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An ecological study of *Matricaria chamomilla* L. var. *chamomilla*

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Abstract

In this study, the phytoremediation potential and essential element utilization potential of *Matricaria chamomilla* var. *chamomilla* species were investigated and the ecological characteristics of the species were determined. The plant and soil samples were collected from the Karaoren road in Aksaray province in April (2023). The research focused on the consantration of the following minerals: Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S, and Zn in plant and soil samples. ICP-MS was used for plant samples and XRF device was used for soil samples. The obtained data were analyzed statistically by SPSS (version 25). According to the analysis results, while the concentrations of Al, Co, Cu, Mn, Ni, and S in the soil were above optimal values, the concentrations of Al, Co, Cu, Mn, Ni, and Pb in the plants were within the optimal range. In the stem part of the plant, the concentration of Cu, Mn, Pb and Zn elements was found being below the reference values. But, Cr and Fe concentrations in the plant were determined above reference values. However, the Bioconcentration Factor (BCF) value was low for all elements in the plant and was less than 1. This means that the potential use of this species in phytoremediation is quite limited.

Keywords: Matricaria, Chamomilla, Trace Element, Phytoremediation, Ecologıcal Features

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INTRODUCTION

Chamomile, belongs to the Asteraceae (Compositae) family, has been known as a world-famous plant since ancient times (Mahdavi 2020). *Matricaria chamomilla* is a native plant of Southern and Eastern Europe, which is now widely grown in Germany, Hungary, France, Russia, the former Yugoslavia, Brazil, North Africa, India Asia, Northand South America, Australia, and New Zealand (Singh, 2011). In Turkey the natural distribution areas of this species are Thrace, Western and Southern Anatolia (Turkish Plants Data Service 2024).

In *M. chamomilla* (Figure 1) the glabrous stem can grow up to 45 centimeters. Lower leaves are 5-7 cm long, glabrous and oblong. Capitula is usually solitary but sometimes it is subcozymbose. Phyllaries may be oblanceolate, obtuse, or acute. The ligules are patent at first, after that they become reflexed. The ray achenes of coronas with 5 whitish ribs on their back surfaces are brown in color (Davis et al. 1975).

M. chamomilla L. var. *chamomilla* is an annual plant which is known as May daisy. Also it is known as chamomile, medicinal chamomile, common chamomile, babunc, akbubac, papatya and papaçya in Turkey, this plant has a wide ecological abundance area and is distributed up to 900 meters above sea level. Geologically, this plant is widely distributed worldwide, growing in various habitats such as roadsides, waste dumps, and cultivated areas (Cemek et al. 2008; Salamon, 2009; Ozdemir et. al. 2021)

Chamomile which has been used in traditional medicine for thousands of years, has exhibited various biological activities such as anti-inflammatory, antioxidant, antiseptic, antispasmodic, antiallergic, antidiabetic, anticancer and anti-microbial in numerous pharmacological studies. These properties scientifically support the plant's wide use in traditional medicine (Mihyaoui et al. 2022). Chamomile is also used extensively in the pharmaceutical, food, hygiene and cosmetic industries in nowadays. Chamomile has gained increasing commercial value worldwide due to high demand from the pharmaceutical and cosmetic industries (Catani et al. 2021). It is consumed in the form of tea, oil, and extracts, this plant has not only maintained its place in traditional medicine but has also become an indispensable part of modern industry (Solouki et al. 2007).

Current scientific studies on *M. chamomilla* focus on the plant's anatomical, genetic, taxonomic, medicinal, chemical, pharmacostatic, cosmetic, nutritional and floristic properties (Solouki et al. 2007; Inceer and Ozcan, 2011; Ayran at al., 2018; Inceer and Bal, 2019; Yaz et al. 2023). However, it has been observed that ecological studies about investigating this plant's capacity for heavy metal accumulation and trace element utilization are relatively limited. Therefore, in this study, the focus was on the trace element utilization potential of naturally growing *M. chamomilla var. chamomilla* in Aksaray based on plant-soil interactions. Additionally, it was investigated whether this plant has phytoremediation potential or not in this study.

When the literature is examined, it is known that studies on heavy metals are mostly concentrated in regions where there is environmental pollution and the number of studies on heavy metal accumulation in the natural environment is quite low (Osma et al. 2023). For this reason, it was thought that elements such as Al (aluminum), Ba (barium), Co (cobalt), Cr (chromium), Cu (copper), Fe (iron), Mn (manganese), Ni (nickel), Pb (lead), S (sulfur) and Zn (zinc) would play an important ecological processes during plant growth and development. Therefore, this research is highly important in terms of determining these ecological processes.

MATERIALS AND METHODS

Description of the sampling sites

Aksaray province in the Central Kizilirmak section of the Central Anatolia Region is located between the 38-39 north parallels and the 33-35 east meridians (Eskin and Doganay, 2019). It is surrounded by Nevsehir in the east, Nigde in the southeast, Konya in the west, Ankara in the north and Kirsehir in the northeast. Aksaray's surface area is 7798 km^2, and its altitude above sea level varies between 900 and 3300 meters (Coskun, 2016). 433,055 people have been living in this area (Turkish Statistical Institute, 2024; Aksaray Governorship, 2024).

Figure 1. General View of the *M. chamomilla* L. var. *chamomilla*

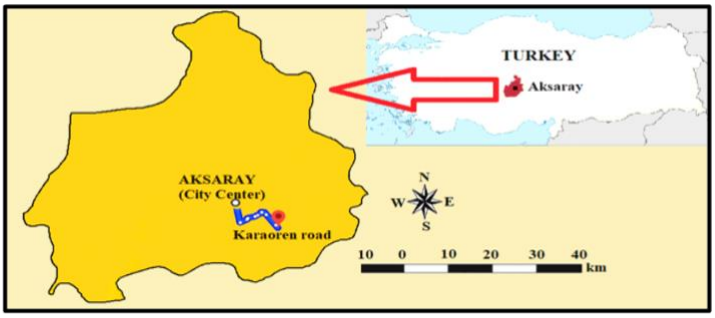

Figure 2. The research area: Location of Karaoren road in Aksaray, Türkiye

The Collection, Preparation and Analysis of Samples

Samples of *M. chamomilla L. var. chamomilla* were collected from Karaoren road in Aksaray, Turkey (Figure 2) during the flower period in April. Five plants and soil samples were taken from five different locations within the study area where the species population was dense. Soil samples were taken from under each plant were mixed and turned into a single sample. The soil samples (approximately 1000 g each) were taken from 0-15 cm depth using a shovel. The collected plants were dried in an oven at 80°C for 48 hours. The dried plants were ground with a hammer and sieved through a 1.5 mm sieve. Then, 0.2 g of plant samples were put in Teflon containers, and 4 ml of 65% HNO_3 was added to them. Next, all the plant samples were mineralized in the microwave oven (CEM MARS 5) at 145°C for 5 min 165°C for 5 min and 175°C for 20 min. The samples were left to the mineralization and cooling process were filtered through Whatman filters. Then, it was completed to 50 ml with ultrapure water and placed in falcon tubes. A multi-element standard solution of -1000 ppm (Merck) was prepared from the stock solution. The numerical values of heavy metals and mineral elements were identified by an Inductively Coupled Plasma Mass Spectrometer device (ICP-MS; Thermo, Xseries 2 Serial number: SN02132C).

Numerical data for the analysis of the same minerals in soil samples were obtained via XRF device (Pan Analytical, Axios Max Serial number: DY5970). In this study, the soil samples were ground to 20 µm size in bearing tungsten carbide vane. 5 grams of the powder sample was mixed homogeneously with 1 gram of Micropulver Wachs C. Then the wax and sample mixture were pelletized under pressure by a Die Attacher. The obtained sample was placed on XRF device, and the element values were identified (Demir et al., 2021).

The Scheibler calcimeter method was used to determine $CaCO_3$ values in the soil (Caglar 1949). pH measurement was done by an electronic pH meter. Also, the organic matter measurements were made according to Walkley-Black (Black, 1965).

Additionally, total phosphorus values in the soil were determined by the Olsen and Sommers method (1982). and available potassium values in the soil were measured by photometric method.

Statistical Analyses

Pearson correlated average and standard deviation values were determined by IBM SPSS Statistics 25 software. The obtained values were demonstrated a statistical significance as $^{**}P<0.01$ and $^{*}P<0.05$ level (2-tailed).

Bioconcentration factor

The Bioconcentration Factor (BCF) is an index that shows a plant's sensitivity to metal pollution. BCF is a numerical value that indicates how much of a metal a plant accumulates in its tissues compared to the concentration of that metal in the surrounding soil. Plants with high BCF values (>1) can accumulate more metal from the soil through phytoremediation (Ghosh and Singh, 2005; Osma et al. 2023; Rashidi et al., 2024).

BCF = metal concentration in the plant tissue/metal concentration in the soil

RESULTS AND DISCUSSION

In this research, the concentrations of Al, Co, and Ni in the roots, stems, leaves, and flowers of *M. chamomilla* were found to be within optimal ranges. The concentrations of Cu and Mn were determined to be at the limit values in both the root and leaf tissues, while the stem and flower tissues exhibited concentrations below the limit values. Also Pb element is below the limit values only in the stem, it was at the limit values in all other plant parts. Zn element remained below limit values in all parts of the plant. The consentration of Cr, Fe and Zn elements in the soil are at limit values, but Al, Co, Cu, Mn, Ni, and S elements are above the limit values. When the concentrations of elements in this plant parts were evaluated, it was observed that the values for Al, Co, Cu, Fe, Mn, and Pb were ranked as root>leaf>stem>flower, while the values for Cr and Zn were ranked as leaf>root>flower>stem. The amount of elements is lined up leaf>root>stem>flower for Ba, stem>root>leaf>flower for Ni, and root>stem>leaf>flower for S (Table 1 and Table 2). Therefore, it can be said that this plant species take all the essential elements necessary for its growth and development from the soil in which it grows. At the same time, the Fe element is found in concentrations above the optimum values in all plant parts other than the stem. Fe is an essential micronutrient for plants. It plays an important role in many physiological processes such as photosynthesis, chlorophyll formation and enzyme activities (Kacar and Katkat, 2010). In addition, in *M. chamomilla var. chamomilla* Cr concentrations exceeded optimal levels in all plant parts. The high level of total Cr in the plant may be due to the conversion of absorbed chromium in the form of chromate (CrO_4^{-2}) to the non-toxic Cr (III) form in the roots by Fe (III) reductase enzymes. (Zayed et al., 1998; Yildiz et al., 2011) This transformation can be considered as a defense mechanism of the plant against chromium toxicity. Also, it can be said that *M. chamomilla var. chamomilla* generally prefers clay-loamy and slightly alkaline soils as its natural habitat. Because these soils provide the optimal conditions for its growth and development. However , the alkaline soils reduce the solubility of Cr in the soil. This may affect the uptake of Cr by plants (Shahid et al 2017). Moreover, the more detailed research is needed to better understand the distribution, transformation, and *M. chamomilla var. chamomilla* availability of different forms of (Cr(III) and Cr(VI)) in the soil. As a result, biomonitoring *M. chamomilla var. chamomilla* throughout its entire vegetation period and evaluating the plant-soil interaction is of great importance for both scientific research and applied fields. Such studies will allow us to better understand the growth and development dynamics of *M. chamomilla var. chamomilla*, reveal its relationship with the soil in detail, and make the best use of this plant.

When the Bioconcentration Factor (BCF) ratios for the *M. chamomilla var. chamomilla* plant are evaluated, it is seen that the BCF value for all elements is less than 1 (<1) (Table 1). It means that the plant is not accumulating the elements from the soil very effectively. The concentration of the element in the plant tissue is lower than the concentration in the soil. This shows that the species does not have the potential to be used in phytoremediation. The accumulation of elements in the plants can be significantly affected by various factors such as soil texture, soil pH, organic matter content, and environmental conditions. Therefore, further research is crucial to fully understand the bioaccumulation potential of this plant species and to identify the key factors influencing BCF values under varying environmental conditions.

Table 1. Chemical Analysis of the Plant Parts (root, stem, leaf and flower) and Soil Samples of P. *M. chamomilla var. chamomilla* and Soil Samples.

Elements	Root	Stem	Leaf	Flower	Soil	Bioconcentration Factor (BCF)
	mg/kg					
Al	626.90	46.43	622.88	258.28	66300	0.023
Ba	14.03	9.20	14.23	2.85	411.2	0.098
Cr	1,69	1.06	1.81	1,11	100	0.0567
Co	0.41	0.10	0.41	0.19	33,3	0.033
Cu	7.13	2.90	7.08	4.07	38,05	0.55
Fe	483.95	38.72	483.89	271.18	41350	0.030
Mn	69.03	8.95	68.69	23.56	800	0.212
Ni	2.71	4.05	2.52	1.47	78,8	0.136
Pb	1.65	0.04	1.64	0.30	25,9	0.140
S	2.50	2.34	2.08	1.65	313,9	0.027
Zn	12.78	9.27	13.91	11.51	69,05	0.687

Tablo 2. Optimum Values (Min.-Max.) of Elements for Plant and Soil Samples

Elements	Values in Plant	Values in Soil
	mg/kg	
Al	7-3400	10000-40000
Ba	-	-
Cr	0.1-0.5	5-120
Co	0.02-0.5	1-10
Cu	5-30	5-30
Fe	5-250	5000-50000
Mn	30-300	270-525
Ni	0.1-5	10-50
Pb	0.05-3	10-30
S	-	10-157
Zn	20-150	10-300

Refrences for limit values in soil and plant (Kabata-Pendias and Pendias, 2001; Ghosh and Singh, 2005; Jones and Jacobsen, 2005; Barker and Pilbeam 2007; Kabata-Pendias and Mukherjee, 2007; Kacar and Katkat, 2010; Blum, et al. 2014)

Table 3 shows that the physical analysis results of soil samples were taken from the distribution area of *M. chamomilla* var. *chamomilla.* When these results are evaluated, it can be observed that the natural habitat of M. *chamomilla* var. *chamomilla* consists of clay-loamy and slightly alkaline soils with a pH of 7.62. The level of $CaCO_3$ is low (5.3%), and the Saturation value is 0.026 % (non-saline). In addition, the organic matter concentration of the soil was found to be of low (1.38 %) value. These findings indicate that *M. chamomilla* var. *chamomilla.* has a certain tolerance to soil type and chemical properties. In the study at the *M. chamomilla* plant was conducted by Rezaeih et al., pH 8.2, $CaCo_3$ 5.9 %, organic matter 1.2 %, P_2O_5 12.2 mg/kg, K_2O 430 mg/kg and texture clay-loam were determined in the soil (Rezaeih et al., 2015) In this case, in both studies, it is seen that the plant prefers soils with similar properties in terms of ecological properties such as texture, $CaCo_3$, organic matter. Therefore, the structure, pH, organic matter content of the soil affect the ability of plants to absorb nutrients.

Table 3. The Physical Analysis Results of the Soil Samples of *M. chamomilla* var. *chamomilla* Habitats

Soil		
Analysis Type	**Numerical value**	**Status**
Texture (%)	57.09	Clayey-loamy
$CaCO_3$ (%)	5.3	Low Chalky
pH	7.62	Slightly Alkaline
Saturation (%)	0.026	Without salt
Organic Matter (%)	1.38	Low
Phosphorus (P_2O_5) kg/da	3.66	Low
Potassium (K_2O) kg/da	189.36	Adequate

In the study, the correlation calculations among root with stem, leaf and flower and between soil with root, stem, leaf and flower were investigated. No significant positive or negative correlation was found between Ba element in the root and Co in the flower and S in the leaf, between Cr in the root and Fe in the leaf, and between Fe in the root and Ba in the stem in this study. In addition, high correlation results were observed for the nutrients Al, Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S and Zn between root and stem, leaf and flower (Table 4). This shows that the nutrients are transported and stored between different organs of the plant.

According to the correlation calculations between soil with root, stem, leaf and flower (Table 5), Ba soil-Mn stem, Cu Soil-Ba rooot, stem, Fe soil-Mn Leaf, Ni Root, Mn soil-Ba leaf, Pb root-Cr stem, Co flower, S leaf, S root-Zn flower have high value (>1) .Correlation matrix (Table 5) also showed high positive correlations (>0.999, >0.720) between Al, Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S and Zn and Zn in soil and Al, Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S and Zn in root, stem, leaf and flower. Except for Ba in the leaf, there are low correlations (>0.699, >0.001) between Al, Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S in the soil and Al, Ba, Cr, Co, Cu, Fe, Mn, Ni, Pb, S in the root, stem, leaf and flower. These results are very important for understanding the plant-soil interactions and determining the nutrient needs of plants.

Table 4. The Correlation Relationship of Mineral Nutrients Between Root and Other Plant Parts

Correlation Matrix (R)											
Root											
	Al	**Ba**	**Cr**	**Co**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**S**	**Zn**
Al Stem	0.996	0.984	0.950	0.774	0.994	0.989	0.153	0.987	0.931	0.971	0.866
Al Leaf	0.916	0.111	0.999**	0.527	0.975	0.983	0.175	0.985	0.999*	0.995	0.657
Al Flower	0.908	0.984	0.999*	0.510	0.970	0.979	0.194	0.982	0.999*	0.993	0.642
Ba Stem	0.975	0.999*	0.984	0.679	0.999*	0**	0.016	0.999*	0.972	0.994	0.766
Ba Leaf	0.965	1**	0.991	0.646	0.997*	0.999*	0.028	0.999*	0.982	0.998*	0.761
Ba Flower	0.957	0.999*	0.991	0.625	0.994	0.998*	0.982	0.998*	0.987	0.999*	0.742
Cr Stem	0.251	0.003	0.142	0.755	0.064	0.025	0.999*	0.011	0.198	0.067	0.640
Cr Leaf	0.937	0.995	0.999*	0.575	0.986	0.992	0.117	0.993	0.995	0.999*	0.700
Cr Flower	0.082	0.173	0.309	0.755	0.106	0.145	0.988	0.159	0.363	0.237	0.500
Co Stem	0.963	0.882	0.785	0.944	0.896	0.878	0.484	0.871	0.749	0.830	0.985
Co Leaf	0.955	0.999*	0.995	0.620	0.994	0.997*	0.999	0.998*	0.987	0.999*	0.738
Co Flower	0.251	0	0.142	0.755	0.064	0.025	0.999*	0.011	0.198	0.067	0.640
Cu Stem	0.997*	0.983	0.949	0.777	0.993	0.988	0.158	0.986	0.929	0.970	0.868
Cu Leaf	0.869	0.966	0.992	0.435	0.946	0.958	0.277	0.962	0.998*	0.981	0.574
Cu Flower	0.743	0.889	0.944	0.233	0.856	0.875	0.475	0.882	0.961	0.917	0.387
Fe Stem	0.851	0.956	0.988	0.403	0.934	0.947	0.311	0.952	0.995	0.973	0.545
Fe Leaf	0.925	0.991	0**	0.546	0.231	0.987	0.152	0.989	0.997*	0.997*	0.674
Fe Flower	0.915	0.987	0.999**	0.526	0.975	0.983	0.175	0.985	0.999*	0.995	0.657
Mn Stem	0.774	0.909	0.958	0.278	0.879	0.897	0.434	0.903	0.973	0.934	0.429
Mn Leaf	0.970	0.999**	0.988	0.662	0.998*	0.999	0.006	1**	0.977	0.996	0.774
Mn Flower	0.936	0.994	0.999*	0.572	0.985	0.991	0.121	0.993	0.995	0.999*	0.697
Ni Stem	0.999*	0.956*	0.906	0.845	0.973	0.964	0.272	0.960	0.880	0.935	0.920
Ni Leaf	0.978	0.998*	0.982	0.688	0.999*	0.999*	0.027	0.999*	0.970	0.993	0.796
Ni Flower	0.996	0.940	0.883	0.871	0.961	0.949	0.320	0945	0.855	0.916	0.939
Pb Stem	0.949	0.998*	0.996	0.604	0.991	0.996	0.081	0.997	0.990	1**	0.725
Pb Leaf	0.783	0.916	0.999*	0.293	0.886	0.904	0.420	0.910	0.976	0.940	0.443
Pb Flower	0.990	0.993	0.966	0.526	0.975	0.983	0.175	0.994	0.999*	0.995	0.657
S Stem	0.930	0.993	0.999*	0.558	0.982	0.989	0.138	0.991	0.996	0.998*	0.685
S Leaf	0.251	0	0.142	0.755	0.064	0.025	0.999*	0.011	0.198	0.067	0.640
S Flower	0.896	0.979	0.998*	0.486	0.963	0.973	0.221	0.976	1**	0.990	0.620
Zn Stem	0.999**	0.963	0.916	0.831	0.979	0.964	0.272	0.967	0.892	0.944	0.685
Zn Leaf	0.162	0.093	0.232	0.693	0.026	0.065	0.997	0.079	0.287	0.158	0.568
Zn Flower	0.998*	0.980	0.943	0.788	0.991	0.985	0.176	0.983	0.922	0.965	0.877

** Correlation is significant at level of 0.01 (2-tailed), * Correlation is significant at level of 0.05 (2-tailed)

Table 5. Correlation Relationship of Mineral Nutrients Between Soil and Plant Parts

Correlation Matrix (R)											
Soil											
	Al	**Ba**	**Cr**	**Co**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**S**	**Zn**
Al Root	0.861	0.779	0.970	0.958	0.967	0.970	0.964	0.997	0.251	0.998	0.277
Al Stem	0.900	0.829	0.947	0.979	0.985	0.987	0.982	0.987	0.170	0.999*	0.197
Al Leaf	0.992	0.965	0.792	0.992	0.987	0.985	0.989	0.883	0.158	0.937	0.131
Al Flower	0.994	0.970	0.780	0.989	0.984	0.982	0.986	0.874	0.177	0.930	0.150
Ba Root	0.962	0.913	0.877	0.999	1**	0.999**	0.999**	0.945	0.003	0.980	0.024
Ba Stem	0.951	0.897	0.894	0.997*	0.999*	0.999*	0.998*	0.957	0.033	0.986	0.060
Ba Leaf	0.964	0.916	0.873	0.999*	1**	0.999*	1**	0.943	0.964	0.916	0.873
Ba Flower	0.971	0.927	0.873	0.999*	0.999*	0.998*	0,999*	0.933	0.038	0.972	0.011
Cr Root	0.990	0.961	0.801	0.994	0.990	0.988	0.991	0.890	0.142	0.942	0.116
Cr Stem	0.275	0.409	0.477	0.033	0.001	0.011	0.014	0.322	1**	0.196	0.999*
Cr Leaf	0.435	0.559	0.320	0.204	0.172	0.159	0.185	0.155	0.985	0.026	0.073
Cr Flower	0.435	0.559	0.320	0.204	0.172	0.159	0.185	0.155	0.985	0.026	0.980
Co Root	0.420	0.287	0.936	0.628	0.653	0.663	0.643	0.863	0.755	0.790	0.773
Co Stem	0.694	0.585	0.999*	0.848	0.653	0.871	0.858	0.980	0.500	0.947	0.523
Co Leaf	0.972	0.929	0.856	0.999**	0.999*	0.998*	0.999*	0.931	0.044	0.970	0.017
Co Flower	0.275	0.409	0.477	0.033	0.001	0.011	0.014	0.322	1**	0.196	0.999*
Cu Root	0.941	0.883	0.907	0.995	0.997*	0.998*	0.996	0.965	0.064	0.991	0.091
Cu Stem	0.897	0.825	0.949	0.977	0,984	0.986	0.981	0.988	0.176	0.999*	0.202
Cu Leaf	0.999*	0.987	0.724	0.973	0.965	0.962	0.969	0.931	0.260	0.895	0.234
Cu Flower	0.980	0.998*	0.560	0.903	0.888	0.882	0.894	0.692	0.460	0.780	0.436
Fe Root	0.953	0.901	0.890	0.998*	0.999*	0.999**	0.999*	0.954	0.025	0.985	0.052
Fe Stem	0.999*	0.992	0.699	0.965	0.956	0.952	0.959	0.810	0.294	0.879	0.268
Fe Leaf	0.989	0.959	0.806	0.994	0.991	0.989	0.992	0.894	0.134	0.945	0.107
Fe Flower	0.992	0.965	0.792	0.992	0.987	0.985	0.989	0.883	0.158	0.937	0.131
Mn Root	0.292	0.425	0.461	0.051	0.019	0.005	0.032	0.305	0.999*	0.179	0.999*
Mn Stem	0.988	1**	0.598	0.922	0.909	0.903	0.914	0.725	0.418	0.808	0.393
Mn Leaf	0.958	0.907	0.883	0.999*	0.999**	1**	0.999*	0.950	0.010	0.982	0.037
Mn Flower	0.984	0.949	0.824	0.997*	0.994	0.993	0.996	0.908	0.103	0.954	0.077
Ni Root	0.958	0.907	0.884	0.999*	0.999**	1**	0.999*	0.950	0.011	0.982	0.038
Ni Stem	0.840	0.754	0.979	0.946	0.956	0.960	0.952	0.999*	0.289	0.995	0.315
Ni Leaf	0.947	0.892	0.899	0.996	0.998	0.999	0.998*	0.960	0.045	0.988	0.072
Ni Flower	0.811	0.720	0.988	0.929	0.940	0.945	0.936	0.999*	0.103	0.954	0.077
Pb Root	0.996	0.975	0.766	0.986	0.980	0.977	0.982	0.863	0.198	0.921	0.172
Pb Stem	0.976	0.936	0.846	0.999*	0.998*	0.997*	0.998*	0.924	0.064	0.966	0.037
Pb Leaf	0.990	1**	0.611	0.928	0.915	0.910	0.920	0.735	0.403	0.817	0.379
Pb Flower	0.923	0.859	0.927	0.988	0.993	0.994	0.991	0.977	0.114	0.996	0.141
S Root	0.977	0.937	0.844	0.999*	0.997*	0.996	0.998*	0.922	0.067	0.965	0.040
S Stem	0.987	0.955	0.814	0.996	0.992	0.991	0.994	0.900	0.120	0.949	0.093
S Leaf	0.275	0.409	0.477	0.033	0.001	0.011	0.014	0.322	1**	0.196	0.999*
S Flower	0.997*	0.976	0.762	0.985	0.979	0.976	0.981	0.860	0.204	0.919	0.178
Zn Root	0.561	0.438	0.980	0.745	0.767	0.775	0.758	0.933	0.640	0.878	0.660
Zn Stem	0.853	0.771	0.973	0.954	0.963	0.967	0.960	0.998*	0.264	0.997*	0.290
Zn Leaf	0.361	0.490	0.395	0.124	0.092	0.079	0.105	0.234	0.995	0.106	0.993
Zn Flower	0.889	0.815	0.954	0.973	0.980	0.983	0.978	0.991	0.194	1**	0.220

** Correlation is significant at level of 0.01 (2-tailed), * Correlation is significant at level of 0.05 (2-tailed)

CONCLUSION

The consentration of Al, Co, Cu, Mn, Ni, and S in the soil is above the optimum values, and it can be said that the soil where *M. chamomilla* var. *chamomilla* grows is contaminated by heavy metals, specifically Al, Co, Cu, Mn, Ni, and S. The fact that *M. chamomilla* var. *chamomilla* grows in these soils with high heavy metal pollution is an indicator of the high biomonitoring value of this species.

Cr and Fe rates in the plant are above optimum values, however, the BCF value of *M. chamomilla var. chamomilla* is low. Therefore, its potential for phytoremediation applications can be considered limited. *M. chamomilla var. chamomilla* generally prefers clay-loamy and slightly alkaline soils as its natural habitat. The soil is not only a growing medium for plants, but also a source of nutrients. The structure, pH, organic matter content of the soil affect the ability of plants to absorb nutrients. Further research should be conducted to monitor this plant during the vegetation period in terms of plant physiology and growth parameters, soil properties and nutrient levels. These detailed monitoring studies will enable a deeper understanding of the factors causes to the plant's low BCF value, allowing for a more accurate assessment of its phytoremediation potential.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Conflict of interest

The authors declare no conflict of interest.

Author contribution

Authors' individual contributions to the article are equal.

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