

Cadmium Numerical Data

Effects of biochar and crop straws on the bioavailability of cadmium in contaminated soil (2020)

Table 1: Assignment of characteristic absorption bands in infrared spectra.

Absorption band position/cm ⁻¹	Absorption band assignment
650-520	Stretching vibration of -OH (carbohydrates)
870	Carbonate substance
1020-970	Stretching vibration of C-O or stretching vibration of inorganic SiO (carbohydrates)
1080-1020	Asymmetric stretching vibration of C-O (phenols or alcohols)
1170-1150	Stretching vibrations of C-OH and C-O (aliphatic)
1220-1210	Asymmetric stretching vibration of C-O or deformable vibration of N-H (hydroxyl)
1250-1230	Stretching vibration of C-O or stretching vibration of SiO in organosilicon compounds (phenols)
1460-1400	Symmetric deformable vibrations of -CH ₃ and -CH ₂ , and asymmetric stretching vibration on hydroxyl group, or stretching vibration of C-OH (aliphatic)
1555-1540	Deformable vibration of -N-H (secondary amide)
1650-1600	Stretching vibration of -C=O, stretching vibration of C=C on aromatic group or antisymmetric vibration of organic carboxylate COO- (aldehyde, ketone)
1720-1690	Stretching vibration of -C=O, stretching vibration of C=O in hydroxyl group (hydrogen bond formed between molecules and within molecules)
2870-2850	Symmetric stretching vibrations of -CH ₃ and -CH ₂
2900	Stretching vibration of C-H (aliphatic)
2930	Asymmetric stretching vibration of -CH ₂ (aliphatic)
2950	Asymmetric stretching vibration of -CH ₃ (aliphatic)
2060-3030	Stretching vibration of -C-H (aromatic nucleus)
3500-3300	Stretching vibrations of -COOH and -OH or stretching vibration of N-H and hydrogen bond association

According to Huang (2013), etc.

Table 2: Effect of biochar and crop straw addition on the biomass and yield of peanut.

Treatments	Biomass				Yield	
	Aboveground (g·plant ⁻¹)	Underground (g·plant ⁻¹)			Number of effective pods per plant	Number of seeds per plant
		Roots	Seeds	Shells		
T _{CK}	9.45 ± 1.54c	1.61 ± 0.29c	6.26 ± 0.46c	3.75 ± 0.34b	15.00 ± 0.58c	19.00 ± 1.15c
T _B	17.61 ± 2.33a	4.05 ± 0.09a	11.17 ± 0.55a	5.17 ± 0.32a	21.00 ± 0.57a	30.67 ± 0.58a
T _P	14.00 ± 1.38b	2.16 ± 0.09b	9.91 ± 1.62b	4.62 ± 1.14b	15.33 ± 1.53b	21.00 ± 1.53b
T _R	14.97 ± 1.25b	2.37 ± 0.24b	10.50 ± 0.82b	4.85 ± 0.77b	16.33 ± 0.57b	22.00 ± 1.15b

Treatments: TCK: control, TB: biochar addition, TP: peanut straw addition, TR: rice straw addition.

All values are presented as mean ± standard error (n = 3), different letters in the same row indicate significant differences between treatments (P < 0.05).

Source: <https://www.nature.com/articles/s41598-020-65631-8>

Table 1: Physiochemical properties of experimental soils, mean \pm standard deviation (n = 3)

Characteristics	Soil 1	Soil 2	Soil 3
Soil pH	5.96 \pm 0.23	5.89 \pm 1.05	6.05 \pm 0.27
Soil ORP	290.30 \pm 21.40	322.30 \pm 20.60	250.80 \pm 18.10
Available N (mg kg ⁻¹)	234.67 \pm 60.48	214.33 \pm 54.05	223.67 \pm 36.75
Available P (mg kg ⁻¹)	0.64 \pm 0.35	4.25 \pm 3.15	1.32 \pm 1.38
Available K (mg kg ⁻¹)	108.33 \pm 17.90	101.67 \pm 9.24	119.67 \pm 19.22
Total N (g kg ⁻¹)	2.38 \pm 0.33	2.12 \pm 0.31	2.28 \pm 0.14
Total P (g kg ⁻¹)	0.48 \pm 0.02	0.66 \pm 0.18	0.54 \pm 0.02
Total K (g kg ⁻¹)	13.7 \pm 0.20	14.7 \pm 0.78	13.77 \pm 0.71
OM (%)	4.66 \pm 0.90	3.79 \pm 0.39	4.26 \pm 0.49
Total Cd (mg kg ⁻¹)	9.09 \pm 0.44	10.03 \pm 0.45	9.73 \pm 1.62

Table 2: Mantel test of different environmental factors and the change of microbial community structure. The r value represents the correlation between different factors, and the p value indicates the correlation is significant

	r	p
Total factors	0.366	0.001
pH	0.447	0.001
ORP	0.163	0.006
Total Cd	0.357	0.001

Source: <https://pubs.rsc.org/en/Content/ArticleLanding/2020/RA/D0RA03935G#!divAbstract>

Mechanism of Remediation of Cadmium-Contaminated Soil with Low-Energy Plant Snapdragon (2020)

Table 1: Enrichment Factor (EF) and Translocation Factor (TF) in snapdragons under different cadmium concentrations.

	TF	EF
Control	0.60	
1.0 mg/kg Cd	0.71	0.17
2.5 mg/kg Cd	0.81	0.10

Table 2: Effects of Cd on mineral nutrient accumulation in snapdragon tissues (mg/kg, DW).

	Zn	B	P	Fe	Mn	Ca	Cu	Mo	Mg
Root									
Control	386 ^a	85 ^a	211 ^a	510 ^a	168 ^a	622 ^a	25 ^a	119 ^a	6,593 ^a
1.0 mg/kg	355 ^{ab}	59 ^{ab}	190 ^b	263 ^{ab}	134 ^{ab}	621 ^a	12 ^a	110 ^b	5,197 ^b
2.5 mg/kg	560 ^b	47 ^b	152 ^b	211 ^b	115 ^b	617 ^b	11 ^a	112 ^b	3,341 ^c
p-value	0.021	0.03	0.009	0.041	0.004	0	0.071	0.001	0.033
Shoot									
Control	17 ^a	58 ^a	145 ^a	28 ^a	32 ^a	379 ^a	11 ^a	39 ^a	1,341 ^a
1.0 mg/kg	13 ^{ab}	36 ^b	129 ^b	16 ^b	20 ^{ab}	314 ^{ab}	7 ^b	27 ^b	689 ^a
2.5 mg/kg	28 ^b	35 ^b	118 ^b	12 ^b	28 ^b	192 ^b	5 ^b	28 ^b	341 ^a
p-value	0.047	0.029	0.001	0.031	0.017	0.033	0.049	0.015	0.114

Different letters stand for statistical differences at $p \leq 0.05$.

Source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7158863/#!po=45.6522>

Cadmium Uptake by Wheat (*Triticum aestivum* L.): An Overview (2020)

Table 1: Cd concentration in wheat and soil globally.

Cd (mg/Kg) in Wheat; Average or Range	Cd (mg/Kg) in Soil; Average or Range	Soil Characteristics	Remarks	Area
0.14 (grain)	0.38	pH = 5.9 CEC (cmol/Kg) = 21.3 OM (%) = NR ** Clay (%) = 15.8	Yangmai16 *	The north of Zhejiang Province, China
0.12 (grain)	0.36	pH = 4.9 CEC (cmol/Kg) = 34.6 OM (%) = NR Clay (%) = 117.5	Yangmai16	The east of Zhejiang Province, China
3.17 (root) 1.11 (stem) 0.25 (grain)	2.06	pH = 7.5 CEC (cmol/Kg) = 7.6 OM (%) = NR Clay (%) = NR	Zhengmai7698	Henan Province, China
0.006 to 0.17 (grain)	0.09 to 1.0	pH = 6.6 CEC (cmol/Kg) = 18.2 OM (%) = 3.0 Clay (%) = NR	NR	Kunshan, China
0.247 (grain)	0.10	pH = 7.5 CEC (cmol/Kg) = NR OM (%) = NR Clay (%) = NR	-	Brandon, Manitoba, Canada
0.01 to 0.08 (grain)	0.21	pH = 5.3 CEC (cmol/Kg) = 31 OM = NR Clay (%) = NR	-	São Gotardo (MG), Brazil
0.95 (root) 0.60 (stem)	0.27	pH = 7.8 CEC (cmol/Kg) = NR OM (%) = 0.7 Clay (%) = NR	-	Khuzestan Province, Iran
0.01 to 0.02 (grain) 0.01 to 0.03 (grain)	3.2	pH = 7.6 CEC (cmol/Kg) = NR OM = 0.14 Clay (%) = 46	Rushan Falat	Qom, Iran
0.93 (grain) 0.16 (stem) 0.67 (root)	NR	pH = NR CEC (cmol/Kg) = NR OM = NR Clay (%) = NR	-	Lahore, Pakistan
0.003 to 0.03 (grain)	NR	pH = NR CEC (cmol/Kg) = NR OM = NR Clay (%) = NR	-	Sydney, Australia

* Local names; ** not reported.

Table 2: Gene families and channels involved in the Cd uptake, transport, and metabolism in wheat.

Name	Remarks
<i>AtIRT1</i>	A plasma membrane transporter. Involved in entrance of Cd into root.
<i>TcZNT1</i>	Involved in entrance of Cd to root.
<i>OsNRAMP1</i>	Cd-influx transporter in the plasma membrane. Involved in entrance of Cd into root.
<i>OsNRAMP5</i>	Cd-influx transporter in the plasma membrane. Involved in entrance of Cd into root.
<i>AtNRAMP6</i>	An intracellular metal transporter. Involved in entrance of Cd into root.
<i>TaLCT1</i>	An influx transporter in wheat. Involved in entrance of Cd into root.
<i>YSL</i>	A kind of oligopeptide transporter. Involved in entrance of Cd into root over Cd-chelates across plant cell membranes.
<i>P_{1B}-ATPases</i>	A group of ubiquitous membranes. Transporting Cd from root to shoot.
<i>CNGC gene family</i>	Ca ²⁺ channels in root protoplast plasma membrane. Indirectly involved in entrance of Cd into root. Responsible for coding of HACCs, VICCs, and DACCs *.
DACCs	Ca ²⁺ channels. Involved in entrance of Cd into root.
HACCs	Ca ²⁺ channels. Involved in entrance of Cd into root.
VICCs	Ca ²⁺ channels. Involved in entrance of Cd into root.

* Depolarization-activated calcium channels (DACCs), hyper polarization-activated calcium channels (HACCs) and voltage-insensitive cation channels (VICCs).

Table 3: Reported methods for decreasing the uptake of Cd by wheat plants.

Decreasing of Cd Accumulation in Root/Stem or Straw/Grains	Cd Concentration in Wheat after Treating (mg/Kg)	Method	Remarks
48.3% (in straw) 97.8% (in grain)	0.80 (in shoot) 0.01 (in grain)	Using rice husk biochar	Mixing silicon-rich biochar with soil
54% (in root) 50% (in shoot) 65% (in grains)	2.0 (in root) 1.1 (in shoot) 0.2 (in grain)	Using co-composted farm manure and biochar	Mixing organic amendments with soil
69% (in root) 67% (in shoot) 62.5% (in grains)	12 (in root) 2.7 (in shoot) 0.15 (in grain)	Using rice husk biochar	Mixing biochar with soil
55% (in root) 51% (in shoot)	1.2 (in root) 0.7 (in shoot)	Using biochar	Mixing biochar with soil under stress conditions
57% (in grains)	0.2 (in grain)	Using biochar	Mixing biochar (5%) with soil
97% (in straw)	>0.2 (in straw)	Using limestone + biochar	Mixing limestone + biochar with soil
77% (in grains)	1.1–0.2 (in grain)	Using zinc oxide nanoparticles	Foliar application
55% to 69% (in root)	1–0.6 (in root)	Using zinc	Using ZnSO ₄ in nutrient solution
7%–24% (in root) 13%–37% (in stem) 13%–50% (in grains)	4–3 (in root) 3.8–2.2 (in stem) 0.2–0.9 (in grain)	Using zinc	Foliar application
10%–31% (in root) 27%–52% (in shoot) 33%–70% (in grains)	2.7–2.0 (in root) 1.6–0.9 (in shoot) 0.5–0.2 (in grain)	Using zinc–lysine	Foliar application
19%–64% (in root) 11%–53% (in shoot) 20%–82% (in grains)	12–5 (in root) 6–2 (in shoot) 1.1–0.3 (in grains)	Using silicon nanoparticles	Foliar application
30% (in shoot)	1.2 (in shoot)	Using inorganic silicon fertilizer	Mixing the fertilizer with soil
24% (in grains)	0.35 (in grain)	Using sodium sulfate	Mixing with soil
40% (in root)	NR	Using bacteria	Using <i>Ralstonia eutropha</i> Q2-8

* NR = Not reported.

Source: <https://www.mdpi.com/2223-7747/9/4/500/htm>

Toxicity of cadmium and its competition with mineral nutrients for uptake by plants: A review (2020)

Table 1: Cadmium contents in primary pollution sources regarding farmland soils^{a)}

Pollution source	mg kg ⁻¹ /mg L ⁻¹ /ng L ⁻¹ /μg L ⁻¹ product ^{b)}	mg kg ⁻¹ P
Fertilizer		
Complete fertilizer	23–29	418–527
Single superphosphate	16–26	186–302
Superphosphate	13–34	151–395
Rock phosphate	7.2–47	54–303
High-analysis fertilizer	< 0.6–5.6	15–118
Double superphosphate	< 0.6–12	< 3.6–72
Triple superphosphate	0.8–7.0	24–35
Mono-ammonium phosphate	1.8–8.1	12–37
Di-ammonium phosphate	4.3–6.6	22–28
Sewage Suldge	5.0–3.32	–c)
Organic manures	0.1–11	-
Irrigation waste water	0.05–0.35	-
Atmospheric deposition		
Dry deposition	0.03–8	-
Wet deposition	0.01–52	-

a)Data adapted from Kidd et al. (2007), Connan et al. (2013), Jiang et al. (2014), Nookabkaew et al. (2016), and Kumarpandit et al. (2017).

b)Unit for Cd content is mg kg⁻¹ except that in irrigation waste water, dry deposition, and wet deposition which is mg L⁻¹, ng m⁻³, μg L⁻¹, respectively.

c)Not applicable.

Table 2: Summary of transporters related to Cd uptake and transport

Transporter	Metal	Plant species	Tissue expression/subcellular localization	References
AtCAX2	Cd/Mn/Ca	Arabidopsis	Vacuolar membrane	Hirschi et al., 2000; Shigaki and Hirschi, 2006
AtCAX4	Cd/Ca	Arabidopsis	Vacuolar membrane	Cheng et al., 2002
AtHMA2	Cd/Zn	Arabidopsis	Plasma membrane	Hussain et al., 2004; Verret et al., 2004
AtHMA3	Cd/Zn/Cu/Pb	Arabidopsis	Vacuolar membrane	Morel et al., 2009
AtHMA4	Cd/Zn/Pb/Co	Arabidopsis	Plasma membrane	Verret et al., 2004; Mills et al., 2005
AtATM3	Cd/Pb	Arabidopsis	Mitochondrial membrane	Kim et al., 2006
AtNRAMP6	Cd	Arabidopsis	Leaves and flowers	Cailliatte et al., 2009
AtPDR8	Cd/Pb	Arabidopsis	Root hairs/epidermal cells	Kim et al., 2006
OsNRAMP5	Cd/Mn	Rice	Roots/plasma membrane	Sasaki et al., 2012
OsHMA2	Cd/Zn	Rice	Roots/plasma membrane	Satoh-Nagasawa et al., 2011; Takahashi et al., 2012; Yamaji et al., 2013
OsHMA3	Cd	Rice	Root/Tonoplast	Ueno et al., 2010; Miyadate et al., 2011
OsIRT1	Cd/Fe	Rice	Roots	Nakanishi et al., 2006
OsIRT2	Cd/Fe	Rice	Roots	Nakanishi et al., 2006
OsLCT1	Cd	Rice	Leaf nodes/plasma membrane	Uraguchi et al., 2011
OsLCD	Cd	Rice	Vascular tissues in roots and phloem companion cells in leaves	Shimo et al., 2011
OsNRAMP1	Cd/Fe	Rice	Plasma membrane	Takahashi et al., 2011
OsNMP5	Cd/Mn/Fe	Rice	Plasma membrane	Ishimaru et al., 2012
OsZIP1	Cd/Zn	Rice	Roots	Ramesh et al., 2003
ZNT1	Cd/Zn	<i>Thlaspi caerulescens</i>	Roots and shoot	Pence et al., 2000

Source: <https://www.sciencedirect.com/science/article/abs/pii/S1002016020600029>

Organic soil additives for the remediation of cadmium contaminated soils and their impact on the soil-plant system: A review (2020)

Table 1: Some selected references of Cd contamination world-wide exceeding permissible limits.

Country (City)	Cd (mg kg ⁻¹)	Allowable limit (country)	Soil pH	References
Spain (Barakaldo)	4.5	1 (mg kg ⁻¹)	8.74	Galdames et al. 2017
Spain (Azkoitia)	0.40	1 (mg kg ⁻¹)	7.5	Galdames et al. 2017
China (Tianjin)	2.1	≤0.60 (mg kg ⁻¹)	7.4	Wang et al. 2017
China (Yixing)	5	≤0.30 (mg kg ⁻¹)	5.36	Bian et al. 2014
China (Xinxiang)	0.88	≤0.60 (mg kg ⁻¹)	8.3	Li et al. 2016
China (Xiangtan)	1.42	≤0.30 (mg kg ⁻¹)	5.01	Shi et al. 2019
China (Youxi)	15.44	≤0.30 (mg kg ⁻¹)	5.70	Chen et al. 2016
Belgium (Sclaigneaux)	24	≤10 (mg kg ⁻¹)	6.57	Houben et al. 2013
Austria (Arnoldstein)	12.5	≤10 (mg kg ⁻¹)	5.97	Karer et al. 2015
Czech Republic (Trhové Dušníky)	42.7	≤10 (mg kg ⁻¹)	6.6	Břendová et al. 2015
Nigeria	0.00 to 1.02	3 (µg g ⁻¹)	5.14–6.73	Diagboya et al. 2015
New Zealand	0.79	3 (mg kg ⁻¹)	6.3	Stafford et al. 2018
New Zealand	0.61	3 (mg kg ⁻¹)	5.6	Stafford et al. 2018
Pakistan (Multan)	7.35	0.6 (mg kg ⁻¹)	7.23	Rehman et al. 2017
Pakistan (Multan)	3.02	0.6 (mg kg ⁻¹)	7.25	Qayyum et al. 2017
Korea (Seosan)	17	b4 (mg kg ⁻¹)	6.3	Ok et al. 2011
Malaysia (Kuala Lumpur)	5.20	0.80 (mg kg ⁻¹)	7.83	Ashrafi et al. 2015
Egypt (Gharbia)	122	≤10 (mg kg ⁻¹)	7.89	Mahmoud and Nasser, 2016
Iran (Zanjan)	41.2	0.80 (mg kg ⁻¹)	7.19	Abbaspour and Ahmad, 2011
United Kingdom (Staffordshire)	119	1.8 (mg kg ⁻¹)	6.2	Beesley and Marmiroli, 2011

Table 2: Biochar as an adsorbent of cadmium.

Biochar type	Pyrolysis temperature and time	Chemical composition of biochar	Instruments used	Adsorbed compound and extraction method	Efficiency	Mechanisms involved	References
Rice straw biochar	500 °C (2 h)	C 54% and N 1.6%, PO ₄ ³⁻ 8.02 mg g ⁻¹ , CO ₃ ²⁻ 10.3 mg g ⁻¹ , Ca ²⁺ 9.69 mg g ⁻¹ , Mg ²⁺ 2.32 mg g ⁻¹	Atomic absorption spectrophotometer	Cd, Pb (BCR fraction, TCLP and CaCl ₂)	Acid-soluble Cd reduced by (27.5–34.8%), TCLP extract (14.7–16.9%), CaCl ₂ (28–32%)	Surface functional groups (hydroxyl, carboxylic, phenolic), adsorption	Bashir et al. 2018a
Sugar cane bagasse feedstock biochar	500 °C (2 h)	C% 640, Total N ⁻¹ 11.40 g kg ⁻¹ , Total P ⁻¹ 16.21 g kg ⁻¹ , Total P ⁻¹ 23.92 g kg ⁻¹ ,	AAS, spectrophotometer	Cd, Cr (DTPA-extracted)	Cd concentration decreased in mash beans tissues by 28.74 and 32% in Cd- and Cr-Cd-contaminated soil	Insoluble mineral formation through complexation and precipitation	Bashir et al. 2018b
Oil palm fibers biochar	700 °C (4 h)	C% 86.7, O% 3.2, H% 1.8, K% 1.3,	ICP-AES, hydrogen generation-atomic fluorescence spectrometer, graphite furnace atomic absorption	Cd, As (Metals fractionation), DCB solution	Cd and As in rice grains were decreased by 93% and 61%	Biochar's liming effect leads to the raise in soil pH, which can greatly reduce the mobility and bioavailability of Cd	Qiao et al. 2018

Wheat straw biochar	485 °C	Total N ₁ 5.9 g kg ⁻¹ , Total P ₁ 4.4 g kg ⁻¹	spectrometer. Atomic absorption spectrometry using a graphite furnace (GFAAS)	Cd, Pb (CaCl ₂),	Biochar addition reduced Cd by 30 and 5% and Pb by 50 and 19%	An increase in soil pH contributed to the decrease in Cd and Pb mobility	Sui et al. 2018
Chicken manure biochar	550 °C	pH 7.5, Cd 1.3 mg kg ⁻¹	ICP-OES, ICP-MS	AS, Cd (1 M NH ₄ NO ₃ extraction)	higher amounts of Cd are extracted by NH ₄ NO ₃	Processes involved (the decline in pH, Cd desorption by NH ₄ ⁺ and the formation of soluble metal-complexes)	Rocco et al. 2018
Rice straw biochar	400 °C (2 h)	Organic carbon 62.5%, Total N 1.38%, Total P 0.65%, Total K 1.18%	X-ray diffraction, FTIR, scanning electron microscopy (atomic absorption)	Cd, Pb	76.8% and 74.2% reduction in Cd and Pb accumulation by canola shoots	Presence of functional groups (C=NH, C-C-C, Al-OH-Fe, i-O-Si, O-P-O, C-OH and C=CC)	Mahmoud et al. 2018
Malaysian Palm Oil Board biochar	250 °C	pH 9.33, Total C (%) 61.87, N (%) 1.096	ICP-OES, Atomic adsorption spectrometry, ICP-OES	Cd, Pb (SRW-extractable)	Cd and Pb significantly decreased with the increasing incubation time	Oxygen-containing functional groups, which are expected to be more effective in retaining heavy metals	Fahmi et al. 2018
Rice straw biochar	450 °C and 550 °C	pH 10.0, C 42.3%, N 1.5%, P 0.3%, K 2.54%	Atomic absorption spectrophotometer	Cd (AB-DTPA extractable)	Cd was lowered by 46%, 45%, and 55% in roots, shoots and grains and BC application reduced bioavailable Cd in soil	The decreased Cd contents may be attributed to increased concentration of organic matter. While, abridged seed Cd may be due to plant high which can hold Cd in shoots and roots.	Abbas et al. 2018
Scot pine and silver birch biochar	450 °C (2 h and 45 min) 700 °C (2 h and 45 min)	pH 8.56, TC (%) 96.3 pH 8.69, TC (%) 95	Atomic absorption spectrophotometer, flame atomic absorption spectrophotometer (FAAS), SEM	Cd, Cu, Pb, Zn	Increase in metals concentration resulted occupying available adsorption sites	Higher cation exchange capacity and increase of specific surface area	Komkiene and Baltrenaitė 2016
Wheat straw biochar	450 °C	Organic Matter (g kg ⁻¹) 467.2, CEC (cmol kg ⁻¹) 21.70, Total N (g kg ⁻¹)	SEM, X-ray spectroscopy, FTIR spectra	Cd, Pb (BCR)	Exchangeable fractions of Cd and Pb were significantly decreased	Decreased content may be attributed to the dilution effect of the amendment	Cui et al. 2016

Bamboo biochar	750 °C (3 h)	5.90 Nitrogen (g kg ⁻¹) 4.5, cation exchange capacity (cmol kg ⁻¹) 15	XRD and FTIR spectroscopy,	Cd, Cu, Pb and Zn (CaCl ₂ and DTPA extraction), Sequential extraction	5% rice straw biochar was more effective in reducing CaCl ₂ and DTPA extractable metals	Possible mechanism (the formation of precipitates, increases in the specific adsorption of metals, increases in electrostatic interactions).	Lu et al. 2017
Peanut shell biochar	350–500 °C	pH(H ₂ O) 9.95, Total C (g kg ⁻¹) 133.7, Total Cd (mg kg ⁻¹) 0.123	FAAS	Cd, Pb (sequential extraction)	Cd and Pb concentrations in rice roots were lower by 50.8 and 22.6% using PBC	Biochar enhanced soil pH, which led to the precipitation of Cd and Pb as CdCO ₃ and Pb ₅ (PO ₄) ₃ OH	Xu et al. 2018
Rice straw biochar	500 °C (3 h)	pH 9.5, total organic C 29.3 g kg ⁻¹ , N 1.83%, P 1.43%, K 18.9%	ICP-MS	Cd (EDTA extraction, sequential extraction)	Bioavailable Cd decreased from 0.45 and 0.85 mg kg ⁻¹ to 0.05 and 0.39 mg kg ⁻¹	Biochar transforms soluble Cd to stable form, especially formation of metal (hydr)oxide, carbonate	Run-Hua et al. 2017

Source: <https://www.sciencedirect.com/science/article/abs/pii/S0048969719361170>

Remediation of Cadmium-Polluted Soil Using Plant Growth-Promoting Rhizobacteria and Natural Zeolite (2020)

Table 1: Mass of barley plants and Cd content in the plants in the earing phase (experiment 1)

Variant	Plant weight (dry matter), g/pot	Cd content in plants, mg/kg dry mass
Vegetative mass		
Control – NPK	2.16 ± 0.05a	Traces
Cd + NPK	2.21 ± 0.03a	7b
Cd + <i>P. fluorescens</i> 21 + NPK	2.14 ± 0.04a	3a
Roots		
Control – NPK	0.52 ± 0.06a	Traces
Cd + NPK	0.54 ± 0.05a	81
Cd + <i>P. fluorescens</i> 21+ NPK	0.62 ± 0.07b	71

Mean data on four replicates of the experiment ± confidence interval are reported. Errors in determining the Cd content in plants did not exceed 15%. The values indicated by different letters differed at a significance level of 5%.

Table 2: Mass of barley plants and Cd content in the plants in the full ripeness phase (experiment 2)

Variant	Plant weight (dry matter), g/pot				Cd content in plants, mg/kg dry mass		
	grain	straw	roots	total	grain	straw	roots
Control – NPK	33.6	33.4	3.7	70.7	Not detected		
Cd + NPK	25.9	29.9	3.7	59.5	2	18	143
Cd + <i>P. fluorescens</i> 21 + NPK	32.4	37.3	4.4	74.0	2	17	88
Cd + <i>P. putida</i> 23 + NPK	33.7	36.5	5.4	75.6	2	19	90
Cd + zeolite + NPK	32.9	33.7	4.8	71.5	2	16	120
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	35.3	37.4	5.6	78.3	2	15	100
LSD ₀₅	3.0	3.7	1.5	10.0	1.0	3.0	11.1

Table 3: Removal of Cd by barley plants in the phase of full ripeness (experiment 2)

Variant	Cd removal by plants				
	grain	straw	roots	total	
	μg/pot			mg/pot	% of added Cd
Control – NPK	Not det.	Not det.	Tr.	Tr.	Tr.
Cd + NPK	52	538	529	1.1	2.2
Cd + <i>P. fluorescens</i> 21 + NPK	65	634	387	1.1	2.2
Cd + <i>P. putida</i> 23 + NPK	68	694	486	1.2	2.5
Cd + zeolite + NPK	66	539	576	1.2	2.4
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	71	561	560	1.2	2.4
LSD ₀₅	8	75	69	0.2	

Table 4: Reaction of the soil medium after barley growing

Experiment no.	Phase of plant development	Variant	pH _{KCl}
1	Earing	Control – NPK	5.13 ± 0.09a
		Cd + NPK	5.23 ± 0.07b
		Cd + <i>P. fluorescens</i> 21 + NPK	5.23 ± 0.08b
2	Full ripeness	Control – NPK	5.31 ± 0.07a
		Cd + NPK	5.47 ± 0.08b
		Cd + <i>P. fluorescens</i> 21 + NPK	5.42 ± 0.09b
		Cd + <i>P. putida</i> 23 + NPK	5.31 ± 0.06a
		Cd + zeolite + NPK	5.27 ± 0.05a
		Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	5.32 ± 0.05a

Table 5: The contents of biophilous elements in barley plants in the phase of full ripeness (experiment 2)

Variant	N	P	K	Ca	Mg	Fe	Zn	M n	Cu
	%				mg/kg plant matter				
	Grain								
Control – NPK	1.59	0.41	0.56	0.05	0.02	66	56	22	8
Cd + NPK	1.68	0.44	0.58	0.04	0.02	85	52	18	8
Cd + <i>P. fluorescens</i> 21 + NPK	1.42	0.47	0.59	0.03	0.02	95	51	18	8
Cd + <i>P. putida</i> 23 + NPK	1.51	0.47	0.57	0.04	0.02	87	52	21	9
Cd + zeolite + NPK	1.42	0.45	0.58	0.03	0.02	100	53	20	8
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	1.50	0.50	0.58	0.04	0.02	101	52	18	9
	Straw								
Control – NPK	0.37	0.04	2.5	0.07	0.01	100	20	98	8
Cd + NPK	0.41	0.06	2.1	0.09	0.01	100	26	78	8
Cd + <i>P. fluorescens</i> 21 + NPK	0.37	0.07	2.1	0.08	0.01	110	32	87	8
Cd + <i>P. putida</i> 23 + NPK	0.42	0.07	2.4	0.06	0.01	110	51	108	9
Cd + zeolite + NPK	0.43	0.05	1.9	0.07	0.01	123	36	94	8
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	0.35	0.06	2.0	0.06	0.01	125	38	89	8
	Roots								
Control – NPK	1.30	0.17	0.19	0.32	0.05	1900	203	151	23
Cd + NPK	0.97	0.18	0.40	0.32	0.05	1700	240	110	33
Cd + <i>P. fluorescens</i> 21 + NPK	1.03	0.15	0.25	0.33	0.07	1600	185	126	27
Cd + <i>P. putida</i> 23 + NPK	1.15	0.16	0.24	0.34	0.06	1800	210	124	28
Cd + zeolite + NPK	1.17	0.16	0.36	0.33	0.06	1600	230	108	27
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	1.00	0.15	0.36	0.33	0.06	1800	257	127	29

The mean of four replicated. Errors in the determination of macro- and microelements for the variants did not exceed 5 and 15%, respectively.

Table 6: Removal of biophilous elements by barley plants in the full ripeness phase (experiment 2)

	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
Variant	Grain								
	mg/pot						µg/pot		
Control – NPK	534	138	188	17	6.7	2.2	1.9	739	269
Cd + NPK	435	114	195	10	5.2	2.2	1.4	518	207
Cd + <i>P. fluorescens</i> 21 + NPK	460	152	191	10	6.5	3.1	1.7	583	201
Cd + <i>P. putida</i> 23 + NPK	509	159	192	14	6.7	3.0	1.8	708	291
Cd + zeolite + NPK	467	148	191	10	6.5	3.2	1.7	592	263
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	530	177	205	14	7.0	3.6	1.8	638	318
	Entire plant								
	mg/pot						µg/pot		
Control – NPK	707	157	1030	52	11.9	12.6	3.2	4.6	622
Cd + NPK	594	139	838	49	10.0	11.4	3.1	3.3	567
Cd + <i>P. fluorescens</i> 21 + NPK	643	185	985	55	13.3	14.4	3.7	4.3	708
Cd + <i>P. putida</i> 23 + NPK	724	194	1080	54	13.6	18.6	4.8	5.3	777
Cd + zeolite + NPK	668	173	848	50	12.8	15.6	4.0	4.3	663
Cd + <i>P. fluorescens</i> 21 + zeolite + NPK	717	208	953	54	14.0	18.2	4.6	4.7	778

The values exceeding those for the Cd-contaminated soil without application of bacteria and zeolite at the significance level of 5% are shown in bold.

Source: <https://link.springer.com/article/10.1134/S1064229320060113>

Potential use of king grass (*Pennisetum purpureum* Schumach. × *Pennisetum glaucum* (L.) R.Br.) for phytoextraction of cadmium from fields (2020)

Table 1: Effects of intercropping with accumulator plants and application of their straw on the biomass of *B. chinensis* in Cd-contaminated soil.

Treatments	Roots (g/plant DW)	Shoots (g/plant DW)	Root/shoot ratio
Experiment 1			
Monoculture	0.36 ± 0.01a	1.70 ± 0.07a	0.21 ± 0.01b
Intercropping with <i>S. media</i>	0.25 ± 0.01c	1.23 ± 0.01d	0.20 ± 0.01b
Intercropping with <i>C. hirsute</i>	0.24 ± 0.01c	1.06 ± 0.03e	0.22 ± 0.02a
Intercropping with <i>C. glomeratum</i>	0.29 ± 0.01b	1.43 ± 0.05b	0.20 ± 0.01b
Intercropping with <i>G. aparine</i>	0.28 ± 0.01b	1.34 ± 0.03c	0.21 ± 0.01b
Experiment 2			
Control	0.33 ± 0.02a	1.81 ± 0.01a	0.18 ± 0.01b
Application of <i>S. media</i>	0.28 ± 0.01d	0.92 ± 0.01e	0.30 ± 0.02a
Application of <i>C. hirsute</i>	0.31 ± 0.01b	1.68 ± 0.01b	0.18 ± 0.01b
Application of <i>C. glomeratum</i>	0.28 ± 0.01c	1.00 ± 0.01d	0.28 ± 0.02a
Application of <i>G. aparine</i>	0.30 ± 0.01b	1.52 ± 0.01c	0.20 ± 0.01b

Table 2: Effects of intercropping with accumulator plants and application of their straw on the water content of *B. chinensis* in Cd-contaminated soil

Treatments	Roots (%)	Shoots (%)
Experiment 1		
Monoculture	83.16 ± 0.05a	90.21 ± 0.12b
Intercropping with <i>S. media</i>	76.76 ± 0.09d	88.00 ± 0.14c
Intercropping with <i>C. hirsute</i>	69.99 ± 0.07e	88.12 ± 0.16c
Intercropping with <i>C. glomeratum</i>	80.88 ± 0.02b	90.48 ± 0.13a
Intercropping with <i>G. aparine</i>	78.88 ± 0.03c	89.99 ± 0.17b
Experiment 2		
Control	79.56 ± 0.16a	90.38 ± 0.07a
Application of <i>S. media</i>	78.82 ± 0.03b	87.53 ± 0.07e
Application of <i>C. hirsute</i>	78.28 ± 0.11c	88.34 ± 0.04c
Application of <i>C. glomeratum</i>	78.93 ± 0.20b	87.98 ± 0.16d
Application of <i>G. aparine</i>	78.88 ± 0.17b	89.21 ± 0.12b

Table 3: Effects of intercropping with accumulator plant and application of their straw on the photosynthetic pigment of *B. chinensis* in Cd-contaminated soil

Treatment	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)	Chlorophyll a/b	Carotenoid (mg/g)
Experiment 1					
Monoculture	0.648 ± 0.002a	0.131 ± 0.004a	0.779 ± 0.006a	4.960 ± 0.036d	0.247 ± 0.002a
Intercropping with <i>S. media</i>	0.499 ± 0.009d	0.083 ± 0.003c	0.582 ± 0.011d	6.014 ± 0.011a	0.184 ± 0.003c
Intercropping with <i>C. hirsute</i>	0.479 ± 0.006d	0.091 ± 0.007c	0.570 ± 0.001d	5.312 ± 0.040b	0.179 ± 0.005c
Intercropping with <i>C. glomeratum</i>	0.578 ± 0.014b	0.111 ± 0.004b	0.689 ± 0.017b	5.232 ± 0.043c	0.207 ± 0.005b
Intercropping with <i>G. aparine</i>	0.544 ± 0.003c	0.117 ± 0.003b	0.661 ± 0.006c	4.662 ± 0.036e	0.201 ± 0.002b
Experiment 2					
Control	0.675 ± 0.016a	0.132 ± 0.008a	0.807 ± 0.008a	5.111 ± 0.011c	0.246 ± 0.007a
Application of <i>S. media</i>	0.426 ± 0.019d	0.068 ± 0.006c	0.494 ± 0.012d	6.273 ± 0.022a	0.163 ± 0.009c
Application of <i>C. hirsute</i>	0.631 ± 0.001b	0.125 ± 0.007a	0.756 ± 0.009b	5.044 ± 0.026d	0.232 ± 0.007a
Application of <i>C. glomeratum</i>	0.544 ± 0.004c	0.102 ± 0.005b	0.646 ± 0.009c	5.344 ± 0.040b	0.201 ± 0.008b
Application of <i>G. aparine</i>	0.547 ± 0.010c	0.109 ± 0.002b	0.656 ± 0.007c	5.030 ± 0.023d	0.201 ± 0.003b

Table 4: Effects of intercropping with accumulator plant and application of their straw on Cd content of *B. chinensis* in Cd-contaminated soil.

Treatment	Roots (mg/kg)	Shoots (mg/kg)	Translocation factor (TF)	Root bioconcentration factor (root BCF)	Shoot bioconcentration factor (shoot BCF)
Experiment 1					
Monoculture	3.54 ± 0.22d	1.75 ± 0.02c	0.49 ± 0.03ab	0.51 ± 0.03d	0.25 ± 0.00c
Intercropping with <i>S. media</i>	3.86 ± 0.08c	1.77 ± 0.04c	0.46 ± 0.00bc	0.55 ± 0.01c	0.25 ± 0.01c
Intercropping with <i>C. hirsute</i>	4.43 ± 0.20b	2.24 ± 0.05a	0.51 ± 0.01a	0.63 ± 0.03b	0.32 ± 0.01a
Intercropping with <i>C. glomeratum</i>	4.05 ± 0.07c	2.08 ± 0.13b	0.51 ± 0.02a	0.58 ± 0.01c	0.30 ± 0.02b
Intercropping with <i>G. aparine</i>	4.81 ± 0.12a	2.29 ± 0.03a	0.48 ± 0.01 b	0.69 ± 0.02a	0.33 ± 0.00a
Experiment 2					
Control	3.74 ± 0.18b	1.90 ± 0.12b	0.51 ± 0.01b	0.53 ± 0.03b	0.27 ± 0.02b
Application of <i>S. media</i>	3.88 ± 0.09b	1.93 ± 0.07b	0.50 ± 0.02b	0.55 ± 0.01b	0.28 ± 0.01b
Application of <i>C. hirsute</i>	4.30 ± 0.08a	2.46 ± 0.07 a	0.57 ± 0.02a	0.61 ± 0.01a	0.35 ± 0.01a
Application of <i>C. glomeratum</i>	2.64 ± 0.03c	1.10 ± 0.05d	0.42 ± 0.02c	0.38 ± 0.00c	0.16 ± 0.01c
Application of <i>G. aparine</i>	2.83 ± 0.14c	1.25 ± 0.04c	0.44 ± 0.01c	0.40 ± 0.02c	0.18 ± 0.01c

Source: <https://link.springer.com/article/10.1007/s11356-020-09148-7>

Cadmium-induced changes in the growth and oxidative metabolism of pea plants (2019)

Table : Effect of Cd treatment on photosynthesis, water use efficiency and transpiration of pea plants

Cd (mM)	Photosynthesis rate	Water use	Transpiration rate
	(mM H ₂ O m ⁻² s ⁻¹)	efficiency (nmol CO ₂ mM ⁻¹ H ₂ O)	(mM H ₂ O m ⁻² s ⁻¹)
0	12.20 a	4872 a	2.52 a
10	8.48 b	3970 b	2.14 b
20	6.46 c	3625 c	1.79 c
30	5.03 d	3052 d	1.65 d
40	4.14 e	2492 e	1.66 d
50	1.84 f	1318 f	1.42 e

Values are means of 12 replicates. Values followed by the same letter are not significantly different (P<0.05) as determined by Duncan's multiple range test.

The growth inhibition of pea plants was accompanied by a significant decrease in the photosynthesis rate, which was about six times reduced at the highest Cd concentration in comparison with control plants. The transpiration rate and water use efficiency were also affected by Cd treatment, undergoing a significant and progressive decrease with increasing Cd concentrations in the nutrient solution. The transpiration rate and water use efficiency were also affected by Cd treatment, undergoing a significant and progressive decrease with increasing Cd concentrations in the nutrient solution.

Source: <http://sci-hub.tw/10.1093/jexbot/52.364.2115>

Cadmium-induced changes in the growth and oxidative metabolism of pea plants (2019)

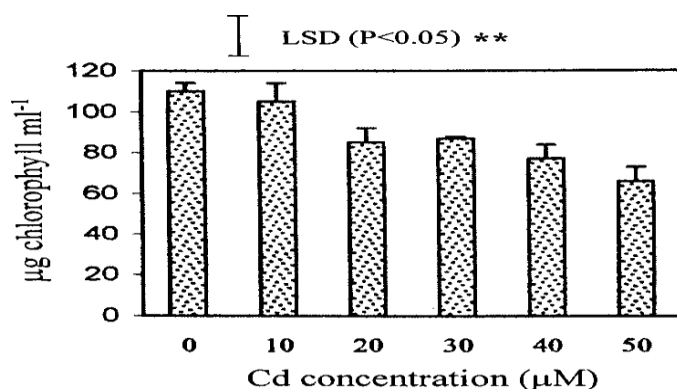
Table: Effect of Cd treatment on growth of pea plants

Cd (mM)	Leaves (g DW)	Roots (g DW)	Leaf area (cm ²)
0	9.95 a	5.98 ab	4340 a
10	8.69 a	6.14 ab	3861 a
20	6.98 b	6.76 a	3013 b
30	6.23 bc	6.70 a	2633 b
40	5.36 c	5.80 ab	2410 b
50	3.89 d	4.39 c	1595 c

Increasing concentrations of Cd in the nutrient solution produced a significant growth inhibition of pea plants, measured as dry weight (Table), the greatest adverse effect being on leaves while root growth was only significantly affected by 50 mM CdCl₂ (Table). The decrease in dry weight of leaves was parallel to a reduction in the leaf area (Table) but no visible symptoms of toxicity, except growth reduction, were observed.

Source: <https://www.ncbi.nlm.nih.gov/pubmed/11604450>

Effect of Cd treatment on the chlorophyll content of pea leaf extracts.(2019)



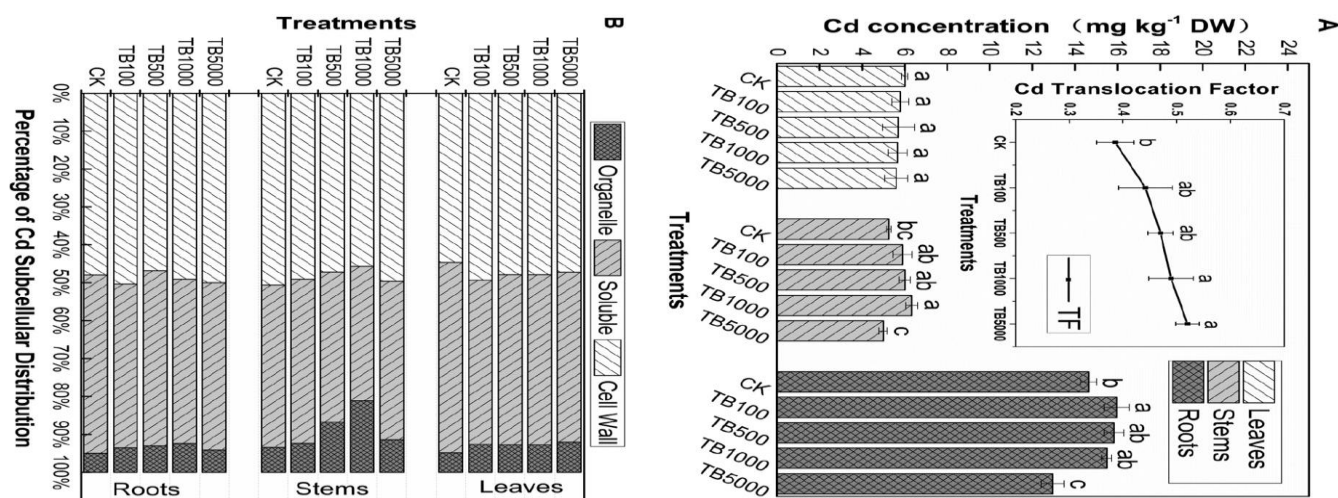
Pea plants were grown with different Cd concentrations (0–50 mM) as described in Materials and methods. Each rectangle represents the mean^aSEM of three replicates. Vertical bars indicate LSD (P<0.05) as determined by the Duncan's multiple-range test.

The chlorophyll content was also affected by Cd, showing a reduction which was proportional to the Cd concentration in the nutrient solution.

Source: <https://www.ncbi.nlm.nih.gov/pubmed/11604450>

Biochar facilitated the phytoremediation of cadmium contaminated sediments: Metal behavior, plant toxicity, and microbial activity(2019)

Cd behaviour in the plants changed by (tea waste derived biochar) TB : Metal behavior in the plants influenced by biochar



The influence of TB on the bio-accumulation and translocation of Cd in ramie seedlings was shown in Fig A. The application of TB increased Cd concentration in ramie roots compared with control, with the exception of the TB5000 treatments, in which the concentration of Cd decreased significantly. Similar to what was observed in roots, TB at 100, 500 and 1000 mg kg⁻¹ increased Cd concentration in ramie stems by 12-20%, whereas the 5000 mg kg⁻¹ TB reduced Cd concentration by 5% relative to the control. However, no statistical difference in Cd concentration was observed in ramie leaves whether the seedlings were treated with TB or not. The TF value of Cd in ramie seedlings increased with increasing the concentration of TB (Fig.A) whereas, the subcellular distribution of Cd in ramie seedlings was influenced by the application of TB (Fig.B).

Source: <http://sci-hub.tw/https://doi.org/10.1016/j.scitotenv.2019.02.215>

Cadmium tolerance and phytoremediation potential of acacia (*Acacia nilotica* L.) under salinity stress (2018)

Table 1: Effects of various levels of Cd and salinity on growth parameters (plant height, stem diameter, number of branches per plant, root length, shoot dry weight, root dry weight) of *A. nilotica* in a pot experiment.

Cd and salinity levels	Plant height (cm)	Stem diameter (cm)	Branches (plant ⁻¹)	Root length (cm)	Shoot dry weight (g plant ⁻¹)	Root dry weight (g plant ⁻¹)
Control	81 § 4.04 a	1.2 § 0.04 a	16 § 0.57 a	80 § 3.0 a	37 § 2.0 a	15.7 § 0.66 a
Cd-0-NaCl-0.5	74 § 2.30 b	1.12 § 0.02 b	15 § 0.57 ab	72 § 1.15 bc	32 § 1.0 bc	13.3 § 0.57 bc
Cd-0-NaCl-1.0	59 § 3.71 d	1 § 0.04 c	13 § 0.67 cd	65 § 1.66 d	23 § 1.45 e	11 § 0.88 e
Cd-5-NaCl-0	76.8 § 1.92 ab	1.17 § 0.05 ab	15 § 0.57 ab	77.2 § 3.28 ab	36 § 0.57 a	15 § 0.66 a
Cd-5-NaCl-0.5	72.3 § 1.76 bc	1.02 § 0.04 c	13.3 § 0.57 c	67.3 § 2.84 cd	30 § 0.57 cd	12.5 § 0.57 cd
Cd-5-NaCl-1.0	57 § 1.85 d	0.9 § 0.02 d	12.5 § 0.3 cd	56.2 § 1.15 e	20 § 0.88 f	9.6 § 0.66 f
Cd-10-NaCl-0	74.3 § 1.45 b	1.11 § 0.03 b	13.7 § 0.7 b	74.2 § 2.72 b	34 § 1.52 ab	14 § 0.33 ab
Cd-10-NaCl-0.5	65 § 3.48 cd	0.89 § 0.04 d	12.7 § 0.66 cd	62.2 § 2.88 de	28 § 0.57 d	11 § 0.33 e
Cd-10-NaCl-1.0	50 § 3.2 e	0.8 § 0.03 e	12 § 0.2 d	48.9 § 3.92 f	16 § 1.45 g	8 § 0.33 g
Cd-15-NaCl-0	69 § 3.60 c	1.05 § 0.05 bc	13.2 § 0.66 bc	70.5 § 1.85 c	31.3 § 2.02 bc	13 § 57 bc
Cd-15-NaCl-0.5	60 § 3.06 d	0.85 § 0.05 de	12 § 0.57 d	57.9 § 2.40 e	23.1 § 1.52 e	9.4 § 0.57 f
Cd-15-NaCl-1.0	44 § 2.8 f	0.7 § 0.03 f	10.5 § 0.57 e	41.2 § 2.90 g	12.5 § 1.45 h	6.5 § 0.33 h

For each parameter, the values (mean § standard error of three replicates) sharing the same letter are not significantly different (LSD test, P D 0.05).

Table 2: Effects of various levels of Cd and salinity on root and shoot ionic (Na, K, Cl) concentrations (mmol g⁻¹ dry weight) of *A. nilotica* in a pot experiment

Cd and salinity levels	Root Na	Shoot Na	Root K	Shoot K	Root Cl	Shoot Cl
Control	0.12 § 0.02 c	0.14 § 0.01 c	0.90 § 0.07 a	1.25 § 0.02 a	0.16 § 0.04 ij	0.18 § 0.01 hi
Cd-0-NaCl-0.5	0.50 § 0.01 b	0.66 § 0.02 b	0.71 § 0.05 c	0.80 § 0.01 e	0.85 § 0.03 gh	0.90 § 0.03 fg
Cd-0-NaCl-1.0	0.90 § 0.03 a	1.10 § 0.03 a	0.35 § 0.03 ef	0.50 § 0.02 h	1.45 § 0.04 d	1.57 § 0.03 d
Cd-5-NaCl-0	0.12 § 0.02 c	0.13 § 0.05 c	0.86 § 0.02 ab	1.15 § 0.02 b	0.17 § 0.05 i	0.19 § 0.04 hi
Cd-5-NaCl-0.5	0.49 § 0.02 b	0.66 § 0.05 b	0.65 § 0.02 cd	0.70 § 0.04 f	0.90 § 0.02 g	0.94 § 0.03 g
Cd-5-NaCl-1.0	0.91 § 0.05 a	1.10 § 0.04 a	0.30 § 0.01 ef	0.39 § 0.05 i	1.55 § 0.02 c	1.64 § 0.02 c
Cd-10-NaCl-0	0.11 § 0.04 c	0.14 § 0.03 c	0.80 § 0.02 bc	1.05 § 0.06 c	0.18 § 0.01 i	0.20 § 0.02 h
Cd-10-NaCl-0.5	0.48 § 0.04 b	0.65 § 0.02 b	0.59 § 0.04 de	0.59 § 0.07 g	0.98 § 0.01 f	1.00 § 0.01 f
Cd-10-NaCl-1.0	0.91 § 0.05 a	1.12 § 0.01 a	0.27 § 0.06 fg	0.35 § 0.03 ij	1.65 § 0.03 b	1.78 § 0.05 b
Cd-15-NaCl-0	0.12 § 0.03 c	0.13 § 0.04 c	0.67 § 0.05 cd	0.90 § 0.01 d	0.20 § 0.04 i	0.21 § 0.06 h
Cd-15-NaCl-0.5	0.49 § 0.04 b	0.66 § 0.05 b	0.35 § 0.05 e	0.42 § 0.02 i	1.07 § 0.05 e	1.12 § 0.07 e
Cd-15-NaCl-1.0	0.92 § 0.02 a	1.14 § 0.03 a	0.20 § 0.03 h	0.28 § 0.05 jk	1.78 § 0.05 a	1.89 § 0.05 a

For each parameter, the values (mean § standard error of three replicates) sharing the same letter are not significantly different (LSD test, P D 0.05).

Table 3: Effects of various levels of Cd and salinity treatments on root and shoot Cd concentrations (mg kg⁻¹), root and shoot Cd uptake (mg plant⁻¹) and tolerance index (%) of *A. nilotica* in a pot experiment.

Cd and salinity levels	Root Cd concentration	Shoot Cd concentration	Root Cd Uptake	Shoot Cd Uptake	Tolerance index
Control	0.19 § 0.15 h	0.24 § 0.15 h	2.97 § 1.4 h	8.88 § 3.5 i	----
Cd-0-NaCl-0.5	0.2 § 0.21 h	0.23 § 0.12 h	2.7 § 1.5 h	7.36 § 3.0 i	90 § 5.0 ab
Cd-0-NaCl-1.0	0.21 § 0.15 h	0.24 § 0.15 h	2.31 § 1.0 h	5.52 § 3.6 i	81.3 § 3.0 c
Cd-5-NaCl-0	2.5 § 0.39 g	3.3 § 0.45 g	36.75 § 1.0 g	115.5 § 4.5 h	96.5 § 4.0 a
Cd-5-NaCl-0.5	3.8 § 0.3 f	4.7 § 0.24 f	47.5 § 1.0 e	141 § 2.5 g	84.1 § 3.0 bc
Cd-5-NaCl-1.0	4.5 § 0.3 e	5.4 § 0.3 ef	43.2 § 2.0 f	108 § 7.8 h	70.3 § 2.0 de
Cd-10-NaCl-0	4.1 § 0.3 ef	6.1 § 0.54 e	56.99 § 1.0 d	200.69 § 2.5 e	92.8 § 2.0 ab
Cd-10-NaCl-0.5	5.8 § 0.2 d	8.9 § 0.6 d	63.8 § 0.8 c	249.2 § 8.6 c	77.8 § 4.0 cd
Cd-10-NaCl-1.0	7.0 § 0.3 c	10.9 § 0.3 c	56 § 1.8 c	174.4 § 4.5 f	61.1 § 3.0 e
Cd-15-NaCl-0	5.8 § 0.45 d	9.3 § 0.66 d	75.4 § 2.5 b	291.09 § 4.5 b	88.1 § 3.0 b
Cd-15-NaCl-0.5	8.9 § 0.39 b	15 § 0.69 b	83.66 § 1.8 a	346.5 § 8.9 a	72.4 § 4.0 d
Cd-15-NaCl-1.0	11.2 § 0.36 a	18.5 § 0.39 a	72.8 § 2.0 b	231.25 § 5.0 d	51.5 § 2.0 f

For each parameter, the values (mean § standard error of three replicates) sharing the same letter are not significantly different (LSD test, P D 0.05)

Source: <https://www.tandfonline.com/doi/pdf/10.1080/15226514.2017.1413339?needAccess=true>

Cadmium Uptake and Distribution in Fragrant Rice Genotypes and Related Consequences on Yield and Grain Quality Traits (2017)

Table 1: Effects of cadmium on rice yield and its parameter

Variety	Treatment	Panicles/pot	Spikelet number/pot	100-grain weight (g)	Seed setting rate (%)	Grain yield/pot (g)
V1	Cd0	30.33 ± 0.33 ^a	121.07 ± 0.58 ^{bc}	23.97 ± 0.33 ^a	89.1 ± 0.11 ^a	78.44 ± 1.40 ^a
	Cd1	23.66 ± 0.88 ^b	127.52 ± 3.88 ^b	19.88 ± 0.38 ^b	85.963 ± 1.45 ^b	51.48 ± 1.61 ^b
	Cd2	20.00 ± 0.57 ^c	142.34 ± 2.87 ^a	19.03 ± 0.32 ^{bc}	82.293 ± 0.74 ^c	44.51 ± 0.48 ^c
	Cd3	17.33 ± 0.88 ^d	113.63 ± 5.25 ^c	18.1 ± 0.11 ^c	79.92 ± 0.45 ^c	28.35 ± 0.05 ^d
V2	Cd0	27.67 ± 0.33 ^a	116.35 ± 2.46 ^c	23.60 ± 0.28 ^a	92.32 ± 0.84 ^a	70.12 ± 1.60 ^a
	Cd1	25.33 ± 0.33 ^b	132.01 ± 2.39 ^{ab}	21.55 ± 0.17 ^b	87.86 ± 1.49 ^b	63.41 ± 2.69 ^b
	Cd2	23.66 ± 0.33 ^c	123.49 ± 2.58 ^{bc}	19.05 ± 0.47 ^c	86.883 ± 0.32 ^b	48.31 ± 0.66 ^c
	Cd3	20.33 ± 0.66 ^d	140.32 ± 7.90 ^a	18.63 ± 0.19 ^c	80.697 ± 1.15 ^c	42.75 ± 1.38 ^c
V3	Cd0	32.33 ± 0.33 ^a	113.11 ± 2.03 ^a	24.98 ± 0.24 ^a	93.79 ± 0.72 ^a	85.63 ± 1.01 ^a
	Cd1	31.66 ± 0.33 ^a	111.66 ± 0.70 ^a	24.03 ± 0.12 ^{ab}	89.90 ± 0.25 ^b	76.37 ± 0.19 ^b
	Cd2	28.67 ± 0.33 ^b	110.93 ± 0.14 ^a	23.38 ± 0.47 ^{bc}	88.12 ± 0.42 ^c	65.5 ± 0.73 ^c
	Cd3	26.66 ± 0.33 ^c	98.58 ± 2.1 ^{5b}	22.66 ± 0.33 ^c	86.22 ± 0.43 ^d	51.42 ± 2.10 ^d
V4	Cd0	25.66 ± 0.33 ^a	131.33 ± 3.60 ^b	22.44 ± 0.67 ^a	90.29 ± 0.96 ^a	68.37 ± 3.59 ^a
	Cd1	23.33 ± 0.33 ^b	139.15 ± 1.73 ^{ab}	21.05 ± 0.49 ^{ab}	87.67 ± 1.03 ^a	59.87 ± 1.46 ^b
	Cd2	21.66 ± 0.33 ^c	148.57 ± 6.18 ^a	19.66 ± 0.22 ^{bc}	83.54 ± 0.74 ^b	52.87 ± 2.43 ^{bc}
	Cd3	19.66 ± 0.33 ^d	150.92 ± 3.7 ^{2a}	19.30 ± 0.60 ^c	81.99 ± 0.47 ^b	46.95 ± 1.73 ^c
V5	Cd0	27.66 ± 0.33 ^a	130.58 ± 0.53 ^{ab}	24.04 ± 0.50 ^a	89.70 ± 0.55 ^a	77.9 ± 1.43 ^a
	Cd1	25 ± 0.5774 ^b	117.65 ± 0.60 ^{bc}	23.44 ± 0.10 ^a	80.05 ± 0.77 ^b	55.19 ± 1.42 ^b
	Cd2	24.33 ± 0.66 ^b	103.53 ± 11.81 ^c	21.83 ± 0.56 ^b	77.13 ± 3.54 ^b	41.94 ± 3.22 ^c
	Cd3	18.33 ± 0.66 ^c	147.21 ± 4.34 ^a	19.65 ± 0.21 ^c	76.98 ± 1.52 ^b	40.77 ± 1.36 ^c

Three replicated means (±SE) were calculated for each treatment. Values with different letters are significantly different at p<0.05. Cd0 = 0 mg Cd/kg, Cd1 = 50 mg Cd/kg, Cd2 = 100 mg Cd/kg, and Cd3 = 150 mg Cd/kg

Source: <https://www.hindawi.com/journals/jchem/2017/1405878/abs>

Physiological responses of water hyacinth, *Eichhornia crassipes* (Mart.) Solms, to cadmium and its phytoremediation potential (2016)

Table 1: Dry biomass (g/plant) of different plant tissues along with root length (cm) and total leaf area (cm²) of *Eichhornia crassipes* grown in different cadmium concentrations.

CdCl₂ (mg L ⁻¹)	Day (d)	Root	Shoot	Leaf	Root length (cm)	Total leaf area (cm ²)
Control	0 d	0.44 ± 0.002	0.51 ± 0.003	0.62 ± 0.009	9.9 ± 0.264	165.0 ± 8.88
	21 d	1.58 ± 0.36	2.13 ± 0.19	2.35 ± 0.22	20.3 ± 0.45	311.4 ± 4.20
5	0 d	0.44 ± 0.002	0.51 ± 0.003	0.62 ± 0.003	9.9 ± 0.173	165.6 ± 1.52
	21 d	0.86 ± 0.02* (-45.56%)	1.25 ± 0.25* (-41.31%)	1.22 ± 0.19* (-48%)	18.2 ± 0.50 (-10.34%)	276.5 ± 7.31* (-11.21%)
10	0 d	0.44 ± 0.003	0.51 ± 0.003	0.62 ± 0.003	9.9 ± 0.20	165.6 ± 3.21
	21 d	0.67 ± 0.01* (-57.34%)	0.76 ± 0.02* (-64.08%)	0.83 ± 0.008* (-64.46%)	17.2 ± 0.37* (-15.27%)	254.7 ± 10.14* (-18.21%)
15	0 d	0.44 ± 0.003	0.50 ± 0.002	0.62 ± 0.006	9.96 ± 0.251	165.3 ± 3.20
	21 d	0.55 ± 0.01* (-64.6%)	0.61 ± 0.01* (-71.12%)	0.72 ± 0.008* (-69.19%)	15.4 ± 0.40* (-24.13%)	225.9 ± 12.15* (-27.45%)
20	0 d	0.44 ± 0.001	0.50 ± 0.003	0.62 ± 0.009	9.9 ± 0.057	164.66 ± 4.5
	21 d	0.46 ± 0.01* (-70.75%)	0.53 ± 0.01* (-75.16%)	0.65 ± 0.01* (-72.17%)	14.5 ± 0.20* (-28.57%)	205.8 ± 4.32* (-33.91%)

* = significantly different from control at P < 0.05; values are mean ± SD of 3 replicates; values in the parentheses include percent decrease in mean values as compared to the corresponding control values.

Source: <http://journals.tubitak.gov.tr/biology/issues/biy-16-40-1/biy-40-1-7-1411-86.pdf>

Table 2: Effect of cadmium treatments on leaf pigment contents of *Eichhornia crassipes* after 21 days

CdCl₂ (mg L ⁻¹)	Chlorophyll (mg g⁻¹ fresh weight)			Carotenoid
	C_a	C_b	C_{a+b}	C_{x+c}
0	6.15 ± 0.081	1.67 ± 0.143	7.83 ± 0.225	2.09 ± 0.035
5	5.69 ± 0.09*	1.86 ± 0.072**	7.55 ± 0.159**	1.8 ± 0.047*
10	4.07 ± 0.042*	1.30 ± 0.132*	5.38 ± 0.174*	1.49 ± 0.022*
15	2.27 ± 0.218*	0.767 ± 0.1*	3.04 ± 0.122*	1.49 ± 0.022*
20	1.48 ± 0.117*	0.202 ± 0.096*	1.68 ± 0.138*	0.687 ± 0.042*

Ca= chlorophyll a; Cb= chlorophyll b; Ca + b= total chlorophyll; Cx + c = carotenoid. Values are mean ± SD (n = 3); * = significantly different and ** = not significantly different at P < 0.05 at various doses of Cd for a particular plant pigment as compared to control values.

Table 3: Effect of cadmium treatments on leaf MDA and protein contents of *Eichhornia crassipes* after 21 days.

CdCl₂ (mg L⁻¹)	Control	5	10	15	20
MDA (μmol g⁻¹ FW)	5.69 ± 0.463	8.3 ± 0.325**	20.51 ± 2.79*	25.98 ± 2.26*	33.55 ± 1.63*
Protein (mg g⁻¹ FW)	24.32 ± 0.58	20.0 ± 1.0*	17.89 ± 0.84*	13.46 ± 0.46*	9.43 ± 0.51*

* = significantly different and ** = not significantly different from control at P < 0.05; values are mean ± SD of 3 replicates.

Table 4: Cadmium accumulation in different plant parts (roots, shoots, and leaves) of *Eichhornia crassipes* after 21 days.

CdCl₂ (mg L⁻¹)	Cadmium concentration (μg g⁻¹ dry wt) in plant parts			
	Root	Shoot	Leaf	Whole plant
5	846.6 ± 43.22	937.9 ± 61.84	850.2 ± 52.47	878.3 ± 51.68
10	956.0 ± 43.44	986.0 ± 76.39	958.8 ± 68.24	966.9 ± 61.16
15	1908.6 ± 18.88*	1966.1 ± 28.58*	1908.6 ± 5.72*	1927.8 ± 17.03*
20	921.97 ± 38.13	967.33 ± 21.79	848.22 ± 76.77	912.5 ± 40.46

Mean ± SD (n = 3); * indicates significance at P < 0.05 at different doses for a particular plant tissue.

Table 5: Bioconcentration factor (BCF), translocation factor (TF), and translocation efficiency (%) of cadmium in different parts of *Eichhornia crassipes*.

CdCl₂ (mg L⁻¹)	BCF_{root}	BCF_{shoot}	BCF_{leaf}	BCF_{whole plant}	TF	Efficiency (%)
5	169.3 ± 8.64	187.5 ± 12.3	170 ± 10.49	526 ± 31.0	1.0 ± 0.017	100.4 ± 1.76
10	95.6 ± 4.34	98.6 ± 7.63	95.8 ± 6.8	290 ± 18.35	1.00 ± 0.03	100.2 ± 3.2
15	127.2 ± 1.25	131.07 ± 1.9	127.2 ± 0.38	385 ± 3.40	1.0 ± 0.007	100 ± 0.78
20	46.09 ± 1.90	48.36 ± 1.08	42.41 ± 3.83	121 ± 33.76	0.92 ± 0.05	91.8 ± 5.3

Source: <https://journals.tubitak.gov.tr/biology/issues/biy-16-40-1/biy-40-1-7-1411-86.pdf>

Effect of cadmium on physiological parameters of cereal and millet plants—A comparative study (2016)

Table 1: Differential Cd assimilation and translocation ratio in wheat and kodo millet.

Cd concentration in μm	Triticum aestivum			Paspalum scrobiculatum		
	Cadmium assimilation (mg/kg)			Cadmium assimilation (mg/kg)		
	Root	Shoot	Shoot/Root Ratio	Root	Shoot	Shoot/Root Ratio
10	14.50±1.24 ^a	1.79±0.40 ^a	1.79±0.40 ^a	73.28±0.88 ^a	7.32±0.44 ^a	0.0996
20	11.08±1.46 ^b	2.45±0.64 ^a	0.22227	103.40±1.6 ^b	19.59±0.83 ^b	0.1986
50	17.52±1.14 ^c	6.43±0.31 ^a	0.3674	164.27±1.5 ^c	57.33±2.83 ^c	0.3488
100	46.29±2.58 ^d	30.00±1.9 ^b	0.6481	248.82±2.4 ^d	150.13±1.91 ^d	0.6028
500	97.32±2.23 ^e	80.43±1.4 ^c	0.8621	896.32±1.9 ^e	896.32±1.9 ^e	0.8182

The values followed by different letters are significantly different at a significance level of $p < 0.05$

Source: www.tandfonline.com/doi/full/10.1080/15226514.2016.1207608?scroll=top...true

Effect of cadmium on physiological parameters of cereal and millet plants—A comparative study (2016)

Table 1: Effect of Cd on induction of PCs in leaves, stems and roots of cabbage variety Pluto

Plant	Cd level	Concentrations of PCs and GSH ^a				
Part	($\mu\text{g L}^{-1}$)	PC ₂	PC ₃	PC ₄	GSH	PCs + GSH
		(mmol thiol [-SH] kg ⁻¹ DW)				
Leaves	Control ^b	0a	0a	0a	2.37a	2.37a
	500	0.20b	0.50b	0.46b	2.24a	3.40b
Stem	Control ^b	0a	0a	0a	5.60a	5.60a
	500	0.30b	0.25b	0.15b	5.50a	6.20b
Roots	Control	0.50 ± 0.03	0.80 ± 0.03	0.55 ± 0.01	4.10 ± 0.15	5.95 ± 0.20
	500	1.50 ± 0.12	2.50 ± 0.40	2.40 ± 0.30	4.85 ± 0.20	11.3 ± 0.80

Plants were harvested after 4 weeks of Cd exposure. For a plant part, means with the same letter are not significantly different ($P > 0.05$). LSD comparisons are valid only within the one plant part and one constituent

^aEach value is the mean of four replicates

^bCadmium in the control is due to background contamination of the hydroponic solution ($1 \mu\text{g L}^{-1}$)

Table 2: Effect of cadmium on selected minerals in different parts of the cabbage variety, Pluto

Plant	Cd level	Measured element concentrations						
Part	($\mu\text{g L}^{-1}$)	(mg kg ⁻¹ DW)			— (% DW) —			
		Cd	Zn	Mn	Cu	Fe	Ca	S
Leaves	1 ^a	1.1a	64a	130a	13a	40a	4.29a	1.65a
	500	107b	36b	100b	11a	31b	3.94b	2.03b
Stems	1 ^a	0.5a	51a	20a	8a	28a	1.92a	0.62a
	500	41b	36b	13b	7a	24b	1.73b	0.60a
Roots	1 ^a	5.0a	260a	146a	319a	— ^b	1.19a	1.26a
	500	686b	173b	66b	302b	— ^b	1.03a	1.28a
Adequate foliar concentration ^c		20–200	25–200	5–15	30–200	1–3	0.3–0.7	

The plants were harvested after 4 weeks of Cd exposure. Each value is the mean of four replicates. Means with the same letter are not significantly different ($P > 0.05$). Comparisons are valid only within one plant part for the one constituent

^aThe concentration of Cd in the control treatment was due to background contamination

^bValues for Fe in roots are not reported, as they were inflated by surface oxide deposits

^cBryson et al. (2014)

Source: <https://link.springer.com/article/10.1007/s11356-015-5779-6#Tab2>