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RESEARCH ARTICLE
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Analysis of Heavy Metals Found in Kenger (*Gundelia tournefortii* L.) and Soil at Different Locations in Sulaimani Region.

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ABSTRACT

The Kurdistan Region, Iraq, is rich in wild plant species that are traditionally used as food and medicine. Due to their chemical compounds, some of these plants are toxic, even in very low doses. *Gundelia tournefortii* L. is one of the wild plant species that contains some toxic compounds, such as heavy metals. Therefore, the analysis of inductivity coupled plasma- optical emission spectroscopy (ICP-OES) is important to determine heavy metals found in *Gundelia tournefortii* L. edible parts, seeds, and soil. Furthermore, the interaction effect between plants and soil is essential for different locations. The protocol of heavy metals analysis was investigated using ICP-OES analysis to determine some metals, including arsenic (As), barium (Br), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), potassium (K), magnesium (Mg), nickel (Ni), lead (Pb), strontium (Sr), and zinc (Zn). The highest levels of Ba, Cr, and Ni were observed in all locations using a factorial experiment conducted in the Completely Randomized Design (CRD). The highest concentrations of Ba, Cr, and Ni were found in Mawat (75.432, 89.520, and 138.627 mg kg^{-1}), respectively, while the minimum levels were found in Hazarmerd (38.522, 68.188, and 50.121 mg kg^{-1}), respectively. It was also found that soil contains the highest amount of all three metals: Ba (145.617 mg kg^{-1}), Cr (232.667 mg kg^{-1}), and Ni (254.667mg kg^{-1}), where Ni was the maximum.

***Keywords*:** heavy metals, *Gundelia tournefortii* L., locations, soil andICP-OES.

INTRODUCTION

Nowadays, the quality of soil, water bodies, and the atmosphere is contaminated by heavy metals, which are threatening not only agriculture but also the environment and ecology [1]. Heavy metals are a number of toxic elements that affect human health and can damage central nervous function, blood composition, liver, lower energy levels, kidneys, lungs, and other organs. The major sources of toxic heavy metals are from various industries, such as textiles, wood, dying, plastic, pharmaceuticals, pesticides, and leather. They are also released from industrial processes in soil, crops, air, ground, and surface water, affecting human beings [2].

Some heavy metals are important to complete various biochemical structures of plant growth and development, electronic transport, and metabolic processes, such as iron (Fe), zinc (Zn), molybdenum (Mo), and manganese (Mn), [3]. However, a few metals that are known as nonessential metals due to their unknown functions are found to be toxic even in small amounts in plants, including mercury (Hg), lead (Pb), chromium (Cr), cadmium (Cd), and copper (Cu). The accumulation of these heavy metals in soils is of concern in the production of agricultural aspects because of the effects on crop growth, marketability, and food safety, as well as the environmental health and phytotoxicity of soil organisms [4, 5].

Kenger is a medicinal plant belonging to the Asteraceae family that grows naturally in the semi-desert areas of Iraq, Iran, Syria, Turkey, Jordan, Azerbaijan, Palestine, and Armenia. Plant leaves and flowers are used as salads, the seeds and roots are also consumed as tea and to prepare gum. Traditionally, kenger has been used against various diseases (chest pain, gastric pain, diabetes, liver diseases, heart stroke, bronchitis, gastric pain, and diarrhoea)

due to their bioactive compounds, including terpenoids, phenols, fatty acids, and steroids [6, 7, 8, 9]. Kenger is also one of these plants that contains the most dangerous heavy metals and is even considered an important medicinal plant. Thus, the study of the determination of these metals is essential using inductively coupled plasma (ICP), [10]. It was found that *Gundelia tournefortii* L. was a higher accumulator for copper, zinc, nickel, and manganese and a medium accumulator for iron and chromium based on the area of soil and the biomass of the plant shoot and root [11]. All plant parts are widely used as a source of food and medicine, even with heavy metal content. However, only a few scientific studies have been conducted thus far [12]. Therefore, this study aimed to determine some heavy metals found in kenger plant edible parts, seeds, and soil based on different locations in the Kurdistan Region/ Iraq.

MATERIALS AND METHODS

Plant collection and preparation

Gundelia tournefortii L. plant materials were collected at four different locations (Mawat, Azmar, Temar, and Hazarmerd) in the Kurdistan Region/ Iraq during March 2023 at the edible growth stage (stem and leaf production), and seeds production based on different elevations as summarized in Table 1. Plant selection was based on the presence of kenger plants in the local market. The Global Positioning System (MGRS UTM GPS version 1.9.4) was used for all locations (Table 1). Samples were deposited and identified at the University of Sulaimani/College of Agricultural Engineering Science/Herbarium (SUFA), for references and further investigation [13]. Plant samples were first dried at room temperature after collection for 48 hours in a dark place; after that, they were dried in an electric oven until the weight was stable and then stored until the laboratory analysis was performed.

Table 1: The line measurement of plant collection places.

Locations	Elevations (MASL)	Latitudes	Longitudes
Mawat	803	35.54.7 N	45.24.52 E
Azmar	857	35.38.5 N	45.28.4 E
Temar	870	35.51.21 N	45.4.38 E
Hazarmerd	1040	35.30.17 N	45.19.37 E

Soil collection and pH determination

In the experiment, soil from four studied locations was collected around the plant area with a depth between (2 and 14cm), [14]. Soil samples were dried in an electric oven until the weight was stable. After drying, place 20 g of dried soil sample into a 100 ml beaker and add 50 ml of distilled water. Keep the mixture for a few minutes and stir it with a glass rod for 15 minutes. Leave the samples for about 2 hours to keep them undisturbed for the determination of pH using a pH meter (Table 2).

Table 2. pH measurement

Locations	pH value
Mawat	7.04
Azmar	7.35
Temar	7.21
Hazarmerd	7.45

Determination of heavy metals using ICP-OES analysis

The analysis of element content was carried out at the University of Kurdistan, Sanandaj, Iran, Faculty of Basic Science, Chemistry Department, using a Spectro Arcos model ICP–OES instrument, supplied by SPECTRO Analytical Instruments in Kleve, Germany. This instrument was equipped with a quartz torch with radial viewing and a fixed 3.0 mm injector tube, along with an automated sampler. The operational parameters for the ICP-OES instrument included an RF power of 1450 W, a plasma gas flow rate of 13.5 L/min, an auxiliary gas flow rate of 1.0 L/min, a nebulizer flow rate of 0.8 L/min, a sample aspiration rate of 2.0 ml/min, and a polychromator temperature set at 15°C. For each measurement, three replicates were taken, with each replicate having a read time of 60 seconds. The calibration curve for mineral analysis was constructed using standard solutions prepared at concentrations of 100, 200, 400, 800, 1000, 1200, 1600, and 2000 µg/L. These standard solutions were obtained by diluting multi-element stock solutions (1000 µg/L) in a 0.1 mol/L HNO3 solution. 2 mol/L of HNO3 solution was used during the measurements of ICP-OES as the rinse solvent [15].

Statistical analysis

The statistical analysis was carried out using a factorial experiment conducted in the Completely Randomized Design (CRD). The four collection sites were considered to be the first factor, and two plant parts with the soil sample were studied to be the levels of the second factor [16]. Means comparisons were performed using the least significant difference (LSD) under the significant levels 0.05 and 0.01.

RESULTS and DISCUSSIONS

Generally, in all locations, fourteen essential and non-essential heavy metals were identified in soil, kenger edible parts, and seeds as main metals. Among them, three metals (Ba, Cr, and Ni) were found in high concentrations compared to others (Tables 3, 4, and 5) and considered to be not only non-essential for plant growth and any specific plant mechanism, but also very toxic as heavy metals even at very low concentrations. They could be easily accumulated in the bodies of all living organisms [17]. Some essential metals were also found, like Ca, Cu, Cd, Hg…etc., which play a main role in plant growth and development [18, 19]. In terms of locations, the highest levels of Ba, Cr, and Ni.

Table 3. Determination of heavy metal concentration (mg kg-1) found in kenger edible parts based on different locations.

Locations	As	Ba	Ca	Cd	Co	Cr	Cu	Hg	K	Mg	Ni	Pb

	Sr	Zn											
Mawat	3.763	75.432	6824.780		3.818	5.181	89.520	12.980	3.604	5376.867		4957.912	
	138.627	6.306	20.542	93.490									
Azmar	4.377	58.658	6656.583		3.764	4.989	78.211	10.048	4.114	12395.254		4171.115	
	128.186	5.572	46.768	84.682									
Temar	5.357	59.972	7308.238		4.182	6.112	87.122	13.489	3.124	6885.276		4427.277	
	53.842	8.769	39.539	79.432									
Hazarmerd		5.154	38.522	6981.666		3.704	5.587	68.188	12.316	4.014	6311.820		
	14284.141		50.121	5.174	21.798	64.667							
LSD (p≤0.05)		0.278	3.179	n.s	n.s	0.537	7.941	n.s	0.308	n.s	n.s	24.280	0.837
	3.077	14.647											
LSD (p≤0.01)		0.377	4.308	n.s	n.s	0.728	10.762	n.s	0.417	n.s	n.s	32.904	1.134
	4.170	19.849											

were found in Mawat (75.432, 89.520, and 138.627 mg kg^{-1}), respectively, whereas the lowest levels were found in Hazarmerd (38.522, 68.188, and 50.121 mg kg^{-1}), respectively (Table 3). Relatedly, some toxic and non-toxic metals in the leaves, stems, and flowers of the *Stevia rebaudiana* plant were identified. Cr (0.006- 18.000 mg kg^{-1}), and Ni (0.100- 3.700 mg kg^{-1}) were found to be harmful for plant growth and metabolisms [20]. These results show that the content of kenger heavy metals significantly varies (LSD p≤0.05 and p≤0.01) from one place to another. This might be due to the fact that the content of soil heavy metals is geographically difference due to the pH values and the alkalinity of soil in our regions [21]. In addition, the maximum concentration of Ni was observed in Azmar (128.186 mg kg^{-1}), however, in Temar, the highest value of Cr was determined (87.122 mg kg^{-1}), (Table 3).

Results of Table 4 show that the concentrations of all studied heavy metals in the soil around kenger plants, plant edible parts and seeds were significantly different (LSD p≤0.05 and p≤0.0). Soil contains the highest amount of all three metals: Ba (145.617 mg kg^{-1}), Cr (232.667 mg kg^{-1}), and Ni (254.667 mg kg^{-1}), where Ni was at the top. This might be related to the variation of pH values at different locations, as shown in Table 2. Edible parts heavy metal content of Ba, Cr, and Ni was followed by soil content (19.107, 9.258, and 14.822 mg kg^{-1}), respectively, where Ba level was the highest. Contrarily, kenger seeds contained a low concentration of Ba (9.715 mg kg^{-1}), Cr (0.356 mg kg^{-1}), and Ni (8.593 mg kg^{-1}), Cr (0.356 mg kg^{-1}), and Ni (8.593 mg kg^{-1}), where the maximum amount of Ba was observed. Similar to these current results, researchers investigated that the levels of Cr (353.300 mg kg^{-1}) and Ni (486.700 mg kg^{-1}) were the highest in Elbasan soil and more than the permissible value of plants and soil. They also reported that the area's soil was contaminated due to the high concentrations of both Cr and Ni [22]. Moreover, based on the data reported by other researchers, Cr is considered to be more mobile compared to other metals found in soil and causes high toxicity to plant seedlings [23].

Table 4. Determination of heavy metal concentrations (mg kg-1) found in soil and both kenger edible parts and seeds.

Studied Factors	As	Ba	Ca	Cd	Co	Cr	Cu	Hg	K	Mg	Ni	Pb
Sr	Zn											
Soil	10.032	145.617	11006.167		6.332	11.988	232.667	15.917	5.883	15881.691		17979.837	
	254.667	13.992	62.773	124.250									
Edible part		3.702	19.107	9821.444		4.870	3.640	9.258	14.714	4.602	7343.333		
	2899.939		14.822	4.922	21.866	72.388							
Seeds	0.256	9.715	0.839	0.400	0.773	0.356	5.993	0.658	1.888	0.558	8.593	0.452	11.847
	45.066												
LSD (p≤0.05)		0.241	2.753	577.988	0.407	0.465	6.877	n.s	0.266	10304.427		12707.046	
	21.027	0.725	2.665	12.684									
LSD (p≤0.01)		0.327	3.731	783.274	0.552	0.631	9.320	n.s	0.361	n.s	n.s	28.496	0.982
	3.611	17.190											

In other words, significant differences (LSD p≤0.05 and p≤0.0) were observed in the interaction effects between locations and heavy metal content, as shown in Table 5. Comparably, soil in all locations contains the highest amount of three main heavy metals (Ba,

Cr, and Ni), where the maximum levels were found in Mawat 202.000, 257.333, and 377.000 mg kg^{-1}, respectively, and the minimum values were in Hazarmerd 86.800, 194.667, and133.333 mg kg^{-1}, respectively. At the same time, plant seeds contain the lowest levels, especially in Hazarmerd. It is considered that the most dangerous and toxic metals remain in the soil around kenger plants and are not absorbed as much by plants. This is an important point that kenger seeds in the current studied locations were suitable to eat due to the low concentration of metals compared to edible

parts especially both Cr (0.356 mg kg^{-1}) and Ni (8.593 mg kg^{-1}), (Table 4), and their concentration were lower than permissible

values found in plants (1.300 mg kg^{-1}, and 10.000 mg kg^{-1}), respectively [22]. Totally, as a result it was demonstrated that the soil around plants, plant edible parts and seeds in Hazarmerd contained the lowest amount of studied heavy metals (Table 5).

Table 5. The interaction effects of locations and mineral positions on the studied characters.

Location		As	Ba	Ca	Cd	Co	Cr	Cu	Hg	K	Mg	Ni	Pb	Sr	Zn
Mawat	Soil	7.953	202.000	10975.667	6.110	11.117	257.333	18.000	5.537	7788.096	10898.347	377.000	13.500	39.067	153.333
	Edible part	3.037	14.250	9497.817	4.900	3.697	10.830	14.847	4.633	8340.000	3974.733	24.333	5.000	14.333	85.070
	Seeds	0.300	10.047	0.857	0.443	0.730	0.397	6.093	0.643	2.503	0.657	14.547	0.417	8.227	42.067
Azmar	Soil	8.590	150.333	10551.000	5.847	10.437	228.333	15.667	6.563	31858.667	10579.333	369.000	11.167	113.667	136.000
	Edible part	4.317	14.417	9417.890	5.087	3.837	5.867	8.987	5.220	5325.333	1933.443	10.927	4.943	18.130	69.067
	Seeds	0.226	11.223	0.860	0.359	0.693	0.433	5.490	0.560	1.763	0.567	4.630	0.607	8.507	48.980
Temar	Soil	12.683	143.333	11349.667	7.343	13.857	250.333	15.000	5.110	13268.000	10441.667	139.333	21.300	59.607	119.000
	Edible part	3.214	27.450	10574.250	4.827	3.640	10.667	18.760	3.540	7386.000	2839.647	12.997	4.497	38.803	72.080
	Seeds	0.173	9.133	0.797	0.377	0.840	0.365	6.707	0.723	1.827	0.517	9.197	0.510	20.207	47.217
Hazarmerd	Soil	10.900	86.800	11148.333	6.027	12.543	194.667	15.000	6.323	10612.000	40000.000	133.333	10.000	38.750	88.667
	Edible part	4.240	20.310	9795.820	4.667	3.387	9.667	16.263	5.016	8322.000	2851.933	11.030	5.247	16.197	63.333
	Seeds	0.323	8.457	0.843	0.420	0.830	0.230	5.683	0.703	1.460	0.490	6.000	0.276	10.447	42.000
LSD ($p \leq 0.05$)		0.482	5.506	n.s	n.s	0.931	13.755	n.s	0.533	n.s	n.s	42.054	1.449	5.330	25.369
LSD ($p \leq 0.01$)		0.653	7.462	n.s	n.s	1.262	18.640	n.s	0.722	n.s	n.s	56.991	1.964	7.223	n.s

CONCLUSION

In conclusion, the ICP-OES analysis of heavy metals has revealed that kenger and soil around plants were rich in metals across different locations. The maximum amount of Ba (145.617 mg kg^{-1}), Cr (232.667 mg kg^{-1}), and Ni (254.667 mg kg^{-1}) were observed in soil, and the minimum levels were found in kenger seeds Ba (9.715 mg kg^{-1}), Cr (0.356 mg kg^{-1}), and Ni (8.593 mg kg^{-1}). Mawat contained the highest values of the three studied metals, and Hazarmerd showed the lowest content. According to our results, it can be concluded that the seeds of kenger are safer to eat than the edible part, and can be used as a traditional medicine, therapeutic agent, or food product.

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تحليل المعادن الثقيلة الموجودة في كينجر (*Gundelia tournefortii L.*)والتربة في مواقع مختلفة في منطقة السليمانية.

بناز جمال محمود

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الخلاصة

إقليم كردستان/العراق غني بأنواع النباتات البرية التي تستخدم تقليديا كغذاء ودواء. ونظرًا لمركباتها الكيميائية، فإن بعض هذه النباتات تكون سامة، حتى بجرعات منخفضة جدًا. *Gundelia Tournefortii L* هو أحد أنواع النباتات البرية التي تحتوي على بعض المركبات السامة مثل المعادن الثقيلة. ولذلك، فإن تحليل التحليل الطيفي للانبعاث البلازمي البصري المقترن بالحث (*ICP-OES*) مهم لتحديد المعادن الثقيلة الموجودة في الأجزاء الصالحة للأكل والبذور والتربة. علاوة على ذلك، فإن تأثير التفاعل بين النباتات والتربة ضروري بناءً على المواقع المختلفة. تم دراسة بروتوكول تحليل المعادن الثقيلة باستخدام تحليل *ICP-OES* لتحديد بعض المعادن، بما في ذلك الزرنيخ (*As*)، الباريوم (*Br*)، الكالسيوم (*Ca*)، الكادميوم (*Cd*)، الكوبالت (*Co*)، الكروم (*Cr*)، النحاس. (*Cu*)، والزئبق (*Hg*)، والبوتاسيوم (*K*)، والمغنيسيوم (*Mg*)، والنيكل (*Ni*)، والرصاص (*Pb*)، والسترونتيوم (*Sr*)، والزنك (*Zn*). وقد لوحظت أعلى مستويات *Ba* و*Cr* و*Ni* في جميع المواقع باستخدام تجربة عاملية أجريت في التصميم العشوائي الكامل (*CRD*). أعلى تركيزات *Ba* و*Cr* و*Ni* وجدت في منطقة موات (75.432، 89.520،

138.627 ملجم/كجم)، على التوالي، في حين وجدت أقل المستويات في هازارمرد (38.522، 68.188، 50.121 ملجم/كجم). على التوالى. وقد وجد أيضًا أن التربة تحتوي على أكبر كمية من المعادن الثلاثة: *Ba (145.617* مجم كجم-1)، الكروم (232.667 مجم كجم-1)، والنيكل (254.667 مجم كجم-1)، حيث كان *Ni* هو الحد الأقصى.

الكلمات المفتاحية: معادن الثقيلة، *Gundelia Tournefortii L*، موقع، تربة، *ICP-OES* .