Title	**Long-Term Effect of Heavy Metal–Polluted Wastewater Irrigation on Physiological and Ecological Parameters of *Salicornia europaea L.***
Author Name	Razieh Khalilzadeh, Alireza Pirzad, Ebrahim Sepehr, Shahbaz Khan & Sumera Anwar
Journal Name	Journal of Soil Science and Plant Nutrition
Year	2020
Volume and Issue	20
Pages	1574–1587
Abstracts	Irrigation of *Salicornia europaea* with heavy metal–polluted wastewater is a promising alternative method for risk mitigation of the Urmia Lake ecosystem from uncontrolled sewage. The objective of the study was to evaluate morphological and physicochemical responses of *Salicornia europaea* under wastewater irrigation at different growth stages. A field experiment was conducted in a split-plot experiment based on randomized complete block design with four replications. Treatments included control and wastewater irrigation (containing zinc (Zn), iron (Fe), copper (Cu), cadmium (Cd), lead (Pb), and nickel (Ni)) at three stages (vegetative, flowering, and reproductive) of plant growth and two times (two and 4 days in each stage). The result showed that the wastewater application at reproductive stage resulted in higher biomass production than that of the control plants. Wastewater irrigation at the flowering stage caused a significant increase in the amount of total chlorophyll and chlorophyll-a, while chlorophyll-b content was decreased at both flowering and reproductive stages. The amount of the total soluble protein was also affected, with wastewater irrigation showing the most significant increase at the reproductive stage. There was significant enhancement of osmolytes in leaves of plant under heavy metal stress, and the increased rate of proline was higher than soluble sugar at the flowering stage. Relative water content in *Salicornia* was not duration- and time-dependent. A 154% increase in catalase activity, 32% increase in peroxidase activity, and 57% increase in polyphenol oxidase activity were observed in the plant exposed to long-term wastewater duration. Based on the observed positive effect of wastewater on shoot length and weight, total soluble protein, proline, soluble sugar, enzyme activities, and plant biomass of *Salicornia europaea*, long-term effect of heavy metal–polluted wastewater irrigation can be approved for *Salicornia* crops in coastal areas.
Keywords	Antioxidants; Development stage; Halophytes; Heavy metals; Sewage irrigation

Title	**Characterization of heavy metal toxicity in some plants and microorganisms—A preliminary approach for environmental bioremediation**
Author Name	MarianaDiaconu, Lucian Vasile Pavel, Raluca-MariaHlihor, MihaelaRosca, Daniela Ionela Fertu, MarkusLenz ,Philippe Xavier Corvini, MariaGavrilescu
Journal Name	New Biotechnology
Year	2020
Volume and Issue	56
Pages	130-139
Abstracts	*In situ* bioremediation processes are important for control of pollution and clean-up of contaminated sites. The study and implementation of such processes can be designed through investigations on natural mechanisms of absorption, biotransformation, bioaccumulation and toxicity of pollutants in plants and microorganisms. Here, the phytotoxic effects of Cr(VI) and Cd(II) on seed germination and plant growth of *Lepidium sativum* have been examined at various concentrations (30−300 mg/L) in single ion solutions. The studies also addressed the *ecotoxicity* of metal ions on Azotobacter chroococcum and Pichia sp. isolated from soil. Microbial growth was estimated by weighing the dry biomass and determining the enzymatic activities of dehydrogenase and catalase. The results showed that Cr(VI) and Cd(II) can inhibit *L. sativum* seed germination and root development, depending on the metal ion and its concentration. The phytotoxic effect of heavy metals was also confirmed by the reduced amounts of dried biomass. Toxicity assays demonstrated the adverse effect of Cr(VI) and Cd(II) on growth of *Azotobacter sp.* and *Pichia sp.*, manifested by a biomass decrease of more than 50 % at heavy metal concentrations of 150−300 mg/L. The results confirmed close links between phytotoxicity of metals and their bioavailability for phytoextraction. Studies on the bioremediation potential of soils contaminated with Cr(VI) and Cd(II) using microbial strains focusing on *Azotobacter sp.* and *Pichia sp.* showed that the microbes can only tolerate heavy metal stress at low concentrations. These investigations on plants and microorganisms revealed their ability to withstand metal toxicity and develop tolerance to heavy metals.
Keywords	Azotobacter sp.; Bioremediation; Cadmium; Chromium; Lepidium sativum; Metal toxicity; Pichia sp.

Title	**Risk assessment of heavy metal toxicity by sensitive biomarker δ-aminolevulinic acid dehydratase (ALA-D) for onion plants cultivated in polluted areas in Kosovo**
Author Name	Bekim Gashi, Mirsade Osmani, Sali Aliu, Muhamet Zogaj &Fitim Kastrati
Journal Name	Journal of Environmental Science and Health, Part B
Year	2020
Volume and Issue	55(5)
Pages	462-469
Abstracts	Biomarkers allow an integrated risk assessment of heavy metal pollution effects in living organisms. In this study, the biochemical effects of Cd, Cr, Ni, Pb and Zn pollution in agricultural soil and their accumulation in *Alium cepa L.* (onion) were evaluated with ALA-D enzyme response as a biomarker, along with δ-aminolevulinic acid (ALA) and total chlorophyll contents in leaves of this plant. Soil samples were randomly selected from agricultural areas in two regions, Mitrovica and Obiliqi, which are considered the most industrially polluted regions in Kosovo. Results show that Pb and Zn concentrations in soil samples from Mitrovica (1953-2576 mg kg^{-1}) and Obiliqi regions (138-179 mg kg^{-1}) and their bioaccumulation levels in onion were significantly higher in comparison with the control group. There was an adverse negative correlation between Pb or Zn concentration and ALA-D activity and total chlorophyll content, and a positive correlation with ALA content. This study indicates that ALA-D activity can be used as a very sensitive biomarker for evaluation of heavy metal pollution. The bioaccumulation of heavy metals from soil polluted areas poses a threat for food contamination and public health.
Keywords	Allium cepa; bioaccumulation; heavy metals; ALA-D activity kosovo

Title	**Deciphering metal toxicity responses of flax (*Linum usitatissimum L.*) with exopolysaccharide and ACC-deaminase producing bacteria in industrially contaminated soils**
Author Name	NidaZainab, Amna, Bashir UdDin, Muhammad TariqJaved, Muhammad SiddiqueAfridi, TehmeenaMukhtar, Muhammad AqeelKamran, Qurat ul ain, Amir AbdullahKhan, JavedAli,Wajid NasimJatoi, Muhammad Farooq, Hussain Munis, Hassan JavedChaudhary
Journal Name	Plant Physiology and Biochemistry
Year	2020
Volume and Issue	152
Pages	90-99
Abstracts	Rapid industrialization is the main reason of heavy metals contamination of soil colloids and water reservoirs. Heavy metals are persistent inorganic pollutants; deleterious to plants, animals and human beings because of accumulation in food chain. The aim of the current work was to evaluate the role of indole acetic acid (IAA), exopolysaccharide (EPS) and ACC-deaminase producing plant growth promoting rhizobacteria (PGPR) i.e .*B. gibsonii* PM11 and *B. xiamenensis* PM14 in metal phytoremediation of metals, their survival and plant growth promotion potential in metal polluted environment as well as alterations in physio-biochemical responses of inoculated *L. usitatissimum* plants towards heavy metal toxicity. Two bacterial strains Bacillus gibsonii (PM11) and *Bacillus xiamenensis* (PM14), previously isolated from sugarcane's rhizosphere, were screened for metal tolerance (50 mg/l to 1000 mg/l) and plant growth promoting traits like IAA, ACC-deaminase, EPS production and nitrogen fixing ability under metal stress. The response of flax plant (*Linum usitatissimum L.*) was analyzed in a pot experiment containing both industrially contaminated and non-contaminated soils. Experiment was comprised of six different treatments, each with three replicates. At the end of the experiment, role of metal tolerant plant growth promoting bacterial inoculation was elucidated by analyzing the plant growth parameters, chlorophyll contents, antioxidative enzymes, and metal uptake both under standard and metal contaminated rhizospheres. Results revealed that root and shoot length, plant's fresh and dry weight, proline content, chlorophyll content, antioxidant enzymatic activity was increased in plants inoculated with plant growth promoting bacteria as compared to non-inoculated ones both in non-contaminated and industrial contaminated soils. In current study, inoculation of IAA, EPS and ACC-deaminase producing bacteria enhances plant growth and nutrient availability by minimizing metal-induced stressed conditions. Moreover, elevated phytoextraction of multi-metals from industrial contaminated soils by PGPR inoculated *L. usitatissimum* plants reveal that these strains could be used as sweepers in heavy metals polluted environment.
Keywords	ACC-Deaminase; B. xiamenensis; B. gibsonii; Exopolysaccharide; Industrial contamination; Flax

Title	**Evaluation of in vivo sub-chronic and heavy metal toxicity of under-exploited seaweeds for food application**
Author Name	Abirami R.Ganesan, KowsalyaSubramani, Balamuralikrishnan , Balasubramanian, Wen ChaoLiu, Mariadhas ValanArasu, Naif AbdullahAl-Dhabi, Veeramuthu, Duraipandiyan
Journal Name	Journal of King Saud University - Science
Year	2020
Volume and Issue	32(1)
Pages	1088-1095
Abstracts	Seaweeds are known to be rich source of micronutrients and bioactive compounds. The main objective of this study was to find the toxicological evaluation and heavy metal accumulation of five under-exploited edible seaweeds in animal model followed by dosage determination for regular consumption as a food by humans and food application. Some under-exploited seaweed like *Acanthophora spicifera*, *Gracilaria edulis*, *Padina gymnospora*, *Ulva fasciata* and *Enteromorphoa flexuosa* were selected forthis study. The ED50 study was conducted in Wistar strain rats for 90 days with single dose administration of seaweed extract of 2000 mg/kg/BW. At the end of 90th day rats were euthanized, serum of the rats examined for biochemical, haematological, liver enzymes, and vital organs were dissected out for heavy metal analysis and urine samples collected intermediary to analyse electrolyte minerals. Result showed that no-observed adverse effect level (NOEL) on five seaweeds, did not cause any death and no significant variation in biochemical and haematological parameters, the values were found within standard values. Locomotor activity suggests normal action, organ necropsy showed no histopathology lesions, regular cell alignment in the tissue cross section. Heavy metals like arsenic, lead were found in trace amount and no mercury accumulation found in kidney, liver and brain of rats. Therefore, these five seaweeds were safe for human consumption and also for food product developement.
Keywords	Seaweed; Sub-chronic toxicity; Acanthophora spicifera; Gracilaria edulis; Padina gymnospora; Ulva fasciata; Enteromorphoa flexuosa

Title	**Genetic diversity of African's rice (Oryza glaberrima Steud.) accessions cultivated under iron toxicity**
Author Name	JunKangGuo, XinLv, HongLeiJia, LiHua , XinHaoRen, HarisMuhammad, TingWei, YongzhenDing
Journal Name	Journal of Environmental Sciences
Year	2020
Volume and Issue	88
Pages	361-369
Abstracts	Phytoremediation is a cost-effective and environment-friendly strategy for decontaminating heavy-metal-contaminated soil. However, the practical use of phytoremediation is constrained by the low biomass of plants and low bioavailability of heavy metals in soil. A pot experiment was conducted to investigate the effects of the metal chelator ethylenediaminetetraacetic acid (EDTA) and EDTA in combination with plant growth-promoting rhizobacteria (*Burkholderia sp.* D54 or *Burkholderia sp.* D416) on the growth and metal uptake of the hyperaccumulator *Sedum alfredii* Hance. According to the results, EDTA application decreased shoot and root biomass by 50% and 43%, respectively. The soil respiration and Cd, Pb, Zn uptake were depressed, while the photosynthetic rate, glutathione and phytochelatin (PC) contents were increased by EDTA application. Interestingly, *Burkholderia sp.* D54 and *Burkholderia sp.* D416 inoculation significantly relieved the inhibitory effects of EDTA on plant growth and soil respiration. Compared with the control, EDTA + D416 treatment increased the Cd concentration in shoots and decreased the Pb concentration in shoots and roots, but did not change the Zn concentration in *S. alfredii* plants. Furthermore, EDTA, EDTA + D54 and EDTA + D416 application increased the cysteine and PC contents in *S. alfredii* ($p < 0.05$); among all tested PCs, the most abundant species was PC2, and compared with the control, the PC2 content was increased by 371.0%, 1158.6% and 815.6%, respectively. These results will provide some insights into the practical use of EDTA and PGPR in the phytoremediation of heavy-metal-contaminated soil by *S. alfredii*.
Keywords	Phytoremediation; EDTA; Plant-growth-promoting bacteria; Sedum alfredii Hance; Phytochelatin

Title	Effects of long-term fertilizer applications on peanut yield and quality and plant and soil heavy metal accumulation
Author Name	Xiaobingwang, Wuxingliu, Zhengaoli, Yingteng, Peterchristie, Yongmingluo
Journal Name	Pedosphere
Year	2020
Volume and Issue	30(4)
Pages	555-562
Abstracts	The status of essential and potentially toxic trace elements in soils and crops can be affected by long-term fertilization practices. This study aimed to investigate changes in peanut (*Arachis hypogaea L.*) yield and kernel quality, and changes in copper (Cu), zinc (Zn), lead (Pb), and cadmium (Cd) concentrations in soil and peanut kernels after 16 years of continuous cropping with different fertilization treatments. Five fertilization treatments were applied at a red soil site in Southeast China: chemical fertilizer (F) containing nitrogen, phosphorus, and potassium, F + trace elements (FT), pig manure (M), M + effective microorganisms (MB), and MB + trace elements (MBT). Properties of soil and pig manure, heavy metal contents in soil and peanut kernels, and the compositions of amino and fatty acids in kernels were determined. Application of pig manure significantly increased peanut biomass, kernel yield, and crude protein and total amino acid contents in kernels, but led to higher amounts of Cu, Zn, and Cd in soil and higher amounts of Zn and Cd in peanut kernels compared with that of chemical fertilizer. There should be greater concern about potential kernel Cd and Zn contaminations resulting from long-term application of pig manure contaminated with potentially toxic metals as an organic fertilizer.
Keywords	amino acid; chemical fertilizer; fatty acid; pig manure; potentially toxic metal

Title	**Promises and potential of in situ nano-phytoremediation strategy to mycorrhizo-remediate heavy metal contaminated soils using non-food bioenergy crops (*Vetiver zizinoides* & *Cannabis sativa*)**
Author Name	A.G. Khan
Journal Name	International Journal of Phytoremediation
Year	2020
Volume and Issue	22(9)
Pages	900-915
Abstracts	Heavy metals (HMs) in soil, air, and water environments effect human health. These HMs cannot be degraded in soil and they can only be transformed from one state to another. Food and energy resources such as coal, oil, petrol, etc. are gradually diminishing due to ever increasing demand and consumption, world faces crisis. There is an urgent need to address these problems by reclaiming the waste/polluted land for food and energy production. Various physicochemical remediation strategies are being proposed, developed, and tested but they are all very costly and only applicable to small contaminated sites. During the past two decades or so, plant-based phytoremediation technology is rapidly evolving as a promising new tool to address the issue with the potential to remediate HM contaminated soils in a sustainable manner. Plants, labeled as phyto-tolerant or phyto-accumulators, surviving on such contaminated soils reduce the toxicity by preventing their translocation or destroying the contaminants by sequestration by synthesizing thiol-containing HM-binding proteins (nano-molecules) and peptides (phytochelators or PCs) which modulate internal levels of metal concentration between deficient and toxic levels. But such plants are very slow growing, producing small biomass, and the process taking a long time to effectively remediate such soils. To overcome limitations of using such plants, plants capable of high biomass production and tolerating multiple HMs, such as non-food bioenergy crops (Vetiver and Hamp), are required. This plant-based remediation strategy can further be enhanced with the use of both plants and rhizosphere microbes like arbuscular mycorrhizal fungi (AMF) and plant growth-promoting bacteria. The combination of three components, i.e. high biomass producing plant, soil, and its rhizosphere harboring plant growth-promoting rhizobial (PGPR) microbiota, particularly AMF, will further improve the process of nano-phytoremediation of HM contaminated soils. This mini review focuses on how phytoremediation, nanotechnology, AMF and PGPR technologies can be merged together to form an integrated nano-mycorrhizo-phytoremediation (NMPR) strategy which synergistically achieve the goal of remediation of soil contaminants and improve the phytoremediation performance of bioenergy plants grown on HM polluted soils. This review also identifies the urgent need to conduct field-scale application of this strategy and use it as potential tool for reestablishing plant cover and population diversity during restoration of derelict land post-industrial/mining activities.
Keywords	arbuscular mycorrhizal fungi (amf); bioenergy crops; biological nanomaterials; cannabis sativa; nano-mycorrhizo-phytoremediation (nmpr); nano-phytoremediation (npr); phytochelators; plant growth-promoting rhizobia (pgpr); vetiver grass

Title	**Understanding Heavy Metal Stress in a Rice Crop: Toxicity, Tolerance Mechanisms, and Amelioration Strategies**
Author Name	Namira Arif , Nilesh C. Sharma , Vaishali Yadav , Naleeni Ramawat , Nawal Kishore Dubey , Durgesh Kumar Tripathi , Devendra Kumar Chauhan & Shivendra Sahi
Journal Name	Journal of Plant Biology
Year	2019
Volume and Issue	Volume 62
Pages	Pages 239-253
Abstracts	Heavy metal (HMs) pollution is regarded as one of the major concerns for soil and water, causing varieties of toxic and stress effects on plants and ecosystems. It has become one of the important limiting factors to crop productivity and quality. Due to an ever-increasing population growth and food demands, this situation has further worsened. Rice, a leading staple food crop that feeds more than 50% populations of the world, is constantly affected by abiotic stressors including HMs. In most of the countries, a major source of HM intake by humans is the rice grain produced through the paddy soils contaminated with HMs such as As, Al, Cu, Cr, Cd, Pb, Hg, Mn, Se, and Zn. Thus, gradual agglomeration of HMs in rice grains and their subsequent transfer to the food chain is a major menace to agriculture and human health. In recent years, several studies examined the impact of HMs toxicity on rice at multiple levels: molecular, biochemical, physiological, cellular and tissue, and demonstrated a correlation between HMs toxicity and the decreasing trend in rice productivity. Therefore, it is necessary to understand the interaction of HMs with rice crop spanning from the cell to whole plant level and devise appropriate effective means to alleviate these stress responses. This review focuses on tracing the pathways involved in stress responses and stress tolerance mechanisms displayed by different varieties of rice. However, it is essential to uncover the mechanisms related to stress responses in rice for designing improved investigations to develop novel varieties with high attributes. Therefore, this communication summarizes various defense strategies induced against HM stress and includes the function of metabolites (metabolomics), trace elements (ionomics), transcription factors (transcriptomics), and various stress-inducible proteins (proteomics) including the role of plant hormones.
Keywords	Heavy metals; Ionomics; Metabolomics; metallophytes; Proteomics; Rice; Transcriptomics

Title	**Nanomaterials and plants: Positive effects, toxicity and the remediation of metal and metalloid pollution in soil**
Author Name	Yi Zhu, Fang Xu, Qin Liu , Ming Chen, Xianli Liu, Yanyan Wang, Yan Sun & Lili Zhang
Journal Name	Science of the Total Environment
Year	2019
Volume and Issue	Volume 662
Pages	Pages 414-421
Abstracts	Currently, the pollution of metals and metalloids in the soil has attracted considerable attention. Phytoremediation is considered an environmentally friendly means of remediating pollution, but often takes a long time to perform. Therefore, the combination of plants and nanomaterials in environmental management has attracted the attention of many researchers because some nanomaterials can promote the germination of plant seeds and the growth of whole plants. However, when the concentration of nanomaterials is not controlled properly, certain toxicity will be produced. This paper reviews research on the combination of plant and nanomaterials for the remediation of contaminated environments, as well as on the effects of nanomaterials on plants.
Keywords	Nanoparticle; Nanomaterial; Heavy metal; PlantsToxicity

Title	**Transport and detoxification of metalloids in plants in relation to plant-metalloid tolerance**
Author Name	Akhilesh Kumar Pandey, Arti Gautam & Rama Shanker Dubey
Journal Name	Plant Gene
Year	2019
Volume and Issue	Volume 17
Pages	----
Abstracts	Metalloids are key environmental contaminants and when present in high concentrations in soil, adversely affect crop productivity. Plants possess several transporters that maintain required level of essential metal ions inside the cells so as to perform different metabolic activities. Transporters are responsible for the entry and distribution of different elements inside various cells and organs of the plant. Many toxic metalloid ions share the transport network of essential ions due to their similar structural properties like phosphate transporters, aquaglyceroporins, hexose transporters, sulphate transporters, etc. Presence of excess amounts of toxic metalloid ions inside the plant tissues causes severe damages to cell biomolecules, affects key metabolic processes, inhibits growth of plants ultimately leading to decreased crop yield. Therefore detoxification strategies of metalloids at the tissue level are essential in order to minimize their toxic effects. Employing mutants, attempts have been made by various groups of workers to restrict the uptake of many pollutant metalloids by plants by reducing the activities of transporters and to overexpress metalloid binding peptides and proteins such as phytochelatins, metallothioneins for sequestration of metalloids in the tissues. Reduced transport of metalloids in the tissues coupled with their increased sequestration inside the cells would lead to generation of metalloid-tolerant crop plants. The present review summarizes our current status of knowledge in this direction related to transport mechanisms and detoxification strategies of metalloids in crop plants in relation to Plant-Metalloid tolerance.
Keywords	Metalloids; Transporters; Aquaglyceroporins; Metallothioneins; Phytochelatins

Title	Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals:Environmental Persistence, Toxicity, and Bioaccumulation
Author Name	Hazrat Ali, Ezzat Khan & Ikram Ilahi
Journal Name	Journal of Chemistry
Year	2019
Volume and Issue	Volume 2019
Pages	14
Abstracts	Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulative nature. Their natural sources include weathering of metal-bearing rocks and volcanic eruptions, while anthropogenic sources include mining and various industrial and agricultural activities. Mining and industrial processing for extraction of mineral resources and their subsequent applications for industrial, agricultural, and economic development has led to an increase in the mobilization of these elements in the environment and disturbance of their biogeochemical cycles. Contamination of aquatic and terrestrial ecosystems with toxic heavy metals is an environmental problem of public health concern. Being persistent pollutants, heavy metals accumulate in the environment and consequently contaminate the food chains. Accumulation of potentially toxic heavy metals in biota causes a potential health threat to their consumers including humans. This article comprehensively reviews the different aspects of heavy metals as hazardous materials with special focus on their environmental persistence, toxicity for living organisms, and bioaccumulative potential. The bioaccumulation of these elements and its implications for human health are discussed with a special coverage on fish, rice, and tobacco. The article will serve as a valuable educational resource for both undergraduate and graduate students and for researchers in environmental sciences. Environmentally relevant most hazardous heavy metals and metalloids include Cr, Ni, Cu, Zn, Cd, Pb, Hg, and As. The trophic transfer of these elements in aquatic and terrestrial food chains/webs has important implications for wildlife and human health. It is very important to assess and monitor the concentrations of potentially toxic heavy metals and metalloids in different environmental segments and in the resident biota. A comprehensive study of the environmental chemistry and ecotoxicology of hazardous heavy metals and metalloids shows that steps should be taken to minimize the impact of these elements on human health and the environment.
Keywords	Bioaccumulative; anthropogenic sources; heavy metals; metalloids; ecotoxicology

Title	Engineering plants for heavy metal stress tolerance
Author Name	Wasia Wani, Khalid Z. Masoodi, Abbu Zaid, Shabir H. Wani, Farheena Shah, Vijay Singh Meena, Shafiq A. Wani, Kareem A. Mosa
Journal Name	Rendiconti Lincei. Scienze Fisiche e Naturali
Year	2018
Volume and Issue	Volume 29,3
Pages	Pages 709-723
Abstracts	We here assess the biodiversity of the rhizosphere microbial communities of metal-tolerant plant species *Arabidopsis arenosa*, *Arabidopsis halleri*, *Deschampsia caespitosa*, and *Silene vulgaris* when growing on various heavy metal polluted sites. Our broad-spectrum analyses included counts for total and metal-tolerant culturable bacteria, assessments of microbial community structure by phospholipid fatty acid (PLFA) profiling and community-level analysis based on BIOLOG-CLPP to indicate functional diversity. The genetic-biochemical diversity was also measured by denaturing gradient gel electrophoresis (PCR-DGGE) and *metabolomic* analysis (HPLC-MS). Different *rhizospheres* showed distinctive profiles of microbial traits, which also differed significantly from bulk soil, indicating an influence from sampling site as well as plant species. However, total bacterial counts and PCR-DGGE profiles were most affected by the plants, whereas sampling site-connected variability was predominant for the PLFA profiles and an interaction of both factors for BIOLOG-CLPP. Correlations were also observed between pH, total and bioavailable Cd or Zn and measured microbial traits. Thus, both plant species and heavy-metals were shown to be major determinants of microbial community structure and function.
Keywords	Heavy metal stress tolerance; Metabolic engineering; Physiological and cellular changes ; Transgenics; Crop improvement

Title	**Heavy metals and metalloids: Sources, risks and strategies to reduce their accumulation in horticultural crops**
Author Name	Menahem Edelstein & Meni Ben-Hur
Journal Name	Scientia Horticulturae
Year	2018
Volume and Issue	234
Pages	431-444
Abstracts	Food production in areas contaminated with heavy metals is associated with health risks because of their adverse effects on food safety and marketability, and on crop growth and yield quality. The present review focuses on sources and risks of heavy metals, mainly in cultivated fields in various regions, and strategies to reduce their accumulation in horticultural crops. The following heavy metals are discussed: arsenic (As), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V) and zinc (Zn). Heavy metal sources in the environment can originate from natural and anthropogenic activities. Their main natural enrichment in soils stems from parent-material weathering. However, in coastal areas, precipitation of sea spray may enrich soil with B. In contrast, the main anthropogenic sources of heavy metals in cultivated areas are irrigation with treated sewage water, application of residual biosolids, and atmospheric pollution. Plants absorb heavy metals predominantly through roots and, to a lesser extent, through leaves. Leaf uptake can occur through the stomata, cuticular cracks, ectodesmata, and aqueous pores. Heavy metal uptake may lead to their accumulation in vegetables and fruit trees, and their consequent introduction into the food chain, which is recognized as one of the major pathways for human exposure to them. This exposure can result in retardation, several types of cancer, kidney damage, endocrine disruption, and immunological and neurological effects. High concentrations of heavy metals can also affect the growth and yield of many crops: Zn and Cd decrease plant metabolic activity and induce oxidative damage; Cu generates oxidative stress and reactive oxygen species; Hg can induce visible injury and physiological disorders; Cr affects photosynthesis in terms of CO_2 fixation, electron transport, *photophosphorylation* and enzyme activities; Pb induces plant abnormal morphology; Ni spoils the nutrient balance, resulting in disorders of cell membrane functions; Fe causes free radical production that irreversibly impairs cell structure and damages membranes, DNA and proteins; As causes leaf necrosis and wilting, followed by root discoloration and retardation of shoot growth. Therefore, international organizations, such as the US EPA and EU bodies, are working on regulating the maximum allowable levels of food pollutants. A number of direct (*mycorrhiza*, transgenic plants and grafting) approaches can be deployed to overcome problems of heavy metal contamination in horticulture.
Keywords	Contamination; Fruits; Health risks; Heavy metals; Pollution; Vegetables; Wastewater

Title	**Toxicity and detoxification of heavy metals during plant growth and metabolism**
Author Name	Sonali Dubey, Manju Shri, Anubhuti Gupta, Vibha Rani & Debasis Chakrabarty
Journal Name	Environmental Chemistry Letters
Year	2018
Volume and Issue	--
Pages	Pages 01-24
Abstracts	Pollution of plants by heavy metals is a critical health issue because metals can be transmitted to animals and humans. Heavy metal exposure induces an oxidative stress in plant, resulting in cellular damage and altered cellular ionic homeostasis. As a consequence, plants start detoxification mechanisms. Here, we review heavy metal toxicity and impact. We discuss metabolism and detoxification strategies of heavy metals and metalloid, with emphasis on the use of *transcriptomics*, *metabolomics*, and proteomics. A section highlights *microRNA* (*miRNA*) as critical regulators of heavy metal stress in plants. We also present bioremediation and *phytoremediation* methods to remove metals.
Keywords	Heavy metal; Toxicity; Plants; Oxidative stress; Tolerance; Detoxification; Defense mechanism; microRNAs; Phytoremediation

Title	**Potential health risk assessment of potato (Solanum tuberosum L.) grown on metal contaminated soils in the central zone of Punjab, Pakistan**
Author Name	Yishu Peng, Ruidong Yang, Tao Jin, Jun Chen & Jian Zhang
Journal Name	Food and Chemical Toxicology
Year	2017
Volume and Issue	120
Pages	328-339
Abstracts	We investigated potentially toxic metal (loid)s (arsenic, As; cadmium, Cd; chromium, Cr; copper, Cu; mercury, Hg; lead, Pb; selenium, Se; and zinc, Zn) in agricultural samples (i.e., *Solanum tuberosum L.* tubers (potatoes) and their planting media) in the indigenous zinc smelting area of northwestern Guizhou Province, China. Based on the pollution index values for As, Cd, Pb and Zn, the order of the samples was as follow: slag > planting soil with slag > planting soil without slag, and the order of the samples in terms of the *bioconcentration* factor was the opposite. Cr, Cu and Hg were present in the planting soil with and without slag at slight pollution levels, and the other potentially toxic metal (loid)s had different degrees of contamination. Additionally, the potentially toxic metal (loid) contents in potato were under their limit values except for Cd (all samples) and Pb and Se (some samples). All *bioconcentration* factors for potatoes were below 0.5, and no health risk index value for potatoes was higher than 0.1. Therefore, although no significant health risk associated with potentially toxic metal (loid)s via consuming potato exists for either adult men or women in the research area, the Cd concentration in this crop should be monitored.
Keywords	Potentially toxic metal(loid); sIndigenous zinc smelting; Solanum tuberosum L.; Enrichment factor; Bioconcentration factor; Health risk index

Title	**Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia**
Author Name	Khaled S.Balkhair, Muhammad Aqeel Ashrafc
Journal Name	Saudi Journal of Biological Sciences
Year	2016
Volume and Issue	23,1
Pages	S32-S44
Abstracts	Wastewater irrigated fields can cause potential contamination with heavy metals to soil and groundwater, thus pose a threat to human beings . The current study was designed to investigate the potential human health risks associated with the consumption of okra vegetable crop contaminated with toxic heavy metals. The crop was grown on a soil irrigated with treated wastewater in the western region of Saudi Arabia during 2010 and 2011. The monitored heavy metals included Cd, Cr, Cu, Pb and Zn for their bioaccumulation factors to provide baseline data regarding environmental safety and the suitability of sewage irrigation in the future. The pollution load index (PLI), enrichment factor (EF) and contamination factor (CF) of these metals were calculated. The pollution load index of the studied soils indicated their level of metal contamination. The concentrations of Ni, Pb, Cd and Cr in the edible portions were above the safe limit in 90%, 28%, 83% and 63% of the samples, respectively. The heavy metals in the edible portions were as follows: Cr > Zn > Ni > Cd > Mn > Pb > Cu > Fe. The Health Risk Index (HRI) was >1 indicating a potential health risk. The EF values designated an enhanced bio-contamination compared to other reports from Saudi Arabia and other countries around the world. The results indicated a potential pathway of human exposure to slow poisoning by heavy metals due to the indirect utilization of vegetables grown on heavy metal-contaminated soil that was irrigated by contaminated water sources. The okra tested was not safe for human use, especially for direct consumption by human beings. The irrigation source was identified as the source of the soil pollution in this study.
Keywords	Health risk; Heavy metals; Sewage water; Metal transfer index; Soil