Title	**Biotransfer, bioaccumulation and detoxification of nickel along the soil - faba bean - aphid - ladybird food chain**
Author Name	Mohd Irfan Naikoo, Fareed Ahmad Khan, Ahmed Noureldeen, Jörg Rinklebe, Christian Sonne, Nishanta Rajakaruna, Parvaiz Ahmad
Journal Name	Science of the Total Environment
Year	2021
Volume and Issue	785
Pages	147226
Abstracts	Nickel release from anthropogenic and natural sources into the environment has resulted in biomagnification in terrestrial ecosystems. Here, we studied the biotransfer and toxicokinetics of nickel (Ni) along the soil < faba bean < aphid-ladybird food chain. The soil was spiked with the following Ni concentrations (in mg kg^{-1} soil ww); T0 (0), T1 (25), T2 (50), T3 (75), and T4 (100). Our results revealed a significant elevation of Ni transfer with increasing Ni doses. The transfer coefficients (TC) indicate Ni biomagnified in soil to root and shoot to aphid >1 while the TC of the biominimisation of Ni in the aphid to ladybird was <1. The Ni removal from aphids through honeydew (excreta) and pupal exuviae during metamorphosis suggests a possible detoxification mech anism operating at two distinctive trophic levels, controlling the bioaccumulation of Ni along the examined food chain. Such toxicokinetics is not reported elsewhere and emphasize the need for future studies aiming to elabo rate the possible mechanisms, potential components and physiological pathways associated with the bioaccumu lation of Ni across food chains of the ecosystem.
Keywords	Biotransfer; Bioaccumulation; Nickel; Faba bean; Aphid; Ladybird; Food chain; Biomagnification

Title	**Organic and inorganic amendments for the remediation of nickel contaminated soil and its improvement on Brassica napus growth and oxidative defense**
Author Name	Fakhir Hannan, Qian Huang, Muhammad A. Farooq, Ahsan Ayyaz, Junyi Ma, Na Zhang, Basharat Ali, Elizabeth Deyett, Weijun Zhou, Faisal Islam
Journal Name	Journal of Hazardous Materials
Year	2021
Volume and Issue	416: 125921
Pages	0304-3894
Abstracts	In-situ stabilization has been considered an effective way to remediate metal contaminated soil. Thus, pot ex periments were undertaken to investigate the effectiveness of multiple stabilization agents such as biochar (BC), mussel shell (MS), zeolite (ZE) and limestone (LS) on the immobilization of Ni, physicochemical features and enzyme activities in polluted soil. Results showed that the sole application of Ni adversely affected the rapeseed growth, photosynthetic pigments, and antioxidative defense. However, the addition of amendments to the contaminated soil significantly reduced Ni bioavailability. The XRD analysis confirmed the formation of Ni related ligands and FTIR showed the presence of hydroxyl, carboxyl and sulfur functional groups, as well as complexation and adsorption of Ni on amendments. Among multiple amendments, biochar significantly enhanced plant biomass attributes and total chlorophyll content. Moreover, addition of amendments also strengthened the antioxidant defense by decreasing Ni induced oxidative stress (H_2O_2 and O_2.-), increased macronutrient availability, reduced Ni uptake and improved soil health. The qPCR analysis showed that the Ni transporters were significantly suppressed by amendments, which is correlated with the lower accumulation of Ni in rapeseed. The present study showed that immobilizing agents, especially biochar, is an effective amend ment to immobilize Ni in soil, which restricts its entry into the food chain.
Keywords	Soil enzyme activity; Ni immobilization; In-situ remediation; Gene expression; Oxidative stress

Title	**Establishing Critical Limits for Nickel in Soil and Plant for Predicting the Response of Spinach (*Spinacia oleracea*)**
Author Name	Dileep Kumar, V.P. Ramani, K.C. Patel and A.K. Shukla
Journal Name	Journal of the Indian Society of Soil Science
Year	2021
Volume and Issue	69:1
Pages	105-110
Abstracts	Nickel (Ni) is an essential element for plants and research reports are available indicating its beneficial effects on growth of higher plants as well. Though abundant information exists on Ni toxicity in soil and plant system but not much is available on its critical level of deficiency (CLD) in soils and plants. A pot experiment was conducted in net-house of the micronutrient research project, Anand Agricultural University, Anand, Gujarat. For assessing the critical limit in soil, three bulk soils viz., low (<0.5 mg Ni kg^{-1}), medium (0.5 to 1.0 mg Ni kg^{-1}) and high (>1.0 mg Ni kg^{-1}) were collected from different locations of Anand district. Six levels of Ni, i.e. Ni0, Ni2, Ni4, Ni6, Ni8 and Ni10 (0, 2.0, 4.0, 6.0, 8.0 and 10.0 mg Ni kg^{-1} soil) were applied in all 20 soils (10 low, 6 medium and 4 high in Ni content in soil). The experiment was conducted in factorial completely randomized design with three replications. The critical limit of Ni in soil was determined by Bray's per cent yield plotted against soil available Ni using the scattered diagram in graphical as well as statistical method. Wide variation in dry matter produce was observed across the soils. The concentration of Ni in spinach plant increased with increasing the level of Ni in soil. The CLD of the 0.005 M DTPA-$CaCl_2$ extractable Ni in soil and plant was worked out as 0.46 and 2.27 mg kg^{-1}, respectively with statistical method. Whereas, in graphical method it was reported as 0.50 and 2.20 mg kg^{-1}, respectively in spinach crops.
Keywords	Critical limit; nickel application; spinach; crop response

Title	**Effects of Bacterial Inoculation to Immobilize Nickel in Wheat Grown on Ni-Contaminated Soil**
Author Name	Atta Rasool, Salar Ali, Waqar Ali, Atta Ur Rehman & Said Muhammad
Journal Name	Geomicrobiology Journal
Year	2021
Volume and Issue	38:1
Pages	14-19
Abstracts	Plant growth stimulating bacteria are very effective in immobilization of metals and reducing their translocation in plants through precipitation, and adsorption. A pot experiment was conducted to investigate the effectiveness of chitosan- and hematite-modified biochar and bacterial inoculations on the immobilization of nickel (Ni) in polluted soil under wheat cultivation. Application of modi fied biochars and inoculation with Pseudomonas putida significantly increased both wheat root and shoot dry matter yields but decreased Ni phytoextraction efficiency. The Ni concentration, translocation factor and uptake in wheat shoot and root significantly decreased the application of either modified or unmodified biochars. Bacterial inoculation significantly decreased mean trans location factor and also root and shoot concentration and the uptake Ni in the shoot. Chitosan modified biochar was the most influential treatment in decreasing Ni uptake by wheat followed by *P. putida* inoculation treatment. The results demonstrated positive effects of chitosan modified biochar and inoculation with *P. putida* in increasing dry matter yield and decreasing Ni uptake in wheat grown on Ni-contaminated soil. According to the results of present study, modified biochars application and bacterial inoculation are influential treatments which prevent Ni toxicity probably.
Keywords	Bacterial inoculation; immobilization; nickel; phytoextraction efficiency; translocation factor; wheat

Title	**Processed animal manure improves morpho-physiological and biochemical characteristics of *Brassica napus L.* under nickel and salinity stress**
Author Name	Muhammad Naveed, Allah Ditta, Maryum Ahmad, Adnan Mustafa, Zulfiqar Ahmad, Manuel Conde-Cid, Shermeen Tahir, Syed Atizaz Ali Shah, Muhammad Mohsin Abrar,Shah Fahad
Journal Name	Environmental Science and Pollution Research
Year	2021
Volume and Issue	28
Pages	45629–45645
Abstracts	Soil contamination with readily soluble salts and heavy metals is a major challenge concerning sustainable crop production. The use of organic wastes in agriculture not only helps in waste reduction but also acts as a soil conditioner and bio-stimulant for enhancing crop growth. In this regard, a pot experiment was conducted to investigate the effect of raw and processed animal manure (AM) on the growth, yield, and physicochemical parameters of *Brassica napus L.* developed under salinity and Ni stress. The experiment comprised two salinity levels (1.05 and 8 dS m^{-1}), two Ni levels (0 and 50 mg kg^{-1}), and two types of AMs (raw and processed at a rate of 2% w/w). A control treatment without AM incorporation was also included. In results, the application of AM markedly increased the growth and yield of *B. napus* under Ni and salinity stress; at the same time, it improved the physiological and chemical parameters of the said crop. Similarly, incorporation of processed AM significantly improved nutrient uptake and decreased Na/K ratios in the shoot and grain under the different stress conditions, as compared to the control. Likewise, Ni uptake in the grain, shoot, and root samples was also significantly reduced under the AM treatment. Also, the application of AM significantly reduced the daily intake of metal (DIM) index and the health risk index (HRI) values under the different stress conditions, as compared to the control. In conclusion, the application of processed AM constitutes an effective agricultural strategy to alleviate the adverse effects of Ni and salinity stress on growth, physiology, and yield of *B. napus*, thus resulting in enhanced productivity, as well as reduced risks associated with human health.
Keywords	Ni stress; Salinity stress; Heavy metal; Animal manure; Health risk assessment; Brassica

Title	**Nickel Application Impact Study on Pea (*Pisum sativum L.*) Under Dominant Soil Series of Jharkhand, India**
Author Name	Arvind Kumar, Manas Denre, Sweta Kachhap, Ruplal Prasad, Binay Kumar Agarwal, and Dhirendra Kumar Shahi
Journal Name	Communications in Soil Science and Plant Analysis
Year	2021
Volume and Issue	52:09
Pages	976–984
Abstracts	Nickel is an essential micronutrient for leguminous plants. It has a large range between limiting and toxic levels. A pot experiment was conducted on two dominant soil series of Jharkhand i.e., Upland [Sidhamantoli (ST-5)] and Lowland [Tetratoli (TT-5)]. Five application levels of Ni, viz. 0.0, 2.5, 5.0, 10.0 and 20.0 mg kg^{-1} with pea (*Pisum sativum L.*) as test crop were arranged in three blocks in a glass house. An increasing trend of pea dry matter was observed with increasing Ni application level up to 10.0 mg kg^{-1}. Nickel content in pea plant over control was found 1.36 to 2.53 folds higher with Ni application 2.5 to 20.0 mg kg^{-1}. Accumulation of Ni in soil of Sidhamantoli series (upland situation) was noticed 1.11–4.29 mg kg^{-1} in top and 1.31–5.68 mg kg^{-1} in bottom of the pot, while in Tetratoli soil series (low land situation) Ni content was found 1.40–5.35 mg kg^{-1} in top and 1.25–4.95 mg kg^{-1} in bottom soil. Nickel application stimulates Plant growth parameters and that gradually increased with increasing Ni application levels up to 5.0 mg kg^{-1} in Sidhamantoli and up to 10.0 mg kg^{-1} in Tetratoli soil series, while at 20 mg kg^{-1} Ni application in both soil conditions showed negative effect. So, appropriate precaution should be maintained in application of Ni in leguminous plants and fixed a threshold value of Ni application level 5.0 mg kg^{-1} in upland Sidhamantoli (ST-5) and 10.0 mg kg^{-1} in low land Tetratoli (TT-5) soil series of Jharkhand plateau.
Keywords	Nickel; soil series; plateau; pea (*Pisum sativum L.*); threshold value

Title	**A two-year field study of nickel-agromining using *Odontarrhena chalcidica* co-cropped with a legume on an ultramafic soil: temporal variation in plant biomass, nickel yields and taxonomic and bacterial functional diversity**
Author Name	R. F. Saad & G. Echevarria & B. Rodríguez-Garrido & P. Kidd & E. Benizri
Journal Name	Plant Soil
Year	2021
Volume and Issue	461
Pages	471–488
Abstracts	Aims Agromining aims to improve the fertility of natu rally metal-rich soils by extracting metals, such as nickel (Ni), using hyperaccumulator plants. Ultramafic soils are characterized by low fertility levels, limiting hyperaccumulator yields. Here, we characterize the potential benefits for phytoextraction efficiency of co cropping a Ni-hyperaccumulator (*Odontarrhena chalcidica*) and a legume (*Vicia sativa*), following a two-year field experiment. Methods A two-year field experiment was set up in an ultramafic zone in North-West Spain. Three treatments were tested: co-cropping, fertilized control with ammonium nitrate and non-fertilized control. Results Over the 2 years, co-cropping increased *O. chalcidica's* biomass by 24% and 403% compared to fertilized and non-fertilized controls, respectively. Moreover, co-cropping had higher Ni-yields for both years, while fertilization had a negative effect on soil parameters. A non-metric multidimensional scaling analysis of the operational taxonomic units showed that the soil bacterial diversity changed over time. Soil ex changeable Ni and organic carbon influenced the phyla's relative abundance. Metabolic genes were dominant and their relative abundances increased over time with co-cropping. Conclusion Pluriannual co-cropping of a hyperaccumulator with a legume improved both hyperaccumulator and Ni yields. In contrast, mineral fertilization was shown to be detrimental to some soil microbial parameters. Thus, ameliorating agromining by replacing mineral fertilizers would combine an eco-efficient strategy with sustainable metal recovery.
Keywords	Agromining; Nickel; Hyperaccumulator; High throughput sequencing; Bacterial functional

Title	**The potential of *Blepharidium* guatemalense for nickel agromining in Mexico and Central America**
Author Name	Dulce Montserrat Navarrete Gutierrez, Philip Nti Nkrumahc, Antony van der Enta, Joseph Pollardd, Alan J. M. Bakera, Francisco Navarrete Torralbab, Marie-No€elle Ponsf, Jesus Axayacatl Cuevas S anchezb,Teodoro Gomez Hern andezb, and Guillaume Echevarriaa
Journal Name	International Journal of Phytoremediation
Year	2021
Volume and Issue	23:11
Pages	1157–1168
Abstracts	The aim of this study was to assess the potential of the woody nickel hyperaccumulator species Blepharidium guatemalense *(Standl.) Standl.* for agromining in southeastern Mexico. Pot trials con sisting of nickel dosing (0, 20, 50, 100, and 250 mg Ni kg^{1}), and synthetic and organic fertilization were conducted. Field trials were also undertaken with different harvesting regimes of B. guatema lense. Foliar nickel concentrations increased significantly with rising nickel additions, with a 300-fold increase at 250 mg Ni kg^{1} treatment relative to the control. Synthetic fertilization strongly increased nickel uptake without any change in plant growth or biomass, whereas organic fertilization enhanced plant shoot biomass with a negligible effect on foliar nickel concentrations. A 5-year-old stand which was subsequently harvested twice per year produced the maximum nickel yield $tree^{1}$ yr^{1}, with an estimated total nickel yield of 142 kg ha^{1} yr^{1}. *Blepharidium guatema* lense is a prime candidate for nickel agromining on account of its high foliar Ni concentrations, high bioconcentration (180) and translocation factors (3.3), fast growth rate and high shoot bio mass production. Future studies are needed to test the outcomes of the pot trials in the field. Extensive geochemical studies are needed to identify potential viable agromining locations.
Keywords	Agronomy; fertilization; hyperaccumulation; neotropics; Ni yield; phytomining

Title	**Growth and Physiology of Maize (Zea mays L.) in a Nickel-Contaminated Soil and Phytoremediation Efciency Using EDTA**
Author Name	Muhammad Imran Tipu, Muhammad Yasin Ashraf, Nadeem Sarwar, Muhammad Akhtar, Muhammad Rashid Shaheen, Sajjad Ali, Christos A. Damalas
Journal Name	Journal of Plant Growth Regulation
Year	2021
Volume and Issue	40
Pages	774–786
Abstracts	Nickel (Ni) element is strongly phytotoxic at high concentrations for several plants, but due to its dual behavior and com plicated chemistry, it has received little attention in plant nutrition and relevant experimental data are limited. The current research was carried out to study the efect of Ni on maize (Zea mays L.) growth and phytoextraction potential with EDTA assistance, a process termed as chemical assisted phytoremediation. Treatments included two levels of EDTA (0 and 0.5 mM), two levels of Ni (0 and 40 µM) and their combination (EDTA+Ni) that were applied to maize plants grown in a pot experi ment. Application of Ni alone or in combination with EDTA reduced maize root and shoot length by 7.8% to 13.3% and by 15.6% to 21.1%, respectively, compared with control, as well as root and shoot dry weight by 42.0% to 60.0% and by 29.8% to 46.6%, respectively. A similar declining trend was observed also for the content of photosynthetic pigments (chl-a, chl-b, total chlorophyll, and carotenoids) as well as total proteins. However, proline, total soluble sugars, and free amino acids showed an increasing trend with application of Ni and EDTA alone or in combination. These treatments signifcantly decreased P and Na content in maize roots, stems, leaves, and grains, while increased K content compared with control. Application of EDTA with Ni was the most efective treatment to enhance Ni accumulation in maize (50.23 mg per plant) compared with Ni alone (40.62 mg per plant), EDTA alone (27.75 mg per plant), and control (15.51 mg per plant). Application of EDTA in combination with Ni enhanced Ni accumulation by 4.9 folds in maize shoots and by 2.6 folds in roots over control. In conclusion, application of EDTA in suitable concentrations may enhance Ni uptake by maize providing an efective and economic phytoremediation method of Ni-contaminated soils.
Keywords	Contamination; Heavy metals; Nutrient uptake; Phytoextraction; Chelators

Title	**Impact of chitosan on nickel bioavailability in soil, the accumulation and tolerance of nickel in *Calendula tripterocarpa***
Author Name	Javad Heidari, Rayhaneh Amooaghaie & Shahram Kiani
Journal Name	International Journal of Phytoremediation
Year	2020
Volume and Issue	22: 11
Pages	1175-1184
Abstracts	Excessive heavy metals in medicinal plants cause critical health issues to humans. Therefore, in the present study, the effect of soil amendment with chitosan (0, 0.125, 0.25, 0.5, and 1%) on bioavailability and tolerance of nickel in Calendula tripterocarpa grown in a soil spiked with Ni (100 and 150 mg/kg soil) was investigated. The results showed that Ni toxicity significantly reduced plant growth and content of chlorophyll a, b but increased carotenoid levels, lipid peroxidation, and catalase (CAT) and superoxide dismutase (SOD) activities in roots and shoots. The Ni bioaccumulation was significantly higher in shoots than roots. The soil amendment with chitosan reduced Ni bioavailability in soil, as well as lowered the biological accumulation of Ni in roots and shoots, and Ni transfer to leaves. The chitosan application also increased growth parameters and levels of chlorophyll a, b and carotenoids under both normal and Ni stress conditions. Furthermore, chitosan reduced the level of malondialdehyde and the activities of SOD and CAT in roots and shoots under Ni stress. In conclusion, results indicated that chitosan through lowering bioavailability of Ni in soils can remarkably relieve adverse effects of Ni toxicity in C. tripterocarpa.
Keywords	Calendula tripterocarpa; chitosan; nickel tolerance; phytoremediation; soil amendment

Title	**Ethephon mitigates nickel stress by modulating antioxidant system, glyoxalase system and proline metabolism in Indian mustard**
Author Name	M. Iqbal R. Khan, Badar Jahan, Mohamed F. AlAjmi, Md Tabish Rehman & Nafees A. Khan
Journal Name	Physiology and Molecular Biology of Plants
Year	2020
Volume and Issue	26: 10
Pages	1201–1213
Abstracts	The role of ethylene (through application of ethephon) in the regulation of nickel (Ni) stress tolerance was investigated in this study. Ethephon at concentration of 200 µl l^{-1} was applied to mustard (*Brassica Juncea*) plants grown without and with 200 mg kg^{-1} soil Ni to study the increased growth traits, biochemical attributes, photosynthetic efficiency, nutrients content, activities of antioxidants such as superoxide dismutase, ascorbate peroxidase, glutathione reductase, and glutathione peroxidase, glyoxalase systems and enhanced the proline metabolism. In the absence of ethephon, Ni increased oxidative stress with a concomitant decrease in photosynthesis, growth and nutrients content. However, application of ethephon positively increased growth traits, photosynthetic parameters, nutrients content and also elevated the generation of antioxidants enzymes and glyoxalase systems, proline production to combat oxidative stress. Plants water relations and cellular homeostasis were maintained through increased photosynthetic efficiency and proline production. This signifies the role of ethylene in mediating Ni tolerance via regulating proline production and photosynthetic capacity. Ethephon can be used as an exogenous supplement on plants to confer Ni tolerance. The results can be exploited to develop tolerance in plants via gene editing technology encoding enzymes responsible for proline synthesis, antioxidant defence, glyoxalase systems and photosynthetic effectiveness.
Keywords	Antioxidant enzymes; Ethylene; Glyoxalase system; Nickel; Proline

Title	**Nickel in foods sampled on the Belgian market: identification of potential contamination sources**
Author Name	Mehrnoosh Babaahmadifooladi, Liesbeth Jacxsens, Bruno De Meulenaer & Gijs Du Laing
Journal Name	Food Additives & Contaminants
Year	2020
Volume and Issue	37: 4
Pages	607-621
Abstracts	Nickel can occur in plant-based, animal-based foods and drinks. It can either naturally occur in plants or it could originate from contamination. The natural occurrence of nickel arises from the fact that the element plays an essential role in the functioning of enzymes involved in the nitrogen fixation process. Besides, contamination can occur at any stage of the production, processing or packing of the foods. More specifically, nickel can leach from contact materials to foods or drinks before their consumption by humans. In recent years, the European Food Safety Authority expressed concern regarding the chronic and acute exposure of the European population to nickel. This study aimed to screen foods available on the Belgian market for their nickel content and to identify potential sources of the contamination. In total, 708 samples were collected from three different main categories of foods, including plant-based products, animal-based products and drinks. Elevated nickel concentrations were found in plant-based products such as chocolate, legumes, nuts, figs, peanut butter, chocolate spreads and breakfast cereals. The nickel concentrations in the animal-based products and drinks were significantly lower compared to the plant-based products. In the beer samples, no correlation between the alcohol percentage and nickel concentration was found. Higher nickel concentrations were found in the tea drinks in comparison to other drinks. Furthermore, the effect of packaging, e.g. storage in cans, on the final nickel concentration of the foods was investigated. No effect of the packaging was found, demonstrating that leaching of nickel from packaging materials is not significantly contributing to the nickel content in foods. The results demonstrate high concentrations of nickel in some plant-based food products and further exposure assessment studies are needed to evaluate the risk due to intake of nickel-enriched food products.
Keywords	Nickel; metals; contamination; foods

Title	Nickel: Human Health and Environmental Toxicology
Author Name	Giuseppe Genchi, Alessia Carocci, Graziantonio Lauria, Maria Stefania Sinicropi and Alessia Catalano
Journal Name	International Journal of Environmental Research and Public Health
Year	2020
Volume and Issue	17: 3
Pages	1-52
Abstracts	Nickel is a transition element extensively distributed in the environment, air, water, and soil. It may derive from natural sources and anthropogenic activity. Although nickel is ubiquitous in the environment, its functional role as a trace element for animals and human beings has not been yet recognized. Environmental pollution from nickel may be due to industry, the use of liquid and solid fuels, as well as municipal and industrial waste. Nickel contact can cause a variety of side effects on human health, such as allergy, cardiovascular and kidney diseases, lung fibrosis, lung and nasal cancer. Although the molecular mechanisms of nickel-induced toxicity are not yet clear, mitochondrial dysfunctions and oxidative stress are thought to have a primary and crucial role in the toxicity of this metal. Recently, researchers, trying to characterize the capability of nickel to induce cancer, have found out that epigenetic alterations induced by nickel exposure can perturb the genome. The purpose of this review is to describe the chemical features of nickel in human beings and the mechanisms of its toxicity. Furthermore, the attention is focused on strategies to remove nickel from the environment, such as phytoremediation and phytomining.
Keywords	nickel; nickel toxicity; nickel allergy; epigenetics; apoptosis; nickel phytoremediation

Title	**Bacterial community diversity in the rhizosphere of nickel hyperaccumulator plant species from Borneo Island (Malaysia)**
Author Name	Séverine Lopez , Antony van der Ent , Sukaibin Sumail , John B Sugau , Matsain Mohd Buang , Zarina Amin , Guillaume Echevarria , Jean Louis Morel, Emile Benizri
Journal Name	Environ Microbiology
Year	2020
Volume and Issue	22: 4
Pages	1649-1665
Abstracts	The Island of Borneo is a major biodiversity hotspot, and in the Malaysian state of Sabah, ultramafic soils are extensive and home to more than 31 endemic nickel hyperaccumulator plants. The aim of this study was to characterize the structure and the diversity of the rhizosphere bacterial communities of several of these nickel hyperaccumulator plants and factors that affect these bacterial communities in Sabah. The most abundant phyla were *Proteobacteria*, *Acidobacteria* and *Actinobacteria*. At family level, *Burkholderiaceae* and *Xanthobacteraceae* (*Proteobacteria phylum*) were the most abundant families in the hyperaccumulator rhizospheres. Redundancy analysis based on soil chemical analyses and relative abundances of the major bacterial phyla showed that abiotic factors of the studied sites drove the bacterial diversity. For all R. aff. bengalensis rhizosphere soil samples, irrespective of studied site, the bacterial diversity was similar. Moreover, the *Saprospiraceae* family showed a high representativeness in the R. aff. *bengalensis* rhizosphere soils and was linked with the nickel availability in soils. The ability of R. aff. bengalensis to concentrate nickel in its rhizosphere appears to be the major factor driving the rhizobacterial community diversity unlike for other hyperaccumulator species.
Keywords	biodiversity; rhizosphere; nickel hyperaccumulator; nickle

Title	**Acetotrophic methanogens are sensitive to long-term nickel contamination in paddy soil**
Author Name	Chen Xueping, Yu Juan, Chen Zheng, Zhang Hongmei, Cheng Wangda, Bai Fayan, Zheng Yu, Khan Imran Ahamed, He Chiquan and Liu Xiaoyan
Journal Name	Environmental Science: Processes & Impacts
Year	2020
Volume and Issue	22: 4
Pages	1014-1025
Abstracts	Paddy soil accounts for approximately one-fifth of the world's cultivated area and faces a serious threat from nickel (Ni). Ni pollution has an impact on the activity, composition and emission of *methanogens* in paddy, which is a major natural source of methane (CH_4) emissions. We combined a high-throughput sequencing approach and laboratory incubation methods to evaluate the impact of long-term Ni pollution on the *methanogenic* archaeal community in paddy soil. The highest rate of CH_4 production was 697 mg kg^{-1} of dry soil per d with the addition of sodium acetate at 50 mg kg^{-1} of Ni, which was significantly negatively correlated with the total and available Ni ($p < 0.05$). While the highest CH_4 production rates were 485 and 544 mg kg^{-1} of dry soil per d with the addition of sodium formate and methanol, respectively, there was no significant difference in the CH_4 production rate and maximum CH_4 accumulation between the different Ni additions. Heavy pollution with 500 mg kg^{-1} of Ni unexceptionally inhibited the relative abundance of various genera of methanogens (22.2% in total). The abundance of acetotrophic *Methanosaeta* decreased with an increasing concentration of Ni (3.25–1.11%). The diverse nutrient types of species belonging to *Methanosarcina* were the highest under treatment with Ni200 (18.0%), and lowest in the soil with 500 mg kg^{-1} of Ni (2.8%). Similarly, the abundances of the most abundant *hydrogenotrophic methanogens* of *Methanocellales* were relatively high with Ni200 (26.2%) compared with those with Ni500 (5.4%). The mcrA gene was enriched under the light pollution treatment (50 mg kg^{-1} of Ni, $6.73 \times 10^7 \pm 9.0 \times 10^6$ copies per g of soil) compared with the control ($4.18 \times 10^7 \pm 5.1 \times 10^6$ copies per g of soil). These results indicate that the long-term pollution by Ni has an impact on the activity and composition of methanogens with heavy Ni pollution, and in particular, acetotrophic methanogens are sensitive to Ni pollution in paddy soil.
Keywords	sodium acetate; methanol; methane; nickel

Title	**Soil amendments affecting nickel uptake and growth performance of tropical 'metal crops' used for agromining**
Author Name	Philip Nti Nkrumah, Guillaume Echevarria, Peter D. Erskine, Rufus L. Chaney, Sukaibin Sumail & Antony van der Ent
Journal Name	Journal of Geochemical Exploration
Year	2019
Volume and Issue	203
Pages	78-86
Abstracts	Ultramafic soils are usually marginal in macronutrients (nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca)) for growth of crop plants. Commercial nickel (Ni) *agromining* is dependent on attaining high yield and high Ni concentration in harvestable biomass of Ni *hyperaccumulator* species. We previously reported on the biomass responses of two promising tropical 'metal crops' (*Phyllanthus rufuschaneyiand Rinorea cf. bengalensis)* to rates of N, P, and K fertilisers. Calcium, sulphur (S) and organic matter amendments have varied effects on the biomass production and Ni uptake in temperate Ni *hyperaccumulat*or species used in *agromining*, but the trends in tropical 'metal crops' are not reported to-date. We investigated the effects of these amendments on the growth performance and the Ni (and other elements) uptake in *P. rufuschaneyi* and *R. cf. bengalensis* The experiments consisted of a large 12-month randomised growth trial in large pots in Sabah (Malaysia) using ultramafic soils under different treatment levels of soluble Ca and S, and organic matter amendments. We found that Ca and S additions had no significant effects on the growth of *P. rufuschaneyi* and *R. cf. bengalensis*. Organic matter amendments had strong positive effect on the growth of R. cf. *bengalensis* ($p < 0.05$), but we recorded significant negative growth response in P. rufuschaneyi. Whereas Ca and S additions improved the Ni uptake in these species, organic matter amendments significantly reduced the shoot Ni concentrations in both species. Our findings indicate that Ca and S additions are important in the agronomy of tropical 'metal crops' to be used in economic Ni *agromining*, but organic matter amendments may not be useful.
Keywords	Biomass production; Hyperaccumulator plants; Metal crops; Nickel tolerance; Nickel yield; Organic matter amendments

Title	**Nickel and ozone stresses induce differential growth, antioxidant activity and mRNA transcription in Oryza sativa cultivars**
Author Name	Herman Eijsackers, Adriaan Reinecke, Sophié Reinecke & Mark Maboeta
Journal Name	Journal of Plant Interactions
Year	2019
Volume and Issue	14, 1
Pages	87-101
Abstracts	This study evaluates the influences of nickel and ozone exposure individually and/ or in combination on growth performance, antioxidant activity and genes up regulation of two rice cultivars Sakha 101 and Giza 178. Ni treatment at high doses (100 µM Ni) and 75 ppb O3 alone reduced the fresh weight, mineral content, membrane integrity and Rubisco content. There was an increase in SOD and APX activity in the shoots of rice cultivars, whereas, there was a decrease in GR and GST in the roots and shoots. In contrast combined stresses appeared to be stimulatory for growth and mineral contents, Rubisco content and antioxidant enzymes. Nonspecific lipid transfer protein and transmembrane protein genes were up regulation in rice cultivars in response to Ni stress. Carotenoid cleavage dioxygenase is upregulated in response to ozone stress; RNA pseudouridine synthase, heat shock proteins and cytochrome P450-like were upregulated in response to combined stresses. The results revealed that the interactive effects of both stresses were antagonistic on growth parameters and antioxidant activities to overcome the adverse effects of both pollutants.
Keywords	Antioxidant enzymes, gene expression, nickel, ozone, Oryza sativa

Title	**Phosphate microbial mineralization removes nickel ions from electroplating wastewater**
Author Name	Xiaoniu Yu & Jianguo Jiang
Journal Name	Journal of Environmental Management
Year	2019
Volume and Issue	Volume 245
Pages	447-453
Abstracts	Nickel ions in electroplating wastewater can be removed by the bio-mineralization method. Bacillus subtilis can produce alkaline phosphatase, which hydrolyzes organophosphate monoesters and produces phosphate ions. Fourier-transform infrared spectroscopy (FTIR) showed that the precipitated material contains phosphate ions. X-ray diffraction (XRD) showed that nickel ions in electroplating wastewater react with Bacillus subtilis and organophosphate monoesters to obtain nickel phosphate octahydrate ($Ni_3(PO_4)_2$•$8H_2O$). The removal efficiency of nickel ions could reach 76.41% with the optimum content of the organophosphate monoester (0.02 mol), Bacillus subtilis powder (2 g), pH (6), standing time (36 h), and reaction temperature (25 °C) in the medium solution (100 mL). The average particle size of $Ni_3(PO_4)_2$•$8H_2O$ was 80.51 nm, which was calculated by the Scherrer formula. The Lorentz–Transmission Electron Microscope (L-TEM) further showed that $Ni_3(PO_4)_2$•$8H_2O$ was composed of clusters of irregular nanoparticles, and the individual particle size was in the range of 40–90 nm. The TGA curve shows that the mass loss of crystal water was 25.45%, which was close to the theoretical total mass loss of 28.24% in bio-$Ni_3(PO_4)_2$•$8H_2O$.
Keywords	Nickel ions, Electroplating wastewater, Bacillus subtilis, Phosphate ions, Nickel phosphate octahydrate

Title	**Rare-earth element yttrium enhances the tolerance of curly-leaf pondweed (Potamogeton crispus) to acute nickel toxicity**
Author Name	Kai Lyu, Xuan Wang, Lei Wang & Guoxiang Wanga
Journal Name	Environmental Pollution
Year	2019
Volume and Issue	248
Pages	114-120
Abstracts	Nickel is a ubiquitous heavy-metal pollutant in lakes and severely affects aquatic organisms. Aquatic plants are often initially linked to having heavy metal contents and further are proposed as *phytoremediation* agent to remove heavy metal from water. Although the toxic effects of nickel on aquatic plants are thoroughly explored, the effective investigation to increase Ni tolerance is still in its infancy. The role of rare-earth elements (REEs) in plant resisting heavy-metal pollution has recently received considerable interest. To explore the physiological effects of REEs on *Potamogeton crispus* under Ni stress, we explored whether or not the additive exposure to low-dose yttrium (Y; 2.5 μM) promotes the polyamine metabolism, antioxidation, and photosynthesis performance of P. crispus under Ni stress values of 0, 50, 100, 150, and 200 μM. Results showed that Y exposure did not influence Ni bioaccumulation in P. crispus. Furthermore, Y exposure alleviated the adverse effects of Ni stress to convergent degrees because Y positively converts putrescine into spermidine and spermine, inhibits oxidative stress, increases the total chlorophyll content, and maximum/potential quantum efficiency of photosystem II. We concluded that low-dose Y can positively regulate polyamine transformation, inhibit oxidative stress, stimulate photosynthesis, and finally promote the resist ability of P. crispus to nickel stress. Thus, REEs have potential to be applied in regulating submerged plant tolerance to aquatic heavy-metal pollution.
Keywords	Heavy metal; REEs; Macrophytes; Polyamine metabolism; Antioxidation

Title	**Nitric oxide induces rice tolerance to excessive nickel by regulating nickel uptake, reactive oxygen species detoxification and defence-related gene expression**
Author Name	Muhammad Rizwan, Mohammad Golam Mostofa , Muhammad Zulfiqar Ahmad, Muhammad Imtiaz, Sajid Mehmood, Muhammad Adeel, Zhihua Dai, Zheyong Li, Omar Aziz, Yihui Zhang, Shuxin Tu
Journal Name	Chemosphere
Year	2018
Volume and Issue	Volume 191, January 2018
Pages	23-35
Abstracts	Soil contamination with nickel (Ni) is a persistent threat to crop production worldwide. The present study examined the putative roles of nitric oxide (NO) in improving Ni-tolerance in rice. Our findings showed that application of exogenous sodium nitroprusside (SNP), a NO donor, significantly improved the growth performance of rice seedlings when grown under excessive Ni. The enhanced Ni-tolerance of rice prompted by SNP could be ascribed to its ability to regulate Ni uptake, decrease Ni-induced oxidative stress as evidenced by reduced levels of hydrogen peroxide, malondialdehyde, and electrolyte leakage in Ni-stressed plants. The positive roles of NO against Ni-toxicity also reflected through its protective effects on photosynthetic pigments, soluble proteins and proline. SNP also boosted antioxidant capacity in Ni-stressed plants by maintaining increased levels of ascorbate, enhanced activities of ROS-detoxifying enzymes, particularly peroxidase (POD) and catalase (CAT) in both roots and shoots compared with Ni-stressed alone plants. Moreover, SNP treatment also upregulated the transcript levels of CAT, POD, ascorbate peroxidase, glutathione reductase and superoxide dismutase genes in shoots under Ni-stress. Using different sulfide compounds and NO scavenger cPTIO, we also provided evidence that NO, rather than other byproducts of SNP, contributed to the improved performance of rice seedlings under Ni-stress. Collectively, our results conclude that exogenous SNP-mediated modulation of endogenous NO enhanced rice tolerance to Ni–stress by restricting Ni accumulation, maintaining photosynthetic performance and reducing oxidative damage through improved antioxidant system, thereby suggesting NO as an effective stress regulator in mitigating Ni-toxicity in economically important rice, and perhaps in other crop plants.
Keywords	Antioxidant system, Gene expression, Nickel stress, Nitric oxide Oxidative stress, Rice

Title	**Nickel biopathways in tropical nickel hyperaccumulating trees from Sabah**
Author Name	Antony Van Der Ent, Damien L.Callahan, Barry N. Noller, Jolanta Mesjasz-Przybylowicz, Wojciech J. Przybylowicz, Alban Barnabas & Hugh H. Harris
Journal Name	Scientific Reports
Year	2017
Volume and Issue	7:41861
Pages	1-21
Abstracts	The extraordinary level of accumulation of nickel (Ni) in hyperaccumulator plants is a consequence of specific metal sequestering and transport mechanisms, and knowledge of these processes is critical for advancing an understanding of transition element metabolic regulation in these plants. The Ni biopathways were elucidated in three plant species, *Phyllanthus balgooyi*, *Phyllanthus securinegioides* (Phyllanthaceae) and *Rinorea bengalensis* (Violaceae), that occur in Sabah (Malaysia) on the Island of Borneo. This study showed that Ni is mainly concentrated in the phloem in roots and stems (up to 16.9% Ni in phloem sap in *Phyllanthus balgooyi*) in all three species. However, the species differ in their leaves – in *P. balgooyi* the highest Ni concentration is in the phloem, but in *P. securinegioides* and *R. bengalensis* in the epidermis and in the spongy mesophyll (*R. bengalensis*). The chemical speciation of Ni^{2+} does not substantially differ between the species or between the plant tissues and transport fluids, and is unambiguously associated with citrate. This study combines ion microbeam (PIXE and RBS) and metabolomics techniques (GC-MS, LC-MS) with synchrotron methods (XAS) to overcome the drawbacks of the individual techniques to quantitatively determine Ni distribution and Ni^{2+} chemical speciation in hyperaccumulator plants.
Keywords	Hyperaccumulator , Biopathways, metabolomics techniques

Title	**Nickel bioaccumulation by the chosen plant species**
Author Name	Jacek Antonkiewicz, Czesława Jasiewicz, Małgorzata Koncewicz-Baran & Renata Sendor
Journal Name	Acta Physiol Plant
Year	2016
Volume and Issue	
Pages	38:40
Abstracts	Concentrations of ground-level ozone ([O_3]) over much of the Earth's The investigations aimed at the evaluation of nickel bioaccumulation ability of plants from various families (Poaceae—maize, Fabaceae—field bean and Asteraceae—lettuce). The research was conducted under hydroponic conditions. The experimental design comprised ten objects differing with nickel concentrations in the solution (ranging from 0.0 to 10.0 mg Ni dm−3 of the nutrient solution). The parameters, assumed as the basis on which nickel bioretention by selected plant species was determined were: the yield, nickel content in various plant parts, uptake and utilization of this element by the plant, tolerance index (TI) and translocation factor (TF), the metal concentrations in the aboveground parts index (CI) and bioacummulation factor (BAF). On the basis of the obtained results it was found that, due to low tolerance of nickel, maize could be used as the indicator plant for the environment quality assessment.
Keywords	Bioaccumulation, Hydroponic, Heavy metals

Title	**Evaluation of nickel tolerance in *Amaranthus paniculatus* L. plants by measuring photosynthesis, oxidative status, antioxidative response and metal - binding molecule content**
Author Name	Fabrizio Pietrini, Valentina Iori, Alexandra Cheremisina, Nina I. Shevyakova, Nataliya Radyukina, Vladimir V. Kuznetsov, Massimo Zacchini
Journal Name	Environmental Science and Pollution Research
Year	2015
Volume and Issue	22, Issue 1
Pages	482-494
Abstracts	Among metals, Ni has been indicated as one of the most dangerous for the environment, and plants exposed to this metal are frequently reported to undergo a severe stress condition. In this work, the tolerance responses to different Ni concentrations at physiological and biochemical levels were evaluated in *Amaranthus paniculatus* L., a plant species previously characterised for their ability to phytoremove Ni from metal-spiked water. Results indicated a good metal tolerance of this plant species at environmentally relevant Ni concentrations, while clear symptoms of oxidative damages were detected at higher Ni concentrations, both in roots and leaves, by measuring lipid peroxide content. At the photosynthetic level, pigment content determination, chlorophyll fluorescence image analysis and gas-exchange parameter measurements revealed a progressive impairment of the photosynthetic machinery at increasing Ni concentrations in the solution. Regarding biochemical mechanisms involved in antioxidative defence and metal binding, antioxidative enzyme (ascorbate peroxidase, APX; catalase, CAT; guaiacol peroxidase, GPX; superoxide dismutase, SOD) activity, polyamine (PA) content, polyamine oxidase (PAO) activity and organic acid (OA) content were differently affected by Ni concentration in the growth solution. A role for GPX, SOD, PAs, and oxalic and citric acid in Ni detoxification is suggested. These results can contribute to elucidate the tolerance mechanisms carried out by plants when facing environmentally relevant Ni concentrations and to identify some traits characterising the physiological and biochemical responses of Amaranthus plants to the presence and bioaccumulation of Ni.
Keywords	Photosynthetic, Amaranthus, bioaccumulation , chlorophyll fluorescence

Title	**Photosynthetic response and proline bioaccumulation in black gram induced by Nickel stress**
Author Name	Das S, Samantaray S, Mohanty RC, Mohanty M, Pradhan C
Journal Name	The International Daily journal
Year	2015
Volume and Issue	27 : 97
Pages	36-42
Abstracts	The present study assesses the impact of varying treatment concentrations of nickel (Ni) on photosynthetic responses and stress induced praline accumulation in a leguminous plant i.e. black gram [*Vigna mungo* (L.) Hepper] cultivars (PU31C and Shekhar1C). After exposure to different concentrations of toxic Ni2+, the two cultivars of *V. mungo* i.e. PU31C and Shekhar1C showed significant changes in their photosynthetic response. Sekhar1C variety showed high chlorophyll content in seedlings treated with toxic Ni (200µM) when compared to Control and other variety. PU31C variety showed four times more Chlorophyll content than seedlings of control treatment. The present hydroponic study exhibited stimulatory effects of nickel on total chlorophyll content, carotenoid and increased proline level after two weeks exposure period. Present preliminary study indicates the tolerance nature of two green gram cultivars to toxic doses of Ni+2.
Keywords	Nickel, Chlorophyll, Proline, Hydroponics

Title	**Estimation of plant growth promoting potential of a nickel accumulating isolate obtained from Dhapa industrial wasteland (Kolkata, India) soil on Indian yellow mustard (*Brassica hirta*)**
Author Name	Santanu Maitra and Pranab Kumar Banerjee
Journal Name	Int.J.Curr.Microbiol.App.Sci
Year	2015
Volume and Issue	4 : 1
Pages	765-772
Abstracts	Plant growth promoting bacteria (PGPB) are known to influence plant growth by various direct or indirect mechanisms. Present study was conducted with an aim to estimate the PGP potential of one nickel tolerant bacterial isolate from Dhapa industrial wasteland, Kolkata, India. Isolate I (Gram negative *coccobacilli*) was observed to tolerate and accumulate significant amounts of nickel and also have multiple Plant Growth Promoting (PGP) activities like IAA production and phosphate solubilization. Present study also shows that seeds of yellow mustard (*Brassica hirta*) inoculated with the test isolate individually, significantly enhanced root and shoot growth and also protected the plant from the various phytotoxic effects of nickel.
Keywords	Nickel, Accumulation, IAA Production, Phosphate Solubilization, Brassica hirta Bioremediation