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COMPARATIVE ANALYSIS OF HEAVY METAL BIOACCUMULATION AND TOLERANCE IN NATIVE WEEDS OF TANNERY-IRRIGATED FIELDS

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Abstract:

This research examines the bioaccumulation and tolerance of heavy metals in seven native weed species from tannery-irrigated fields in Jammu & Kashmir. Soil and plant samples from Miran Sahib, Raipur Domana, Gho Manhasan, and Bishnah were analyzed for metal content and plant growth parameters. The study identifies Cannabis sativa and Chenopodium album as highly effective bioaccumulators, highlighting their potential for phytoremediation of contaminated soils. These findings contribute to the development of targeted soil remediation strategies in polluted agricultural regions.

Keywords: Bioaccumulation, Tolerance Index, Heavy Metals, Tannery Effluents, Cannabis sativa, Phytoremediation, Soil Remediation

Introduction:

The discharge of untreated tannery effluents into agricultural fields has led to significant soil contamination in Jammu & Kashmir. These effluents contain high concentrations of heavy metals such as chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and cadmium (Cd), which pose substantial risks to soil health, crop productivity, and ultimately, human health (Johnson, 1978; Hinesly et al., 1978). Addressing this issue requires innovative and sustainable remediation strategies that are both cost-effective and environmentally friendly. Phytoremediation, which utilizes plants to extract, stabilize, or degrade pollutants from the soil, emerges as a promising solution (Cunningham et al., 1995; Pilon-Smits, 2005). This study focuses on evaluating the bioaccumulation and tolerance of heavy metals in native weed species, with the goal of identifying effective bioaccumulators and proposing viable phytoremediation strategies for the contaminated soils in this region.

Background

Heavy metals such as Cr, Cu, Ni, Pb, and Cd are common pollutants in tannery effluents. These metals accumulate in the soil, leading to toxicity that adversely affects plant growth and soil microbial activity (Salt et al., 1995; Kochlaar et al., 2004). The contamination of soil by heavy metals can lead to a decrease in agricultural productivity and pose health risks to humans through the food chain (Meharg, 1994; Blaylock et al., 1997). Traditional remediation techniques, such as excavation and chemical treatments, are often expensive and disruptive to the environment. Phytoremediation offers a more sustainable approach by using plants to extract and stabilize these pollutants, thereby cleaning the soil while maintaining its structure and fertility (Gosh & Singh, 2005; Trotta et al., 2006). Various studies have demonstrated the potential of certain plants to accumulate high levels of heavy metals in their tissues, making them suitable candidates for phytoremediation (Wei et al., 2005; Zhao et al., 2003).

Rationale

The need for efficient and environmentally friendly soil remediation methods necessitates the investigation of native plant species capable of bioaccumulating heavy metals (Di Salvatore et al., 2021; Reisinger et al., 2021). Native species are particularly advantageous because they are already adapted to local conditions, ensuring better survival and growth rates compared to non-native species. This study aims to identify such species among the native weeds of Jammu & Kashmir and evaluate their potential for large-scale application in contaminated agricultural regions (Macnair, 1997; Li et al., 2005). By focusing on species that are both effective in bioaccumulation and resilient to heavy metal stress, the research seeks to develop practical phytoremediation strategies that can be implemented to

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mitigate soil contamination and restore agricultural productivity in affected areas (Blaylock et al., 1997; Chaney et al., 2000).

Methodology:

- **Sample Collection:** Soil and plant samples were collected from four tannery-affected sites and a control site.
- **Phytochemical Analysis:** Soil pH and metal content were measured, and phytochemical properties of plants were analyzed.
- **Growth and Tolerance Studies:** Seed germination, plant height, biomass, and root/shoot development were assessed under metal stress conditions.
- **Metal Bioaccumulation:** The concentration of heavy metals in plant tissues was quantified using the ICAP-AES method.

Results and Analysis:

- **Soil Contamination Levels:** Higher concentrations of heavy metals were found in contaminated sites compared to the control site (Table 4.1).

Table 4.1: Soil analysis of different types of soils from five villages of study areaat Jammu & Kashmir

Location	Texture	pH	Metal Concentration (µg/g)				
			Cr	Cu	Ni	Pb	Cd
Miran Sahib	Sandy loam	7.83	11.73	3.65	7.53	4.82	0.35
Raipur Domana	Sandy loam	8.01	420.16	62.89	68.56	43.14	20.05
Gho Manhasan	Sandy loam	7.94	236.16	7.85	12.57	10.35	15.56
Bishnah	Sandy loam	7.95	17.25	5.95	9.56	8.26	11.35

The sandy loam soil pH ranges from 7.8 to 8.03 throughout all of the fields. Table 4.1 shows that heavy metal levels, including Cr, Cu, Ni, Pb, and Cd, were lower in soil samples taken from the control field compared to soil samples taken from the contaminated region. The control site had a total chromium content of 11.73 µg/g, whereas the contaminated soils in the areas impacted by the tannery had a value ranging from 17.25 to 420.16 µg/g. Fields at Gho Manhasan had the second-highest concentration of heavy metals, followed by soil at the Miran Sahib site. These metals include Cr, Cu, Ni, Pb, and Cd. Soil metal concentrations in Bishnah fields, which are somewhat close to the control location.

- **Plant Growth Inhibition:** Metal stress inhibited plant growth, with variations among species. Cannabis sativa and Chenopodium album showed higher tolerance and biomass (Tables 4.2-4.18).

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Table 4.2: Morphological Character of Various Species

Dimensions (cm)	Location			
	Miran Sahib	Raipur Domana	Gho Manhasan	Ebbam
Amaranthus spinosus				
Plant Height	32.67±1.1	29.67±1.74	32.18±2.24	37.75±1.55
Leaf Length	2.94±0.25	2.96±0.35	2.28±0.42	3.15±0.55
Leaf Breadth	2.14±0.23	1.23±0.12	1.17±0.34	1.68±0.43
Cannabis sativa				
Plant Height	38.7±0.9	35.58±0.6	39.58±0.6	36.68±0.74
Leaf Length	7.51±0.4	5.29±0.3	4.62±0.9	4.27±0.63
Leaf Breadth	2.57±0.9	2.21±0.9	3.43±0.4	3.64±0.75
Cassia tora				
Plant Height	34.64±0.9	26.67±0.8	29.72±0.8	29.75±0.7
Leaf Length	3.31±0.6	35.6±0.4	3.68±0.6	3.69±0.2
Leaf Breadth	2.22±0.09	1.65±0.08	1.89±0.02	1.87±0.09
Plant Height	27.99±0.8	22.54±0.5	29.58±0.8	28.82±0.1
Leaf Length	4.91±0.8	6.61±0.2	5.61±0.6	2.67±0.6
Leaf Breadth	1.79±0.6	1.49±0.2	1.71±0.6	1.86±0.5
Plant Height	65.31±1.3	53.47±0.8	59.87±1.4	49.97±1.8
Leaf Length	9.57±0.6	7.71±0.5	5.65±0.8	4.72±0.6
Leaf Breadth	6.69±0.6	4.87±0.3	3.85±0.6	2.42±0.6
Rumex dentatus				
Plant Height	37.48±1.1	32.51±2.1	41.68±0.7	43.00±0.9
Leaf Length	4.62±0.8	4.58±0.9	5.87±0.3	6.61±0.4
Leaf Breadth	1.72±0.7	1.83±0.5	2.71±0.3	3.51±0.8
Solanum nigrum				
Plant Height	29.08±0.4	31.31±0.6	28.77±0.9	31.86±0.5
Leaf Length	5.02±0.3	5.77±0.2	6.62±0.8	5.53±0.7
Leaf Breadth	2.31±0.2	2.86±0.8	2.79±0.6	2.76±0.8

a. *Cannabis sativa* Linn.

An plant that grows upright once a year, *Cannabis sativa* Linn. The somewhat scented, stalked, palmate leaves have 1–5 lobes on the top side and 5–11 lobes on the lower side; these lobes are linear–lanceolate, with the biggest being in the center. On average, the C. sativa plants gathered from Raipur Domana were somewhat smaller than the others, but the plants gathered from Gho Manhasan village were noticeably taller. Plants native to Bishnah have the tiniest leaves.

b. *Cassia tora* Linn.

The annual herb *Cassia tora* Linn. grows beneath shrubs. Below the herbaceous top layer, you'll find a woody stem. Each of the 6–10 paripinnate leaflets is attached to the petiole by a globose sessile gland. Each leaflet is 2.5–7.5 cm long, with an acuminate tip, and is glaucous. On average, plants from the Samba village were taller than the rest of the plants, whereas those from the Miran Sahib village were somewhat shorter. Greater size was found in the plants retrieved from the fields of Gho Manhasan and Bishnah.

c. ***Chenopodium album*** Linn.

The upright, annual or biennial herb *Chenopodium album* Linn. may be 30-180 cm tall and has a green or white coating. The stems tend to be angular and ribbed. Full, toothed, lobed, rhombic, oblong, or deltoid-ovate leaves are just a few examples of the many sizes and shapes seen in this plant. Plants gathered from Gho Manhasan village were taller than those from Miran Sahib, which had somewhat shorter plants overall. In the fields of Bishnah, the plant leaves were the tiniest.

d. ***Parthenium hysterophorus*** Linn.

Prone to rapid expansion, the ephemeral plant *Parthenium hysterophorus* Linn stands tall and strong. It may reach a height of 1.5 meters and has branching branches, delicately lobed leaves, and a light green coloration. Pinnately split into lobes are the leaves. The plants in the control group outshone the other four groups in terms of both height and leaf size. The tiniest plants were those taken from Bishnah, followed by those from Raipur Domana.

e. ***Rumex dentatus*** Linn.

The glabrous, upright, 30-100 cm tall, ribbed-stemmed annual plant *Rumex dentatus* Linn. stands erect and has deep roots. The roots are crimson in color, and the cauline leaves are obtuse at the base and sharp at the tip. The tallest plants were found in Bishnah, however the height of the plants ranged from 32 to 43 cm. The tiniest leaves were found in plants gathered from Raipur Domana, measuring 6.1 x 3.1 cm, in contrast to the larger leaves found in plants obtained from Bishnah.

f. ***Solanum nigrum*** Linn.

A weak annual plant, *Solanum nigrum* Linn. is upright and spreading with many branches; it is almost hairless. The branching stem is herbaceous on top and woody below. The dark-green leaves are alternating and stalked; they are oval or oblong in shape and have little teeth or lobed edges. Plants gathered from Bishnah village were taller than the others, while those from Raipur Domana were somewhat shorter. Plants in the fields of Gho Manhasan and Raipur Domana have noticeably larger leaves than those in the other communities.

4.2.2 Cytological analysis

Seven different types of weeds were studied using meiotic investigations to find out what their cytological state was. To achieve this goal, we gathered immature flower buds from all five sites for each species. You can find the specific chromosomal counts for each group in Table 4.3.

Table 4.3: Chromosome number (n) in the plants inhabiting different villagesusing tanney effluents rich water for irrigation and control site

Plant sp.	Chromosome number(n)			
	Miran Sahib	Raipur Domana	Gho Manhasan	Ebbam
Amaranthus spinosus	17	17	17	17
Cannabis sativa	10	10	10	10
Cassia tora	13	13	13	13
Chenopodium album	18	18	18	18
Parthenium hysterophorus	17	17	17	17
Rumex dentatus	20	20	20	20
Solanum nigrum	36	36	36	36

4.2.3. Pollen Fertility

One way to measure a species' reproductive capacity is by looking at its pollen fertility. For each species, pollen fertility was assessed in five different plant populations. The pollen fertility was examined by collecting flowers and mature anthers from the plants. Glycero-acetocarmine was used to produce the slides. At Miran Sahib, Raipur Domana, Gho Manhasan, and Bishnah, the following outcomes were attained. You may find the information on pollen fertility in Table 4.4.

Table 4.4: Pollen fertility data of five populations of various weeds

Species	Locations			
	Miran Sahib	Raipur Domana	Gho Manhasan	Ebbam
Amaranthus spinosus	75.11±8.47	62.11±5.11	65.31±3.21	60.17±4.84
Cannabis sativa	80.71±4.91	71.51±2.53	69.33±1.65	73.54±8.3
Cassia tora	78.55±4.11	60.99±8.6	63.55±9.12	65.19±4.47
Chenopodium album	77.51±7.25	69.55±6.63	66.12±5.17	68.18±7.53
Parthenium hysterophorus	80.58±8.15	72.99±5.33	71.99±5.32	73.78±8.11
Rumex dentatus	82.77±3.71	71.62±6.23	73.75±8.77	70.75±2.57
Solanum nigrum	81.77±5.54	60.77±5.91	67.77±8.81	65.7±8.62

a. *Amaranthus spinosus* Linn.

The five populations of *A.spinosus* plants exhibited typical meiotic behavior, and meiotic analysis confirmed that all of them possessed n=17 chromosomes. The pollen fertility of the plants obtained from contaminated areas ranged from 60.17±4.84% to 65.31±3.21%, whereas the control site plants exhibited 75.11±8.47% pollen fertility.

b. ***Cannabis sativa*** Linn.

Research on meiosis in all five groups revealed the expected pattern of events. The presence of diakinesis M-1 and A-1 in many PMCs (Fig.II.8-13 (Annexure)) verified a chromosomal number of 2n=20. The pollen fertility of C. sativa plants obtained from the control site was 80.71±4.91%, whereas in contaminated areas it ranged from 67.51±5.57% to 73.54±8.3%.

c. ***Cassia tora*** Linn.

Observed plants exhibited typical meiotic behavior with n=13, according to meiotic analysis of all five species populations (Fig.II.14-17 (Annexure)). Plants sampled from contaminated areas showed a wide range of pollen fertility, from 60.99±8.6% to 65.19±4.47%. Pollen fertility was measured at 78.55±4.11% in the *C.tora* plants that were gathered from the control location.

d. ***Chenopodium album*** Linn.

Multiple PMCs at diakinensis corroborated the results of the meiotic study, which demonstrated that all five populations exhibited typical meiotic behavior with a n=18 (Fig.III.18-19 (Annexure)). The pollen fertility of plants obtained from various sites ranged from 66.12±5.17% to 75.11±8.47%, with the control fields yielding the most fertile plants.

e. ***Parthenium hysterophorus*** Linn.

Based on the data collected from various populations, it was found that there are 17 haploid chromosomes in diakinensis and M-1 (Fig. III.20 (Annexure)). The plants observed exhibited typical meiotic behavior, with pollen fertility ranging from 70.91±9.77% to 73.78±8.11% in the Miran Sahib, Raipur Domana, Gho Manhasan, and Bishnah fields, and 80.58±8.15% in the Samba plants.

f. ***Rumex dentatus*** Linn.

The usual meiotic behavior with n=20 was seen in *R.dentatus* plants gathered from Miran Sahib, Raipur Domana, Gho Manhasan, Bishnah, and Samba (Fig.III.21-26 (Annexure)). For plants in fields damaged by tanneries, pollen fertility ranged from 69.77±7.53% to 73.75±8.77%, whereas for plants in control conditions, it was 82.77±3.71%.

g. ***Solanum nigrum*** Linn.

With a sample size of 36, meiotic study of all five species populations demonstrated that the plants studied exhibited typical meiotic behavior (Fig.III.27-29 (Annexure)). Pollen fertility ranged from 60.77±5.91% to 67.77±8.81% in the contaminated plants, whereas it was 81.77±5.54% in the control site.

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4.2.4. Biochemical Analysis

Table 4.5: Quantitative estimates (mg/g) the mature leaves of various plants fromdifferent fields in the study area

Biochemical Concentrations (in mg/g)	Locations			
	Miran Sahib	Raipur Domana	Gho Manhasan	Ebbam
Amaranthus spinosus				
Chlorophyll	68.71±1.31	55.92±1.92	56.98±4.36	49.72±3.32
Carbohydrate	0.539±0.01	0.352±0.03	0.287±0.08	0.289±0.04
Protein	0.459±0.05	0.393±0.03	0.277±0.01	0.279±0.05
Cannabis sativa				
Chlorophyll	68.22±7.53	58.23±9.13	57.92±9.12	59.77±2.53
Carbohydrate	0.371±0.01	0.342±0.02	0.299±0.93	0.292±0.93
Protein	0.395±0.06	0.331±0.07	0.347±0.09	0.349±0.05
Cassia tora				
Chlorophyll	78.05±1.45	69.55±6.35	65.93±9.95	66.33±7.97
Carbohydrate	0.09±0.01	0.05±0.05	0.05±0.05	0.06±0.06
Protein	0.395±0.09	0.335±0.07	0.376±0.01	0.321±0.08
Chenopodium album				
Chlorophyll	79.52±7.55	72.33±5.62	71.52±6.43	70.21±94.5
Carbohydrate	0.061±0.02	0.049±0.09	0.053±0.08	0.057±0.05
Protein	0.383±0.01	0.372±0.07	0.295±0.05	0.287±0.06
Parthenium hysterophorus				
Chlorophyll	75.05±5.92	66.92±6.63	65.93±9.16	67.95±5.56
Carbohydrate	0.091±0.01	0.043±0.05	0.053±0.09	0.057±0.06
Protein	0.337±0.93	0.301±0.08	0.277±0.06	0.297±0.05
Rumex dentatus				
Chlorophyll	72.55±1.73	59.52±1.93	61.72±4.94	65.93±5.38
Carbohydrate	0.631±0.09	0.559±0.02	0.593±0.03	0.442±0.09
Protein	0.592±0.031	0.337±0.07	0.359±0.09	0.382±0.03
Solanum nigrum				
Chlorophyll	79.55±9.21	75.09±8.23	62.55±9.25	61.99±8.65
Carbohydrate	0.185±0.07	0.147±0.06	0.151±0.09	0.138±0.08
Protein	0.391±0.09	0.267±0.08	0.255±0.06	0.259±0.06

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Chlorophyll, protein, and glucose concentrations in plants grown in various regions have been measured quantitatively. For this study, we gathered mature leaves from plants in the control area at Samba as well as those in the tannery effluent-irrigated fields in the villages of Miran Sahib, Raipur Domana, Gho Manhasan, and Bishnah. The amount of chlorophyll was determined by collecting young leaves from weed plants at various sites and then using a UV-Visible Spectrophotometer to quantify chlorophyll a (Chl a) and chlorophyll b (Chl b) at 645 and 663 nm, respectively. Using a conventional approach, foliar protein was quantified from mature leaves of plants across five sites and species (Lowry et al., 1951).Anthrone technique was used to acquire total soluble sugar, and foliar sugar % was calculated from randomly chosen leaves of each weed (Ashwell, 1957). When comparing leaves from fields in villages with contaminated soils to those from fields near Samba (Control), all seven species showed that the former had much higher quantities of chlorophyll, protein, and carbs. Reduced protein, carbohydrate, and chlorophyll content is a common symptom of environmental stress in plants. Table 4.5 shows that, compared to other plants now under study, those from the hamlet of Gho Manhasan had the lowest concentrations of these bio components. Even the vegetation of Miran Sahib hamlet followed this pattern.

4.2.5 Metal Bioaccumulations

Miran Sahib, Raipur Domana, Gho Manhasan, and Bishnah were the five sites where plant specimens of the species under consideration were gathered. Acid digestion was performed on the dried shoots and roots of each species independently, and the heavy metal concentration was determined using the ICAP-AES technique.

Heavy metals such as Cr, Cu, Ni, Pb, and Cd were estimated. Tables 4.2–4.8 offer the data about the metal content in each species.

Table 4.2: Metal content (µg/gm) in *Amaranthus spinosus* collected from studyarea

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	4.28	12.63	6.15	18.57	6.55	11.38	2.18	8.34	0.13	0.48
Raipur Domana	77.58	66.48	3.16	43.47	25.66	27.83	21.91	13.4	0.76	2.16
Gho Manhasan	72.35	72.95	37.15	52.37	26.95	29.18	20.85	17.88	0.95	2.54
Bishnah	88.59	69.87	26.64	41.29	25.76	24.71	20.63	16.78	0.89	2.27

Table 4.3: Metal content (µg/gm) in *Cannabis sativa* collected from study area

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	13.98	27.68	21.78	17.95	2.14	2.65	9.35	14.65	0.66	0.86
Raipur Domana	59.45	16.75	58.98	65.33	15.34	9.35	23.56	5.45	2.25	1.55
Gho Manhasan	81.23	18.93	67.52	51.66	26.78	24.45	30.52	26.95	2.96	3.75
Bishnah	67.68	36.94	44.33	91.67	27.34	14.35	22.74	19.65	0.86	0.65

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Table 4.4: Metal content (µg/gm) in *Cassia tora* collected from study area

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	1.84	2.54	15.88	4.15	2.15	2.26	8.89	9.67	0.15	0.18
Raipur Domana	4.25	5.96	21.43	24.53	3.35	3.87	22.78	21.67	0.18	0.19
Gho Manhasan	4.76	7.89	21.73	29.75	3.33	2.94	32.56	17.34	0.16	0.21
Bishnah	4.94	5.34	20.87	25.66	4.22	4.16	26.45	15.56	0.23	0.23

Table 4.5: Metal content (µg/gm) in *Chenopodium album* collected from studyarea

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	17.38	13.46	45.16	34.59	4.23	3.39	12.55	4.81	1.18	0.13
Raipur Domana	87.86	44.56	56.55	89.55	27.95	17.75	40.74	21.52	2.78	0.29
Gho Manhasan	92.26	52.53	67.77	78.44	40.65	18.96	34.66	19.76	2.67	0.76
Bishnah	75.97	54.53	69.47	28.56	52.05	21.08	40.53	23.87	2.75	1.23

Table 4.6: Metal content (µg/gm) in *Parthenium hysterophorus* collected fromstudy area

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	7.95	2.66	29.58	17.81	5.56	3.05	11.64	7.92	0.63	0.42
Raipur Domana	41.49	15.04	15.52	13.72	1.39	2.93	6.47	8.72	0.13	0.18
Gho Manhasan	21.44	20.49	12.04	11.41	3.34	12.18	8.93	24.03	0.38	0.57
Bishnah	11.58	11.68	38.59	72.41	12.36	13.93	28.53	5.85	1.25	0.25

Table 4.7: Metal content (µg/gm) in *Rumex dentatus* collected from study area

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	43.42	28.65	31.89	39.56	10.44	4.65	12.65	7.58	0.59	0.49
Raipur Domana	60.41	35.95	73.56	88.45	13.86	14.46	29.15	13.35	2.78	2.38
Gho Manhasan	57.53	32.77	79.56	79.56	13.95	12.26	32.36	14.29	0.69	0.99
Bishnah	39.15	31.55	78.45	43.23	13.75	13.55	21.56	14.6	0.65	0.65

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Table 4.8: Metal content (µg/gm) in *Solanum nigrum* collected from study area

Location	Metals Concentration(µg/gm)									
	Cr		Cu		Ni		Pb		Cd	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Miran Sahib	16.38	4.42	33.42	17.59	2.11	1.75	2.76	2.14	0.09	0.08
Raipur Domana	60.35	12.71	42.57	54.55	3.18	4.72	9.18	9.74	0.15	0.23
Gho Manhasan	45.59	17.71	36.97	67.95	19.55	2.76	25.35	27.47	0.49	0.31
Bishnah	47.63	21.23	36.65	62.86	19.45	5.86	24.78	26.15	0.33	0.19

- **Phytoremediation Potential:** These species demonstrated high phytoextraction capacities, making them suitable for soil remediation (Tables 4.9-4.12, Fig 4.1).

Table 4.9: The Biological Concentration Factor (BCF) in various species in potexperiment

Metal exposure	Metal				
	Cr	Cu	Ni	Pb	Cd
Amaranthus spinosus					
25ppm	0.971	0.785	0.308	0.308	0.311
50ppm	0.852	0.733	0.189	0.118	0.140
100ppm	0.616	0.568	0.079	0.028	0.097
Cannabis sativa					
25ppm	0.648	1.447	0.306	0.467	0.867
50ppm	0.737	1.383	0.157	0.457	0.455
100ppm	0.786	0.719	0.097	0.368	0.419
Cassia tora					
25ppm	0.170	0.388	0.304	0.951	0.096
50ppm	0.166	0.375	0.086	0.671	0.073
100ppm	0.179	0.377	0.077	0.466	0.063
Chenopodium album					
25ppm	0.609	1.305	0.510	0.827	0.787
50ppm	0.685	1.353	0.512	0.834	0.815
100ppm	0.386	0.697	0.413	0.447	0.588
Parthenium hysterophorus					
25ppm	0.118	0.596	0.257	0.672	0.787
50ppm	0.193	0.534	0.273	0.609	0.754
100ppm	0.106	0.569	0.259	0.405	0.427
Rumex dentatus					
25ppm	0.188	1.108	0.188	0.758	0.632
50ppm	0.179	1.316	0.175	0.654	0.716
100ppm	0.127	0.680	0.168	0.529	0.508
Solanum nigrum					
25ppm	0.552	1.645	0.327	0.671	0.367
50ppm	0.474	1.357	0.334	0.697	0.416
100ppm	0.458	0.019	0.327	0.486	0.409

According to Li et al. (2007) and Cui et al. (2007), the Biological Accumulation Coefficient (BAC)

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was determined by comparing the concentration of heavy metals in shoots and soil. The BAC for Cr of the shoots of several marijuana species in the pot experiment ranged from lowest in *Parthenium hysterophorus* to highest in *Amaranthus spinosus* and *Cannabis sativa*. Listing 4.86. There was exactly one in every single instance. In the cases of *Cannabis sativa*, *Chenopodium album*, and *Rumex dentatus*, the BAC values for Cu were more than one. While all of the BAC values for Ni were less than one, the ones in *Chenopodium album*, *Amaranthus spinosus*, and *Cassia tora* were much higher. The BAC for lead was greatest in *Cassia tora*, then in *Rumex dentatus* and *Chenopodium album*, and lowest in *Amaranthus spinosus*. The marijuana experiment found that among the several cannabis varieties, *Cannabis sativa*, *Chenopodium album*, and *Parthenium hysterophorus* had the highest BAC for Cd in their shoots.

Table 4.10: Biological Accumulation Coefficient (BAC) in various species in potexperiment

Metal exposure	Metal				
	Cr	Cu	Ni	Pb	Cd
Amaranthus spinosus					
25ppm	0.808	0.6918	0.2698	0.216	0.2962
50ppm	0.7334	0.6026	0.1528	0.0966	0.0716
100ppm	0.6112	0.4204	0.0619	0.07235	0.0428
Cannabis sativa					
25ppm	0.7022	1.5486	0.1412	0.5066	1.011
50ppm	0.7436	1.4756	0.1251	0.4756	0.5574
100ppm	0.7839	0.7888	0.07265	0.30715	0.3164
Cassia tora					
25ppm	0.4822	0.5416	0.2186	1.5916	0.1076
50ppm	0.4543	0.5644	0.1935	0.7065	0.1276
100ppm	0.4019	0.40025	0.15295	0.469	0.11715
Chenopodium album					
25ppm	0.6092	1.4648	0.705	1.4716	0.9316
50ppm	0.706	1.425	0.8503	1.1458	0.9958
100ppm	0.74155	0.717	0.45035	0.4367	0.5379
Parthenium hysterophorus					
25ppm	0.0714	0.5092	0.221	0.4852	0.4822
50ppm	0.1569	0.4945	0.2476	0.3253	0.5476
100ppm	0.0706	0.40705	0.2379	0.3928	0.3468
Rumex dentatus					
25ppm	0.1422	1.3516	0.2046	1.3892	0.4116
50ppm	0.1189	1.3661	0.1958	0.8848	0.4858
100ppm	0.11305	0.6374	0.22285	0.5128	0.4279
Solanum nigrum					
25ppm	0.113	0.6496	0.0978	0.9124	0.2658
50ppm	0.2306	0.4539	0.0959	0.827	0.354
100ppm	0.2622	0.2603	0.08945	0.42315	0.32145

One normal measurement for estimating contamination remediation viability is the TF, which addresses a plant's capacity to gather metals in its higher parts. This is described as the top portion's metal concentration relative to the roots (Chakroun et al., 2010). The proportion of weighty metals in the plant's shoots to those in its underlying foundations is known as the movement factor (TF; Cui et al., 2007; Li et al., 2007). The translocation factor indicates a plant's ability to transport metals from its roots to its shoots. A translocation factor value greater than 1 indicates metal transfer from roots to aboveground parts (Jamil et al., 2022). Yoon and others 2006) states that... To be considered for contamination remediation, a plant animal types should have a TF bigger than 1. In this investigation, the effectiveness of plant metal transfer was evaluated using the translocation factor (TF) for heavy metals (Cr, Cu, Ni, Pb, and Cd).

The current work screened seven species using pot experiments. *Cassia tora* had the highest TF for Cr (2.25-2.84), followed by *Chenopodium album* and *Cannabis sativa*. The following plants were found to have TF values larger than one for Cu: *Solanum nigrum* (14.07), *Cassia tora* (1.50), and *Rumex dentatus* (1.22). In the pot experiment, Ni TF values larger than one were noted for *Cassia tora* (1.99), *Chenopodium album* (1.09-1.38) and *Rumex dentatus* (1.33). *Cannabis sativa*, *Cassia tora*, and up to six more species are now under testing. Pb showed TF values larger than one in *Chenopodium album*, Rumex dentatu, *Amaranthus spinosus*, and *Solanum nigrum*. *Cassia tora* (1.87), *Cannabis sativa* (1.23) and *Chenopodium album* all had TF values greater than one in the marijuana trial (1.22).

Table 4.11: The Translocation factor (TF) in various species in pot experiment

Metal exposure	Metal				
	Cr	Cu	Ni	Pb	Cd
Amaranthus spinosus					
25ppm	0.83	0.88	0.88	0.70	0.95
50ppm	0.86	0.82	0.81	0.82	0.51
100ppm	0.99	0.74	0.79	2.57	0.44
Cannabis sativa					
25ppm	1.17	1.07	0.46	1.09	1.17
50ppm	1.07	1.07	0.80	1.04	1.23
100ppm	1.01	1.10	0.75	0.84	0.76
Cassia tora					
25ppm	2.84	1.40	0.72	1.67	1.12
50ppm	2.74	1.50	2.26	1.05	1.74
100ppm	2.25	1.06	1.99	1.01	1.87
Chenopodium album					
25ppm	1.00	1.12	1.38	1.78	1.18
50ppm	1.03	1.05	1.66	1.37	1.22
100ppm	1.92	1.03	1.09	0.98	0.92
Parthenium hysterophorus					
25ppm	0.61	0.85	0.86	0.72	0.61
50ppm	0.81	0.93	0.91	0.53	0.73
100ppm	0.66	0.71	0.92	0.97	0.81
Rumex dentatus					
25ppm	0.75	1.22	1.09	1.83	0.65
50ppm	0.66	1.04	1.12	1.35	0.68
100ppm	0.89	0.94	1.33	0.97	0.84
Solanum nigrum					
25ppm	0.20	0.39	0.30	1.36	0.72
50ppm	0.49	0.33	0.29	1.19	0.85
100ppm	0.57	14.07	0.27	0.87	0.79

The selection of phytoremediating species is mostly influenced by the degree of metal removal. Biomass and metal accumulation factor are two critical parameters that determine a species'

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phytoextraction efficiency (Blaylock et al., 1997). For the purpose of remediation species selection, both metal hyperaccumulator and non-accumulator species have been investigated. Hyperaccumulator plants may have limited use due to their diminutive stature and sluggish development. In order to make up for their limited ability to absorb metals, non-accumulator species may produce a lot of biomass (Ebbs et al., 1997). However, metal pollution is severe enough at many places to reduce biomass significantly and induce toxicity to plant species. Plants may be unsuitable for metal cleaning operations if they acquire large levels of one metal but are vulnerable to another (Hinesly et al., 1978). Several maize inbred lines that were found to accumulate high amounts of Cd could not be employed for soil cleaning at the standard Zn: Cd ratio of 100:1, according to Chaney et al. (1999).

Soil contamination's physical properties also play a role in the remediation plant selection process. As an example, shallow-rooted species would be suitable for remediating surface-contaminated soils, whereas deep-rooted plants would be preferred for more thorough pollution.

Table 4.12: The Phytoextraction capacity (PC) of various species raised in potsamended with different

Metal exposure	PC (µg) per plant				
	Cr	Cu	Ni	Pb	Cd
Amaranthus spinosus					
25 µg/g	3.52	2.79	1.19	0.89	1.29
50 µg/g	5.58	4.71	1.34	0.74	4.75
100 µg/g	6.79	4.84	1.05	0.91	0.43
Cannabis sativa sativa					
25 µg/g	2.41	3.98	4.98	1.09	5.40
50 µg/g	4.94	6.82	5.72	1.96	5.83
100 µg/g	9.99	6.51	5.49	2.37	6.37
Cassia tora					
25 µg/g	1.56	1.51	5.72	4.79	3.37
50 µg/g	2.63	3.02	1.02	3.90	7.32
100 µg/g	4.12	3.96	1.40	4.97	1.32
Chenopodium album					
25 µg/g	4.11	10.45	10.14	10.13	6.89
50 µg/g	9.02	18.71	14.53	14.58	13.72
100 µg/g	17.40	17.32	10.58	10.24	14.28
Parthenium hysterophorus					
25 µg/g	0.56	3.95	3.77	3.69	3.67
50 µg/g	1.66	7.11	4.68	4.79	7.71
100 µg/g	1.32	10.82	10.44	11.40	6.72
Rumex dentatus					
25 µg/g	3.74	4.14	0.62	4.16	1.21
50 µg/g	0.62	7.77	1.09	0.51	2.56
100 µg/g	1.16	6.56	2.26	5.78	4.18
Solanum nigrum					
25 µg/g	0.80	4.34	0.68	6.28	1.87
50 µg/g	3.27	5.74	1.32	1.13	4.75
100 µg/g	7.41	6.50	2.45	11.56	7.51

Plants of *Chenopodium album* achieved the highest phytoextraction capacity value (PC) in the pot

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trials when grown on soil amended with 50 µg/g of Cu (18.71 µg per plant), followed by *Chenopodium album* at 17.40 µg per plant when grown on soil amended with 100 µg/g of Cr. The PC values for chromium varied from 0.37 to 17.41 µg across several plants. The plants of *Chenopodium album* had the highest PC values, followed by *Cannabis sativa* with 9.99 and *Amaranthus spinosus* with 6.79. The plants identified as having the highest PC value in relation to copper were *Chenopodium album* (18.71 µg per plant) when grown on soil amended with 50 µg/g of Cu. *Parthenium hysterophorus* (10.82 µg per plant) and *Rumex dentatus* (7.77 µg per plant) were the next plants in line. *Chenopodium album* had the highest PC for Ni among the plant species tested in the pot trial at 14.53, followed by *Parthenium hysterophorus* at 10.44, and finally *Cannabis sativa* and *Cassia tora* at 5.72.

Chenopodium album had the lowest Pb phytoextraction capacity value at 14.58 µg/g, followed by *Solanum nigrum* at 11.56 µg/g and *Parthenium hysterophorus* at 11.40 µg/g. *Chenopodium album* plants grown in soil with 100 µg/g of Cd had the highest PC value at 14.28 µg per plant, followed by *Solanum nigrum* at 7.51 µg and *Parthenium hysterophorus* at 7.71 µg/g.

It is also possible to assess the pollution remediation utility of different species by comparing their mean PC values. In Figure 4.8, we can see the average PC values of the seven species that are being studied at the moment.

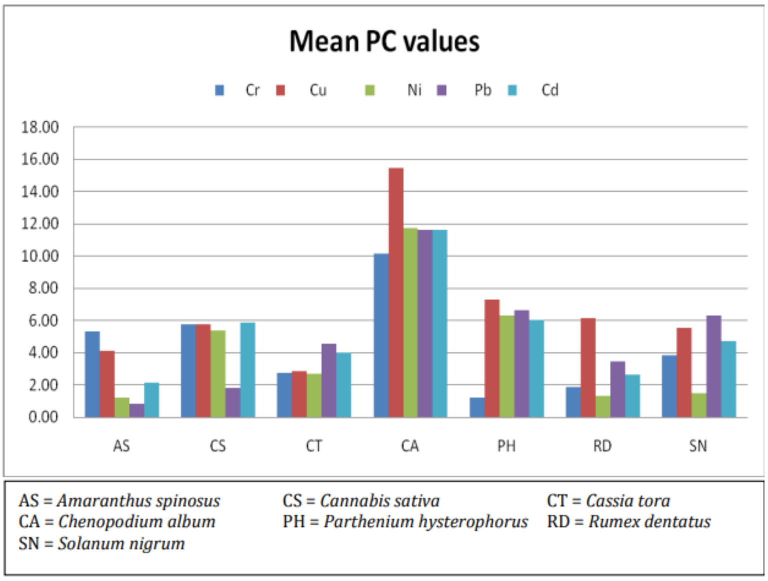

Fig 4.1. Mean PC values of different species raised on metal rich soils.

The mean data indicate that of the five metals often found in tannery-affected regions, *Chenopodium album* gathered from Miran Sahib village is the most effective in removing them. With the exception of chromium, *Parthenium hysterophorus* is the second-best heavy metal species. *Cannabis sativa* is the second-best plant, although it isn't ideal for lead soil remediation.

Conclusion:

The findings of this study demonstrate the significant potential of native weed species, particularly Cannabis sativa and Chenopodium album, for the phytoremediation of tannery-contaminated soils in Jammu & Kashmir. Through comprehensive analysis of soil and plant samples from multiple sites, it was observed that these species exhibit high levels of heavy metal bioaccumulation and tolerance, essential traits for effective phytoremediators. The study revealed that heavy metal concentrations, including Cr, Cu, Ni, Pb, and Cd, were considerably higher in contaminated soils compared to control sites, posing substantial risks to soil health and agricultural productivity. Both Cannabis sativa and Chenopodium album showed remarkable resilience and biomass production under metal stress conditions, suggesting their suitability for large-scale remediation projects. The ability of these plants to accumulate metals primarily in their aerial parts, combined with their high tolerance indices and phytoextraction capacities, underscores their utility in reducing soil metal concentrations. This research contributes valuable insights into the development of sustainable and environmentally friendly remediation strategies tailored to specific contaminated sites. Further research should focus on optimizing growth conditions, enhancing metal uptake efficiency, and scaling up these phytoremediation practices to achieve practical applications in real-world scenarios. By integrating these native weed species into soil remediation efforts, it is possible to mitigate the adverse effects of heavy metal contamination, improve soil quality, and support sustainable agricultural practices in affected regions.

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