Title	**Combination of *Siderophore-Producing Bacteria* and *Piriformospora indica* Provides an Efficient Approach to Improve Cadmium Tolerance in Alfalfa**
Author Name	Mozhgan Sepehri & Behnam Khatabi
Journal Name	Microbial Ecology
Year	2021
Volume and Issue	81
Pages	717–730
Abstracts	Application of siderophore-producing microorganisms (SPMs), as an environmentally friendly approach, facilitates plant growth and survival under heavy metals toxicity. This study evaluated the effectiveness of SPMs, belonging to the bacterial genera Rhizobium and Pseudomonas and a root endophytic fungus (*Piriformospora indica*) to improve the fitness of alfalfa under cadmium (Cd) stress. A greenhouse experiment was performed as a randomized design with factorial arrangement of treatments. Treatments included microbial inoculations (Sinorhizobium meliloti, Pseudomonas fluorescence, and *P. indica*) and different Cd concentrations (0, 2, 5, 10 mg/kg) with three replications in potting media containing sand and sterile perlite (v/v, 2:1). The effect of Cd on plant growth and development, antioxidant enzymes activities, and accumulation of Cd and nutrients in alfalfa plant was investigated. Alfalfa inoculated with SPMs showed significantly higher biomass and nutrients uptake under both normal and Cd stress conditions than the controls. Under the highest Cd concentration (10 mg/kg), alfalfa plants inoculated with *P. fluorescens* and *P. indica*, either alone or in combination, showed the highest shoot dry weights. Cd-induced oxidative stress was mitigated by SPMs through enhanced antioxidant enzyme activities of catalase, ascorbate peroxidase, and guaiacol perox idase. We showed that *P. indica* either alone or in combination with the siderophore producing bacteria (SPB) minimized the toxicity of Cd by enhanced growth rate and the lower Cd concentration in the shoots. In conclusion, metal-resistant SPMs could assist alfalfa to survive in Cd-contaminated soil by enhancing plant growth and development. Application of plant-associated microbes is an efficient, environmentally friendly approach to surmount the adverse effects of heavy metals toxicity on plants, animals, and humans.
Keywords	Plant growth-promoting microorganisms . Antioxidant activity . Plant stress responses . Host adaptation

Title	***Bacillus pumilus* induced tolerance of Maize (*Zea mays L.*) against Cadmium (Cd) stress**
Author Name	Asim Shahzad1, Mingzhou Qin1, Mahmood Elahie, Muhammad Naeem, Tasmia Bashir, HumairaYasmin, MuhammadYounas, AhsanAreeb, Muhammad Irfan, Motsim Billah, Abdul Shakoor & Saman Zulfqar
Journal Name	Nature Portfolio
Year	2021
Volume and Issue	11
Pages	17196
Abstracts	Heavy metals contaminate the soil that alters the properties of soil and negatively affect plants growth. Using microorganism and plant can remove these pollutants from soil. The present investigation was designed to evaluate the induced effect of *Bacillus pumilus* on maize plant in Cadmium (Cd) contaminated soil. Three different concentrations of Cd (i.e. 0.25, 0.50 and 0.75 mg-kg^{-1}) were applied in soil under which maize plants were grown. The germination percentage, shoot length, leaf length, number of leaves, root length, fresh weight and nutrient uptake by maize plant were determined. The experiment was conducted by using complete randomized design (CRD) with three replicates. The result indicated that germination percentage, Shoot length, leaf length, root length, number of leaves, and plant fresh weight were reduced by 37, 39, 39, 32 and 59% respectively at 0.75 mg-kg^{-1} of $CdSO_4$ concentration but when maize seeds inoculated with *Bacillus pumilus* significantly increased the germination percentage, shoot length, leaf length, number of leaves, plant fresh weight at different concentrations of $CdSO_4$. Moreover, the plant protein were significantly increased by 60% in T6 (0.25 mg-kg^{-1} of $CdSO_4$ + inoculated seed) and Peroxidase dismutase (POD) was also signifcantly higher by 346% in T6 (0.25 mg-kg^{-1} of $CdSO_4$ + inoculated seed), however, the Superoxide dismutase (SOD) was significantly higher in T5 (0.75 mg-kg^{-1} of $CdSO_4$ +uninoculated seed) and was 769% higher as compared to control. The Cd contents in *Bacillus pumilus* inoculated maize roots and shoots were decreased. The present investigations indicated that the inoculation of maize plant with *Bacillus pumilus* can help maize plants to withstand Cd stress but higher concentration of Cd can harm the plant. The *Bacillus pumilus* has good potential to remediate Cd from soil, and also have potential to reduce the phyto availability and toxicity of Cd.
Keywords	Cadmium (Cd) stress; Cadmium; Complete Randomized Design (CRD);

Title	**Interactive effect of potassium and cadmium on growth, root morphology and chlorophyll a fuorescence in tomato plant**
Author Name	Rachida Naciri, Meryeme Lahrir, Chahinez Benadis, Mohamed Chtouki & Abdallah Oukarroum
Journal Name	Nature Portfolio
Year	2021
Volume and Issue	11
Pages	5384
Abstracts	A hydroponic experiment was conducted to evaluate the role of potassium (K) in tomato plant growth exposed to cadmium (Cd) stress. In this work, the effects of three potassium nutrition regimes (155, 232 and 310 ppm of K) combined with Cd at different levels (0, 12 and 25 µM of $CdCl_2$) on chlorophyll content index, root and shoot dry weights, root morphology, chlorophyll a fluorescence and translocation factor were analyzed. The results showed a negative effect of cadmium, at different concentrations, on all these parameters. However, optimization of K nutrition has shown promising results by limiting the negative effect of Cd. A positive effect of the high concentration of K (310 ppm) was observed on leaf chlorophyll content and chlorophyll a fluorescence compared to 232 and 155 ppm under Cd stress. K supply improved the electron transport at PSI side indicated by the increase in the amplitude of the I–P phase of OJIP transient. Also, K at a concentration of 310 ppm significantly reduced Cd translocation from root to shoot and improved root and shoot growth parameters in the presence of Cd. K supplementation can reduce the negative effect of Cd by improving photosynthesis and promoting chlorophyll synthesis. The optimization of nutrients composition and concentration might be a good strategy to reduce the impact of Cd on plant growth and physiology.
Keywords	Cadmium (Cd) stress; OJIP transient; Plant Growth

Title	**Progress in our understanding of plant responses to the stress of heavy metal cadmium**
Author Name	Tingting Zhu, Lingyu Li, Qixin Duan, Xiuling Liu, and Min Chen
Journal Name	Plant Signaling & Behavior
Year	2021
Volume and Issue	16(1)
Pages	1836884
Abstracts	Heavy metal pollution is a major environmental stress affecting plant growth and development. The heavy metal cadmium inhibits various physiological processes in plants, including seed germination and seed ling growth, photosynthesis, and antioxidation. Extensive research has been conducted on the toxic effects of Cd^{2+} on plants and the mechanisms of Cd^{2+} tolerance. Here, we review recent advancements in our understanding of the absorption, transport, and accumulation of Cd^{2+} in plants and the mechanisms of Cd^{2+} tolerance.
Keywords	Heavy Metal; Cadmium; Chelation; Tolerance

Title	**Novel Bacillus cereus Strain, ALT1, Enhance Growth and Strengthens the Antioxidant System of Soybean under Cadmium Stress**
Author Name	Atlaw Anbelu Sahile, Muhammad Aaqil Khan, Muhammad Hamayun, Muhammad Imran, Sang-Mo Kang and In-Jung Lee
Journal Name	Agronomy 2021
Year	2021
Volume and Issue	11
Pages	404
Abstracts	Cadmium stress significantly decreases agricultural productivity worldwide. Plant growth promoting rhizobacteria (PGPR) are eco-friendly and inexpensive tool for mitigating heavy metal stress in crops. We isolated rhizospheric bacteria and screened them for various plant growth promoting (PGP) traits as well as Cd tolerance. Only 6 bacterial isolates out of 55 assessed showed multiple PGP traits in response to different Cd concentrations. The *Bacillus cereus* ALT1 strain showed high tolerance to increased Cd amounts in the culture medium, while secreting indole-3-acetic acid (IAA) and organic acids into the culture medium. High Cd concentrations (0.7 mM, 1.4 mM, and 2.1 mM) reduced soybean shoot and root length, root/shoot fresh and dry weight, as well as chlorophyll content; however, inoculation with the bacterial isolate ALT1 mitigated Cd stress and enhanced both soybean growth parameters and chlorophyll content. It also decreased abscisic acid(ABA) amounts, enhanced salicylic acid (SA) production, and promoted antioxidant response by increasing total proteins (TP) and superoxide dismutase (SOD), while decreasing glutathione (GSH) content, lipid peroxidation (LPO), peroxidase (POD), superoxide anion (SOA), and polyphenol oxidase (PPO) in soybean plants. In addition, inductively coupled plasma mass spectrometry (ICP MS) showed that soybean plants treated with the bacterial isolate ALT1 enhanced K uptake and decreased Cd amounts in comparison to control plants. The present study reveals that Cd-tolerant bacterial isolate ALT1 can alleviate Cd toxicity on plants by increasing their growth, thus imposing itself as an eco-friendly bio-fertilizer under Cd stress.
Keywords	cadmium stress; Bacillus cereus ALT1; hormonal and antioxidant regulation; soybean

Title	**Responses of nitric oxide and hydrogen sulfide in regulating oxidative defence system in wheat plants grown under cadmium stress**
Author Name	Cengiz Kaya, Muhammad Ashraf, Mohammed Nasser Alyemeni and Parvaiz Ahmad
Journal Name	Physiologia Plantarum
Year	2020
Volume and Issue	168
Pages	345-360
Abstracts	We conducted a study to evaluate the interactive effect of NO and H_2S on the cadmium (Cd) tolerance of wheat. Cadmium stress considerably reduced total dry weight, chlorophyll a and b content and ratio of Fv/Fm by 36.7, 48.6, 26.7 and 19.5%, respectively, but significantly enhanced the levels of hydrogen peroxide (H_2O_2) and malondialdehyde (MDA), endogenous H_2S and NO, and the activities of antioxidant enzymes. Exogenously applied sodium nitroprusside (SNP) and sodium hydrosulfide (NaHS), donors of NO and H_2S, respectively, enhanced total plant dry matter by 47.8 and 39.1%, chlorophyll a by 92.3 and 61.5%, chlorophyll b content by 29.1 and 27.2%, Fv/Fm ratio by 19.7 and 15.2%, respectively, and the activities of antioxidant enzymes, but lowered oxidative stress and proline content in Cd-stressed wheat plants. NaHS and SNP also considerably limited both the uptake and translocation of Cd, thereby improving the levels of some key mineral nutrients in the plants. Enhanced levels of NO and H_2S induced by NaHS were reversed by hypotuarine application, but they were substantially reduced almost to 50% by cPTIO (a NO scavenger) application. Hypotuarine was not effective, but cPTIO was highly effective in reducing the levels of NO and H_2S produced by SNP in the roots of Cd-stressed plants. The results showed that interactive effect of NO and H_2S can considerably improve plant resistance against Cd toxicity by reducing oxidative stress and uptake of Cd in plants as well as by enhancing antioxidative defence system and uptake of some essential mineral nutrients.
Keywords	Hydrogen Peroxide; Malondialdehyde; Sodium Nitroprusside; Sodium Hydrosulfide; Chlorophyll; Oxidative Stress

Title	Mechanisms of Cadmium Accumulation in Plants
Author Name	Thibault Sterckeman & Sébastien Thomine
Journal Name	Critical Reviews in Plant Sciences
Year	2020
Volume and Issue	39(4)
Pages	322-359
Abstracts	Cadmium is a non-essential trace metal, which is highly toxic to nearly all living organisms. Soil pollution causes Cd contamination of crops, thereby rendering plant products responsible for the chronic low level Cd over-exposure of numerous populations in the world. For this reason, Cd accumulation in plants has been studied for about five decades now. The research first focused on the relationships between plant and soil Cd levels, on the factors of the metal availability in soil, as well as the root uptake processes. Cd distribution in plant organs was also investigated, first using a macroscopic and eco-physiological approach, and then with the help of molecular biology tools, at both tissue and cell scales. Cadmium has no biological function and hijacks the transport pathways of micronutrients such as Fe, Mn, or Zn, in order to enter the plant through the roots and be distributed to all its organs. The study of the genes that control the influx and efflux of the Cd^{2+} ion in the cytosol, vacuoles, and vascular tissues has significantly contributed to the understanding of the metal root uptake and of its transfer to the aerial parts. However, the mechanisms responsible for its distribution to the different above-ground tissues and specially to fruits and seeds have yet to be clarified. This review summarizes current knowledge in order to present a detailed overview of Cd transport and storage, from the rhizosphere to the different organs and tissues of the plant.
Keywords	Cell wall; chelation; inter-element competition; ion transporter; iron; manganese; nitrogen; organic acid; phloem; phytochelatin; silicon; speciation; vacuolar sequestration; xylem sap; zinc

Title	**Potential use of king grass (Pennisetum purpureum Schumach.× *Pennisetum glaucum (L.)* R.Br.) for phytoextraction of cadmium from fields**
Author Name	Zhiqiang Zhou, Yangyang Guo, Li Hu, Lan He, Bo Xu, Zhenrui Huang, Guo Wang & Yanhui Chen
Journal Name	Environmental Science and Pollution Research
Year	2020
Volume and Issue	27
Pages	35249–35260
Abstracts	Using king grass (Pennisetum purpureum Schumach. × *Pennisetum glaucum (L.)* R.Br.) for phytoextraction is a promising technology for producing large amounts of biomass fuel while remediating contaminated soil. To assess the practical phytoextraction capacity of king grass, we conducted a field experiment with three different soil types (loam, sandy loam, clay loam) and cadmium (Cd) concentrations (0, 0.25, 0.5, 1, 2, 4, 8, and 16 mg kg−1, aged stably for 6 years). King grass were harvested at two different periods (elongation and maturity) to identify the optimal harvest time for extraction efficiency. The results showed that all treatments had bioconcentration factor (BCF) > 1 and translocation factor (TF) < 1; Cd is mainly stored in the roots. However, due to a high shoot biomass, the highest quantity of Cd extracted from shoots was 2.75 mg plant^{-1}, from the experimental group with 16 mg kg^{-1} Cd added in sandy loam. A significant positive relationship ($P < 0.05$) was observed between the amount of Cd extracted from king grass stems, leaves, and roots from soil with the diethylene triamine pentacetate acid (DTPA) extractable Cd concentration. The Cd concentration in shoots at the maturity stage is lower than at the elongation stage, mainly due to the effect of biological dilution. Meanwhile, there is significantly more biomass ($P < 0.05$) at the maturity stage than at the elongation stage. At the latter, the extraction efficiency of the three soils was loam > sandy loam > clay loam, while at maturity it was sandy loam > clay loam > loam. This change in extraction efficiency can be attributed mainly to differences in soil DTPA-extractable Cd concentration and growth rate caused by differences in soil physical and chemical properties. According to calculations from multiple harvests using three types of soil, remediating contaminated soil with 0–16 mg kg^{-1} Cd would take 13.9–224.5 and 19.5–250.6 years, extracting 7.21–265.23 and 4.96–330.52 g ha^{-1} Cd while producing 33.62–66.50 and 73.8–110.5 t ha^{-1} dry biomass at the elongation (90 days) and maturity (120 days) stages, respectively. In summary, king grass has major potential for remediating Cd-contaminated soil while producing large volumes of biofuel.
Keywords	Cadmium; Growth period; Phytoextraction; Pennisetum purpureum Schumach. × Pennisetum glaucum (L.) R.Br.; Soil type

Title	**Effects of intercropping accumulator plants and applying their straw on the growth and cadmium accumulation of *Brassica chinensis L.***
Author Name	Yi Tang, Liming Wang, Yongdong Xie, Xuena Yu, LiJin Lin, Huanxiu Li, Ming'an Liao, Zhihui Wang, Guochao Sun, Dong Liang, Hui Xia, Xun Wang & Lihua Tu
Journal Name	Environmental Science and Pollution Research
Year	2020
Volume and Issue	27
Pages	39094–39104
Abstracts	Two pot experiments were conducted to study the effects of intercropping cadmium (Cd) accumulator plants (*Stellaria media (L.)* Villars, Cardamine hirsuta, Cerastium glomeratum Thuill, and *Galium aparine L.*) and applying their straw on the growth and Cd accumulation of *Brassica chinensis L*. Intercropping with four accumulator plants reduced the biomass, water content, and photosynthetic pigment content of *B. chinensis* compared with monoculture. Intercropping with accumulator plants increased the Cd content in the roots and shoot of *B. chinensis*, and the translocation factor (TF), root bioconcentration factor (root BCF), and shoot bioconcentration factor (Shoot BCF) increased. The soil pH decreased and the soil available Cd content increased by intercropping. Thus, intercropping with four accumulator plants can promote the Cd uptake of *B. chinensis*. The straw of four accumulator plants reduced the biomass, water content, and photosynthetic pigment content of *B. chinensis* compared with the control. The straw of *S. media* and *C. hirsute* increased the Cd content in the roots and shoots of *B. chinensis*, TF, root BCF, and shoot BCF. The straw of *C. glomeratum* and *G. aparine* decreased the Cd content in the roots and shoots of *B. chinensis*, TF, root BCF, and shoot BCF. The soil pH increased and the soil available Cd content decreased by application of straw. Thus, the straw of *C. glomeratum* and *G. aparine* can reduce the Cd uptake of *B. chinensis*.
Keywords	Accumulator plants; Intercropping; Straw; *Brassica chinensis L*; Cadmium

Title	**Cadmium Stress and Toxicity in Plants: An Overview**
Author Name	Bala Murugan Shanmugaraj, AshwiniMalla & Sathishkumar Ramalingam
Journal Name	Cadmium Toxicity and Tolerance in Plants (From Physiology to Remediation)
Year	2019
Volume and Issue	1
Pages	1 - 17
Abstracts	Heavy metal pollution has long been a major environmental problem, and threatens all living forms globally. Cadmium (Cd) is one of the nonessential, highly toxic environmental pollutants worldwide that causes deleterious effects and serious problems in agriculture. Plants growing in Cd-contaminated soil uptake the heavy metal through their roots, which accumulates in different organs, eventually reducing plant growth and productivity. Bioaccumulation of high concentrations of Cd in plants enters the food chain and affects both animals and humans. In plants, several metabolic processes are associated with Cd toxicity and its tolerance. This chapter summarizes the effects of Cd toxicity in plant growth and other related physiological and metabolic processes, including an overview of phytoremediation technologies to clean up Cd contamination in the environment.
Keywords	Abiotic stress; Accumulation; Cadmium; Heavy metals; Phytoremediation; Toxicity

Title	**Characteristics of cadmium accumulation and isotope fractionation in higher plants**
Author Name	Rongfei Wei, Qingjun Guo, Liyan Tian, Jing Kong, Yang Baia,Chukwunonso Peter Okoli & Liyuan Wang
Journal Name	Ecotoxicology and Environmental Safety
Year	2019
Volume and Issue	Volume 174
Pages	1 -11
Abstracts	Cadmium (Cd) pollution of the soil is an important global environmental issueowing to its great toxicity. The study of metal isotope fractionation is a novel technique that could be used to identify and quantify metal uptake and transport mechanisms in plant. In this study, cadmium tolerant Ricinus communis and hyperaccumulator Solanum nigrum have been cultured in different Cd concentration nutrient solutions. The Cd isotope values, metal elements concentrations in the organs (root, stem and leaf) in the two plant species have been measured during the growth periods (10d, 15d, 20d, 25d, and 30d). The results indicate that the organs of S. nigrum could be enriched with lighter Cd isotopes compared with R. communis. In addition, the Cd isotope fractionation become smaller when the plants were subjected to high Cd toxicity, which indicates that Cd isotope fractionation reflected the extent of Cd toxicity to plants. This study advances our current view of Cd translocation machination in plants.
Keywords	Cd; Isotope fractionation; Ricinus communis; Solanum nigrum; Plants

Title	**Phytoremediation of cadmium-polluted soils with Ipomoea asarifolia (Desr.) Roem. & Schult**
Author Name	S Shehu, R.S.U. Wasagu, S.A. Anka, J.C. Okoro & Y Saidu
Journal Name	Journal of Applied Sciences and Environmental Management
Year	2019
Volume and Issue	23, 2
Pages	253 - 259
Abstracts	Phytoremediation is an alternative method for restoring soils polluted with heavy metals which is cost-effective and environment-friendly. The present study evaluated the potential of Ipomoea asarifolia to remediate soils experimentally-amended with Cadmium. The plant was grown on soils amended with 0, 1500, 2000, and 2500 mg $CdCl_2$ salt. The salt was mixed with small portions of the soils and made upto 3kg salt/soil mixtures each. These were applied into 4 separate polythene-pots labelled; A, B, C and D respectively. Sample A containing 3kg non-amended soil (without Cd) served as the control. The concentrations of Cd applied to the soils were therefore; 0, 306.61, 408.82 and 511.02 mg/kg soils in the samples A-D respectively. Atomic absorption spectrophotometry (AAS) was used to analyse the bioaccumulation of Cd in the plant's parts, over three harvesting phases of the study period. The results revealed that I. asarifolia is a good phytoaccumulator as it accumulated a total biomass of 0.23 ± 0.63, 272.85 ± 1.99, 377.40 ± 0.63 and 459.48 ± 0.60 mg/kg Cd from the amended soils A-D respectively. The Transportation Indices; RTI and STI for translocation of Cd to the plant's stems and leaves were both greater than 1 (TI >1), indicating that the plant has a phytoextraction potential for Cadmium. These results therefore, suggest that I. asarifolia could be effective in phytoremediation of Cadmium-polluted environments.
Keywords	Heavy metals; cadmium; pollution; phytoremediation; Ipomoea asarifolia

Title	**Biochar facilitated the phytoremediation of cadmium contaminated sediments: Metal behavior, plant toxicity, and microbial activity**
Author Name	Xiaomin Gong, Danlian Huang, Yunguo Liu, Guangming Zeng, Sha Chen, Rongzhong Wang, Piao Xu, Min Cheng, Chen Zhang & Wenjing Xue
Journal Name	Science of The Total Environment
Year	2018
Volume and Issue	Volume 666
Pages	1126-1133
Abstracts	Cadmium (Cd) contamination in river sediments becomes increasingly serious, and phytoremediation has been used to remediate Cd contaminated sediments, but the remediation efficiency needs to be improved. In this study, tea waste derived biochar (TB) was used to facilitate the phytoremediation of Cd contaminated sediments. Results showed that TB at 100, 500 and 1000 mg kg^{-1} increased Cd accumulation and translocation in ramie seedlings by changing Cd speciation in sediments and altering the subcellular distribution of Cd in plant cells. TB at low contents alleviated Cd induced toxicity in ramie seedlings by promoting plant growth and mitigating the oxidative stress. In addition, the activities of urease-, phosphatase-, and catalase-producing microbes in the Cd contaminated sediments were promoted by the application of TB. These findings demonstrated that biochar at low concentrations could improve the phytoremediation efficiency and mitigating Cd-induced toxicity to plants and microbes in Cd contaminated sediments. This study herein provides a novel technological application of waste biomass in controlling and mitigating risks of heavy metals.
Keywords	Phytoremediation; Cadmium; Plants; Microbes; Sediments

Title	**Sulfide alleviates cadmium toxicity in Arabidopsis plants by altering the chemical form and the subcellular distribution of cadmium**
Author Name	Mei Yan,Guan,Hai Hua Zhang,Wei Pan,Chong Wei Jin, Xian Yong Lin
Journal Name	Science of The Total Environment
Year	2018
Volume and Issue	Volume 627
Pages	663-670
Abstracts	Several sulfur compounds are thought to play important roles in the plant tolerance to cadmium (Cd), but the role of inorganic sulfide in Cd tolerance remains largely unknown. In this study, we found that Cd exposure increased the accumulation of soluble sulfide in Arabidopsis plants. When exogenous sulfide, in the form of NaHS, was foliarly applied, Cd-induced growth inhibition and oxidative stress were alleviated. In addition, although the foliar application of sulfide did not affect the total Cd levels, it significantly decreased the soluble Cd fractions in plants. Furthermore, foliar applications of sulfide decreased Cd distribution in the cytoplasm and organelles, but increased Cd retention in the cell wall, which is a less sensitive compartment. These results suggest that the Cd-induced accumulation of soluble sulfide alleviates Cd toxicity in plants by inactivating Cd and sequestering it into the cell wall.
Keywords	Arabidopsis thaliana, Cadmium, Sulfide, Cadmium tolerance

Title	**Selenium mitigates cadmium-induced oxidative stress in tomato (*Solanum lycopersicum L.*) plants by modulating chlorophyll fluorescence, osmolyte accumulation, and antioxidant system.**
Author Name	Mohammed Nasser Alyemeni,Mohammad Abass Ahanger, Leonard Wijaya,Pravej Alam,Renu Bhardwaj,Parvaiz Ahmad
Journal Name	Protoplasma
Year	2017
Volume and Issue	--
Pages	1-11
Abstracts	Pot experiments were conducted to investigate the role of selenium in alleviating cadmium stress in Solanum lycopersicum seedlings. Cadmium (150 mg L^{-1}) treatment caused a significant reduction in growth in terms of height and biomass accumulation and affected chlorophyll pigments, gas exchange parameters, and chlorophyll fluorescence. Selenium (10 μM) application mitigated the adverse effects of cadmium on growth, chlorophyll and carotenoid contents, leaf relative water content, and other physiological attributes. Lipid peroxidation and electrolyte leakage increased because of cadmium treatment and selenium-treated plants exhibited considerable reduction because of the decreased production of hydrogen peroxide in them. Cadmium-treated plants exhibited enhanced activity of antioxidant enzymes that protected cellular structures by neutralizing reactive free radicals. Supplementation of selenium to cadmium-treated plants (Cd+Se) further enhanced the activity of superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), and glutathione reductase (GR) by 19.69, 31.68, 33.14, and 54.47%, respectively. Osmolytes, including proline and glycine betaine, increased with selenium application, illustrating their role in improving the osmotic stability of *S. lycopersicum* under cadmium stress. More importantly, selenium application significantly reduced cadmium uptake. From these results, it is clear that application of selenium alleviates the negative effects of cadmium stress in *S. lycopersicum* through the modifications of osmolytes and antioxidant enzymes.
Keywords	Solanum lycopersicum , Cadmium , Growth , Chlorophyll fluorescence , Proline , Lipid peroxidation , Antioxidants , Selenium

Title	**Uptake, sequestration and tolerance of Cadmium at cellular levels in the hyperaccumulator plant species Sedum alfredii**
Author Name	Shengke Tian Ruohan Xie Haixin Wang Yan Hu Dandi Hou Xingcheng LiaoPatrick H. Brown Hongxia Yang Xianyong Lin John M. Labavitch
Journal Name	Journal of Experimental Botany
Year	2017
Volume and Issue	68 Issue 9
Pages	2387-2398
Abstracts	*Sedum alfredii* is one of a few plant species known to hyperaccumulate cadmium (Cd). Uptake, localization, and tolerance of Cd at cellular levels in shoots were compared in hyperaccumulating (HE) and non-hyperaccumulating (NHE) ecotypes of *Sedum alfredii*. X-ray fluorescence images of Cd in stems and leaves showed only a slight Cd signal restricted within vascular bundles in the NHEs, while enhanced localization of Cd, with significant tissue- and age-dependent variations, was detected in HEs. In contrast to the vascular-enriched Cd in young stems, parenchyma cells in leaf mesophyll, stem pith and cortex tissues served as terminal storage sites for Cd sequestration in HEs. Kinetics of Cd transport into individual leaf protoplasts of the two ecotypes showed little difference in Cd accumulation. However, far more efficient storage of Cd in vacuoles was apparent in HEs. Subsequent analysis of cell viability and hydrogen peroxide levels suggested that HE protoplasts exhibited higher resistance to Cd than those of NHE protoplasts. These results suggest that efficient sequestration into vacuoles, as opposed to rapid transport into parenchyma cells, is a pivotal process in Cd accumulation and homeostasis in shoots of HE *S. alfredii*. This is in addition to its efficient root-to-shoot translocation of Cd.
Keywords	Cadmium, Fluorescence microscopy, localized, micro X ray fluorescence, protoplasts, tolerance, Vacuole

Title	**Salicylic acid-induced protection against cadmium toxicity in wheat plants**
Author Name	F.M.Shakirova,Ch.R.Allagulova,D.R.Maslennikova,E.O.Klyuchnikova,A.M. Avalbaev,M.V.Bezrukova
Journal Name	Environmental and Experimental Botany
Year	2016
Volume and Issue	Volume 122
Pages	19-28
Abstracts	We have studied the influence of pretreatment of wheat seedlings (*Triticum aestivum L.*) with 50 μM salicylic acid (SA) on plant resistance to subsequent action of 1 mM cadmium acetate. SA pretreatment decreased the extent of detrimental effect of cadmium on wheat plants, as judged by the decline in the level of stress-induced accumulation of MDA and electrolyte leakage. Furthermore, SA-pretreatment contributed to maintenance of growth characteristics of wheat seedlings at the level close to the control under stress conditions and to acceleration of growth recovery during post-stress period. Detected defense effect of SA may be due to a decline in the amplitude of cadmium-induced accumulation of abscisic acid (ABA) and to reduced fall of indoleacetic acid (IAA) and cytokinins (CK) in stressed plants. In the course of one day treatment, SA activated phenylalanine ammonia-lyase (PAL), the key enzyme of lignin biosynthesis, in roots of seedlings under normal growth conditions contributing to the strengthening of carrier functions of cell walls. This assumption is supported by the data showing significant decline in cadmium accumulation in SA-pretreated Detected defense effect of SA may be due to a decline in the amplitude of cadmium-induced accumulation of abscisic acid (ABA) and to reduced fall of indoleacetic acid (IAA) and cytokinins (CK) in stressed plants. In the course of one day treatment, SA activated phenylalanine ammonia-lyase (PAL), the key enzyme of lignin biosynthesis, in roots of seedlings under normal growth conditions contributing to the strengthening of carrier functions of cell walls. This assumption is supported by the data showing significant decline in cadmium accumulation in SA-pretreated.
Keywords	Abscisic acid, Cadmium stress, Dehydrins, Hormonal balance, Phenylalanine ammonia-lyase, Lignin deposition, Plant growth, Salicylic acid Wheat *(Triticum aestivum L.)*

Title	**Modulation and significance of nitrogen and sulfur metabolism in cadmium challenged plants**
Author Name	M. Iqbal R. Khan,Noushina Iqbal,Asim Masood,Mohammad Mobin,Naser A. Anjum
Journal Name	Plant Growth Regulation
Year	2016
Volume and Issue	78, Issue1
Pages	1–11
Abstracts	As a result of rapidly increasing anthropogenic activities, input of varied metal (loids) such as cadmium (Cd) to worldwide agricultural soils and its subsequent accumulation, and obvious toxicity in plants are increasing. The role of mineral nutrients in the mitigation of Cd-accrued consequences in plants has been credibly suggested. In isolated studies, two essential mineral nutrients such as nitrogen (N) and sulfur (S) have been reported to minimize Cd-impacts in plants, and improve overall plant growth, metabolism and productivity under Cd-exposure. However, the information on the significance of N and S metabolism, and also on cross-talks on the coordination therein in Cd-challenged plants is lacking. Given the highlighted lacunae, in the light of recent research outcomes, the present review attempts to: (a) overview Cd in soil, and its major toxicity and mitigation avenues in plants, (b) appraise Cd-mediated modulation of N and S metabolism, (c) summarize the role of exogenously-sourced N and S for the mitigation of Cd toxicity, (d) critically discuss the significance of coordination between N and S metabolism for Cd-impact-mitigation, and finally to (e) highlight the major aspects to explore in the current context. The literature appraised herein suggests that a fine coordination among major pathways of N and S assimilation can enhance defense metabolites and enzymes that in turn can strengthen overall defense system, and efficiently mitigate Cd-impacts in plants. However, efforts are required to get more insights into the mechanism(s) of (co)regulation of sulfate and nitrate assimilation at the molecular level. Additionally, molecular approaches should be narrowed to enhance the production of thiols, and their products in plants through manipulating major enzymes involved in sulfate and nitrate assimilation in plants under Cd-challenged environment.
Keywords	Cadmium-phytotoxicity, Nitrogen metabolism, Sulfur metabolism, Plant-cadmium tolerance