Title	Chromium Stress in Plants: Toxicity, Tolerance and Phytoremediation
Author Name	Dipali Srivastava , Madhu Tiwari, Prasanna Dutta, Puja Singh, Khushboo Chawda, Monica Kumari, andDebasis Chakrabarty, ORCID
Journal Name	Sustainability
Year	2021
Volume and Issue	13(9)
Pages	4629
Abstracts	Chromium is one of the major pollutants in water and soil. Thus, it is urgent to develop a new method for chromium removal from the environment. Phytoremediation is a promising approach for heavy metal pollution recovery. As a perennial giant grass with a fast growth rate, *Pennisetum sinese* has been widely used as livestock feed, mushroom culture medium and biomass energy raw material. Interestingly, we have found a high adsorption capacity of *P. sinese* for chromium. *P. sinese* was treated with different concentrations of chromium for 15 days. Results showed that *P. sinese* plantlets grew well under low concentrations (less than 500 µM) of chromium (VI). The plantlet growth was inhibited when treated with high concentrations of chromium (more than 1000 µM). Up to 150.99 and 979.03 $mg \cdot kg^{-1}$ DW of chromium accumulated in the aerial part and root, respectively, under a treatment of 2000 µM Cr. The bioaccumulation factor (BCF) of P. sinese varied from 10.87 to 17.56, and reached a maximum value at the concentration of 500 µM. The results indicated that *P. sinese* showed strong tolerance and high accumulation capability under Cr stress. Therefore, the chromium removal potential of P. sinese has a great application prospect in phytoremediation.
Keywords	chromium (Cr); detoxification; phytoremediation; phytotoxicity

Title	***A Bacillus* and *Lysinibacillus sp.* bio-augmented *Festuca arundinacea* phytoremediation system for the rapid decontamination of chromium influenced soil**
Author Name	He Peng, Ke Liang, Huanyan Luo, Huayan Huang, Shihua Luo, AKang Zhang, Heng Xu, Fei Xu
Journal Name	Chemosphere
Year	2021
Volume and Issue	283
Pages	131186
Abstracts	Phytoremediation as an efficient and eco-friendly soil detoxification method has received widespread attention. In this study, two newly screened Chromium (Cr) reducing strains (*Bacillus sp.* AK-1 and *Lysinibacillus sp.* AK-5) were used to remediate Cr contaminated soil in conjunction with the application of hyperaccumulator tall fescue (*Festuca arundinacea*), thus establishing a soil Cr decontamination system. In this system, soil urease and dehydrogenase activities were increased, the malondialdehyde (MDA) contents in leaves of tall fescue were significantly decreased, while glutathione (GSH) contents increased. In terms of Cr fractions, the proportion of acetic acid extractable Cr decreased by 12.82–20.00% in treatment groups, respectively, compared with CK, while residual Cr increased by 9.41–22.37%. Moreover, biomass, root length and shoot length of tall fescue in treatment groups increased by 80.77–139.74%, 60.85–68.04%, 7.06–27.10%, respectively. In addition, the root system of tall fescue accumulated 303.887–372.167 mg kg^{-1} of Cr, and the aboveground part accumulated 16.289–19.289 mg kg^{-1} of Cr. Therefore, the application of strains AK-1 and AK-5 reduced the toxicity of Cr to plants and greatly increased plant accumulation potential, which indicated that AK-1 and AK-5 could improve removal efficiency of phytoremediation in Cr contaminated soil by reducing its bio-toxicity and promoting growth of tall fescue growth.
Keywords	Hexavalent chromium; Combination remediation; *Festuca arundinacea*; Phytoremediation; Bacteria

Title	**Phytoremediation of hexavalent chromium by mung bean through bio-accumulation and bio-stabilization in a short duration**
Author Name	Y. Chen, W. Hu, P. Li, Y. Liu, X. Chen, H. Xie, J. Wang, Y. Xie, Y. Wang & Y. Zhang
Journal Name	International Journal of Environmental Science and Technology
Year	2021
Volume and Issue	18 (353)
Pages	3023–3034
Abstracts	Phytoremediation is an effective approach to remove the challenging pollutant of hexavalent chromium [Cr(VI)] in the environment, however, which requires a relatively long work duration. Herein, we reported the utilization of mung bean (*Vigna radiata*) as a highly efficient accumulator for Cr(VI). Typically, within a short work duration of only 7 days, 5041 $mg \cdot kg^{-1}$ of chromium (Cr) could be accumulated in the whole plants of mung bean. Moreover, about 80% of Cr in the mung bean plants are transformed to fractions with low bioavailability. This study demonstrated that mung bean could be a promising candidate for phytoremediation of Cr(VI), not only accumulating but also stabilizing Cr(VI) within very short time.
Keywords	Chromium contamination; Stress tolerance; Bioremediation; Translocation; Bioavailability

Title	**Comparative growth analysis of okra *(Abelmoschus esculentus)* in the presence of PGPR and press mud in chromium contaminated soil.**
Author Name	Zain Mushtaq, Hafiz Naeem Asghar, Zahir AhmadZahir
Journal Name	Chemosphere
Year	2021
Volume and Issue	262
Pages	127865
Abstracts	Chromium is a toxic heavy metal. Plants, animals and human metabolic processes are disturbed due to higher levels of chromium. PGPR are involved in seed germination, growth improvement, metabolic process and in most of the physiological processes of plants. Press mud in soil provides substrate to the microbes. PGPR can convert the more toxic form of Cr (VI) into less toxic form Cr (III). This study was conducted to find out the reduction potential of pre-isolated rhizobacteria and their role in strengthening of plant growth and physiological attributes. Soil collected from the research area was spiked with 20 mg kg^{-1} of Cr (VI) by using potassium dichromate ($K_2Cr_2O_7$) salt before sowing. Results revealed that Cr (VI) significantly suppressed the shoot length, root length and photosynthetic rate of okra up to 19, 37 and 31%, respectively. However, inoculation decreases the uptake of Cr (VI) in root and shoot up to 37 and 31% and by press mud 33 and 20%, respectively. Combined application of inoculation and press mud significantly recovered the negative impact of chromium and plant growth was almost at par compared with contaminated treatment without inoculation.
Keywords	Bio-remediation; Cr6+ reducing bacteria; Heavy metals; Cr6+ reduction

Title	**Improved chromium tolerance of *Medicago sativa* by plant growth-promoting rhizobacteria (PGPR)**
Author Name	Nabil Tirry, Aziza Kouchou, Bouchra El Omari, Mohamed Ferioun and Naïma El Ghachtouli
Journal Name	Journal of Genetic Engineering and Biotechnology
Year	2021
Volume and Issue	19:149
Pages	01-14
Abstracts	**Background** Soil pollution by heavy metals increases the bioavailability of metals like hexavalent chromium (Cr (VI)), subsequently limiting plant growth and reducing the efficiency of phytoremediation. Plant growth-promoting rhizobacteria (PGPR) have substantial potential to enhance plant growth as well as plant tolerance to metal stress. The aim of this research was to investigate Cr (VI) phytoremediation enhancement by PGPR. **Results** The results showed that the 27 rhizobacterial isolates studied were confirmed as Cr (VI)-resistant PGPR, by using classical biochemical tests (phosphate solubilization, nitrogen fixation, indole acetic acid, exopolysaccharides, hydrogen cyanide, siderophores, ammonia, cellulase, pectinase, and chitinase production) and showed variable levels of Cr (VI) resistance (300–600 mg/L). The best four selected Cr (VI)-resistant PGPR (NT15, NT19, NT20, and NT27) retained most of the PGP traits in the presence of 100–200 mg/L concentrations of Cr (VI). The inoculation of *Medicago sativa* with any of these four isolates improved the shoot and root dry weight. The NT27 isolate identified using 16S rDNA gene sequence analyses as a strain of Pseudomonas sp. was most effective in terms of plant growth promotion and stress level decrease. It increased shoot and root dry weights of *M. sativa* by 97.6 and 95.4%, respectively, in the presence of Cr (VI) when compared to non-inoculated control plants. It also greatly increased chlorophyll content and decreased the levels of stress markers, malondialdehyde, hydrogen peroxide, and proline. The results of the effect of Pseudomonas sp. on Cr content and bioaccumulation factor (BAF) of the shoots and roots of *M. sativa* plants showed the increase of plant biomass concomitantly with the increase of Cr root concentration in inoculated plants. This would lead to a higher potential of Cr (VI) phytostabilization. **Conclusions** This study demonstrates that the association *M. sativa*-Pseudomonas sp. may be an efficient biological system for the bioremediation of Cr (VI)-contaminated soils.
Keywords	Plant growth-promoting rhizobacteria; Metallic stress; *Medicago sativa*; Oxidative stress; Phytoremediation

Title	***Pennisetum sinese:* A Potential Phytoremediation Plant for Chromium Deletion from Soil**
Author Name	Xiaofei Chen, Jianhua Tong, Yi Su, Langtao Xiao
Journal Name	Sustainability
Year	2020
Volume and Issue	12 (9)
Pages	1-11
Abstracts	Chromium is one of the major pollutants in water and soil. Thus, it is urgent to develop a new method for chromium removal from the environment. Phytoremediation is a promising approach for heavy metal pollution recovery. As a perennial giant grass with a fast growth rate, *Pennisetum sinese* has been widely used as livestock feed, mushroom culture medium and biomass energy raw material. Interestingly, we have found a high adsorption capacity of *P. sinese* for chromium. *P. sinese* was treated with different concentrations of chromium for 15 days. Results showed that *P. sinese* plantlets grew well under low concentrations (less than 500 µM) of chromium (VI). The plantlet growth was inhibited when treated with high concentrations of chromium (more than 1000 µM). Up to 150.99 and 979.03 $mg \cdot kg^{-1}$ DW of chromium accumulated in the aerial part and root, respectively, under a treatment of 2000 µM Cr. The bioaccumulation factor (BCF) of P. sinese varied from 10.87 to 17.56, and reached a maximum value at the concentration of 500 µM. The results indicated that *P. sinese* showed strong tolerance and high accumulation capability under Cr stress. Therefore, the chromium removal potential of P. sinese has a great application prospect in phytoremediation.
Keywords	Pennisetum sinese; chromium; bioaccumulation factor; phytoremediation

Title	**Synergistic use of biochar and acidified manure for improving growth of maize in chromium contaminated soil**
Author Name	Aown Abbas, Muhammad Azeem, Muhammad Naveed, Abdul Latif, Saqib Bashir, Amjad Ali, Muhammad Bilal, Liaqat Ali
Journal Name	International Journal of Phytoremediation
Year	2020
Volume and Issue	22
Pages	52-61
Abstracts	Chromium (Cr) contamination in farmlands has become a serious environmental concern due to the excessive use of industrial wastewater as an irrigation source. Therefore, some important measures need to be taken for reducing its mobility in a soil profile. A pot study was conducted to evaluate the effectiveness of sugarcane bagasse derived biochar and acidified manure on Cr mobility and its uptake by maize plant. Results showed that the application of biochar and acidified manure significantly changed soil pH, improved crop growth and as well as reduce the antioxidant response of maize in Cr contaminated soil. The concentration of bioavailable (AB-DTPA) extractable Cr in soil decreased with the addition of co-use of biochar (3%) and acidified manure (5%) by 36% relative to control. The maximum reduction in superoxidase dismutase (SOD), peroxidase dismutase (POD), and catalase activity assay (CAT), and ascorbate peroxidase activity (APX) was occurred by 41%, 51%, 20%, and 55%, respectively when biochar (3%) amended with the combination of acidified manure in Cr contaminated soil. Among all the amendments, biochar at 3% application combination with acidified manure (B2 + AMS) offered significantly minimize Cr mobility (Cr-III (44%) and Cr-VI (22%)) and thereby reduce its uptake by maize plant.
Keywords	Acidified manure; antioxidant; biochar; chromium; maize.

Title	**Assisted phytoremediation of chromium spiked soils by *Sesbania Sesban* in association with *Bacillus xiamenensis* PM14: A biochemical analysis**
Author Name	Bashir UdDin, Amna, MazharRafique, Muhammad Tariq Javed, Muhammad Aqeel Kamran, Shehzad Mehmood, Mursalin Khan, TariqSultan, Muhammad Farooq Hussain Munis, Hassan Javed Chaudhary
Journal Name	Plant Physiology and Biochemistry
Year	2020
Volume and Issue	146
Pages	249-258
Abstracts	Due to anthropogenic activities, chromium (Cr) contamination is ubiquitous with deleterious effects on plant and soil microbiota. Present study was designed to address beneficial effects of *Bacillus xiamenensis* PM14 on *Sesbania sesban*. Its physiological and biochemical attributes along with enhanced antioxidant enzyme activities under different levels of Cr toxicity (50, 100 and 200 mg kg^{-1}) were evaluated. After harvesting at 50 days of sowing, plant growth attributes (root and shoot length, fresh and dry weight), physiological parameters (chlorophyll a, b and carotenoid content), antioxidant activities (superoxide dismutase, peroxidase and catalase), malondialdehyde content, electrolyte leakage, proline, relative water content and total Cr uptake in *S. sesban* were recorded. Experiment was statistically managed as complete randomized design (CRD). Results revealed that Cr stress reduced plant growth, relative water content at all levels of Cr contamination. However, inoculation of *B. xiamenensis* PM14 positively influence all parameters of *S. sesban* both under normal and stressed conditions. Inoculation of *B. xiamenensis* PM14 promoted plant growth (root length 17.08%, shoot length 28.36%) physiological attributes (chlorophyll a 55.26%, chlorophyll b 59.13%), antioxidant activities (superoxide dismutase 30.09%, peroxidase 6.96% and catalase 0.89%), relative water content 25.79%, enhanced total Cr uptake 47.33% and reduced proline 12.33%, malondialdehyde content 27.53% and electrolyte leakage 2.73% in S. sesban at 200 mg kg−1 Cr stress as compared to uninoculated plants grown under the same level of Cr. Our findings revealed first report of *B. xiamenensis* as phytoremediator and its inoculation on Sesbania plant. It also exposed dual effects of *B. xiamenensis* to ameliorate Cr stress along with improved plant growth and induced heavy metal stress tolerance in spiked soils.
Keywords	Antioxidant enzymes; B. xiamenensis; Chromium; PGPR; Phytoextraction; Sesbania

Title	Chromium Accumulation by Avicennia alba Growing at Ecotourism Mangrove Forest in Surabaya, Indonesia
Author Name	Harmin Sulistiyaning Titah, Herman Pratikno
Journal Name	Journal of Ecological Engineering
Year	2020
Volume and Issue	21
Pages	222-227
Abstracts	The Ecotourism Mangrove Forest at Wonorejo in East Coast Surabaya area is one of large mangrove forest inside in the metropolitan city in Indonesia. There are many ecological values of mangrove forest in most tropical countries such as marine fisheries, wildlife habitat, improving coastal water quality, and endangered mangrove coastlines and human development. The role of mangrove to improving coastal water quality can be showed through mangroves maintain coastal water quality by abiotic and biotic retention, removal, and cycling of nutrients, pollutants, and particulate matter from land-based sources. One of inorganic pollutant that can be removed by mangrove is heavy metal such as chromium (Cr). Wonorejo River is one of the rivers that receive disposal of wastewater in Surabaya East Coast area. Many wastewater from industries and households were released to this river. The concentration of Cr at the Wonorejo Estuary reached 0.0325 mg/L and 2.7761 mg/L in sediments. The aim of this research was to determine the potency of Cr accumulation by Avicennia alba that was grown for ten years at Wonorejo Ecotourism Mangrove Forest. Sampling activities were conducted using a transect quadrat sampling method with a 10x10 m dimension. Sediment and mangrove root samples were extracted before being analysed using an atomic absorption spectrophotometer (AAS). The results showed that the Cr accumulation by roots of A. alba reached 25.4 ± 1.6 to 55.3 ± 1.1. The BCF value in A. alba were 0.32 ± 0.01 to 0.83 ± 0.5 with the concentration Cr in sediment were 60 ± 1.4 to 79.3 ± 1.1. A. alba showed potential as a moderate accumulator for Cr. In conclusion, A. alba can be considered for use in phyto-monitoring and phytoremediation of Cr in coastal areas.
Keywords	Avicennia alba; BCF; Coastal area; chromium; mangrove forest; root; sediment

Title	Mitigation of chromium toxicity in Arabidopsis thaliana by sulfur supplementation
Author Name	Guotao Ding, ZengjunJin, Yonghong Han, Peng Sun, Guiying Li & WeihaoLi
Journal Name	Ecotoxicology and Environmental Safety
Year	2019
Volume and Issue	182
Pages	--
Abstracts	Chromium (Cr) contamination of soil and water has become a severe threat to human health. In this study, a series of experiments were conducted to examine the ameliorative effects of Cr toxicity, by exogenous 100 μM sodium sulfate. Our team has examined the plant growth, Cr content, chlorophyll, antioxidant index and soluble protein content, before and after the addition of sodium sulfate. The results showed that the addition of sulfur (S) can reduce the enrichment of Cr and the content of malonyldialdehyde (MDA) under Cr stress. After addition of S in the culture solution, the biomass and roots length of Arabidopsis thaliana increased under Cr stress. Furthermore, the content of chlorophyll, superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), glutathione (GSH), and soluble protein increased with the addition of sulfur. Transmission electron microscope observation point to that the chloroplasts can be damaged in leaf. All data demonstrate that S supplementation should help to alleviate the negative effects caused by both Cr(III) and Cr(VI) on Arabidopsis thaliana.
Keywords	Sulfur supplementation; Chromium toxicity; Chloroplasts; Arabidopsis thaliana

Title	Management of chromium (VI) toxicity by calcium and sulfur in tomato and brinjal: Implication of nitric oxide
Author Name	Samiksha Singh Sheo & Mohan Prasad
Journal Name	Journal of Hazardous Materials
Year	2019
Volume and Issue	373
Pages	212-223
Abstracts	To reduce pressure of toxic metals on crop plants, several strategies are being employed of which nutrient management is gaining much importance. Moreover, whether nitric oxide (NO), has any role in nutrients-mediated management/amelioration of metal toxicity is still not known. Therefore, the role of Ca and S in managing Cr(VI) toxicity was investigated in tomato and brinjal with an emphasis on possible involvement of NO. Cr(VI) reduced growth in both vegetables which was accompanied by increased accumulation of Cr(VI), lignin and reactive oxygen species (ROS), and altered cell cycle dynamics and photochemistry of photosynthesis. However, external addition of either Ca or S reversed these effects and hence improved growth noticed in both vegetables. Cr(VI) toxicity was further increased by NG-nitro-l-arginine methyl ester even with additional Ca and S while sodium nitroprusside either restored growth up to the control level or increased it in both vegetables, even in the presence of L-NAME, suggesting that NO might have a positive role in nutrients-mediated management/amelioration of Cr(VI) toxicity. In this study, role of Ca, S and NO with reference to Cr(VI) and NO accumulation, components of phenylpropanoid pathway, cell cycle dynamics, photosynthesis, ROS and antioxidant potential in managing Cr(VI) toxicity is discussed.
Keywords	Chromium toxicity management; Calcium; Nitric oxide; Sulfur; Vegetables

Title	**Selenium modulates dynamics of antioxidative defence expression, photosynthetic attributes and secondary metabolites to mitigate chromium toxicity in *Brassica juncea L.* plants**
Author Name	Neha Handa, Sukhmeen Kaur Kohli, Anket Sharma, Ashwani Kumar Thukral, Renu Bhardwaj, Elsayed Fathi Abd_Allah, Abdulaziz A. Alqarawi & Parvaiz Ahmad
Journal Name	Environmental and Experimental Botany
Year	2019
Volume and Issue	161
Pages	180-192
Abstracts	The study envisages the stress protective role of selenium (Se) against chromium (Cr) toxicity in *Brassica juncea L.* Plants were raised in pots with soils containing Cr (0 and 300 μMKg^{-1}) and Se (0, 2, 4 and 6 μMKg^{-1}) in binary combinations and harvested after 30 days of sowing. The harvested plant material was processed for several biochemical and molecular parameters. The observations made on significant results suggested that Se was able to protect the plants by restoring growth, reducing the oxidative damage (low levels of superoxide anions and hydrogen peroxide), and strengthened the enzymatic and non-enzymatic defence systems of B. juncea plants. Quantitative real time PCR studies on gene expression revealed that the expression of genes encoding the antioxidative enzymes (SOD, POD, CAT, GR and GST-1) was enhanced with Se application. Elevated contents of chlorophylls, carotenoids and gas exchange parameters also indicated that Se is instrumental in promoting photosynthetic efficiency, thereby ameliorating Cr toxicity. The expression of genes related to chlorophyll degradation also confirmed the observations. The contents of secondary metabolites (total phenols, flavonoids and anthocyanins) and the relative gene expression of phenylalanine ammonialyase and chalcone synthase, also showed enhanced levels in response to Se. The results thus indicated that Se application improves the overall physio-chemical characteristics of plants and helps them to overcome stress induced by Cr in the soil.
Keywords	Selenium; Chromium; Brassica juncea; Gene expression & Antioxidative defence

Title	**Consequence of chromium-tainted soil on physical and biochemical responses of Vigna radiata L.**
Author Name	Bibhu Prasad Rath, Sujata Hota, Subhra Subhadarshini, Debasis Dash & Prabhu Kaibalya Das
Journal Name	Journal of Applied Biology & Biotechnology
Year	2019
Volume and Issue	7, 1
Pages	35-41
Abstracts	Mung bean (*Vigna radiata L.*) is one of the important leguminous plants of India, with shorter growing season. In this work, the intention was to correlate the effects of chromium on physical and biochemical responses of *V. radiata L.* Mung bean seeds were germinated and grown under controlled treatment, with different concentrations of waste soil mixed with garden soil. Physical parameters such as shoot length, root length, and fresh weight were found highest in control soil and 25% of contaminated soil, whereas 50% and pure contaminated soil showed poor growth stage and poor quality physical parameters. Biochemical parameters such as total chlorophyll content, protein content, and starch content were found highest in control soil and 25% contaminated soil, but these parameters were found to be less in 50% and pure contaminated soil. It was observed that physical and chemical parameters were declining with increasing chromium contamination.
Keywords	Leguminous; Vigna radiate; Biochemical; chlorophyll & chromium

Title	**Chromium bioaccumulation, oxidative stress metabolism and oil content in lemon grass *Cymbopogon flexuosus (Nees ex Steud.) W*. Watson grown in chromium rich over burden soil of Sukinda chromite mine, India**
Author Name	Deepak Kumar Patra, Chinmay Pradhan & Hemanta Kumar Patra
Journal Name	Chemosphere
Year	2019
Volume and Issue	218
Pages	1082-1088
Abstracts	Lemon grass plants grown in Cr rich over burden soil of Sukinda chromite mine (India) countered Cr toxicity and oxidative stress with the production of reactive oxygen species and induced antioxidative defense system. Varied percentage of Cr rich over burden soil was applied to lemon grass pants to evaluate the actions of oxidative inhibitors enzymes extracted and assayed from both roots and shoots. The study also assessed the oil content and its composition in response to the different percentage of Cr available in over burden soil. In order to evaluate the defense system of a plant against oxidative stress and determine the level of reactive oxygen species, the experiments were undertaken in the presence and absence of Cr in soils. The results indicated that the action of oxidative inhibitor enzymes increased significantly in roots as compared to shoots with increasing concentration of Cr in overburden soil. Higher concentration of Cr in soils inhibited the enzyme activity both in roots and shoots. The level of ROS in plants also enhanced with the increase in the concentration of Cr in the soil. In order to control the oxidative damage in plants, lemon grass can be considered defensive in nature to build up the antioxidant system which can scavenge the reactive oxygen species (ROS).
Keywords	Lemon grass; over burden soil; oxidative stress; reactive oxygen species & lemon grass oil

Title	**A comparative evaluation towards the potential of *Klebsiella sp.* and *Enterobacter* sp. in plant growth promotion, oxidative stress tolerance and chromium uptake in *Helianthus annuus (L.)*.**
Author Name	Gupta P, Kumar V, Usmani Z, Rani R, Chandra A, Gupta VK.
Journal Name	Journal of Hazardous Materials
Year	2019
Volume and Issue	337
Pages	391-398
Abstracts	Prevalence of metal pollutants exerts negative effects on human health and environment, thus propounding an urgent need for a safer substitute. This study was conducted to compare the chromium bioremediation and plant growth promotion ability of two bacterial strains, *Klebsiella* sp. strain CPSB4 (MH266218) and *Enterobacter* sp. strain CPSB49 (MH532567), isolated from the rhizospheric soils. A pot scale experiment was setup with *Helianthus annuus* (L.) as a test plant to compare the efficiency of both isolates in enhancement of plant growth, nutrients uptake, anti-oxidative enzymes production, lipid *peroxidation*, and chromium bioremediation. Inoculation of strains, CPSB4 and CPSB49 enhanced plant biomass, plant growth, nutrient uptake, anti-oxidative enzymes, and chromium bioremediation, while reduction in lipid *peroxidation* was observed compared to *uninoculated* control under chromium stress. The maximum increase in plant growth and nutrient uptake was found in treatments inoculated with CPSB49, while maximum chromium uptake by sunflower was observed in treatments inoculated with CPSB4. Moreover, an increase in anti-oxidative enzyme production and decrease in lipid *peroxidation* was observed on inoculation of the selected strains. Thus, the strains *Klebsiella* sp. and *Enterobacter* sp. can be effectively used in chromium bioremediation and plant growth promotion under chromium stress conditions.
Keywords	Chromium; Enterobacter sp.; Klebsiella sp.; Oxidative stress; Plant growth promotion

Title	Chromium tolerance, bioaccumulation and localization in plants: An overview
Author Name	Vibha Sinha, Kannan Pakshirajan, Rakhi Chaturvedi
Journal Name	Journal of Environmental Management
Year	2018
Volume and Issue	Volume 206
Pages	715-730
Abstracts	In the current industrial scenario, chromium (Cr) as a metal is of great importance, but poses a major threat to the environment. Phytoremediation provides an environmentally sustainable, ecofriendly, cost effective approach for environmental cleanup of Cr. This review presents the current status of phytoremediation research with particular emphasis on cleanup of Cr contaminated soil and water systems. It gives a detailed account of the work done by different authors on the Cr bioavailability, uptake pathway, toxicity and storage in plants following the phytoextraction mechanism. This paper also describes recent findings related to Cr localization in hyperaccumulator plants. It gives an insight into the processes and mechanisms that allow plants to remove Cr from contaminated sites under varying conditions. These detailed knowledge of changes in plant metabolic pool in response to Cr stress would immensely help understand and improve the phytoextraction process. Further, this review provides a detailed understanding of Cr uptake and detoxification mechanism by plants that can be applied in developing a suitable approach for a better applicability of the process.
Keywords	Cr; Phytoremediation; Hyperaccumulator; Metal stress; Uptake mechanism

Title	**Biomonitoring chromium III or VI soluble pollution by moss chlorophyll fluorescence**
Author Name	Yang-ErChena, Hao-Tian Mao, Jie Ma, Nan Wu, Chao-Ming Zhang, Yan-Qiu Su, Zhong-Wei Zhang, Ming Yuan, Huai-Yu Zhang, Xian-Yin Zeng, ShuYuan
Journal Name	Chemosphere
Year	2018
Volume and Issue	Volume 194
Pages	220-228
Abstracts	We systematically compared the impacts of four Cr salts (chromic chloride, chromic nitrate, potassium chromate and potassium bichromate) on physiological parameters and chlorophyll fluorescence in indigenous moss Taxiphyllum taxirameum. Among the four Cr salts, K2Cr2O7 treatment resulted in the most significant decrease in photosynthetic efficiency and antioxidant enzymes, increase in reactive oxygen species (ROS), and obvious cell death. Different form the higher plants, although hexavalent Cr(VI) salt treatments resulted in higher accumulation levels of Cr and were more toxic than Cr(III) salts, Cr(III) also induced significant changes in moss physiological parameters and chlorophyll fluorescence. Our results showed that Cr(III) and Cr(VI) could be monitored distinguishably according to the non-photochemical quenching (NPQ) fluorescence of sporadic purple and sporadic lavender images respectively. Then, the valence states and concentrations of Cr contaminations could be evaluated according to the image of maximum efficiency of PSII photochemistry (Fv/Fm) and the quantum yield of PSII electron transport (ΦPSII). Therefore, this study provides new ideas of moss's sensibility to Cr(III) and a new method to monitor Chromium contaminations rapidly and non-invasively in water.
Keywords	Chromium; Antioxidants; Chlorophyll fluorescence; Moss; Oxidative stress

Title	**Removal of Chromium from Soils Cultivated with Maize (*Zea Mays*) After the Addition of Natural Minerals as Soil Amendments**
Author Name	**A**. Molla, Z. Ioannou, S. Mollas, E. Skoufogianni & A. Dimirkou
Journal Name	Bulletin of Environmental Contamination and Toxicology
Year	2017
Volume and Issue	98, Issue 3
Pages	347-352
Abstracts	The efficiency of natural minerals, i.e. zeolite, bentonite and goethite, regarding the retention of chromium, from maize was examined. Specifically, 1.0 kg of soil, 1.0 g of soil amendment and either 50 mg L^{-1} Cr(III) or 1 mg L^{-1} Cr(VI) were added in plant pots. Then, seeds of maize were cultivated. Each treatment was repeated three times. The statistical results of the experiments were analyzed by LSD test. Cr(III) addition in soil has shown that zeolite was the only amendment that increased the dry weight. Zeolite and bentonite reduced significantly the total chromium in plants after the addition of 50 mg L^{-1} Cr(III). The addition of Cr(VI) in soil has shown that bentonite was the only amendment that increased the dry weight of biomass and the plants' height. All soil amendments reduced to zero the total chromium concentration measured to plants after the addition of 1 mg L^{-1} Cr(VI).
Keywords	Zeolite; Bentonite; Goethite; Maize; Soil amendments

Title	**Isolation of indigenous *Staphylococcus sciuri* from chromium-contaminated paddy field and its application for reduction of Cr(VI) in rice plants cultivated in pots**
Author Name	Avishek Dutta, Sayanti Ghosh, Jayanta D. Choudhury, Riddhi Mahansaria, Malancha Roy, Asish Kumar Ghosh, Tarit Roychowdhury & Joydeep Mukherjee
Journal Name	Bioremediation Journal
Year	2017
Volume and Issue	21, Issue1
Pages	30-37
Abstracts	Accumulation of Cr(VI) in rice seeds cultivated in Cr-contaminated soil of the Sundarbans (India) is an environmental problem. Cr(VI) concentration in this soil was 6.2 ± 0.3 mg/kg, whereas total chromium was 32.04 ± 1.60 mg/kg. A Cr(VI)-removing bacterium isolated from Cr-contaminated paddy field soil of Sundarbans was identified as*Staphylococcus sciuri*. Enrichment culture of *S. sciuri* was applied to pot cultivation of rice in Cr-contaminated soil. After 8 weeks, 71 ± 3% Cr(VI) (final concentration 2.15 ± 0.01 mg/kg) and 65 ± 2% total Cr removal (end concentration 11.3 ± 0.5 mg/kg) were attained in bacterium-treated soils. Growth parameters indicated healthy development of plants cultivated in bacterium-treated soils that was not observed in control plants. Total Cr removal attained in rice seeds of plants cultivated in bacterium-treated soils compared with control rice seeds was 78 ± 4%. Total Cr concentration in test seeds was 0.72 ± 0.05 mg/kg (World Health Organization [WHO] permissible limit: 1.30 mg/kg), whereas the same in control seeds was 3.27 ± 0.16 mg/kg. Cr(VI) reduction achieved in rice seeds cultivated in bacterium-treated soil compared with control rice seeds was 95 ± 5%. Cr(VI) concentration in rice seeds cultivated in treated soil was 0.050 ± 0.003 mg/kg, whereas the same in untreated control was 0.93 ± 0.05 mg/kg. Successful paddy field soil bioremediation by any *Staphylococcus* species was demonstrated for the first time.
Keywords	Agriculture; biotransformation; 16SrRNA; Sundarbans; tannery

Title	**Synergistic effect of chickpea plants and Mesorhizobium as a natural system for chromium phytoremediation**
Author Name	Pilar A. Velez, Melina A. Talano,Cintia E. Paisio, Elizabeth Agostini & Paola S. González
Journal Name	Environmental Technology
Year	2017
Volume and Issue	38, Issue17
Pages	2164-2172
Abstracts	The presence of chromium in soils not only affects the physiological processes of plants but also the microbial rhizosphere composition and metabolic activities of microorganisms. Hence, the inoculation of plants with Cr(VI)-tolerant rhizospheric microorganisms as an alternative to reduce Cr phytotoxicity was studied. In this work, chickpea germination was reduced by Cr(VI) concentrations of 150 and 250 mg/L (6 and 33%, respectively); however lower Cr(VI) concentrations negatively affected the biomass. On the other hand, its symbiont, *Mesorhizobium ciceri*, was able to grow and remove different Cr(VI) concentrations (5–20 mg/L). The inoculation of chickpea plants with this strain exposed to Cr(VI) showed a significantly enhanced plant growth. In addition, inoculated plants accumulated higher Cr concentration in roots than those noninoculated. It is important to note that Cr was not translocated to shoots independently of inoculation. These results suggest that *Mesorhizobium*'s capability to remove Cr(VI) could be exploited for bioremediation. Moreover, chickpea plants would represent a natural system for phytoremediation or phytostabilization of Cr *in situ* that could be improved with *M. ciceri* inoculation. This strategy would be considered as a phytoremediation tool with great economic and ecological relevance.
Keywords	Chromium; chickpea; phytoremediation; microsieve; Mesorhi zobium; interaction

Title	**Chromium Accumulation in Medicinal Plants Growing Naturally on Tannery Contaminated and Non-contaminated Soils**
Author Name	S. Jaison,T. Muthukumar
Journal Name	Biological Trace Element Research
Year	2017
Volume and Issue	175, Issue1
Pages	223-235
Abstracts	Herbal preparations used to treat human ailments globally can be contaminated with various heavy metals (HMs) originating from the raw materials or from the manufacturing processes. Therefore, we assessed 22 medicinal plants growing naturally on tannery pollutant contaminated (Site-C) and non-contaminated (Site-NC) sites for their ability to accumulate chromium (Cr). The Cr contents in soil and various plant parts were estimated using an atomic absorption spectrophotometer. Translocation and bioconcentration factors were calculated. The soil at Site-C had 27-fold higher concentration of total Cr than at Site-NC. Chromium accumulation is reported for the first time in 50 % of the medicinal plants examined and varied significantly among the sites. Shoots of Ricinus communis and Amaranthus viridis had maximum concentrations of Cr at Site-C, whereas in Site-NC, none of the plants had Cr accumulation >30 ppm. Ricinus communis, Amaranthus viridis, andAmaranthus spinosus had translocation factor (TF) greater than the one in the Site-C andLantana camara had TF >1 in Site-NC. The bioconcentration factor (BCF) was >1 only forRicinus communis at both the sites. The majority of the medicinal plants at Site-NC had Cr content exceeding the permissible limit of 2 ppm suggested for herbal raw material. The results of the study clearly emphasize the need for screening plants of therapeutic value for the presence of HMs even when collected from non-contaminated soils. Moreover, proportional allocation of Cr in different plant parts provided an insight on the safety of these parts when specifically used in herbal preparations.
Keywords	Bioconcentration factor; Heavy metal; Herbal raw material; Potential risk; Traditional medicine; Translocation factor

Title	**Phyto-Toxicity of Chromium in Maize: Oxidative Damage, Osmolyte Accumulation, Anti-Oxidative Defense and Chromium Uptake**
Author Name	Shakeel Ahmad Anjum, Umair Ashraf, Imran Khan,Mohsin Tanveer, Muhammad Shahid, Abdul Shakoor, Longchang Wang
Journal Name	Pedosphere
Year	2017
Volume and Issue	27, Issue2
Pages	262-273
Abstracts	Agricultural production systems are immensely exposed to different environmental stresses in which heavy metal stress receives serious concerns. This study was conducted to explore the deleterious effects of different chromium (Cr) stress levels,i.e., 0, 30, 60, 90, 120, and 150 μmol L−1, on two maize genotypes, Wandan 13 and Runnong 35. Both genotypes were evaluated by measuring their growth and yield characteristics, Cr accumulation in different plant tissues, alterations in osmolyte accumulation, generation of reactive oxygen species (ROS), and anti-oxidative enzyme activity to scavenge ROS. The results showed that Cr stress decreased the leaf area, cob formation, 100-grain weight, shoot fresh biomass, and yield formation, while Cr accumulation in different maize tissues was found in the order of roots > leaves > stem > seeds in both genotypes. The increased Cr toxicity resulted in higher free proline, soluble sugars and total phenolic contents, and lower soluble protein contents. However, enhanced lipid peroxidation was noticed in the forms of malondialdehyde, hydrogen peroxide (H2O2) and thiobarbituric acid reactive substance accumulation, and electrolyte leakage. The hyperactivity of superoxide dismutase, peroxidase, catalase, ascorbate peroxidase, especially glutathione peroxidase and glutathione reductase indicated that these anti-oxidative enzymes had a central role in protecting maize from Cr toxicity, especially for Wandan 13. Moreover, higher uptake and less translocation of Cr contents into the grains of Wandan 13 implied its importance as a potential candidate against soil Cr pollution.
Keywords	agronomic characteristics; anti-oxidative enzyme activity; Cr accumulation; Cr translocation; heavy metal stress; reactive oxygen species