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Potential of Purslane (*Portulaca oleracea* L.) in Phytoremediation: A Study on the Bioaccumulation and Bio-Transfer of Cadmium, Nickel, and Copper in Contaminated Soils

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ABSTRACT

As industrial and agricultural activities intensify and technology rapidly advances, soil pollution has escalated to alarming levels. The increasing contamination of agricultural areas and the crops cultivated therein has emerged as a significant contemporary issue. Phytoremediation, the use of plants to remove pollutants, is a promising method for mitigating soil heavy metal contamination.

This study investigates the bioaccumulation capacity of purslane (*Portulaca oleracea* L.), a potential phytoremediator, in soils artificially contaminated with cadmium (Cd), nickel (Ni), and copper (Cu). The purslane was cultivated under controlled conditions with varying doses of Cd, Ni, and Cu. After 55 days, the plants were harvested and analysed for heavy metal concentrations in their roots, stems, and leaves. The results demonstrated a direct correlation between environmental heavy metal concentration and plant heavy metal content, with the most significant accumulation occurring in the roots. The leaf chlorophyll content was adversely affected by increased Cd, Ni, and Cu applications. The highest Cu, Ni, and Cd contents were found in the roots at 140 mg kg^{-1} Cu, 80 mg kg^{-1} Ni, and 20 mg kg^{-1} Cd applications, respectively. The bio-transfer coefficient (BTC), a measure of heavy metal transport from the root region to the leaves, was calculated. The BTC values ranged from 0.84-1.09 for Cu, 0.39-0.84 for Ni, and >1 for Cd at the Control and 5 mg Cd kg^{-1} treatments.

These findings suggest that purslane has potential for phytoremediation of heavy metal-contaminated soils, although the bioaccumulation and bio-transfer of heavy metals are dependent on the specific metal and its concentration in the soil. The study also highlights the potential risks associated with the consumption of plants grown in heavy metal-contaminated soils, as heavy metals can accumulate in different plant tissues, potentially entering the food chain.

Keywords: Purslane, Heavy metal, Pollutants, Bio-transfer, Plant tissues, Chlorophyll index

1. Introduction

Soil is an indispensable source of life for every living being. However, since the mid-20th century, our soils have become increasingly polluted through ever increasing industrialization and urbanization, as well as improper agricultural practices such as excessive use of pesticides and chemical fertilizers. Consequently, the quality of soil, necessary for plant life, is degrading in quality in many parts of the world. In crop-growing areas, heavy metals are absorbed from the soil into the body of plants, affecting their physiological activities and causing yield losses. Some heavy metals, particularly cadmium (Cd), lead (Pb), and copper (Cu), can negatively affect plant growth and development even at very low concentrations. Plants under heavy metal stress due to soil pollution must adapt themselves through changes in their physiological, biochemical, anatomical, and morphological systems. In addition, heavy metals affect not only the plant but also the health of all living things that ingest these plants through the food chain. Many leafy vegetables and fruits have been found to contain varying amounts of heavy metals (Ramteke et al. 2016; Negi 2018).

Purslane is a plant resistant to negative edaphic and climatic factors and is capable of growing in fields, roadsides, and infertile areas. Purslane (*Portulaca oleracea*) is a nutritious plant with high vitamin A, vitamin C, total protein, calcium, iron, potassium, magnesium, and betacyanin in its vegetative parts (Salehi et al. 2008). It is used in soups, salads, and as a leafy vegetable in Mediterranean and tropical Asian countries, including India. Purslane, which has antibacterial, antiseptic, antidiabetic, antioxidant, antispasmodic, diuretic, antiscorbutic, and wound-healing properties, is designated by the World Health Organization as one of the most widely consumed medicinal plants (Xu et al. 2006). *Portulaca oleracea* has a high nutritional content with significant medicinal properties. Its tolerance to stress conditions during the production is as well important. Because of its resistance to unfavorable factors, it grows as weed in fields, roadsides, and infertile areas. Consequently, the heavy metal content of purslane in plants grown in industrially polluted areas has been previously identified (Yadegari 2018; Ren & White 2019). Although there is some literature on the heavy metal uptake of purslane, detailed studies on heavy metal accumulation are lacking.

For this reason, this study evaluates the bioaccumulation capacity and tendency of purslane plants growing in a soil treated with different doses of Cd (0, 5, 10, and 20 mg kg^{-1}), Cu (0, 70, 140, and 210 mg kg^{-1}) and Ni (0, 20, 40, and 80 mg kg^{-1}).

2. Material and Methods

This study was performed as a pot experiment in the greenhouses of Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition according to the principles of randomized experimental design with three replications. There were 36 pots (3 different heavy metals × 4 doses × 3 replicates = 36 pots), and each pot was filled with 1 kg of soil (dry weight) sieved through 2 mm. Prior to the start of the experiment, the soil was analysed for its physical and chemical properties (Table 1). Since the soil has high fertility and is suitable for purslane cultivation, no fertilizer was applied. At the beginning, 10 purslane seeds were sown in each pot, and 4 of the plants that showed uniform development were left to be studied after the germination stage. As the treatments of the experiment, 4 different doses of $CuSO_4$ (0, 70, 140, 210 mg Cu kg^{-1}), $NiSO_4$ (0, 20, 40, 80 mg Ni kg^{-1}) and $CdSO_4$ (0, 5, 10, 20 mg Cd kg^{-1}) were mixed with irrigation water and applied to the purslane plants in the pots every 15 days. The plants were harvested after 55 days. At harvest, the purslane plants were dissected into leaf, stem, and root parts, and the heavy metal accumulation capacity of the plant parts was examined.

Table 1- Some physical and chemical properties of the experimental soil

Texture	*pH*	*EC µS/cm*	*$CaCO_3$*	*N_{total}*	*OM*	*Total (mg kg^{-1})*		
			%			*Cu*	*Ni*	*Cd*
	6.94	1015	3.32	0.022	1.48	25	5.28	0.38
Available (mg kg^{-1})								
P	**K**	**Ca**	**Mg**	**Fe**	**Zn**	**Cu**	**Ni**	**Cd**
8.40	250	672	110	31	3.40	0.60	0.60	0.12

The physical and chemical properties of the soil are provided in Table 1. The pH, water-soluble salts, $CaCO_3$, texture and organic matter contents were determined (Kacar 2016) and their plant extractable/available P, K, Ca, Mg, Na, Fe, Zn, Cu, Mn, Ni and Cd contents were measured (Alloway 2013) (Table 1). The total concentration of the non-essential heavy metals (Cd, Ni and Cu) were determined using the aqua regia ($HCl:HNO_3$, 3:1) extraction method (ISO 1995) and the heavy metal concentrations were measured by AAS analysis (Varian SpectrAA 220, FS).

The plant samples; 5 g from each stem, leaves and roots were sampled, dried and digested to measure the heavy metals (Cu, Ni, Cd), all of which were measured using an Atomic Absorption Spectrophotometer.

The results were subjected to a statistical variance of analysis, program JMP. The effect of treatments (heavy metal doses) and their interactions on purslane leaves, stem and roots were determined.

The Biological Accumulation Coefficient (BAC) was calculated according to the ratio of heavy metal concentration in the shoot divided by the metal concentration in the studied soil (Zu et al. 2005).

BAC = heavy metal concentration in shoot / heavy metal concentration in soil

Bio-Concentration Factor (BCF) was calculated as the ratio of heavy metal concentration in plant roots to that of soil (Yoon et al. 2006).

BCF = heavy metal concentration root / heavy metal concentration in soil

The Bio-Transfer coefficient (BTC) of purslane was also determined to assess the extent of the heavy metal transfer from root to leaves. It is the ratio of the heavy metal concentration in the plant stem to the heavy metal concentration in the plant root (Yoon et al. 2006).

BTC = leaf heavy metal concentration/root heavy metal concentration

3. Results and Discussion

The effect of different doses of heavy metal (Cu, Ni, and Cd) applications on the bio-absorption capacity of purslane by its different parts (root, stem, leaf) was investigated, and the tendency of it to bioaccumulation was evaluated.

3.1. Copper accumulation in the plant tissues

The Cu content of purslane leaves, stems, and roots was found to increase as a function of increasing Cu doses (Table 2). The highest Cu content (22.61 mg kg^{-1}) was in the roots, and the lowest in the stem (2 mg kg^{-1}). In this regard, if the Cu content of leaves is examined, the results are found to be statistically significant, P≤0.05, compared to that of the Control treatment. The lowest leaf Cu content (13.83 mg kg^{-1}) was determined in the Control (0), and the highest (19.73 mg kg^{-1}) in the 210 mg kg^{-1} Cu applied treatment.

As a function of increasing Cu doses, the Cu contents in the plant body also increased. The Cu content of the purslane stem was determined to be 2 mg kg^{-1} in the Control treatment (0); 3.66 mg kg^{-1} at 70 mg kg^{-1} Cu application; 4.83 mg kg^{-1} at 140 mg kg^{-1} Cu application and; and 4.80 mg kg^{-1} at 210 mg kg^{-1} Cu application. The increase in Cu content in the purslane stem as a function of the Cu doses was statistically significant. However, no statistically significant difference was found between the 140 mg kg^{-1} and 210 mg kg^{-1} Cu treatments. The Cu content in roots increased similarly to the Cu content in leaves and stems as a function of Cu treatments. The Cu content in the root was 12.71 mg kg^{-1} in the Control application (0);19.51 mg kg^{-1} at the 70 mg kg^{-1} application; 22.61 mg kg^{-1} at the 140 mg kg^{-1} application; and 20.46 mg kg^{-1} at the 210 mg kg^{-1} application. The highest Cu content (22.61 mg kg^{-1}) in the roots of the purslane plant was found at the 140 mg kg^{-1} Cu application. The plant biomass decreased as a result of the Cu accumulation in plants (Kabata & Pendias 2001). A high Cu application has been reported to affect root length, damage root cells, and membranes, and cause imbalances in plant nutrient uptake (Lothe et al. 2016). Copper toxicity is also known to disrupt physiological processes such as protein synthesis, photosynthesis, respiration, ion uptake, and cell membrane stability (Sossé et al. 2004). However, in a study investigating the effects of $CuSO_4$ applications in 9 different purslane species, Cu uptake, and plant biomass were found to change depending on the genetic variation of the purslane species (Ren & White 2019).

In our study, 4 chlorophyll indexes were measured in one-week intervals after Cu applications, and the effects of increasing Cu doses on purslane chlorophyll contents were determined (Table 2).

Table 2- Effect of different Cu doses on Cu content of purslane leaves, shoots, roots and Chlorophyll Index

Cu (mg kg^{-1})	***Leaf***	***Shoot /Stem***	***Root***	***Chlorophyll Index***			
				I	***II***	***III***	***IV***
0	13.83b	2.00c	12.71c	167	177b	218a	221a
70	19.70a	3.66b	19.51b	206	216ab	187c	174b
140	18.90a	4.83a	22.61a	211	237a	197b	166c
210	19.73a	4.80a	20.46a	181	221ab	178c	164c
Mean	18.04	3.82	18.82	191	213	195	181
	*	**	*	ns	*	**	*

*: P≤0.05 statistically significant within error limits; **: P≤0.01 statistically significant within error limits

To monitor the effects of Cu applications on leaf chlorophyll content, the effects of preharvest Cu doses on plant chlorophyll content were found to be statistically significant when measurements were taken at different time points. Particularly, in the last two pre-harvest measurements (04/06/2021 and 11/06/2021), the change in leaf chlorophyll content as a function of Cu doses was significant (Figure 1). In a study investigating the effects of Cu toxicity on cucumber growth, the response of cucumber leaves to Cu stress was found to vary depending on the growing season. Photosynthesis decreased by 52% in the mature leaves of cucumbers and 27% in young leaves compared to the Control treatment. The loss of stomata explains the further decrease in photosynthetic rate in mature leaves and thus the ability to assimilate CO_2 (Dunand et al. 2002).

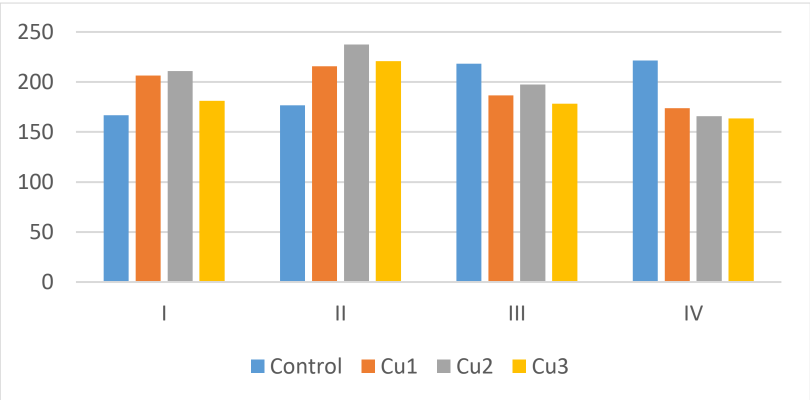

Figure 1- Chlorophyll index of purslane

The accumulation of Cu in the cells affects the photosynthetic process negatively since Cu has negative effects on plant pigment contents (Jaime -Pérez et al. 2019; Lwalaba et al. 2019). In this regard, the synthesis of photosynthetic enzymes is inhibited due to the changes in the composition of photosynthetic membrane pigments and proteins (Silva et al. 2018). It has been reported that the pigment content and photosynthetic activity of tomato plants treated with 100 mg kg^{-1} Cu for 40 days decreased (Nazir et al. 2019; Kafkasyalı 2021).

3.2. Nickel accumulation in the plant tissues

The results showed that as Ni application doses in the treatments increased, the Ni contents in the leaves, stem, and roots of the purslanes increased (Table 3). The highest Ni content was found in the roots (9.57 mg kg^{-1}) when 80 mg kg^{-1} Ni was applied and the lowest in the leaves of the Control treatment (0.85 mg kg^{-1}). If the Ni content of the purslane leaves are examined with respect to treatments, the effect of different doses of Ni applications compared to the Control treatment was found to be statistically significant at $P \leq 0.05$ and $P \leq 0.01$. Our findings showed that 0.85 mg kg^{-1} of Ni was found in the Control treatment (0); 2.15 mg kg^{-1} at 20 mg kg^{-1} Ni application dose; 3.65 mg kg^{-1} at 40 mg kg^{-1} Ni dose; and 3.71 mg kg^{-1} at 80 mg kg^{-1} Ni dose. These results indicate that Ni accumulation in purslane leaves does not exceed a certain limit. The results related to purslane stems showed that in the Control treatment the Ni content was 0.86 mg kg^{-1}; in this regard, 0.92 mg kg^{-1} at 20 mg kg^{-1} dose; 1.90 mg kg^{-1} at 40 mg kg^{-1} dose; and 2.43 mg kg^{-1} at of 80 mg kg^{-1} dose, respectively. The change in the Ni content of purslane stems due to enhancements in Ni applications is shown to be statistically significant.

The Ni content of purslane root was 1.01 mg kg^{-1} in the Control; 4.08 mg kg^{-1} in the case when 20 mg kg^{-1} Ni applied, 6.77 mg kg^{-1} at the 40 mg kg^{-1} application; and 9.57 mg kg^{-1} when 80 mg kg^{-1} Ni applied. The results showed that Ni accumulated particularly in the roots provided that there is high Ni in the soil. However, similar to Cd, the Ni transfer to leaves and stem was low.

Table 3- Effects of Ni applications on the Ni contents of purslane leaves, shoots, roots and Chlorophyll Index

Ni (mg kg^{-1})	*Leaf*	*Shoot /Stem*	*Root*	*Chlorophyll Index*			
				I	*II*	*III*	*IV*
0	0.85c	0.86c	1.01d	167b	177b	218a	221b
70	2.15b	0.92c	4.08c	212 a	217a	195b	168a
140	3.65a	1.90b	6.77b	179b	195ab	151c	151a
210	3.71a	2.43a	9.57a	203a	214ab	167c	162a
Mean	2.59	1.53	5.36	190	200	183	176
	*	**	**	*	*	**	*

*: $P \leq 0.05$ statistically significant within error limits;**: $P \leq 0.01$ statistically significant within error limits

In different parts of the purslane plant, Ni accumulation from highest to lowest was found as root > leaf > stem (Table 3). Yadegari (2018) noted that high Ni and high Cd in the soils negatively affect the shoot and root development of purslane. It has also been reported that the elemental content of *Portulaca oleracea L.* is significantly affected by the heavy metal density of the soils. Excess Ni in the plant negatively affects chlorophyll synthesis and lipid metabolism. It also damages thylakoid membranes and granules, reduces granule size, and increases the number of lamellae, negatively affecting photosynthetic activity. In addition, Ni is known to compete with essential elements such as Fe, Zn, Cu, Fe, Mn, and Mg, reducing the rate of uptake and transport of these elements by plants (Angulo-Bejarano et al. 2021). This prevents plant roots from absorbing other nutrients and leads to nutrient deficiency (Fryzova et al. 2017). For this reason, in this study 4 chlorophyll index measurements were performed at one-week intervals after applying different doses of Ni, and the effects on chlorophyll in purslane were determined (Figure 2). The effect of the last two pre-harvest measurements on plant chlorophyll content was statistically significant in monitoring the change in leaf chlorophyll content after Ni applications (Table 3).

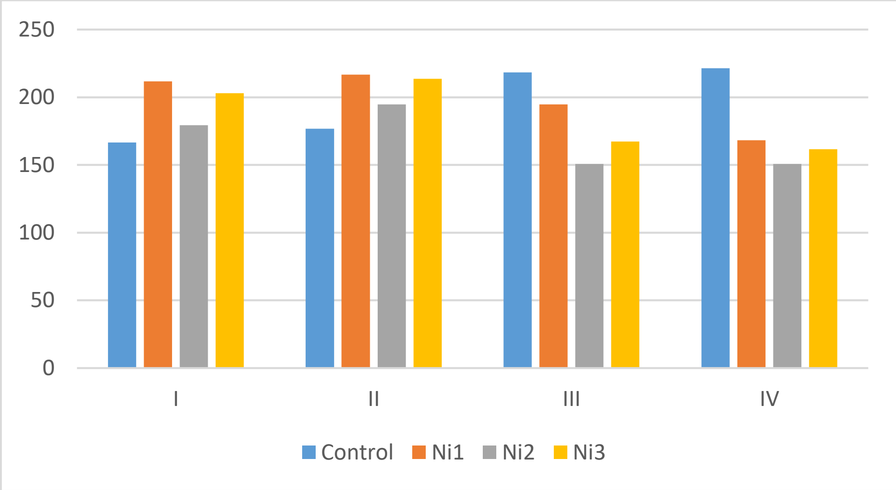

Figure 2- Chlorophyll index of purslane

If high Ni content is present in the environment where the plant grows, Ni can replace Mg, which is the building block of chlorophyll (Kumar et al. 2021). This process causes a change in the chlorophyll molecule (Angulo-Bejarano et al. 2021). In a study, the effect of increasing Ni applications (0.1, 0.3, and 0.5 mM) on beans was examined and the findings showed that there were decreases in chlorophyll a, chlorophyll b, carotenoids, total pigment I, and total pigment II contents of the beans (Macedo et al. 2016). High Ni content leading to changes in the number of photosynthetic pigments (such as chlorophyll a, chlorophyll b, and carotenoids) has also been found to cause leaf chlorosis and necrosis (Kumar et al. 2022).

3.3. Cadmium accumulation in the plant tissues

Purslanes were treated with four different doses of $CdSO_4$ (0, 5, 10, 20 mg kg^{-1}) and likewise in the case of Cu and Ni applications, each plant was dissected into leaf, stem, and root parts at harvest. The Cd accumulation capacity of these parts was investigated and the results showed that the Cd content of purslane leaves, stem, and root parts significantly increased ($P \leq 0.05$), as a function of increasing the Cd doses (Table 4). The highest Cd (1.47 mg kg^{-1}) was determined in the root, and the lowest in the stem (0.12 mg kg^{-1}). In the evaluation of leaf Cd contents, the highest value (1.12 mg kg^{-1}) was obtained at the 5 mg kg^{-1} application treatment, followed by the applications of 20 mg kg^{-1} Cd (0.79 mg kg^{-1}) and 10 mg kg^{-1} Cd (0.60 mg kg^{-1}). These results indicate that Cd accumulation in purslane leaves occurs up to a certain value i.e. increasing the Cd content in the medium does not affect Cd accumulation in purslane leaves.

The cadmium content of the stem was 0.12 mg kg^{-1} in the Control treatment (0). With respect to increasing applications of Cd (5 mg kg^{-1}, 10 mg kg^{-1}, 20 mg kg^{-1}), 0.26 mg kg^{-1}, 0.30 mg kg^{-1} and 0.28 mg kg^{-1} Cd contents were found respectively (Table 4). When the results of the stem Cd contents of purslane is evaluated, the findings indicated that enhanced Cd doses increased the Cd of stem compared to Control treatment. However, no statistical difference was found between treatments.

The effects of the different Cd doses on the Cd content of purslane roots were statistically significant (Table 4). In the Control treatment, the purslane roots had 0.15 mg kg^{-1} Cd; 0.46 mg kg^{-1} when 5 mg kg^{-1} Cd was applied; 0.93 mg kg^{-1} in the 10 mg kg^{-1} Cd treatment and when 20 mg kg^{-1} Cd was applied, it was 1.47 mg kg^{-1} Cd. The highest Cd in roots was in the highest application of Cd (20 mg kg^{-1}) but this was not so in the case of leaves and stems. Therefore, the transfer of Cd to leaves and stems is low. Cadmium applications have been reported to decrease plant biomass, but Cd accumulation in the plant occurs as a function of increasing concentration (Yadegari 2018).

Table 4- Effects of Cd applications on Cd contents of the leaves, stems, roots and Chlorophyll Index

Cd (mg kg^{-1})	*Leaf*	*Shoot /Stem*	*Root*	*Chlorophyll Index*			
				I	*II*	*III*	*IV*
0	0.30c	0.12b	0.15d	167b	177c	218a	221a
70	1.12a	0.26a	0.46c	202ab	212ab	190ab	189b
140	0.60bc	0.30a	0.93b	176ab	201b	189ab	170b
210	0.79ab	0.28a	1.47a	210a	224a	186c	179b
Mean	0.70	0.24	0.75	189	203	196	190
	*	*	**	*	*	**	**

*: $P \leq 0.05$ statistically significant within error limits, **: $P \leq 0.01$ statistically significant within error limits

Cadmium accumulation in different parts of the purslane plant is found as root > leaf > stem. Tiryakioglu et al. (2006) reported that increasing Cd applications lead to an increase in the Cd concentration of the green parts; however, much of the Cd particularly accumulated in the roots. Similarly, Pietrelli et al. (2022), in their study, exposed the plants to heavy metal pollution and found that the root parts of the plants generally accumulated higher Cd concentrations.

Cadmium, an element not essential for plant growth, negatively affects the plant uptake, transport, and utilization of plant nutrients and water. Cadmium causes physiological toxicity symptoms such as chlorosis, stunting, and leaf deformation. In addition, Cd toxicity in plants was found to cause a decrease in stomata density, respiratory and photosynthetic activities. (Rostami & Azhdarpoor 2019). High doses of Cd have been reported to affect chlorophyll biosynthesis by inhibiting protochlorophyllide reductase, which plays a role in chlorophyll biosynthesis and the synthesis of aminolaevulinic acid (Awan et al. 2020).

For this reason, four chlorophyll index measurements were performed at one-week intervals after Cd applications and the effects of increasing Cd doses on the chlorophyll of purslane were determined (Figure 3).

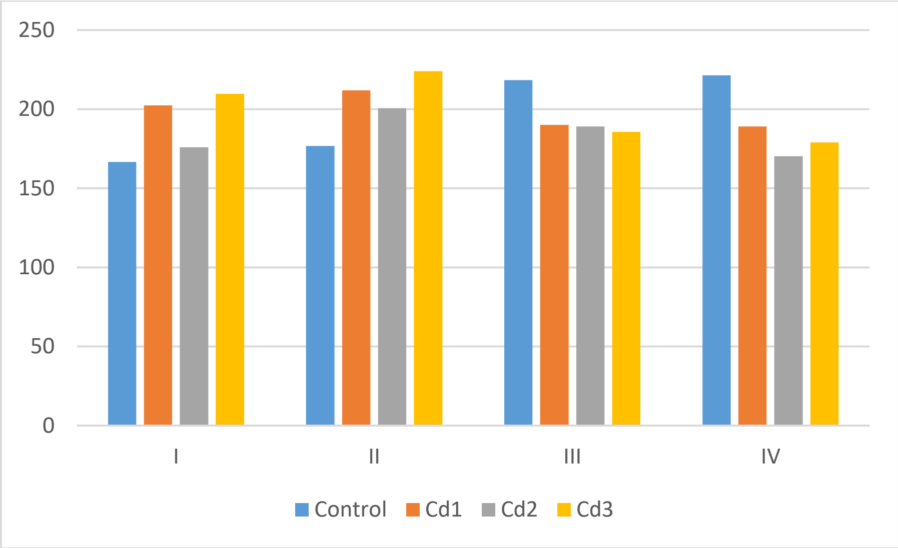

Figure 3- Chlorophyll index of purslane

No statistical difference was found in leaf chlorophyll contents when measured immediately after Cd applications (Table 4). In contrast, the effect of Cd doses on plant chlorophyll content was found statistically significant in the pre-harvest measurements. In the last two measurements, in particular, before harvest (04/06/2021 and 11/06/2021) the change in leaf chlorophyll content as a function of application doses is evident.

3.4. Bioaccumulating plant tendency of purslane

Copper and Ni hyperaccumulator plants can accumulate >1000 mg Cu and Ni kg^{-1} in their aboveground tissues (Baker et al. 2000; Sytar et al. 2021) while Cd hyperaccumulator plants can accumulate >100 mg Cd kg^{-1} in their aboveground tissues (Baker et al. 2000). In this study, >1000 mg Cu and Ni kg^{-1}, >100 mg Cd kg^{-1} were not determined in different parts of the purslane plant. However, Cu, Ni, and Cd accumulations were observed in different parts of purslane as a function of increasing Cu and Ni doses. A transfer factor greater than 1 is another important criterion for evaluating heavy metal hyperaccumulator plants (McGrath & Zhao 2003). In this study, the biological transfer coefficient (BTC) is also calculated to evaluate the transport of Cu, Ni, and Cd from the purslane root region to the leaves (Figure 4).

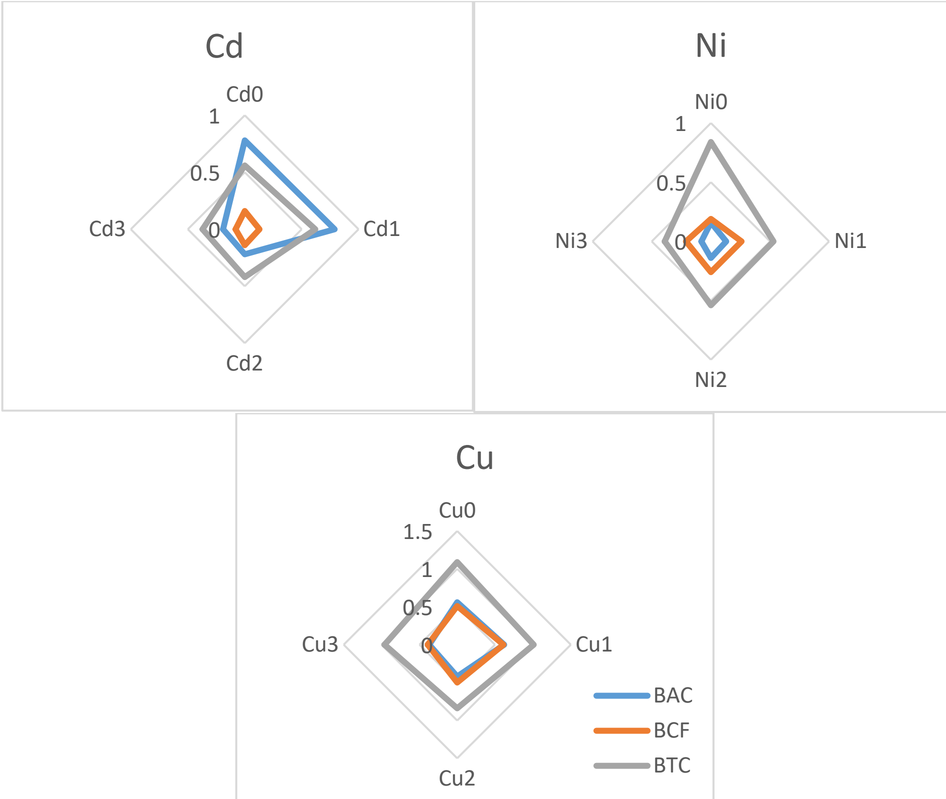

Figure 4- Effect of different doses of Cd, Ni, and Cu on the transfer coefficient of purslane

The Cu bio-transfer coefficient was determined in the range of 0.84-1.09. This coefficient, >1, is related to the Cu exposure of purslane. As the Cu content in the culture medium increases, the Cu content of purslane increases. However, the higher Cu accumulation in the purslane root region suggests that metal accumulation occurs mainly in plant roots because the transport of metals from root to shoot is slow compared to other elements. In this regard, Chandra et al. (2004) reported that many metals are higher in the roots than in the aboveground parts and that rhizofiltration affects the translocation and accumulation of metals in the root structure.

The bio-transfer coefficient for Ni was found in the range of 0.39-0.84 which is smaller than the references value (<1). Even though Ni content of the growing medium was high, the low uptake by the purslane (leaf+stem) plant shows Ni accumulation in the root zone. All of these results indicate safe consumption of the purslanes. The bio-transfer coefficient for the evaluation of Cd transport was found to be >1 for the Control and 5 mg Cd kg^{-1} treatments. The fact that this coefficient is >1 indicates that the availability of purslane is limited depending on the Cd load in the growth medium or that Cd accumulation occurs only in the root region. It is known that some elements compete with each other in plants, so their uptake and transport may change; metal ions enter plant cells via metal ion carriers or channels (Jabeen et al. 2009). Substances dissolved in water that pass through the endodermal layer in a symplastic manner, thus enter the xylem. The apoplastic transport of heavy metal ions into the xylem can occur at the root tip (Dalyan 2012; Manara et al. 2020). Microelements also use transmembrane carriers. and toxic heavy metals such as Cd compete for this transporter. Shrivastava et al, in their 2019 study, showed that Cu^{+2} and Zn^{+2} compete with Ni^{+2} and Cd^{+2} for the same transmembrane transporters (Shrivastava et al. 2019).

4. Conclusions

This study determined that the accumulation of heavy metals under consideration in different plant parts of purslane (*Portulaca oleracea*) changed with increasing Cu, Ni, and Cd doses, and that the accumulation of heavy metals was noticeably higher in the roots and leaves.

During the measurements to monitor the change in leaf chlorophyll content after the application of heavy metal, the results showed that the chlorophyll biosynthesis was disturbed, especially before harvest, and the chlorophyll content decreased accordingly.

The transfer coefficient was calculated to evaluate Cu transport from the purslane root zone to the leaves. In this respect, the transfer coefficient changed as a function of the dose increase (0.84-1.09). The fact that, this coefficient is > 1 indicates that purslane can absorb Cu when the Cu content in the medium in which the purslane grows increases.

The transportation of Ni to different parts of the purslane plant also changed in response to increasing doses, and the transfer coefficient changed in the range of 0.39-0.84 (< 1). The fact that this coefficient is <1 indicates low uptake of purslane even though the Ni content of the medium is high. This shows Ni accumulation in the roots which indicates that the above ground parts of purslane (leaf+stem) can be reliably consumed.

In relation to Cd transport, the transfer coefficient TK >1 at the Control and 5 mg Cd kg^{-1} treatments and TK<1 at the 10 and 20 mg kg^{-1}. The fact that this coefficient is >1 at the Control and 5 mg Cd kg^{-1} indicates that purslane takes up Cd to a certain concentration in the medium and that the accumulation capacity is limited with increasing Cd concentration, or that Cd accumulation occurs only in the root region.

It is concluded that purslane, which can be grown under natural conditions in the world and Turkey in general, and thus is a widely consumable plant, can accumulate Cu, Ni, and Cd in the environment up to a certain concentration, may be more in the roots. This is a very important result, especially in terms of public health. However, it is believed that heavy metal accumulation may change according to the genetic variation of purslane species. Therefore, it is recommended to study in detail the heavy metal accumulation ability of this commonly used plant, including different genetic variations.

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