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Assessment of The Use of Artemisia Dracunculus L and Erigeron Canadensis in The Remediation of Heavy Metal Contaminated Soils and Their Ability to Phytoextraction and Biomass Yield

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Abstract: Different hyperaccumulator plants growing in the same contaminated soil may have excessive accumulation of different metals or produce biomass. Therefore, it is important to determine the ability of the plant to improve the soil under natural conditions in the improvement of heavy metal-contaminated lands with hyperaccumulator plants. This study focused on the phytoremediation and biomass production capabilities of *Artemisa Dracunculus L.* and *Erigeron Canadensis plants*. Considering this fact, *Erigeron Canadensis* was determined to have the highest phytoextraction potential between the two plants, as it produces more biomass (96%) and mineral content (169%) than *Artemisa Dracunculus L*. This shows that *Erigeron Canadensis* has more phytoremediation potential than *Artemisa Dracunculus L.* and that *Erigeron Canadensis* plant is one of the alternative hyperaccumulator plant candidates and is more effective for soil reclamation. In addition, when the plants were categorized according to their BAF values, accumulator (1<Cd-Pb<10), heavy metal exclusionary (Cr-Hg-Sn<1), and Hyperaccumulator (10<Ni) were identified for both plants. On the other hand, *Artemisa Dracunculus L.* was defined as the accumulator for Se, but *Erigeron Canadensis* was excluder for Se.

Artemisia Dracunculus L ve Erigeron Canadensis'in Ağır Metalle Kirlenmiş Toprakların İyileştirilmesinde Kullanımının ve Bunların Fitoekstraksiyon, Biyokütle Veriminin Değerlendirilmesi.

Öz: Aynı kirlenmiş toprakta büyüyen farklı hiperakümülatör bitkiler, farklı metallerin aşırı birikimine sahip olabilir veya biyokütle üretebilirler. Bu nedenle ağır metal kirlenmiş arazilerin hiperakümülatör bitkilerle ıslahında bitkinin tarla koşullarında toprağı iyileştirme kabiliyetinin belirlenmesi önemlidir. Bu çalışma, *Artemisa Dracunculus L.* ve *Erigeron Canadensis* bitkilerinin fitoremediasyon ve biyokütle üretim yeteneklerine odaklanmıştır. Bu gerçek göz önüne alındığında, *Erigeron Canadensis*'in *Artemisa Dracunculus L.*'den daha fazla biyokütle (%96) ve mineral içeriği (%169) ürettiği için en yüksek fitoekstraksiyon potansiyeline sahip olduğu belirlendi. *Erigeron Canadensis* bitkisi, *Artemisa Dracunculus L.* Bitkisine göre toprak ıslahında daha etkilidir. Bu nedenle 'de alternatif hiperakümülatör bitki adayıdır. Ayrıca bitkiler BAF değerlerine göre sınıflandırıldığında her iki bitki için Cd ve Pb akümülatör (1<Cd, Pb<10), Cr, Hg, Sn için ağır metal dışlayıcı özelliğinde (Cr-Hg-Sn<1) ve Ni için hiperakümülatör (10<Ni) bitkiler olarak belirlenmiştir. Öte yandan *Artemisa Dracunculus L*, Se için akümülatör olarak tanımlanırken, *Erigeron Canadensis* Se için dışlayıcı bitkidir.

1. INTRODUCTION

Soils contaminated by heavy metals occurred primarily following the industrial revolution and it has become a growing threat because of intense agriculture and rapid urbanization [1]. The presence of heavy metals affects not only soil quality, but plant health and crop productivity as well [2]. Moreover, it reduces soil, water, and crop quality, in additionally, it poses serious risks

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for human health in the food chain [3, 4]. In fact that they are a long-term environmental threat [5]. Therefore, remedial measures are required to prevent heavy metals from entering terrestrial, atmospheric and aquatic environments and to reduce soil contamination [6, 7]. Physical and chemical methods of removing heavy metals from contaminated areas on a large scale are generally not available. Because the cost is high and is not acceptable to the public [8]. There are also disadvantages, including irreversible soil properties and secondary pollution [9, 10]. Thus, this is a major environmental concern. Remediation of metal-contaminated sites usually involves excavation of contaminated soil and the next step is to immobilize metal contaminants using solidification or stabilization technology at a licensed landfill [11]. Consequently, phytoremediation has become an alternative method that removes pollutants from polluted environmental components such as water, soil and air [12]. There are currently more than 450 species of hyperaccumulator plants in 45 families that meet the criteria for hyperaccumulation. Most of them are Ni hyperaccumulators (75%) [13] and most of hyperaccumulator plant species can over accumulate and over tolerate a single metal. However, some plant species are capable of accumulating and tolerating multiple metals at elevated concentrations. As a solution, Plants with well-developed roots and large biomass that can tolerate elevated concentrations of metals [14] and their phytoremediation capacity should be determined. Because they can fix or remove heavy metals from contaminated soil [14].

The aim of this study was to compare the accumulative capacity of heavy metals and the remediation capacity of two plants grown in soils polluted with industrial waste. Their biomass production was also compared due to heavy metal buildup. As a result, the translocation factor (TF), the bioaccumulation factor (BAF) for determining the phytoextraction and the hyperaccumulation capacity of *Artemisa Dracunculus L.* (AD) and *Erigeron Canadensis* (EC) from the family *Astéraceae* was studied. As well, it was assessed together pollution loads of the sampling sites.

2. MATERIAL AND METHOD

2.1. Sampling Area

Karabuk is a province where steel industries and their sub-industries are active in Turkey. It is located on the western side of the Black Sea region. it consists of mountains and forest regions to an elevation of 240. Plant and soil samples were collected from the landfill where the waste from the steel and construction industries (PS) was discharged (N 410 10' 42,60146' and E 320 38'42,07808'). As a reference sampling (RS) was carried out on agricultural land without industrial pollution (N 410 12' 45,47' and E 320 40' 38,09''). All samples were collected in the last quarter of July 2021.

2.2. Plant and Soil Sampling

Plant and soil samples in five random replicates were collected from both two plant varieties on a square hectare area. First, soil surface was swept away from organic residual as 2-3 cm thin, and soil samples were then taken around the plant roots by 20 cm deep. The same procedure was applied to the reference area plant and soil samples.

2.3. Preparing Soil and Plant Samples for Analysis

AD and *EC* collected in their natural environment were brought to the laboratory. They were washed 3 times with distilled water to clean the contaminants in them. Allowed to dry for one day at ambient temperature. Following weighing of the plant samples, they were divided into leaves, stems, and roots. Plant parts were dried in the oven at 80ºC for 48h until it reached a constant weight. Dried plant samples were granulated to small particles using a blender and stored in closed containers for analysis. The root or other residues were cleaned in soil samples collected on the root surface. Soil samples was sieved using a 2 mm sieve and dried at 105^0C for 48h until it reached a constant weight. The dried soil samples were stored in closed containers for analysis.
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2.4. Analysis of Heavy Metal Concentrations

For the heavy metal contents of the 1 g dried samples, 3 ml HNO_3 +9 ml HCl was incinerated in 3 different steps and prepared for analysis. First step; (5 minutes at 145 ºC at 75% microwave power), second Step; (10 minutes at 180 ºC at 90% microwave power) and third step (10 min. at 100 ºC at 40% microwave power) were kept in a microwave, burning unit resistant to 40 bars (speedwave MWS-2 Berghof products + Instruments Harresstr.1. 72800 Enien Gernmany) [15]. After the samples were prepared for analysis, the ICP OES spectrophotometer (Perkinelmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA) was used to determine the heavy metal content of the plant.

2.5. Plant Combustion

0.5 g of dried plant sample was weighed and placed in melting pots. Combustion was conducted in an electric furnace at 550°C and 900°C in the atmosphere. A temperature of 550 °C was selected. Because (i) it is enough to decompose the organic material and is the conventional temperature of the determination of the ash yield of the biomass. (ii) There is no significant loss of inorganic volatiles at this temperature [16]. The temperature of 900°C is the estimated temperature achieved in the boiler used for the pilot to burn tests [17]. Incineration was performed under conditions consistent with NF EN ISO 18122 to determine the ash content. the temperature was raised to 250°C at 25°C min^{-1}. It was kept constant for 60 minutes. It was then elevated to 550 at 10°C min^{-1} and kept constant for 120 minutes, then 900 ^{0}C at 10 ^{0}C min^{-1} and kept constant for 120 min. The crucibles were put into a desiccator

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until their temperature decreased to room temperature (20°C), and the sample was measured [18]. It was repeated three times for each plant.

2.6. SEM-EDX Characterization

Zeiss sigma 300 field emission gun scanning electron microscope (SEM), energy dispersive X-Ray (EDX) analysis and UV-1280 UV–VIS Spectrophotometer were used. The morphology of heavy metals between plant cells was analyzed. These analyzes were carried out in Van Yüzüncü Yıl University laboratories in Turkey.

2.7. Translocation Factor (TF)

The translocation factor is evaluated translocation of metals from roots to shoots by equation (1). it was computed as the ratio of metal concentration in the shoots to those in the roots [19-21]. as follows:

$$TF = \frac{heavy\ metal\ concentration\ in\ shoot}{heavy\ metal\ concentration\ in\ root} \quad (1)$$

TF > 1 signifies that the plant effectively translocated metals from the roots to the shoots [22].

2.8. Bioaccumulation Factor (BAF)

The Bioaccumulation factor (BAF) is determined for quantitative expression of metal accumulation in the plant shoots from the soil by equation (2) [23].

$$BAF = \frac{heavy\ metal\ concentration\ in\ shoot}{heavy\ metal\ concentration\ in\ soil} \quad (2)$$

Plants with different BAF values are categorized as (excluder)1<(accumulator)<10 (hyperaccumulator) [24].

2.9. Phytoremediation Efficiency

The Translocation Factor and Bioaccumulation Factor were calculated to evaluate the efficiency of phytoextraction of heavy metals [24, 25]. TF is the ability of a plant to move metal from roots to shoots. But the bioaccumulation factor refers to the capacity of a plant to accumulate soil metals. An accumulator of plants with BAF shoot values >1 according to the classification of existing plants used as phytoremediation media [26]. The plants for which the BAF shoot value < 1 is assumed to be metal excluder. Moreover, plants are classified as potential hyperaccumulators if the shoot values of BAF >10 [24].

2.10. Contamination Factor (CF)

Contamination Factor is also called single pollution index (PI). CF is the quotient obtained by dividing the concentration of metals related to the target area by reference area. The contamination factor can be calculated by equation 3 [27].

$$CF = \frac{concentration\ of\ metals\ in\ the\ target\ area}{concentration\ of\ metals\ in\ the\ reference\ area.} \quad (3)$$

Contamination factor categorized [28]. as below.

(LP) Low (CF < 1), (MP) Moderate (1≤ CF<3), (CP) Considerate (3≤CF<6), (VHP) Very high (CF>6).

2.11. Pollution Load Index

Pollution Load Index (PLI) is simple statistical technique used to determine elemental contents in soil beyond the reference concentration [29, 30]. PLI can be determined by equation (4)

$$PLI = \sqrt[n]{CF1xCF2xCF3 \dots CFn} \quad (4)$$

PLI represents the pollution load index, CF is the contamination factor, and "n" is the number of elements. The indicates polluted (PLI >1), no pollution (PLI <1).

2.12. Enrichment Factor (EF)

The Enrichment factor is identified as an effective tool for evaluating the amount of pollutants in the environment [31]. The EF for each component was calculated to assess anthropogenic effects on hazardous soil components by equation (5) [32, 33].

$$EF = \frac{\frac{concentration\ of\ heavy\ metal\ in\ the\ soil\ sample}{Fe\ content\ in\ the\ soil\ sample}}{\frac{heavy\ metal\ content\ in\ Geo\ ref.}{Fe\ content\ in\ Geo\ ref.}} \quad (5)$$

Classification of enrichment factors (EF).
EF < 2 Low enrichment, 2 ≤ EF < 5 Medium enrichment, 5 ≤ EF < 20 Significant enrichments, 20 ≤ EF < 40 Very high enrichment, EF ≥ 40 Excessive enrichments.

2.13. The Rate of Phytoextraction

The rate of phytoextraction was calculated using by equation (6) [34]. Metal contamination was assumed to occur only in the active root zone, in the top 20 cm of soil. It results in a total soil mass of 2600 t ha^{-1} (Supposing a soil mass density of 1,3 t m^{-3}).

$$\% soil\ metal\ removed\ by\ plant = \frac{(Plant\ metal\ concentration\ Biomass)\ x100}{(Soil\ metal\ concentration\ x\ Soil\ mass\ in\ the\ rooting\ zone)} \quad (6)$$

2.14. Statistical Analysis

Data were analyzed by One-Way ANOVA using SPSS software (version 22.0). Duncan's test was used to identify significant differences between the means (p < 0.05).

3. RESULTS AND DISCUSSIONS

The mean pH for two plant soils sampled from PS were 6.80-7.07, while it was 7.92–7.21 in two soil samples from RS. The EC values of soil sampled from PS was 92.19 and 100.57 μs cm^{-1}. The EC values for the RS samples was 67.64 and 64.49 μs cm^{-1}. The concentration of CaCO$_3$% of the two plant soils from the PS was 0.36 and 0.39, whereas it was 0.59 and 0.84 in soil samples

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from the RS. Organic Matter content of sampled soils from RS for *AD* and *EC* (1.90-2.21%) was higher than PS (1.48-0.89%) (Table 1).

Table 1. Soil samples taken from plant root zones

	AD (PS)	*EC* (PS)	*AD* (RS)	*EC* (RS)
pH	6.80	7.07±0.15	7.92±0.04	7.21±0.06
EC mikromhos cm^{-1}	92.19±7.03	100.57±6.03	67.64±1.86	64.49±1.69
Calc. %	0.36±0.24	0.39±0.08	0.59±0.04	0.84±0.04
OM %	1.48±0.11	0.89±0.04	1.90±0.07	2.12±0.09
Total N %	0.10±0.04	0.03±0.01	0.06±0.03	0.06
P ppm	21.33±2.36	26.51±0.58	32.16±1.49	59.20±7.34
K cmol kg^{-1}	2.05±1.20	1.24±0.08	2.64±0.08	2.94±0.12
Ca	11.40±0.41	6.88±0.11	14.70±8.29	16.36±0.67
Mg cmol kg^{-1}	7.66±1.20	9.36±1.87	15.16±0.51	17.24±0.80
Na cmol kg^{-1}	2.56±0.41	2.29±0.11	3.68±0.22	1.01±0.08
Total Ni	2786.01±222.88	2291.25±160.37	255.21±12.75	210.02±14.7
Total Cd	335.83±23.45	323.07±22.61	23.21±9.28	22.55±1.58
Total Pb	1297.80±90.79	1157.25±92.56	29.85±2.67	30.30±1.72
Total Cr	3319.12±165.95	4209.92±294.63	268.84±21.51	245.96±14.76

Depending on the contaminant factor categorized by [28]. The levels of contamination of heavy metals where studied area was determined by Cd (very high), Hg (considerate), Se-Pb (moderate), Ni-Cr and Sn (low). The CF of PS area was calculated as the mean of the results of the two sampled soils because of represents in the same area. CF of heavy metals were computed as (Cd 99.4, Hg 5.29, Se 1.78, Pb 1.17, Ni 0.37, Cr 0.13, Sn 0.05). The pollution load index was determined 22.91 (means of two soil samples) because of contamination factors. According to these results, soils sample of *AD* and *EC* plant from PS, the pollution factor was very high (PLI 26,76-19,05). The enrichment factor (EF) is often used to assess soil contamination by HM [35, 36]. The total EF was also computed to understand the pollution dimension. It was 63.33 on PS soil samples. Our results showed that anthropological pollution because of high EF and PLI value was caused by waste from the iron and steel industry in Karabük province. The EF value focuses on the fact that it adequately represents our field of study and may serve as a reference in the future.

Moreover, these results showed that the studied plants could be able to detoxify heavy metals and the capacity of the hyperaccumulator. As a result of heavy metal analysis of soil and plant samples taken from both PS and RS fields, there were statistically significant differences in heavy metal accumulation between organs of both *AD* and *EC* plants ($p<0.05$) (Table 2, Figure 1).

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Table 2. Heavy metal concentrations in AD and EC plants (leaf-stem-root) and soils.

Plants	Area	Site	Cd	Cr	Hg	Pb	Ni	Sn	Se
			mg g^{-1} dry weight						
AD	PS	Leaf	13.28±1.14**a**	0.90±0.10**b**	0.13±0.01**b**	32.47±1.12**a**	11.31±0.56**a**	0.21±0.01**b**	2.95±0.12**a**
		Stem	8.66±0.74**b**	0.74±0.08**b**	0.11±0.01**b**	24.15±0.83**b**	7.37±0.36b	0.16**b**	1.92±0.08**ab**
		Root	5.66±0.45**c**	0.14±0.02**b**	0.01**c**	13.10±0.58**d**	0.21±0.01**d**	0.03**c**	1.17±0.05**b**
		Soil	2.93**d**	5.89±1.20**a**	2.31±0.11**a**	16.80±3.32**c**	1.04±0.15**c**	0.56±0.10**a**	2.96±1.75**a**
	RS	Leaf	0.97±0.10a	0.06±0.01b	0.00c	0.80±0.11a	0.13b	0.02b	0.00b
		Stem	0.63±0.07b	0.07±0.01b	0.00c	0.60±0.08b	0.09bc	0.01c	0.00b
		Root	0.43±0.04c	0.16±0.02a	0.02b	0.30±0.02c	1.56±0.07a	0.03a	0.00b
		Soil	0.08d	0.18±a	0.05±0.01a	0.29±0.04c	0.03±0.01c	0.02±b	0.07±0.06a
EC	PS	Leaf	12.39±1.36**a**	0.78±0.07**b**	0.10**b**	27.93±1.12**a**	9.02±1.50a	0.22±0.04**b**	2.06±0.04**ab**
		Stem	8.08±0.88**b**	0.64±0.06**c**	0.09**b**	20.77±0.91**b**	5.88±0.97**b**	0.16±0.03**b**	1.34±0.03b
		Root	5.85±0.18**c**	0.13±0.02**d**	0.01**b**	11.32±0.16**d**	0.19±0.03**d**	0.02±0.01**c**	0.8±0.04**b**
		Soil	3.05±0.07d	5.81±0.05**a**	2.53±0.35**a**	17.13±2.43**c**	1.16±0.21**c**	0.64±0.03**a**	4.34±2.68**a**
	RS	Leaf	0.96±0.11a	0.06±0.01c	0.00c	0.81±0.03a	0.11±0.01b	0.02b	0.00b
		Stem	0.62±0.07b	0.05±0.01c	0.00c	0.60±0.02b	0.08±0.01b	0.01b	0.00b
		Root	0.39±0.02c	0.15±0.01b	0.02b	0.32±0.01c	1.28±0.22a	0.03±0.01a	0.00b
		Soil	0.08d	0.17a	0.06±0.01a	0.29±0.04c	0.03±0.01b	0.02±b	0.10±0.06a
Duncan abc ($p<0.05$)									
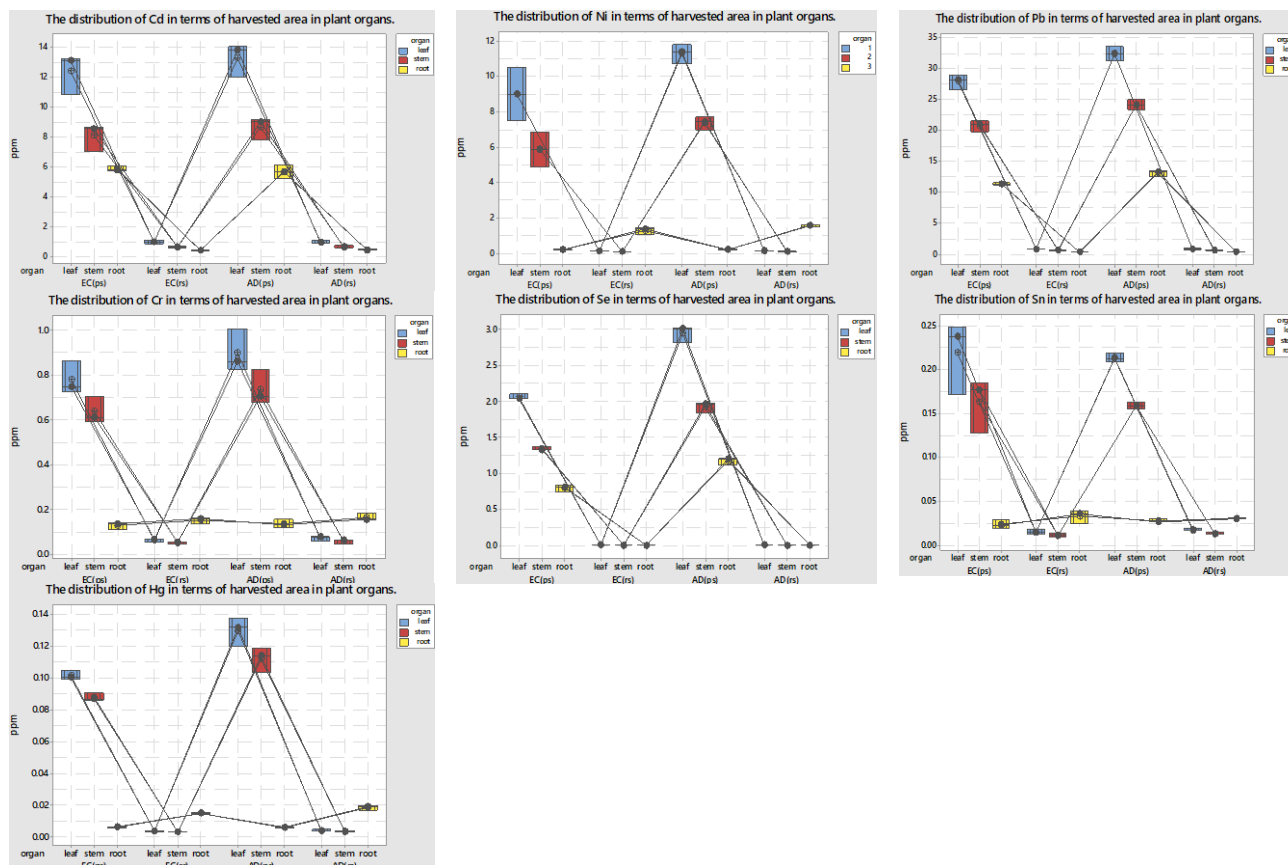
Figure 1. The distribution of heavy metals in terms of harvested area in plant organs.

On the other hand, the nutrient concentration of plant samples collected from the PS was lower than plant samples collected in RS areas (Figure 2). According to the *AD* and *EC* plant leaves from PS had a high accumulation of heavy metal compared to the RS. These increases in the *AD* leaves were at Cd 1269%, Cr 1400%, Hg 3150%, Pb 3959%, Ni 8600%, Sn 950%, Se 98233%. It was for the *EC* leaves at Cd 1270%, Cr 1200%, Hg 2400%, Pb 3348%, Ni 8100%, Sn 1000%, Se 102900%. These increases in the xylem of *AD* and *EC* were at Cd 1274-1203%, Cr 957-1200%, Hg 2650-2400%, Pb 3925-3361%, Ni 8088-7250, % Sn 1500-1000%, Se 95900-66900%. Therefore, it was determined that was the ability to accumulate more heavy metals into aerial components.

TF is an indicator of the accumulation of heavy metals in plants or the mobility of heavy metals in soil. It is also quantified the differences in metal bioavailability for the plant. According to the results of samples from PS, the accumulation of heavy metals was the highest in the aerial parts of plant. Both *AD* and *EC* samples showed the mobility of HMs from root to stem and leaf. TF (stem<leaf) was obtained at TF_{Cd} (1.53-1.38<2.34-2.12), TF_{Cr} (5.29-4.92<6.42-6), TF_{Hg}(18.34-15<21.67-1667), TF_{Pb}(1.84<2.48-2.47), TF_{Ni} (35.01-30.95<53.86-47.47), TF_{Sn}(5.3-8<7-11), TF_{Se}(1.64-1.68<2.52-2.58). Moreover, the BAF values were computed for phytoremediation efficiency for both plants. BAF value was as BAF_{Cd} (7.5-6.71), BAF_{Cr} (0.28-0.24), BAF_{Hg} (0.10-0.08), BAF_{Pb} (3.37-2.84), BAF_{Ni} (17.96-12.85), BAF_{Sn} (0.71-0.6), BAF_{Se} (4.17-0.78) (Table 3). BAF and TF have been

widely used to assess heavy metal transport in growing plant tissues [37]. In both samples, the accumulation capacity of heavy metals in plants was determined by the absorption of metal ions and their transport to the aerial parts. Depending on the results of the analysis, the accumulation of heavy metals in plant samples from the polluted area was highest in the aerial parts and especially leaves. The highest concentration of heavy metals was as Pb>Cd>Ni>Se>Cr>Sn>Hg respectively. BAF values for both plants showed that accumulator (1<Cd-Pb<10), heavy metal excluder (Cr-Hg-Sn<1), Hyperaccumulator (10<Ni). On the other hand, *AD* was identified as accumulator for Se, whereas *EC* was Se excluder plant property (Table 3). Some plant species may absorb and over-accumulate metal contaminants and/or excess nutrients in roots and shoots from growing substrate to plant extraction [38]. In research in Iran, the maximum bioaccumulation of Pb was observed in *Artemisia Dracunculus L.* [39] and it was also reported that new natural Se accumulator was identified by [40]. Another study showed that low levels of Cd accumulated by Artemisa Dracunculus, but they have not been identified as heavy metal accumulator by [41]. In a study was found that the BAF and TF of C. canadensis (L.) Cronq. were all <1. it was indicated that C. canadensis (L.) Cronq. was not a hyperaccumulator [42]. Furthermore, it reported that was strong resistance to heavy metal stress and high concentration of heavy metal. Therefore, as a candidate species for phytoremediation, *C.Canadensis* (L.) *Cronq.* has a certain application prospect in phytoremediation of cadmium-contaminated soil [43].
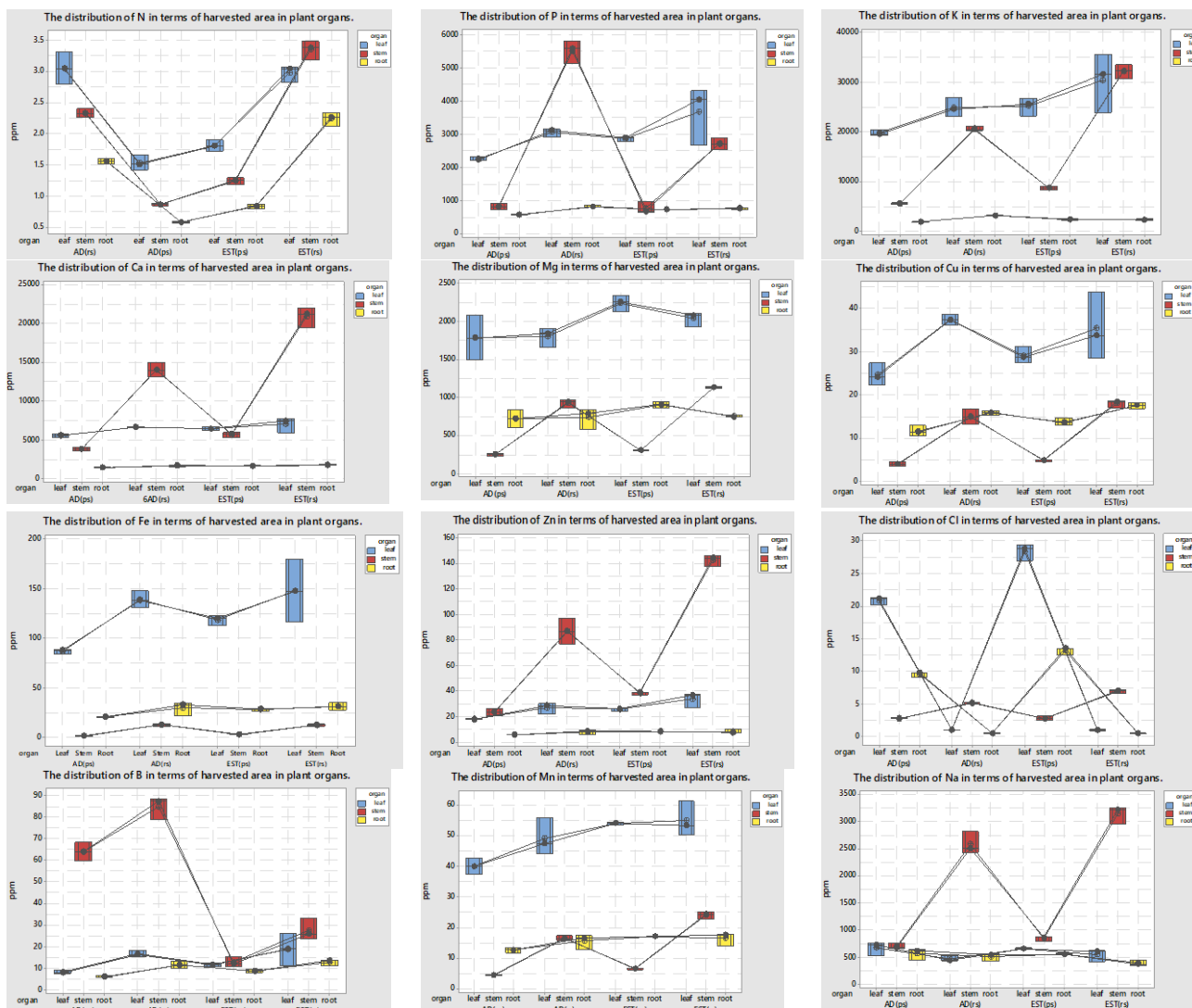
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Figure 2. The distribution of nutrients concentration in terms of harvested area in plant organs

Table 3. Phytoremediation efficiency charts

	AD				EC			
	TF_{leaf}	TF_{stem}	CF	BAF	TF_{leaf}	TF_{stem}	CF	BAF
Cd	2.34	1.53	101[VHP]	7.5[A]	2.12	1.38	97.98	6.71[A]
Cr	6.42	5.29	0.13[LP]	0.28[E]	6	4.92	0.12	0.24[E]
Hg	21.67	18.34	5.12[CP]	0.10[E]	16.67	15	5.45	0.08[E]
Pb	2.48	1.84	1.24[MP]	3.37[A]	2.47	1.84	1.10	2.84[A]
Ni	53.86	35.01	0.4[LP]	17.96[H]	47.47	30.95	0.33	12.85[H]
Sn	7	5.3	0.05[NP]	0.71[E]	11	8	0.05	0.6[E]
Se	2.52	1.64	1.8[MP]	4.17[A]	2.58	1.68	1.76	0.78[E]
PLI	26.76				19.05			

Plant biomass of AD and EC was computed using bio consumption methods.0.45 g biomass and 0.05 g mineral content were obtained from AD (RS) plants. 0.47 g biomass and 0.03 g mineral content were also obtained from EC (RS) plant, after 0.5 g dry plant samples were put in a 550 0C ash kiln. The total biomass rate for AD, EC sampled from the RS was 90-94%. In addition, the mineral content was 10-6 %. The volatiles content of mineral ash was 72.60-93.77%. In contrast, 0.39 g biomass and 0.11 g mineral content were obtained from EC (PS) plants. 0.42 g biomass and 0.08 g mineral content were also obtained from AD (PS) plant, after 0.5 g dry plant samples were put in a 550 0C ash kiln. EC and AD plants collected from PS had lower biomass, and higher mineral content. EC and AD biomass % were achieved at 78-84%. The mineral content for AD and EC from PS was 22-16%. The volatiles content of mineral ash was 81.35-72.43%. In additionally, the mineral content of the where sampled soil from PS was 76.53%. The distribution of heavy metal accumulation in plant organs was shown in Figure 3, 4, 5 and 6 by SEM-EDX observation.

In additionally, bright points in the images showed the distribution of heavy metals observed SEM. Heavy metal residues were identified in the tissues of plant organs. Therefore, these investigations could show the possibility of heavy metal chelation in the leaf and stem of the plant. Furthermore, the EDX detection proved to be close to our real results. The amount of AD biomass (% wt) was 72.96-94.47% (leaf-stem), for EC (% wt) was 80.33-71.22% (leaf-stem).
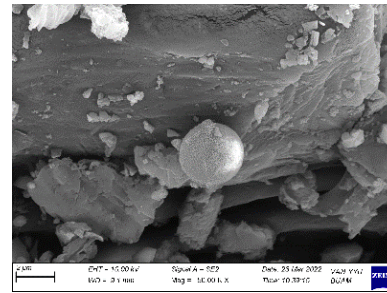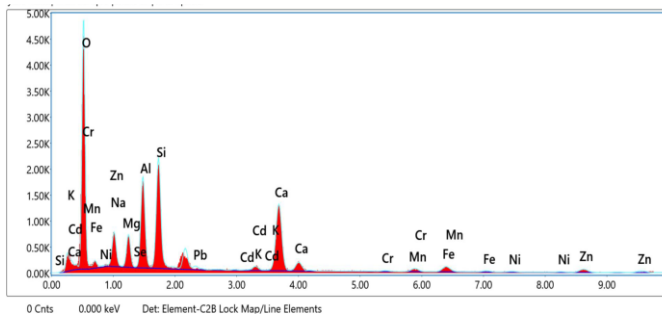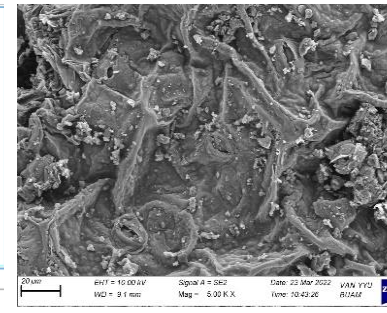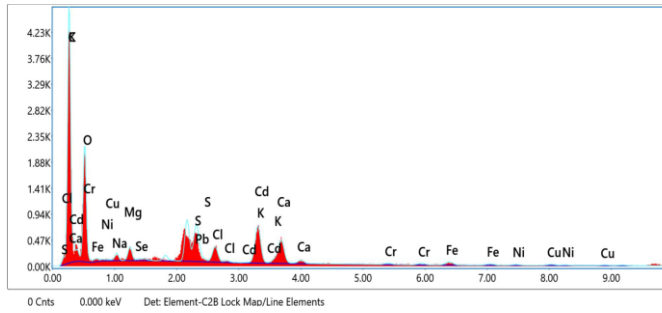

Element	Weight %
O K	40.55
NaK	0.59
MgK	3.66
K K	0.77
CaK	17.72
MnK	1.98
ZnK	7.69

Figure 3. SEM and EDX investigation of the distribution of heavy metals in the tissues of AD leaves (PS)
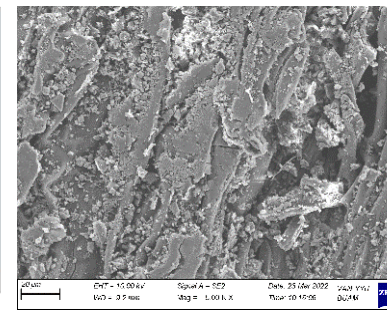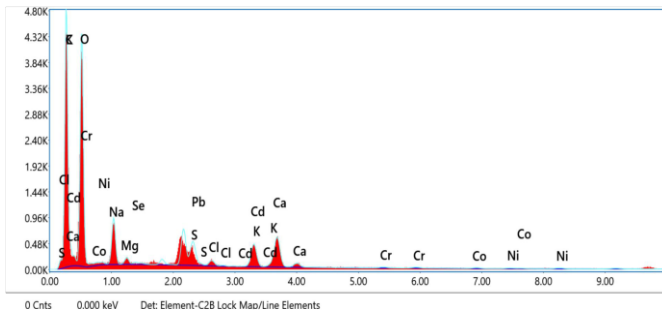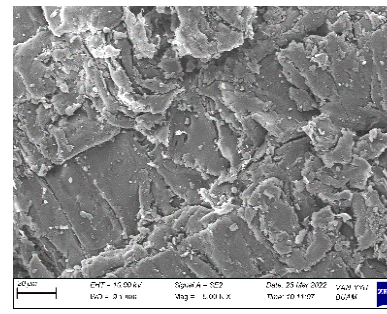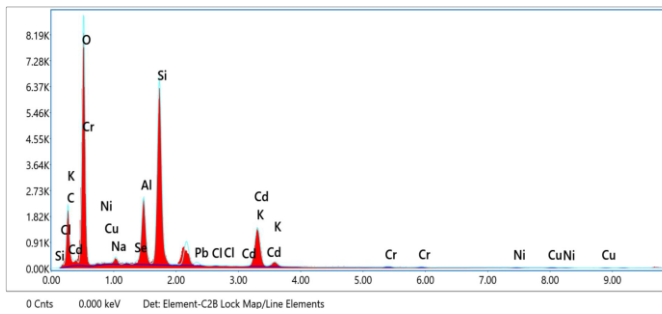

Element	Weight %
C K	32.50
O K	41.47
NaK	6.16
MgK	0.62
S K	1.52
ClK	0.48
K K	4.36
CaK	7.36

Figure 4. SEM and EDX investigation of the distribution of heavy metals in the tissues of AD stem (PS)

Element	Weight %
O K	52.56
NaK	1.40
MgK	0.74
AlK	7.69
SiK	23.05
AuM	7.96
ClK	0.40
K K	2.36
CaK	1.50
FeK	2.34

Figure 5. SEM and EDX investigation of the distribution of heavy metals in the tissues of EC leaves (PS)

Element	Weight %
C K	17.27
O K	43.89
NaK	1.01
ClK	0.01
K K	9.04

Figure 6. SEM and EDX investigation of the distribution of heavy metals in the tissues of EC stem (PS)

According to plants organs of biomass rate for AD collected from PS, it was 94.98-94.95-72.63% (Root>stem>leaf), mineral content 5.02-5.05-27.37%, volatile minerals range in mineral content 49.54-69.31-98.43% (Root-Stem-Leaf) respectively. For the AD collected from RS, it was 94.10-92.91-92.83% (Leaf>stem>root), mineral content 5.90-7.09-7.17%, the volatiles content of mineral ash 83.01-58.43-76.36% (leaf>stem>root) respectively. Plants organs of % biomass for EC collected from PS, it was 85.89-79.02-67.62-% (Root>stem>leaf), mineral content 14.11-20.98-32.38%, the volatiles content of mineral ash 72.11-73.51-98.41% (root-stem-leaf) respectively. For the EC collected from RS, it was 93.05-94.94-93.53% (Leaf>stem>root), mineral content 6.95-6.47-5.06%, the amount of volatile minerals in mineral content 99.72-95.38-86.22% respectively.

The means of collected AD and EC plant samples of dry weight from PS was 27.14 ±7.78 plant-1 0.20m2, 74.

50 ± 13.23 plant-1 0.25 m². The biomass of AD and EC was determined to be 23.61 g plant^{-1} 0. 20m2 and 57.75 g plant-1 0. 25m2. 1.181kg ha^{-1} and 2.310 kg ha^{-1} of biomass were determined from the AD, EC samples from PS, respectively. It was also calculated on 188.96 kg ha^{-1}, 508.2 kg ha^{-1} mineral content. Moreover, 1989.80 t ha^{-1} mineral content was determined soil sampled area.

Assuming both plant of biomass ha-1 year-1, AD and EC plant had a capable of eliminating heavy metals from the soil at Cd (0.34-0.60%), Cr (0.01-0.02%), Hg (0.005%), Pb (0.15-0.25%), Ni (0.82-1.14%), Sn (0.03-0.05%), Se (0.08-0.7%). In terms of results, the rate of Phytoextraction of AD and EC was determined at 9.5%- 25.54% for one harvesting in a year. Research determined that it took 14 years to eliminate low concentrations of Cd in soil [44]. It was also reported that T. Caerulescens remove approximately (200 and 8 ppm) Zn and Cd from industrial contaminated soil for 391 days [45]. Another study indicated that V. Baoshanens removed about (20, 268 and 15 ppm) of contaminated Pb, Zn and Cd for more than 140 days [44]. EC generated more biomass (96%) and mineral content (169%) than the AD. This suggests that EC has more phytoremediation potential than AD.

EC plant was determined one of alternative candidate of hyperaccumulator plant and more effective for the soil remediation. Moreover, it presents a possibility of secondary productions. Apart from the removal of heavy metals from the ground, hyperaccumulating plants have the advantage of secondary uses of the biomass they produce. Thus, they contribute to countries' economies and contribute to reducing carbon emissions. [46]. As biochar, bio-brick, bio-hydrogen, Biomethane, bioethanol, bioethanol, organic acids, bioelectricity, etc. For example, Bio-brick is carbon-negative and sustainable. It is a cost-effective and profitable alternative to incineration of crop residues. Furthermore, Bio-bricks have a lower thermal conductivity of about 0.27 W mk-1 and can be used as a good source of sound and heat insulation in walls. In additionally, During the development of the bio-brick, the researchers revealed that a single block of bio-brick can hold 322.2 gm of CO_2.

4. CONCLUSION

This study focused on the phytoremediation and biomass production capabilities of AD and EC plants. In the process of determining of the phytoremediation potential, not only the BAF and TF values, but also the biomass of the plants are very important, because the amount of metal absorbed increases sufficiently in parallel with its increase of Biomass. Considering this fact, the highest phytoextraction potential of between two plants was determined that was EC. It was also generated more biomass (96%) and mineral content (169%) than the AD. This suggests that EC has more phytoremediation potential than AD. Therefore, EC plant was determined one of alternative candidate of hyperaccumulator plant and more effective for the soil

remediation. Moreover, it presents a possibility of secondary productions. Apart from the removal of heavy metals from the ground, hyperaccumulating plants have the advantage of secondary uses of the biomass they produce. Thus, they contribute to countries' economies and contribute to reducing carbon emissions.

The EC plant has an important Phyto chelator potential to tolerate soils contaminated by heavy metals. It is also able to survive under different environmental conditions and may accumulate large quantities of metal in its harvestable parts. This would allow researchers to choose this plant as a plant remediation tool.

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