NUMERICAL DATA

Efficiency of Heavy Metals-Tolerant Plant Growth Promoting Bacteria for Alleviating Heavy Metals Toxicity on Sorghum (2019)

Effect of heavy metals on photosynthetic pigments in sorghum leaves

Treatments		Chlo.A		Chlo. B		Carotenoids	
		Inoculation with HMT-PGPB					
		Without	With	Without	With	Without	With
Control		0.9^{h}	2.1^{b}	0.5^{e}	1.2^{bc}	1.3^{f}	3.1^{ab}
Cu^{2+} (mg/kg)	100	1.9^{b}	0.7^{i}	1.1^{a}	1.3^{b}	3.1^{ab}	3.2^{a}
	200	1.4^{d}	2.1^{b}	0.7^{cd}	1.2^{bc}	2.6^{bc}	2.9^{cd}
	400	1.3^{de}	1.9^{c}	0.6^{de}	0.5^{i}	2.1^{cde}	2.6^{e}
Cd^{2+} (mg/kg)	10	1.4^{d}	1.4^{g}	0.9^{b}	1.3^{b}	2.6^{bc}	3.2^{a}
	20	1.3^{de}	2.9^{a}	1.2^{a}	1.1^{cd}	2.2^{cd}	2.8^{d}
	40	1.3^{de}	1.7^{de}	1.2^{a}	0.6^{hi}	2.0^{de}	2.3^{f}
Pb^{2+} (mg/kg)	200	2.2^{a}	1.5^{gf}	1.2^{a}	1.0^{de}	3.4^{a}	3.1^{ab}
	400	1.7^{c}	1.2^{h}	0.8^{bc}	1.6^{a}	2.6^{bc}	2.9^{cd}
	800	1.1^{fg}	1.4^{g}	0.6^{de}	0.7^{gh}	1.3^{f}	2.5^{e}
Zn^{2+} (mg/kg)	250	1.8^{bc}	1.8^{cd}	1.2^{a}	0.9^{ef}	3.2^{a}	3.1^{ab}
	500	1.2^{ef}	1.6^{ef}	0.7^{cd}	0.8^{gf}	1.8^{def}	2.1^{f}
	1000	1.0^{gh}	1.1^{h}	0.9^{b}	0.6^{hi}	1.6^{ef}	1.9^{g}
Mixture (mg/kg)		1.3^{de}	2.2^{b}	0.5^{e}	0.9^{ef}	1.9^{de}	3.0^{bc}

$^{a,b,\,c}$ Means with different superscript in the same column are significantly different at ($P<0.05$).

Data presented in Table indicates that photosynthetic pigments increased in inoculated plants than uninoculated ones. This due to the beneficial effects of HMT-PGPB for alleviation the toxic effects of heavy metals. In this respect, Popova et al. (2012) demonstrated the relationship between total chlorophyll content in heavy metal exposed and bacterial treated plants. He proved that because the ability of the bacteria to metabolize heavy metal, the chlorophyll content was affected and cause increase in photosynthetic activity followed by increase in plant growth.

Source: https://www.sciencedirect.com/science/article/abs/pii/S0098847219302497

Efficiency of Heavy Metals-Tolerant Plant Growth Promoting Bacteria for Alleviating Heavy Metals Toxicity on Sorghum (2019)

Effect of different heavy metals concentrations on oxidative enzymes in sorghum

Treatments		PO (Abs. at 425 nm/g FW/15 min.)		PPO (Abs. at 420 nm/g FW/ 30 min.)	
		Inoculation with HMT-PGPB			
		Without	With	Without	With
Control		4.048^{a}	4.550^{a}	1.034^{g}	1.293^{h}
Cu^{2+} (mg/kg)	100	4.133^{a}	4.280^{c}	1.792^{b}	2.014^{b}
	200	3.751^{a}	3.775^{k}	1.145^{e}	1.168^{j}
	400	3.076^{b}	3.483^{m}	0.571^{k}	1.079^{l}
Cd^{2+} (mg/kg)	10	4.113^{a}	4.327^{b}	1.910^{a}	1.912^{c}
	20	3.978^{a}	4.252^{d}	0.833^{i}	0.977^{m}
	40	3.693^{a}	4.038^{e}	0.830^{i}	0.933^{n}
Pb^{2+} (mg/kg)	200	4.102^{a}	3.828^{i}	0.910^{h}	1.761^{d}
	400	3.979^{a}	3.818^{j}	0.830^{i}	1.531^{f}
	800	3.956^{a}	3.763^{l}	0.806^{j}	1.173^{i}
Zn^{2+} (mg/kg)	250	4.154^{a}	3.998^{f}	1.473^{c}	1.566^{e}
	500	4.000^{a}	3.954^{h}	1.315^{d}	1.492^{g}
	1000	3.948^{a}	3.245^{n}	1.317^{d}	1.081^{k}
Mixture (mg/kg)		3.859^{a}	3.987^{g}	1.091^{f}	2.583^{a}

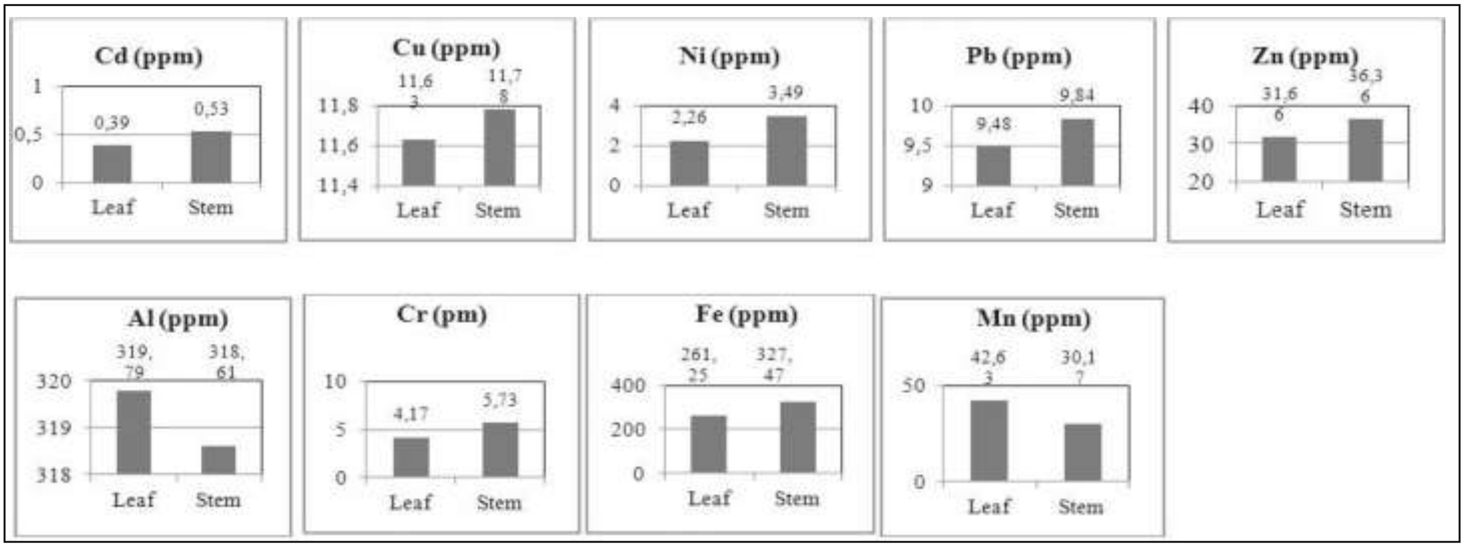
$^{a, b, c}$ Means with different superscript in the same column are significantly different at ($P<0.05$).

PO: peroxidase, PPO: polyphenol oxidase

Respecting the effect of heavy metals mixture on sorghum growth, it was clear that all estimated parameters were lower in uninoculated plants than inoculated plants. This could be because the toxic effect of heavy metals and role of HMT-PGPB which possess many strategies (salicylic acid, proline, exopolysaccharide, biosurfactant and sidrophores) to alleviate the toxic effect of heavy metals as previously confirmed and as many researchers demonstrated.

Source: http://sci-hub.tw/https://doi.org/10.1016/j.envexpbot.2019.03.005

Heavy metal accumulation in rosemary leaves and stems exposed to traffic-related pollution near Adana-İskenderun Highway (Hatay, Turkey) (2019)



Accumulation level of heavy metals in the plants' leaves and stem (ppm)

Source: https://link.springer.com/content/pdf/10.1007%2Fs10661-019-7714-7.pdf

Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils (2019)

Maximum permissible limits for toxic heavy metals concentration in irrigation water, soil and plants.

Metal	Irrigation water (µg/mL)	Soil (µg/g)	Plant (µg/g)
Lead (Pb)	0.015	300	0.30
Cadmium (Cd)	0.01	3	5
Chromium (Cr)	0.10	150	0.2
Arsenic (As)	0.01	20	0.1
Nickel (Ni)	1.40	50	67
Mercury (Hg)	0.01	30	0.03
Copper (Cu)	0.20	80	40
Iron (Fe)	0.50	50,000	450
Zinc (Zn)	2.0	300	60
Manganese (Mn)	0.20	140	500

Lead and cadmium can influence the absorption of Cu^{2+}, Fe^{2+}, Zn^{2+} and Mn^{2+} through competition for sites or processes shared by these cations (Xu and Shi, 2000). Hence, metal contaminated crops mainly vegetables are not safe for human edible purpose due to their network of roots in upper layer of soil (Smolen et al., 2010; Qureshi et al., 2016; Gupta et al., 2019). The maximum permissible limits of toxic heavy metals in irrigation water, soil and plants are presented in the table.

Source: https://www.sciencedirect.com/science/article/pii/S0147651319302271

Multi-criteria decision analysis of optimal planting for enhancing phytoremediation of trace heavy metals in mining sites under interval residual contaminant concentrations (2019)

The comparison of measured and simulated cumulative metal uptake for all scenarios (t ¼ 180 days; values ¼ averaged data, n ≤ 4).

Samples	**Measured**	**values**	**Simulated**	**values**	**RMSE (Zn)**		**RMSE (Pb)**	**RMSE (Cd)**
	Zn	Pb	Cd	Zn	Pb	Cd		
Setaria viridis	85.86	75.74	8.05	87.2	75.21	7.77	1.61	**4.16**
Phragmites australisis	119.74	40.71	4.28	115.7	41.21	4.22	1.27	**2.04**
Echinochloa crus-galli	**228.65**	**37.36**	**11.44**	**240.21**	**38.67**	**11.22**	**1.12**	**1.43**

Table shows the growth characteristics of the 3 plant species (Setaria viridis, Echinochloa crus-galli and Phragmites australis) in this area.

Table compared the modeled solute plant uptake with those observed values in the surveyed area (t 180 days). Due to the complexity of predicting the rate of degradation and transportation of trace metal contaminants in the unsaturated zone, it was considered accept- able if root mean square error was less than 50%. The average values of RMSE between the predicted and observed Zn, Pb and Cd uptake is shown in Table, where the highest RMSE is 1.61(Zn), 4.16(Pb) and 6.01(Cd). Nevertheless, a maximum concentration croot for Pb uptake was modified to 0.21. This requirement was used due to (1) extremely low Pb translocation from the study area and (2) a relatively high initial Pb concentration.

Source: https://sci-hub.tw/10.1016/j.envpol.2019.113255

Assessment of Metalloid and Metal Contamination in Soils from Hainan, China.(2018)

Table: 1 Statistics of studied elements (mg•kg^{-1}) in soils (0–20 cm) of Hainan Island

	As	Cd[a]	Cr	Cu	Hg[a]	Ni	Pb	Se	Zn
N	8713	8713	8713	8713	8713	8713	8713	8713	8713
Minimum	0.01	2	0.1	0.25	1	0.1	1	0.02	2
Maximum	988.04	3064	860.3	192.9	3540	327.1	619.6	4.68	800
Geometrical mean	2.17	60.19	26.50	9.43	33.34	8.74	22.20	0.26	39.64
Variation coefficient	4.05	1.16	1.58	1.35	1.77	1.91	0.67	0.88	0.74
Std. Deviation	21.42	93.61	96.32	23.34	75.20	48.18	17.51	0.30	37.91
Skewness	24.91	10.52	2.65	2.35	29.30	2.74	7.79	3.39	2.51
Kurtosis	858.68	219.08	7.09	4.97	1127.52	6.93	191.20	22.67	22.31
China BK[b]	9.20	74.00	53.90	20.00	40.00	23.40	23.60	0.22	67.70
Threshold of the first grate[c]	15	200	90	35	150	40	35		100
Canadian soil quality guidelines[d]	12	10000	64	63	6600	45	140	1	200
Target value of Dutch soil guidelines[e]	29	800	100	36	300	35	85		140

[a] μg.kg^{-1}; [b]Background values of Chinese soils, A layer (0–20 cm), more than 4000 samples; [c]Class I value of the Environmental Quality Standard for Soils in China; [d] Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (Residential); [e] Values for soil remediation proposed by Dutch Ministry of Housing, Spatial Planning and Environment.

Source: https://www.mdpi.com/1660-4601/15/3/454

Heavy Metals bio-adsorption by *Hibiscus Sabdariffa* l. from contaminated water.(2018)

Mean Cd content (mg/L)	Time of contact					
	1 min	5 min	10 min	15 min	30 min	40 min
sepal + 1 % black tea residue						
0.2 % bio-adsorbent H. sabdariffa L.	48.04 ^{a}	42.338 ^{b}	33.217 ^{c}	32.574 ^{c}	32.111 ^{c}	26.788 ^{d}
sepal + 2 % black tea residue						
0.3 % bio-adsorbent H. sabdariffa L.	47.03 ^{a}	38.195 ^{b}	32.067 ^{c}	28.974 ^{c}	26.571 ^{c}	17.454 ^{d}
sepal + 3 % black tea residue						
0.5 % bio-adsorbent H. sabdariffa L.	44.12 ^{a}	34.187 ^{b}	30.107 ^{c}	27.651 ^{c}	14.092 ^{d}	8.732 ^{d}
sepal + 3 % black tea residue						
untreated contaminated Effluent	50.032 ^{a}	50.021 ^{a}	49.868 ^{a}	49.866 ^{a}	49.964 ^{a}	49.866 ^{a}
Mean Co content (mg/L)	1 min	5 min	10 min	15 min	30 min	40 min
0.1 % bio-adsorbent H. sabdariffa L.	103.42 ^{a}	97.106 ^{a}	95.602 ^{a}	93.116 ^{a}	93.217 ^{a}	91.181 ^{b}
sepal + 1 % black tea residue						
0.2 % bio-adsorbent H. sabdariffa L.	100.88 ^{a}	98.419 ^{a}	94.333 ^{a}	91.018 ^{b}	89.806 ^{b}	88.112 ^{b}
sepal + 2 % black tea residue						
0.3 % bio-adsorbent H. sabdariffa L.	100.01 ^{a}	90.154 ^{b}	89.094 ^{b}	86.731 ^{b}	80.556 ^{c}	78.667 ^{c}
sepal + 3 % black tea residue						
0.5 % bio-adsorbent H. sabdariffa L.	98.65 ^{a}	87.28 ^{b}	86.564 ^{b}	83.211 ^{b}	78.444 ^{c}	70.193 ^{c}
sepal + 3 % black tea residue						
untreated contaminated Effluent	110.21 ^{a}	110.45 ^{a}	109.89 ^{a}	109.88 ^{a}	110.23 ^{a}	110.35 ^{a}
Mean Ni content (mg/L)	1 min	5 min	10 min	15 min	30 min	40 min
0.1 % bio-adsorbent H. sabdariffa L.	106.52 ^{a}	100.03 ^{a}	95.556 ^{b}	93.213 ^{b}	90.617 ^{b}	82.187 ^{c}
sepal + 1 % black tea residue						
0.2 % bio-adsorbent H. sabdariffa L.	102.89 ^{a}	97.632 ^{a}	92.206 ^{b}	90.111 ^{b}	85.345 ^{c}	78.432 ^{d}
sepal + 2 % black tea residue						
0.3 % bio-adsorbent H. sabdariffa L.	95.498 ^{a}	91.222 ^{b}	89.704 ^{b}	84.532 ^{c}	80.556 ^{c}	76.562 ^{d}
sepal + 3 % black tea residue						
0.5 % bio-adsorbent H. sabdariffa L.	90.478 ^{b}	80.778 ^{c}	74.306 ^{d}	68.092 ^{d}	60.232 ^{d}	50.32 ^{f}
sepal + 3 % black tea residue						
untreated contaminated Effluent	110.15 ^{a}	111.9 ^{a}	110.16 ^{a}	110.87 ^{a}	110.34 ^{a}	110.28 ^{a}

Mean value ±SD of Cadmium, Cobalt and Nickel contents (mg /L) after addition of different percentages of H. sabdariffa L. sepal and black tea residue

Source: http://repositsc.nuczu.edu.ua/bitstream/123456789/6848/1/22-32-Parisa%20Ziarati.pdf

Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake.(2017)

Table 1: Heavy metal levels in air reported in different countries

Country	**Poland**	**Pakistan**	**Spain**	**Algeria**	**Iran**	**India**	**UK**	**Nigeria**
Metal	Concentration	Concentration in	Concentration in	Concentration in	Concentration in	Concentration	Concentration	Concentration
	in air (ng/^{m3})	air (ng/^{m3})	air (ng/^{m3})	air (ng/^{m3})	air (ng/^{m3})	in air (ng/^{m3})	in air (ng/^{m3})	in air (ng/^{m3})
Pb	23.6	16.24	9.24	299	120.92	-	10.22	0.832
Cd	0.806	31.66	0.25	21.2	0.33	0.02	0.2	-
Zn	66.5	0.85	354	-	164.58	7.13	-	1.712
Ni	2.15	65.78	3.38	42.4	5.33	0.29	1.74	0.478
As	0.534	-	0.55	-	7.77	-	0.91	-
Fe	-	-		639.8	652.41	20.81	-	1.081
Co	0.271	12.69		37.7	5.13		-	-
Al	0.058	3.01	-	-	241.51	13.89	-	-

Source: https://doi.org/10.1016/j.jhazmat.2016.11.063

Table 2: Foliar heavy metal uptake by vegetables and associated health risks near industrial areas

Metal		**Vegetable**	**Concentration in atmospheric fallouts (mg cm^{-2})**	**Concentration in plant shoot (mg /kg)**	**Concentration in grains**	**GEF**	**DIM (mg kg/ day)**	**HRI**
Cd		Spinach		317.3	-	396.6	0.127	25.493
Cd		Rice		30.1	2	0.1	0.012	2.418
Cd		Lettuce	0.9	1.7		1.9	0.001	0.137
Pb		Lettuce		335		300.1	0.135	26.915
Pb		Lettuce		171.5		248.7	0.069	13.779
Pb		Lettuce	456.2	122		0.3	0.049	9.802
Pb		Spinach		485	-	79.5	0.195	38.966
Zn		Lettuce	6.9	29.1		4.2	0.012	2.338
Zn		Wheat		31.68	43.61	1.4	0.013	2.545
Zn		Spinach		144.2	-	5.7	0.058	11.585
Zn		Wheat		86.8	43.4	0.5	0.035	6.974
Sb		Lettuce	1.9	1.4		0.7	0.001	0.112
Sb		Spinach		276.3	-	50.2	0.111	22.199
Ni		Birch	58.2	4.8		0.1	0.002	0.386
Cu		Ryegrass	1.7	7		4.1	0.003	0.562
As		Lettuce	0.2	1.1		5.5	0	0.088

GEF; Global Enrichment Factor, DIM; Daily Intake of Metals, HRI; Health Risk Index

Source: https://sci-hub.tw/10.1016/j.jhazmat.2016.11.063

Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia (2016)

Table 1: Daily intakes of metals (DIM) (mg kg^{-1} person^{-1} d^{-1}) and the Health Risk Index (HRI) for individual heavy metals in food crops irrigated with sewage water

Metals	**Translocation factor AF^{a}**	**Risk assessment index**			**RDA^{b} (mg day ^{1})**	**RfD^{c} (mg kg ^{1} day ^{1})**
		DIM	HRI	THQ		
Cu	0.0122–0.0246	3.30E-03	2.20 E-03	0.873	6.0–9.0	0.2
Ni	0.1265–0.1489	3.20E-03	1.62 E-01	0.902	2.0–8.0	0.4
Mn	1.0777–1.0964	4.06E-02	2.90 E-01	1.164	1.8–2.3	0.14
Pb	1.0124–1.0429	2.85E-02	8.14 E-00	1.803	2.0–6.5	0.6
Cd	0.0991–0.1820	1.70E-03	1.67 E-00	2.904	1.8–6-8	0.5
Zn	1.1422–1.1622	4.00E-04	3.00 E-04	0.065	8.0–11.0	0.3
Fe	0.6162–0.8354	1.90E-03	9.68 E-02	0.442	8.0–18.0	0.8
Cr	1.6730–1.8240	2.28E-02	1.63 E-01	2.279	5.0–9-0	0.3

The accumulation factors of the metals in the consumed parts of the plants were less than the values obtained for Fe and Cr. Chromium, with AF values in the range of 1.6730–1.8240, was the most accumulated. Thus, the bio-concentration factor (BCF) values of metals in the food crops showed a trend in the order of Cr > Zn > Ni > Cd > Mn > Pb > Cu ≈ Fe. The best accumulators for Cr are okra plants that preferentially concentrate metals in their leaves, the consumable part of the plant.

Source: https://www.sciencedirect.com/science/article/pii/S1319562X15002181