growth of mays and their ability to remove pollutants (Van Ginneken *et al.*, 2007).

The main objective of the present study is to investigate the Lead bioaccumulation and translocation factors in Mustard and maize to evaluate the ability of two species for phytoremediation of Pb polluted soils and the capacity them in Pb uptake and distribution.

MATERIALS AND METHODS

Description of study site

The current research was conducted from June until the end of August 2020 in the lath house (Table 1) nursery of Horticulture, in Akre city with GPS reading of, elevation (636m) (Latitude: 36°43"N) and Longitude: 43°51"E). The place is located within the interior zone of the Mediterranean Sea climate. The total annual precipitation was (600-650) mm. The minimum and maximum temperatures were 27-44Cº, respectively, and the relative humidity was nearly 25%. Two crop species seedlings (maize (*Zea mays*) and Indian mustard) were irrigated as required during the research with two types of water (waste and groundwater of Akre city), to evaluate bioaccumulation and translocation factors of lead.

Selection of seeds

Indian mustard and maize (*Brassica juncea*) (*Zea mays L.*) Native seeds from the area were used as research

*** Corresponding author.**
E-mail address: nizarshushi85@gmail.com
DOI: 10.21608/jssae.2021.174527

plants, which were planted in pots containing 10 kg of soil mixture. In June 2020, ten seeds of each plant were sown in each pot, and five plants were randomly selected after germination. During the experiment time, the water addition was modified to 75 percent of the field potential. After 70 days from sowing, the shoot (stem and leaves) was gently cut just above the soil surface, and the roots were gathered, washed carefully with tab water and twice with purified water to remove dust and dirt, and dried at 65.7°C. After recording the dry weight of the samples, they were milled with a steel blade mixer, and the concentration of Pb was determined using a wet digestion method with sulfuric acid H2SO4 and perchloric acid HClO4 using atomic absorption spectrophotometer (AASP) type GBC 932AA

Soil sampling and analysis

Soil samples were taken from the horticulture nursery in June 2020, at a depth of 0-30 cm. Soil samples were air-dried, sieved through a 4 mm sieve for the pot experiment and a 2 mm sieve for analyzing some of the physical and chemical characteristics and lead content of the soil, then mixed uniformly and filled into plastic pot 23 cm in height and 24 cm in diameter with 10 kg soil mixed with 4 lead [Pb (NO3)2] level, as follow

1. Soil without Pb as control (A1).
2. Soil contaminated with 200 $mg.kg^{-1}$ Pb (A2).
3. Soil contaminated with 400 $mg.kg^{-1}$ Pb (A3).
4. Soil contaminated with 800 $mg.kg^{-1}$ Pb (A4).

Each 10 kg of soil was spread on the ground on a plastic sheet, and 250 ml of Pb (NO3)2 solution containing one of the above concentrations was sprinkled on the soil, in this process good homogeneity in contamination process and contamination period was achieved.

Soil analysis

The determination of physical and chemical properties and the extracted Pb in the soil were assessed (at the beginning and at the end of the study) in Duhok University-College of Agricultural engineering sciences, Soil Lab according to the adopted methods shown in Table (1).

Table 1. Some physical and chemical characteristics of the studied soil.

Characteristics		values
Soil particle size distribution		
Sand (%)		36.69
Silt (%)		45.00
Clay (%)		18.31
Soil texture		Loam
Soil chemical analysis		
Soil pH		7.71
Electrical conductivity (EC)	$dS\ m^{-1}$	0.39
Cation exchange capacity (CEC)	$Cmole.kg^{-1}$	12.18
Organic matter (OM)	$mg.\ kg^{-1}$	1.01
Total nitrogen	$mg.\ kg^{-1}$	95
Available phosphorus	$mg.\ kg^{-1}$	5.12
Total carbonate	$mg.\ kg^{-1}$	8.34
Sodium (Na^{+})	$meq.L^{-1}$	1.65
Potassium (K^{+})	$meq.L^{-1}$	0.16
Calcium (Ca^{2+})	$meq.L^{-1}$	1.51
Magnesium (Mg^{2+})	$meq.L^{-1}$	1.21
Chloride (Cl^{-})	$meq.L^{-1}$	0.8
Sulphate (SO_4^{2-})	$meq.L^{-1}$	0.96
HCO_3	$meq.L^{-1}$	2.68
Ca CO_3	(%)	5.63
Lead (Pb)	$mg.\ kg^{-1}$	3.4

The studied soil was loam, non-saline, very low in organic matter and total nitrogen. The concentration of Pb in the soil (3.4$mg.kg^{-1}$) was below the toxicity levels. Therefore, the soil was contaminated with concentrations more than the permitted level. Soil pH was 7.71, which shows that the soil was slightly alkaline, and total insoluble carbonate consists only 8.34%; soil available phosphorous content was 5.12 $mg.kg^{-1}$. Soil samples were also air dried, ground and pass a 2 mm sieve for analysis. 10 g of air-dried soil was taken and treated with 20 ml of extracting reagent (AB – DTPA) for extraction of Pb. The contents were shaken for 15 min., filtrate through Whatman No. 42, and analyzed by atomic absorption spectrophotometer (AASP), type GBC 932AA.

Treatments and experimental designs

A factorial Randomized Completely Block Design (RCBD) was used, to study potential ability of crop species Zea mays (*Zea mays* L.) and Indian mustard (*Brassica juncea* L), two water types (waste and ground water) and using four replicates with five plants for each experimental unit. Therefore, number of experimental units = 2 (plant) × 2 (irrigation water) × 4 (Pb concentration) × 4 (replicates) = 64 experimental units.

Bioaccumulation factor (BAF)

The ratio of metal concentration in plant shoots to metal concentration in soil is known as the bioaccumulation factor (B A F) (Gupta and Sinha, 2009) as follows:

$$\mathbf{BAF = (C\ shoot)/(C\ soil)}$$

Where

C shoot = concentration in the shoot and C soil = metal concentration in the soil.

Translocation factor (TF)

The ability of a plant to translocation metals from the roots to the shoots is determined by the ratio of metal concentration in plant shoots to metal concentration in the root (Yoon *et al.*, 2006) (Gupta and Sinha, 2007).

TF can be determined by this equation:

$$\mathbf{TF = (C\ shoot)/(C\ root)}$$

Where:

C shoot and C root are the concentration of metal in shoot and root respectively.

Statistical analysis

The statistics have been organized in the form of factorial experiments with randomized complete block design (RCBD). The impact of the researched treatments and their interactions on the parameters was investigated by the analysis of variance (ANOVA). According to Duncan's multiple range tests at P-value < 0.05, differences between means were performed. The statistical analysis was performed by SAS 9.0 program.

RESULTS AND DISCUSSION

Pb content in roots

Table (2) shows a significant difference between roots Pb concentration of tested plants, the Pb concentration of mustard plant was more than that of Zea mays, which was (31.97) $mg.kg^{-1}$ compared to (28.88) $mg.kg^{-1}$, in mays root. The variation may be due to genetic factor and their ability for Pb uptake from soil.

It was also found that irrigated with wastewater caused an increase in lead concentration in the roots, which was (32.31); mg.kg^{-1} compared to (28.54) mg.kg^{-1} irrigated with groundwater, and the difference was significant.

Increasing the lead concentration from 0 to 800 mg.kg^{-1} showed a significant effect on the content of lead in the roots, which increased significantly with increasing concentration, which were (12.30 to 45.98) mg.kg^{-1} for the four applied concentrations.

Table 2. The effect of plant species, Pb concentration, water type, on Pb content in the roots of the two plants.

plants	Water	Pb Conc. mg kg^{-1} 0	200	400	800	plant* Water effect	plants effect
Maize	Ground water	10.89n	22.85k	30.48h	42.84c	26.77d	28.88b
	Waste water	12.89ml	29.16i	36.87e	45.08b	31.00b	
Mustard	Ground water	12.21m	27.68j	35.78f	45.54b	30.30c	31.97a
	Waste water	13.21l	31.38g	39.47d	50.45a	33.63a	
Plant* Pb	Maize	11.89h	26.01f	33.68d	43.96b	water effect	
	Mustard	12.71g	29.53e	37.63c	48.00a		
Water* Pb	Ground water	11.55h	25.27f	33.13d	44.19b	28.54b	
	Waste water	13.05g	30.27e	38.17c	47.76a	32.31a	
pb effect		12.30d	27.77c	35.65b	45.98a		

Within the key factor and their interactions, values followed by identical alphabetical letters are not important (at 0.05 level) according to DMRT (1955).

The two-way interaction between plant and water type started with a significant effect on the lead concentration of roots. The highest concentration was (33.63) mg.kg^{-1} for mustard plants irrigated with wastewater, while the lowest value was (26.77) mg.kg^{-1} for Zea mays plants irrigated with groundwater.

The interaction between the type of water and the concentration of lead used in the experiment showed a significant effect on the mentioned characteristic. The highest Pb concentration was (47.76) mg.kg^{-1} for plants irrigated with wastewater and treated with a Pb concentration of 800 mg.kg^{-1}, while the lowest concentration was (11.55) mg.kg^{-1} recorded for groundwater with control. However, the interaction between plant species and the concentration of applied lead showed a significant effect on the lead concentration in the roots. The highest concentration was (48.00) mg.kg^{-1} for mustard plant treated with concentration 800 mg kg^{-1} while the lowest value was (11.89) mg.kg^{-1} for Zea mays plant treated with control.

The triple interaction among the studied factors (plant species, water type, and lead concentration) showed a significant effect on the lead concentration in the roots. The lead concentration of mustard plants irrigated with wastewater and treated with a concentration of 800 mg.kg^{-1} reached (50.45) mg.kg^{-1}, while the lowest value was (10.89) mg.kg^{-1} recorded for Zea mays irrigated with groundwater with no lead addition (control).

Pb concentration in shoot

The results from shoots Pb concentration of tested plants (Table 3) showed clear variation in their ability for Pb absorption from the soil, while the concentration of lead in the shoots of the mustard plant was more than that of Zea mays, reaching (45.38) mg.kg^{-1} compared to (38.94) mg.kg^{-1}, and the difference was significant.

Table 3. The effect of plant species, Pb concentration, water type, on Pb content in shoots.

plants	Water	Pb Conc. mg.kg^{-1} 0	200	400	800	plant*Water effect	Plants effect
Maize	Ground water	16.18l	34.70h	40.40g	51.54c	35.71c	38.94b
	Waste water	19.03j	42.51f	49.28d	57.91b	42.18b	
Mustard	Ground water	17.90k	41.82f	51.52c	58.39b	42.41b	45.38a
	Waste water	20.58i	47.74e	58.22b	66.85a	48.35a	
Plant* Pb	Maize	17.61f	38.60d	44.84c	54.73b	water effect	
	Mustard	19.24e	44.78c	54.87b	62.62a		
Water* Pb	Ground water	17.04h	38.26f	45.96d	54.97b	39.06b	
	Waste water	19.81g	45.12e	53.75c	62.38a	45.27a	
pb effect		18.42d	41.69c	49.86b	58.67a		

Within the key factor and their interactions, values followed by identical alphabetical letter or letters are not important (at 0.05 level) according to DMRT (1955).

In addition, it was found that the irrigation with wastewater had a greater effect on the Pb concentration of shoots which was (45.27) mg.kg^{-1} compared to (39.06) mg.kg^{-1} that irrigated with groundwater, and the difference was significant. Increasing in the applied lead concentrations from 0 to 800 mg.kg^{-1} showed a significant effect on lead concentration in the shoots, which increased significantly with increasing Pb levels concentration, which were (18.42 to 58.67) mg.kg^{-1} for the four concentrations.

The two-way interaction between plant species and water type declared a significant effect on the concentration of lead in the shoots. The highest concentration was (48.35) mg kg^{-1} for mustard plants irrigated with wastewater, while the lowest concentration (35.71) mg kg^{-1} for Zea mays plants irrigated with groundwater.

The interaction between the types of water and the concentration of lead used in the experiment showed a significant effect on the content of the shoot. The highest Pb concentration was (62.38) mg.kg^{-1} for plants irrigated with wastewater and treated with 800 mg.kg^{-1}, while the lowest concentration was (17.04) mg.kg^{-1} for plants irrigated with by groundwater, with control. In the same ways, the interaction between plant species and the concentration of applied lead showed a significant effect on lead concentration in the shoots. The highest lead concentration was (62.62) mg.kg^{-1} for mustard plant treated with 800 mg Pb kg^{-1} while the lowest concentration was (17.61) mg.kg^{-1} for Zea mays plant treated with control. On the other hand, the triple interaction among the studied factors (plant species, water type, and lead concentration), showed a significant effect on the concentration of lead in the shoots. Where the highest values recorded for mustard plant irrigated with wastewater and treated with 800 mg.kg^{-1} which reached (66.85) mg.kg^{-1}, while the lowest content was (16.18) mg.kg^{-1} recorded for zea mays irrigated with groundwater with no lead addition.

Pb concentration in soil

Regarding the Pb status in the soil and its relation to the studied treatments, (Table 4) showed clear variation in their ability for Pb absorption from the soil, while the concentration of lead in the Zea mays plants was more than that of mustard which was (24.31) and (20.75) mg.kg^{-1}, respectively.

Table 4. The effect of plant species, Pb concentration, water type, on Pb concentration in the soil.

plants	Water	Pb Conc. mg.kg^{-1}				plant * Water effect	plants effect
		0	200	400	800		
Maize	Ground water	4.32j	22.73g	27.23ed	33.24c	21.88c	24.31a
	Waste water	6.86i	28.19d	33.06c	38.84a	26.74a	
Mustard	Ground water	3.74j	18.38h	21.93g	27.69d	17.93d	20.75b
	Waste water	6.09i	24.28f	26.55e	37.36b	23.57b	
Plant* Pb	Maize	5.59g	25.46d	30.15c	36.04a	water effect	
	Mustard	4.92g	21.33f	24.24e	32.53b		
Water* Pb	Ground water	4.03g	20.56e	24.58d	30.47b	19.91a	
	Waste water	6.48f	26.24c	29.81b	38.10a	25.16b	
pb effect		5.25d	23.40c	27.19b	34.28a		

Within the key factor and their interactions, values followed by identical alphabetical letters are not important (at 0.05 level) according to DMRT (1955).

It was also found that the irrigation with wastewater caused a higher increase of lead in the soil (25.16) mg.kg^{-1} compared to (19.91) mg.kg^{-1} for irrigation with groundwater, and the difference was significant.

Increasing the lead concentration from 0 to 800 mg.kg^{-1} showed that a significant effect on the content of lead in the soil, which increased significantly with increasing concentration, which was (5.25 to 34.28) mg.kg^{1} for the four concentrations.

The two-way interaction between plant and water type started with a significant effect on the concentration of lead in the soil. The highest content was (23.57) mg.kg^{-1} for mustard plants irrigated with wastewater, while the lowest concentration was (21.88) mg.kg^{-1} for Zea mays plants irrigated with groundwater.

The interaction between the type of water and the concentration of lead used in the experiment showed a significant effect on the Pb content of the soil. The highest content was (38.10) mg kg^{-1} for plants irrigated with wastewater and treated with concentration 800 mg.kg^{-1}, while the lowest concentration was (4.03) mg.kg^{-1} for plants irrigated with groundwater, and control. Moreover, the interaction between plant species and the concentration of lead showed a significant effect on the concentration of lead in the soil. The highest content was (32.53) mg.kg^{-1} for mustard plant treated with concentration 800 mg.kg^{-1} while the lowest content was (5.59) mg.kg^{-1} for Zea mays plant treated with control.

The triple interaction among the studied factors (plant species, water type, and lead concentration) showed a significant effect on the content of lead in the soil. Where the highest content of Pb in the soil was for mustard plant irrigated with wastewater and treated with a concentration of 800 mg.kg^{-1} that reached (37.36) mg.kg^{-1}, while the lowest content was (4.32) mg.kg^{-1} recorded for Zea mays irrigated with groundwater with no lead addition.

The bioaccumulation factor of lead

Bioaccumulation factor (BAF) values of lead for the tested plants (Table 5) demonstrated that THE bioaccumulation value of lead in the mustard plant was more than that of Zea mays, which were (2.61) and (1.96), respectively and the difference was significant. It was also found that the groundwater had a higher value of lead bioaccumulation (2.49) compared to (2.07) for wastewater, and the difference was significant. increasing the lead concentration from 0 to 800 mg.kg^{-1} showed a significant effect for bioaccumulation of two plans while increasing significantly concentration the result showed decreasing bioaccumulation, reaching (3.69 to 1.47) for the four concentrations.

Table 5. The effect of plant species, Pb concentration, water type, on Bioaccumulation factor

plants	Water	Pb Conc. mg.kg^{-1}				plant * Water effect	plants effect
		0	200	400	800		
Maize	Ground water	3.82b	1.53h	1.48h	1.55h	2.10c	1.96b
	Waste water	2.78d	1.51h	1.49h	1.49h	1.82d	
Mustard	Ground water	4.81a	2.28fe	2.35e	2.11f-g	2.89a	2.61a
	Waste water	3.38c	1.97fg	2.19fe	1.79h	2.33b	
Plant* Pb	Maize	3.30b	1.52e	1.49e	1.52e	water effect	
	Mustard	4.09a	2.12dc	2.27c	1.95d		
Water* Pb	Ground water	4.31a	1.90c	1.92c	1.83dc	2.49a	
	Waste water	3.08b	1.74dc	1.84dc	1.64d	2.07b	
pb effect		3.69a	1.82b	1.88b	1.74b		

Within the key factor and their interactions, values followed by identical alphabetical letters are not important (at 0.05 level) according to DMRT (1955).

The two-way interaction between plant and water type started with a significant effect on the bioaccumulation of lead. The highest value was (2.33) for mustard plants irrigated with wastewater, while the lowest value (2.10) for Zea mays plants irrigated with groundwater.

The interaction between the type of water and the concentration of lead used in the experiment showed a significant effect on this characteristic. The highest value was (4.31) mg.kg^{-1} for plants irrigated with groundwater and treated with control, while the lowest value was (1.64) mg.kg^{-1} for plants irrigated with wastewater concentration with 800 mg.kg^{-1}. However, the interaction between plant species and the concentration of lead showed a significant effect on lead bioaccumulation. The highest value was (3.30) for Zea mays plant treated with control while the lowest value was (1.95) mg.kg-1 for mustard plant treated with concentration 800 mg.kg^{-1}.

At the triple interaction between the studied factors (plant species, water type, and lead concentration), the values showed a significant effect on the bioaccumulation of lead. The highest value of Zea mays plant irrigated with groundwater with no lead addition reached (3.82) while the lowest value was (1.79) recorded for mustard irrigated with wastewater and treated with a concentration of 800 mg.kg^{-1}.

The translocation factor of lead

Table (6), shows the translocation factor (TF) values of lead for the tested plants, the TF value of lead in the mustard plant was more than that of Zea mays, which was (1.45) compared to (1.39) for mays and the difference was significant.

Table 6. The effect of plant species, Pb concentration, water type, on Translocation factor

plants	Water	Pb Conc. mg.kg^{-1}				plant * Water effect	plants effect
		0	200	400	800		
Maize	Ground water	1.49b-c	1.52b-c	1.33e	1.20f	1.38c	1.39b
	Waste water	1.48b-c	1.46dc	1.34e	1.29e	1.39c	
Mustard	Ground water	1.47b-c	1.51b-c	1.44d	1.28e	1.42b	1.45a
	Waste water	1.56a	1.52ba	1.48b-c	1.33e	1.47a	
Plant* Pb	Maize	1.48ba	1.49ba	1.33c	1.24d	water effect	
	Mustard	1.51a	1.52a	1.46b	1.30c		
Water*Pb	Ground water	1.48b	1.51ba	1.38c	1.24e	1.40b	
	Waste water	1.52a	1.49ba	1.41c	1.31d	1.43a	
pb effect		1.50a	1.50a	1.39b	1.27c		

Within the key factor and their interactions, values followed by identical alphabetical letters are not important (at 0.05 level) according to DMRT (1955).

It was also found that the wastewater had a higher value of translocation factor of lead which was (1.43) compared to (1.40) for groundwater, and the difference was significant.

Increasing the lead concentration from zero to 800 mg.kg^{-1} showed a significant effect on the value of translocations of two plants while increasing the concentration of Pb caused a decrease in the translocations value, which was ranged between 1.50 to 1.27 for the four levels of lead.

The two-way interaction between plant and water type started with a significant effect on the value of translocation factor, the highest value was (1.47) for mustard plants irrigated with wastewater, while the lowest value (1.38) for Zea mays plants irrigated with groundwater.

The interaction between the type of water and the concentration of lead in the experiment showed a significant effect on this characteristic. The highest value was (1.48) for plants irrigated with groundwater with control, while the lowest value was (1.31) for plants irrigated with wastewater and treated with concentration 800 mg.kg^{-1}.

The interaction between plant species and the concentration of lead showed a significant effect on the value of translocation. The highest value was (1.48) for Zea mays plant treated with control, while the lowest value was (1.30) recorded for mustard plant treated with concentration 800 mg.kg^{-1}.

The triple interaction among the studied factors (plant species, water type, and lead concentration) showed a significant effect on the value of the lead translocation factor. The highest value was recorded from Zea mays plant irrigated with groundwater with no lead addition that reached (1.49) while the lowest value was (1.33) which was recorded for mustard irrigated with wastewater and treated with a concentration of 800 mg.kg^{-1}.

The phytoremediation potential of mustard and corn plants wAS assessed using both bioaccumulation factor (BAF) and translocation factor (TF) (Malik *et al.*, 2010) (Roychowdhury *et al.*, 2017). The results of lead (BAF) for both plants were represented in Table (5), which demonstrated that Pb (BAF) in the mustard plant was significantly more than that Zea mays plant these results were agreed with the (Rezvani and Zaefarian, 2011). increasing the lead concentration from 0 to 800 mg.kg^{-1} showed a significant effect on bioaccumulation of lead for two plants, while increasing concentration the result showed decreasing bioaccumulation factor, from (3.69 to 1.47) for the four levels. And there was a gradually decrease in the lead BAF values at Pb levels has been applied, but overall, all treatments showed high BAF values indicating that these plants accumulate Pb in their roots and then translocated it from roots to the aerial (Suman *et al.*, 2018). The obtained values of Pb BAF >1 demonstrated that mustard and corn considered as a Pb accumulators (Aladesanmi *et al.*, 2019) (Kaur, 2018). In addition, the values of lead (TF) for mustard and mays were shown in figure (6). Generally, the PbTF values were less than that of bioaccumulation that means translocated of some quantity of Pb which absorbed by roots to shoots, and increasing the lead concentration from 0 to 800 mg.kg^{-1} showed a significant effect on the value of translocations of two plants while increasing concentration the result showed decreasing the translocations value from (1.50 to 1.27) for the four concentrations. In spite of the differences in Pb TF values between the two plant species, the Pb TF values for two species were >1, therefore both plant species can be considered as (Pb accumulator) (Kumar *et al.*, 2018). Lead tolerant plants with high BAF and TF have a chance to be utilized for phytoextraction of contaminated soils, and this suitability could be determined through its high lead content in the roots and translocation to shoots (de Jesus and Yllano, 2005) (Grzegórska *et al.*, 2020).

Overall, the accumulation of Pb in plant roots was higher than in its shoots, which showed that the roots of mustard and mays are more effective in the uptake of Pb. The retention of Pb in both plant roots and translocation to the shoots can be attributed to the Pb tolerance of both plants more researchers whom reported that the two plants mustard and corn have the ability to absorbed contaminants from soil and translocated to the aerial plants (Bassegio *et al.*, 2020) (Amin *et al.*, 2018) (CHAI *et al.*, 2011) (Ibrahim *et al.*, 2015) (Awokunmi *et al.*, 2015).

CONCLUSION

The results showed that both mustard and maize plant species have certain degrees of Pb accumulation. The highest content of Pb was found in the root of plants; therefore, the roots are considered as the best bio-monitors. They are also more active than other parts for extracting Pb, thus both plants are considered highly efficient species for phytoremediation. Additionally, the results concluded that the application of different concentrations of lead could increase the Pb content of different plants such as mustard and maize. The data represented high BAF, TF values >1. For that reason, mustard and corn are appropriate for phytoextraction of polluted land with Pb. The preservation of Pb in mustard and corn roots and translocation to the above-ground parts could be attributed to the Pb tolerance of both species.

Finally, using mustard and maize for Pb phytoremediation have enormous ecological and economical value, and both plant species were capable of phytoextraction of Pb contaminated soil.

REFERENCE

Abdul, G., 2010. Effect of lead toxicity on growth, chlorophyll and lead (Pb^+) contents of two varieties of maize (Zea mays L.). Pak. J. Nutr. 9, 887–891.

Aladesanmi, O.T., Oroboade, J.G., Osisiogu, C.P., Osewole, A.O., 2019. Bioaccumulation factor of selected heavy metals in Zea mays. J. Health Pollut. 9.

Al-Salman, I., Abdul-Aziz, M., 2002. Lead Bio-accumulation in Baghdad City- Iraq. Jordan J. Appl. Sci. 4, 6–11.

Amin, H., Arain, B.A., Jahangir, T.M., Abbasi, M.S., Amin, F., 2018. Accumulation and distribution of lead (Pb) in plant tissues of guar (Cyamopsis tetragonoloba L.) and sesame (Sesamum indicum L.): profitable phytoremediation with biofuel crops. Geol. Ecol. Landsc. 2, 51–60.

Awokunmi, E., Adefemi, O., Asaolu, S., 2015. Tissues accumulation of heavy metals by maize (Zea maize L.) cultivated on soil collected from selected dumpsites in Ekiti State, Nigeria. Am. Chem. Sci. J. 5, 156–162.

Baikhamurova, M., Sainova, G., Abseyit, A., Tashmetova, G., Kelesbayev, K., 2020. The influence of lead on the growth and development of various mustard types. EurAsian J. Biosci. 14, 57–64.

Bassegio, C., Campagnolo, M.A., Schwantes, D., Gonçalves Junior, A.C., Manfrin, J., Schiller, A. da P., Bassegio, D., 2020. Growth and accumulation of Pb by roots and shoots of Brassica juncea L. Int. J. Phytoremediation 22, 134–139.

CHAI, Z., WANG, X., SUN, X., JIANG, P., 2011. Influence of Different Application Ways of Biogas Waste Fertilizer on Photosynthetic Characteristics and Yield of Zizyphus jujube. Acta Agric. Boreali-Occident. Sin. 2.

De Jesus, B.R., Yllano, O.B., 2005. Bioaccumulation and bioconcentration of Pb in the tissues of Zea mays L. Philipp. J. Sci. 134, 21.

Eun, S., Shik Youn, H., Lee, Y., 2000. Lead disturbs microtubule organization in the root meristem of Zea mays. Physiol. Plant. 110, 357–365.

Grzegórska, A., Rybarczyk, P., Rogala, A., Zabrocki, D., 2020. Phytoremediation—from Environment Cleaning to Energy Generation—Current Status and Future Perspectives. Energies 13, 2905.

Gupta, A., Sinha, S., 2007. Phytoextraction capacity of the Chenopodium album L. grown on soil amended with tannery sludge. Bioresour. Technol. 98, 442–446.

Gupta, A.K., Sinha, S., 2009. Growth and metal accumulation response of Vigna radiata L. var PDM 54 (mung bean) grown on fly ash-amended soil: effect on dietary intake. Environ. Geochem. Health 31, 463–473.

Hall, J., 2002. Cellular mechanisms for heavy metal detoxification and tolerance. J. Exp. Bot. 53, 1–11.

Ibrahim, K., Yet, Z., Som, A., Razali, N., Rohaizah, N., Othman, E., Burok, N., Yunos, Y., Othman, R., Yahya, T., 2015. Theavy metal concentration (Pb, Cu, Fe, Zn, Ni) in plant parts of Zea mays L. cultivated in agricultural area near Alor Gajah, Melaka, Malaysia. Am J Env. Eng 5, 8–12.

Juberg, D.R., Kleiman, C.F., Kwon, S.C., 1997. Position paper of the American Council on Science and Health: lead and human health. Ecotoxicol. Environ. Saf. 38, 162–180.

Kaur, L., 2018. Accumulation potential of Indian mustard (Brassica juncea var. arawali) and fenugreek (Trigonella foenum-graecum L.) planted on Lead and Nickel contaminated soil. Trop Plant Res 5, 217–223.

Kumar, V., Singh, J., Chopra, A., 2018. Assessment of plant growth attributes, bioaccumulation, enrichment, and translocation of heavy metals in water lettuce (Pistia stratiotes L.) grown in sugar mill effluent. Int. J. Phytoremediation 20, 507–521.

Long, S.P., ZHU, X., Naidu, S.L., Ort, D.R., 2006. Can improvement in photosynthesis increase crop yields? Plant Cell Environ. 29, 315–330.

Mahar, A., Wang, P., Ali, A., Awasthi, M.K., Lahori, A.H., Wang, Q., Li, R., Zhang, Z., 2016. Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: a review. Ecotoxicol. Environ. Saf. 126, 111–121.

Malik, R.N., Husain, S.Z., Nazir, I., 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Pak J Bot 42, 291–301.

Meers, E., Van Slycken, S., Adriaensen, K., Ruttens, A., Vangronsveld, J., Du Laing, G., Witters, N., Thewys, T., Tack, F., 2010. The use of bio-energy crops (Zea mays) for 'phytoattenuation'of heavy metals on moderately contaminated soils: a field experiment. Chemosphere 78, 35–41.

Pilon-Smits, E., 2005. Phytoremediation. Annu Rev Plant Biol 56, 15–39.

Rathore, S., Kapila, S., Premi, O., Kandpal, B., 2013. Water use efficiency, productivity, photosynthesis and sustainability of pressurized irrigation systems for Indian mustard [Brassica juncea (L.) Czern and Coss.] under semi-arid conditions of Rajasthan. Res. Crops 14, 140–150.

Rezvani, M., Zaefarian, F., 2011. Bioaccumulation and translocation factors of cadmium and lead in'Aeluropus littoralis'. Aust. J. Agric. Eng. 2, 114.

Roychowdhury, R., Roy, M., Zaman, S., Mitra, A., 2017. Bioaccumulation of heavy metals in Brassica juncea: an indicator species for phytoremediation. Int. J. Innov. Reasearch Multidiscip. Field 3, 92–95.

Sinha, P., Dube, B., Srivastava, P., Chatterjee, C., 2006. Alteration in uptake and translocation of essential nutrients in cabbage by excess lead. Chemosphere 65, 651–656.

Suman, J., Uhlik, O., Viktorova, J., Macek, T., 2018. Phytoextraction of heavy metals: a promising tool for clean-up of polluted environment? Front. Plant Sci. 9, 1476.

Van Ginneken, L., Meers, E., Guisson, R., Ruttens, A., Elst, K., Tack, F.M., Vangronsveld, J., Diels, L., Dejonghe, W., 2007. Phytoremediation for heavy metal-contaminated soils combined with bioenergy production. J. Environ. Eng. Landsc. Manag. 15, 227–236.

Verma, S., Dubey, R., 2003. Lead toxicity induces lipid peroxidation and alters the activities of antioxidant enzymes in growing rice plants. Plant Sci. 164, 645–655.

Yoon, J., Cao, X., Zhou, Q., Ma, L.Q., 2006. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Sci. Total Environ. 368, 456–464.

"عوامل التراكم الحيوي للرصاص والانتقال في نباتى الخردل والذرة الشامية في التربة الجيرية لإقليم كردستان العراق _ مدينة عقرة "

نزار على محمد [1] و عبدالرحمن سمو حسين[2]

[1] كلية عقرة التقنية ، جامعة دهوك بوليتكنيك ، إقليم كوردستان ، العراق

[2] معهد شنكال التقني ، جامعة دهوك بوليتكنيك ، إقليم كوردستان ، العراق

تم إجراء البحث فى يونيو 2020 حتى نهاية أغسطس 2020 في مشتل البساتين بمدينة عقرة وتم .زراعة نوعين من شتلات المحاصيل (الذرة الشاميه (Zea mays) - والخردل الهندي) وريهم بنوعين من المياه (مياه عادمه ، ومياه الجوفية) ، لتقييم التراكم الحيوي وعوامل الانتقال للرصاص. وذلك لنباتى الخردل والذرة الشامية وكان الهدف من هذه الدراسة هو تحديد عوامل التى تؤدى الى تراكم عنصر الرصاص والانتقال داخل نبات الخردل والذرة الشامية ، حيث تم اضافة اربعة تركيزات من الرصاص وهى صفر ، 200 ، 400 ، 800 ميلليجرام لكل كيلوجرام الى محصولى الخردل والذرة الشامية ، وتم اخذ العينات النباتية بعد 70 يوم من الزراعة لاجراء التحليلات عليها وهى حوالي 1 جرام من أجزاء الجذور والبراعم لأنواع النباتات المختارة التي كانت تنمو في الموقع بشكل منفصل. إلى جانب ذلك ، تم أيضًا اخذ 10 جرام من عينات التربة من نفس الاصص التى أخذ منها عينات النباتات. التحليلات: تم تحليل عنصر الرصاص فى كلا من التربة والنباتات بواسطة مقياس الامتصاص الذري (AASP) من النوع .GBC 932AA ثم تم قياس عامل التراكم الحيوي (BAF) في الأنواع النباتية وتم الحصول عليه من نسبة محتوى الرصاص في جذر النبات إلى محتوى الرصاص في التربة. وتم الحصول على عامل النقل (TF) من نسبة محتوى الرصاص في براعم النبات إلى تلك الموجودة في جذور النبات ،اهم النتائج التي تم الحصول عليها : - ان عامل التراكم الحيوى وعامل النقل لنباتى الخردل والذرة الشامية كان اكبر من واحد (BAF و 1 <TF) ، مما يشير إلى قابليتهما للتطبيق في استخراج الرصاص الملوث. - التربة في موقع الدراسة. منذ تراكم الرصاص وانتقاله ، كانت العوامل في كلا النوعين من النباتات أكثر من عامل واحد ، لذا فهم يعتبرونها نباتات تراكمية ويقترحون أن أنواع النباتات ذات القدرة على تراكم الرصاص بداخلها لها القدرة على معالجة التربة الملوثة بالرصاص.