Title	**Potential use of *Solanum lycopersicum* and plant growth promoting rhizobacterial (PGPR) strains for the phytoremediation of endosulfan stressed soil**
Author Name	Rupa Rani, Vipin Kumar, Pratishtha Gupta, Avantika Chandra
Journal Name	Chemosphere
Year	2021
Volume and Issue	279
Article No.	130589
Abstracts	This study aimed to assess the role of *Solanum lycopersicum* and plant growth promoting rhizobacterial (PGPR) strains to remove endosulfan present in the soil. *S. lycopersicum* was grown in endosulfan amended soil (5, 10, 25, and 50 mg kg^{-1}) inoculated with PGPR strains for 40, 80, and 120 days. The influence of PGPR inoculation on endosulfan accumulation in plant tissues, endosulfan degradation in soil, and plant growth parameters were evaluated. The oxidative stress tolerance was assessed by determining the malondialdehyde formation in *S. lycopersicum* planted in endosulfan stressed soil inoculated with PGPR strains. The results showed that uptake of endosulfan followed root > shoot pathway in association with a reduction in endosulfan accumulation in inoculated plants as related to un-inoculated plants. Moreover, inoculation of PGPR strains showed a beneficial influence on the degradation of endosulfan, *Bacillus* sp. PRB101 showed maximum degradation (89% at 5 mg kg^{-1} of soil) of endosulfan at 120 days after sowing. Furthermore, the content of malondialdehyde was lower in inoculated plants as related to un-inoculated plants. Inoculation of PGPR strains efficiently enhanced plant biomass. The findings showed the effectiveness of PGPR strains to increase the decontamination of endosulfan stressed soil and decline endosulfan concentration in the plant tissues.
Keywords	Endosulfan; Phytoremediation; *Solanum lycopersicum*; Plant growth promoting rhizobacteria (PGPR)

Title	**Organochlorine pesticide residues in plants and their possible ecotoxicological and agri food impacts**
Author Name	Rachna Chandra, N. Sharpanabharathi, B. Anjan Kumar Prusty, P. A. Azeez, and Rama Mohan Kurakalva
Journal Name	Scientific Reports
Year	2021
Volume and Issue	11
Article No.	17841
Abstracts	Scientific investigations on levels of Organochlorine Pesticide (OCP) residues in plants largely consider the edible parts (crops, vegetables, and fruit plants). Though the non-edible parts of plants are not eaten by human beings directly, these parts are consumed by livestock and other animals, thereby facilitating the flow of chemical residues through the food chain. The objective of the present investigation was to evaluate the concentration of OCP residues in non-edible plant parts to provide insights on their potential ecotoxicological impacts. Eighteen OCP residues were extracted in nine different plant species (banana *Musa acuminate*, brinjal *Solanum melongena*, *Casuarina equisetifolia*, *Eucalyptus globulus*, *lotus Nelumbo nucifera*, *paddy Oryza sativa*, *sugarcane Saccharum officinarum*, *tapioca Manihot esculenta*, *tomato Lycopersicon esculentum*) following QuEChERS method. The concentrations of OCP residues in plant extracts were determined using Gas Chromatography coupled with Mass Spectrometry (GC–MS). The OCP residues, namely: γ-HCH (lindane), heptachlor epoxide isomer, dieldrin, endrin, endrin aldehyde and endrin ketone were found predominantly in seven plant species. Residues of γ-HCH (lindane) were reported in different parts of plant species such as stem (581.14 ng/g in paddy and 585.82 ng/g in tapioca) and leaf (583.3 ng/g in tomato). Seven samples contained residues of heptachlor epoxide isomer (512.53 to 1173.8 ng/g). Dieldrin was found in paddy stem (489.97 ng/g), tapioca stem (490.21 ng/g) and tapioca leaf (490.32 ng/g). The detected OCPs in the present study were 10–50 times higher than the Maximum Residue Limits (MRL, 0.01–0.1 mg/Kg) as prescribed in the Codex Alimentarius of the FAO/WHO. Their elevated concentrations in the plant parts therefore pose risk of contamination to the consumers in the food chain, including human beings those are dependent on the animals as source of protein. The findings of this study are the first report on residue levels of OCPs in non-edible plant parts in the agricultural landscape of Puducherry region, India. Since, this study assumes significance for the strategic location of Oussudu Lake, an interstate lake spread over Puducherry and Tamil Nadu states, regular monitoring of OCP residues in different environmental segments in strategic locations in both the states is suggested, which will help the authorities in devising a comprehensive environmental management plan aiming at the ecosystem at large.
Keywords	Environmental sciences; Health care

Title	**Effect of the Pesticide Endosulfan and Two Different Biostimulants on the Stress Responses of *Phaseolus leptostachyus* Plants Grown in a Saline Soil**
Author Name	Anbu Landa-Faz, Sara González-Orenga, Monica Boscaiu, Refugio Rodríguez-Vázquez and Oscar Vicente
Journal Name	Agronomy
Year	2021
Volume and Issue	11(6)
Pages	1208
Abstracts	Soil salinity and the indiscriminate use of agrochemicals has significantly reduced the productivity of the 'Chinampas' agroecosystem in Mexico City. Crop improvement under these stressful conditions may be achieved by soil bioremediation. In this study, we checked the effects of the organochlorine pesticide endosulfan and bioremediation with *Penicillium crustosum* or a citric waste on the growth of *Phaseolus leptostachyus* plants in saline soil from the Chinampas area. Biochemical markers associated with specific stress responses were also determined after one month of growth in the different substrates. Plant growth was stimulated by bioremediation of the soil. Both biostimulants reduced the degree of stress affecting the plants, as shown by the increase in photosynthetic pigments and the reduction of proline, malondialdehyde (MDA), and H_2O_2 contents, and the activation of antioxidant systems. However, the biostimulants appeared to mitigate oxidative stress through different mechanisms. Endosulfan contamination inhibited seed germination—which was reverted to control values in the presence of the biostimulants—and further decreased plant growth. No clear patterns of variation of biochemical stress markers were observed combining endosulfan and the biostimulants. In any case, bioremediation with *P. crustosum* and/or citric waste is recommended to improve the germination and growth of *P. leptostachyus* plants.
Keywords	chinampas agroecosystem; organochlorine pesticides; seed germination; salt stress; oxidative stress; oxidative stress markers; antioxidant systems; proline

Title	**Bioremediation of an agricultural saline soil contaminated with endosulfan and *Escherichia coli* by an active surface agent induced in a *Penicillium crustosum* culture**
Author Name	Anbu Landa-Faz, Refugio Rodríguez-Vázquez, Teresa-Guadalupe Roldán-Carrillo , María-Eugenia Hidalgo-Lara , Ricardo Aguilar-López , and Mariano-Enrique Cebrián-García
Journal Name	Preparative Biochemistry & Biotechnology
Year	2021
Volume and Issue	52(3)
Pages	292-301
Abstracts	This study evaluates the production of a biological active surface agent (BASA) through its surface tension (ST) and emulsifying activity (E_{24}) for endosulfan degradation (ED) and Escherichia coli growth inhibition (EcGI) in an agricultural saline soil. The fungus, identified as *Penicillium crustosum* was isolated from the Citrus sinensis peel (CsP), then the surface properties were evaluated in 9 culture media through a Taguchi L9 experimental design. The culture conditions included: stirring speed, pH, carbon (C) and nitrogen (N) sources; being glucose, NH_4N0_3, 120 rpm and pH of 5, the most significant parameters in the BASA production. The BASA identified as a lipopeptide type, showed a ST = 38 mN m^{-1} and E_{24}=71%. Both properties were stable at 80 °C, while ST presented stability in the pH range of 2 – 12, and a saline concentration of 200 g L^{-1}; E_{24} was also stable at a pH between 8–12. Further application of BASA and fungal inoculum to a contaminated agricultural saline soil presented an EcGI of 99.8% on the 8th day, and ED of 92.9 ± 4.7% in 30 days, respectively; being the first report that uses this fungus for pesticide and bacteria elimination from an agricultural saline soil.
Keywords	Active surface properties; bioremediation; endosulfan; *Escherichia coli*; *Penicillium crustosum*

Title	**Mycoremediation of an agricultural salty soil contaminated with endosulfan by *Penicillium crustosum*: and agronomic bioassays with *Phaseolus leptostachyus***
Author Name	A. Landa-Faz, R. Rodríguez-Vázquez, T. G. Roldán-Carillo
Journal Name	Journal of Environmental Science and Health
Year	2021
Volume and Issue	56 (9)
Pages	838-844
Abstracts	The fungus *Penicillium crustosum* was employed for endosulfan biodegradation, finding that sulphate endosulfan and mono alcohol endosulfan were the main compounds produced; therefore, an oxidative degradation pathway was suggested. A $93 \pm 4.7\%$ of Endosulfan degradation after one month of treatment of a highly salty agricultural soil was obtained, where ΔST was up to 17 ± 0.58 mN m^{-1}, (related to the water value of 72 mNm^{-1}), that was induced by the fungus during soil mycoremediation Additionally, an improvement in soil quality (reduction of clay proportion and salinity, as well as an increase of soluble phosphorus, carbon content and organic matter) was observed during the mycoremediation treatment. The phytotoxicity of the pesticide on *Phaseolus leptostachyus* was evaluated in the soil without the fungus addition (control), where the pesticide was translocated in the crop, presenting a negative effect in germination index, root length and weight, aerial weight, humidity, and proline content. This contrasted with the effect on the crop grown in the soil treated with P. crustosum, which had better agronomic characteristics. This is first report in which the effect of this property allows the pesticide biodegradation, due to a combined Endosulfan bioavailability and fungal biodegradation.
Keywords	Endosulfan biodegradation; organochlorine pesticides; surface-active agents; crops; agronomic parameters

Title	Biodiversity of butterflies in endosulfan-affected areas of Kerala, India
Author Name	K. N. Raghavendra, Kumar Arvind, G. K. Anushree & Tony Grace
Journal Name	The Journal of Basic and Applied Zoology
Year	2020
Volume and Issue	81 (58)
Pages	832
Abstracts	Butterflies are considered as bio-indicators of a healthy and diversified ecosystem. Endosulfan was sprayed indiscriminately in large plantations of Kasaragod district, Kerala which had caused serious threats to the ecosystem. In this study, we surveyed the butterflies for their abundance and diversity in three differentially endosulfan-affected areas viz., Enmakaje—highly affected area, Periye—moderately affected area, Padanakkad—unaffected area, carried out between the end of the monsoon season and the start of the winter season, lasting approximately 100 days. Seven variables viz., butterfly abundance (N), species richness (S), Simpson's reciprocal index (D), the Shannon–Wiener index (H′), the exponential of the Shannon–Wiener index (expH′), Pielou's evenness (J) and species evenness (D/S), related to species diversity were estimated, followed by the one-way ANOVA ($F = 25.01$, $p < 0.001$) and the Kruskal-Wallis test ($H = 22.59$, $p < 0.001$).
Keywords	Butterflies; Diversity; Ecosystem; Endosulfan; Kerala

Title	**Analytical protocol for determination of endosulfan beta, propham, chlorpyrifos, and acibenzolar-s-methyl in lake water and wastewater samples by gas chromatography–mass spectrometry after dispersive liquid–liquid microextraction**
Author Name	Süleyman Bodur, Cansu Özlü, Büşra Tışlı, Merve Fırat, Dotse Selali Chormey & Sezgin Bakırdere
Journal Name	Environmental Monitoring and Assessment
Year	2020
Volume and Issue	192 (253)
Pages	155
Abstracts	Two greenhouse experiments were carried out to evaluate the phytoremediation potential, physiological responses and zinc (Zn) uptake kinetics of water lettuce (*Pistia stratiotes L.*). The phytoextraction experiment evaluated four doses of Zn (0.7 mg L^{-1} – represented the Zn in the nutrient solution, 1.8, 18 and 180 mg L^{-1} – corresponded to ten, hundred and a thousand times, respectively, the maximum permitted content for fresh water) at four different culture times (24, 48, 72 and 168 h). The Zn uptake kinetics of water lettuce were evaluated at two concentrations of Zn (1.8 and 18 mg L^{-1}). The water lettuce attained the highest percentage removal at the lowest evaluated doses (0.7 and 1.8 mg L^{-1}), reaching a maximum value of approximately 72% removal (when cultivated in 1.8 mg L^{-1} of Zn after 168 h of culture). The Zn uptake increased with culture time, increasing the synthesis of carotenoids at all doses evaluated. The highest doses of Zn resulted in a reduction in photosynthetic efficiency. The results showed a high potential of water lettuce to absorb and tolerate Zn, accumulating preferably in the roots, demonstrating that these plants are able to absorb large quantities of Zn in contaminated solution.
Keywords	Aquatic environments contaminated; aquatic macrophytes; bioremediation decontamination; heavy metal; sphotosynthetic efficiency

Title	Phytotoxicity Increase Induced by Zinc Accumulation in Cichorium intybus
Author Name	Mohammad Mariane Wolf & Alexandre Tadeu Paulino
Journal Name	Bulletin of Environmental Contamination and Toxicology
Year	2020
Volume and Issue	105
Pages	405-410
Abstracts	The accumulation of zinc (Zn) in Cichorium intybus and effects of phytotoxicity during 90 days of growth on (natural) non-contaminated and Zn-contaminated soils were studied. The phytotoxicity effects were monitored by evaluating the leaf area, leaf biomass, leaf length and root length of the vegetable. The Zn concentrations ranged from 5.35 ± 1.05 to 37.5 ± 3.89 mg kg^{-1} in leaves of plants grown on natural soil, and from 334.0 ± 25.6 to 2232 ± 16.7 mg kg^{-1} when grown on Zn-contaminated soils. Zn accumulation caused a decrease in growth on contaminated soils and an increase in phytotoxicity. These effects were associated to high metal concentration, mobility and bioavailability in the soil as well as changes in the translocation mechanism from the roots to the leaves. Then, it must be avoided the organic fertilization of soils with either animal manure or other agricultural inputs containing high zinc concentrations.
Keywords	Metal accumulation; Soil; Zinc; Plant growth; Phytotoxicity

Title	**Impacts of citric acid on the phytoextraction of zinc (zn) using sorghum (sorghum bicolor (l.) moench) plants**
Author Name	Hamza Badamasi, Muhammad Saminu Dagari, Isyaku Sale
Journal Name	Malaysian Journal of Analytical Sciences
Year	2020
Volume and Issue	24 (4)
Pages	587-598
Abstracts	Greenhouse hydroponic experiments were carried out to examine the impacts of citric acid on Zn uptake and phytoextraction potentials of sorghum (*Sorghum bicolor (L.) Moench*). Two-week-old seedlings transplanted in hydroponic solutions were treated with different doses of Zn in the concentration range of 5, 25, 50, 100, and 200 mg/L alone or in combination with 10 mM citric acid. After 21 days of culture, the plants were harvested, separated into roots and shoots, and then dried. Fresh and dry weights were measured using Sartorius balance, Zn uptakes in the roots and shoots were determined by atomic absorption spectrometry. Translocation factor (TF) was determined by dividing Zn concentrations in roots by Zn concentration in the shoots, bioconcentration factor (BCF) was determined as a ratio of Zn concentration in the roots to Zn concentration in the hydroponic solution. Proline, pigments, protein, and ascorbate content were measured spectrophotometrically using acid ninhydrin, acetone, Lowry assay, and dinitrophenyl hydrazine methods respectively. The results indicate that Zn uptake, fresh and dry weights, TF, BCF, proline, and ascorbate contents were concentration dependent with a more significant increase ($p < 0.05$) after the application of citric acid. Pigments and protein contents were, however severely decreased with increasing Zn concentrations and appreciated gradually with the addition of citric acid. Thus, citric acid efficiently increased phytoextractability of Zn and reduced Zn-induced toxicity; Sorghum bicolor LM was non-hyperaccumulator of Zn but may be used for phytoremediation of Zn contaminated environments with assistance of citric acid.
Keywords	citric acid; hydroponic; phytoextraction; Sorghum bicolor (L) Moench; Zn

Title	**Zinc seed treatments improve productivity, quality and grain biofortification of desi and kabuli chickpea (Cicer arietinum)**
Author Name	Aman Ullah, Muhammad Farooq, Faisal Nadeem, Abdul Rehman, Ahmad Nawaz, Muhammad Naveed, Abdul Wakeel and Mubshar Hussain
Journal Name	Crop and Pasture Science
Year	2020
Volume and Issue	71(7)
Pages	668-678
Abstracts	Chickpea (*Cicer arietinum L.*) is a leading food legume primarily grown in marginal areas and consumed all over the world. However, its production is limited owing to zinc (Zn) deficiency in many chickpea-based cropping systems. This study was conducted over two years to evaluate the effect of Zn application through seed treatments on productivity and grain Zn biofortification of kabuli and desi chickpea types in Punjab, Pakistan. Pre-optimised doses of Zn were applied as (i) seed priming (0.001 M Zn) and (ii) seed coating (5 mg Zn kg^{-1} seed), using $ZnSO_4.7H_2O$ (33% Zn). Hydropriming (soaking in water) and non-primed dry seeds were used as control treatments. Zinc seed treatments significantly improved leghemoglobin contents, nodulation, grain yield, grain Zn yield, grain bioavailable Zn, grain minerals and grain Zn concentration compared with control treatments in both chickpea types. During both years, kabuli chickpea receiving Zn seed coating had higher grain yield (2.22 and 2.73 t ha^{-1}) and grain Zn yield (103 and 129 g ha^{-1}) than kabuli receiving other treatments. Likewise, during both study years, maximum grain bioavailable Zn (4.58 and 4.55 mg Zn day^{-1}) was recorded with Zn seed coating in both chickpea types. Kabuli chickpea had more grain bioavailable Zn than desi. With regard to seed treatments, desi chickpea was more responsive to Zn osmopriming, whereas kabuli was more responsive to Zn seed coating. In conclusion, Zn seed treatments, as seed priming and seed coating, are effective methods for improving the productivity, grain quality and Zn biofortification of both desi and kabuli chickpea.
Keywords	grain Zn, mineral matter, phytate concentration, protein, seed coating, seed priming.

Title	**Impact of selenium, zinc and their interaction on key enzymes, grain yield, selenium, zinc concentrations, and seedling vigor of biofortified rice**
Author Name	Hla Hla Ei, Tengda Zheng, Muhammad Umer Farooq, Rui Zeng, Yang Su, Yujie Zhang, Yuanke Liang, Zhichen Tang, Xiaoying Ye, Xiaomei Jia & Jianqing Zhu
Journal Name	Environmental Science and Pollution Research
Year	2020
Volume and Issue	27
Pages	16940–16949
Abstracts	Selenium (Se) is an essential micronutrient and important component of oxidase which protects cell membranes, eliminate the role of free radicals in the human body. Se is necessary for low Se rice genotypes and Se deficient areas. Zinc (Zn) is a micro-battalion that affects the growth, development, aging, drought resistance, disease resistance, and many other aspects for rice. The effects of Se and Zn fertilization on Se and Zn concentrations were evaluated including the response of superoxide dismutase (SOD), catalase (CAT) enzymes activity, and grain yield under single Se, Zn, and combined Se-Zn application using R725 rice variety in pot experiment with 8 treatments (0, Zn5, Zn10, Zn15, Se1, Zn5 + Se1, Zn10 + Se1, and Zn15 + Se1) mg/kg of soil and three replications. Moreover, germination% and seedling growth of resulted seeds from this experiment were evaluated for the agronomical benefit of farmers. The results revealed that Se and Zn had a cumulative effect on each other, but more Se increase was activated than Zn under the combined Se-Zn application. Zinc application had the small effect on Zn concentration in the different fractions but the positive effect on carotenoids and the yield (both applied alone and in combination with Se). Single Se application resulted in a positive effect on Zn accumulation in grain and husk with the high effectiveness of Se accumulation and loss during processing. Combined Se-Zn application had positive effect on carotenoids, CAT, grain yield, and total dry matter. Moreover, single Zn and combined Se-Zn application had a positive effect on germination% and seedling growth. Agronomic biofortification with combined Se-Zn supply provided both agronomic and nutritional benefits for rice in the current pot trail. However, as Se preferably accumulated in the edible part as compared to Zn, 1 mg Se/kg fertilization was unsafe for edible purposes according to the national standard of China (0.04–0.3 mg/kg) but could be recommended as medicine.
Keywords	Selenium; Zinc; Selenium-zinc interaction; Key enzymes; Grain yield; Seedling vigor; Rice

Title	Effects of exogenous zinc on the photosynthesis and carbonic anhydrase activity of millet (*Setaria italica L.*)
Author Name	M.L. CAO, Y.X. LI, and H.L. DU
Journal Name	Photosythetica
Year	2020
Volume and Issue	58(3)
Pages	712-719
Abstracts	This study aimed to evaluate the effects of Zn on the growth safety and activity of carbonic anhydrase (CA) in foxtail millet (*Setaria italica L.*). The photosynthetic characteristics, CA activity, and relative gene expression of different varieties of millet at the seedling stage were studied by spraying Zn solution under pot experiment and indoor culture conditions. Results showed that spraying low-concentration Zn solution (20, 40, and 60 mg L^{-1}) reduced malondialdehyde content and intercellular CO_2 concentration (Ci) but increased antioxidant enzyme activity, pigment content, and photosynthetic gas-exchange parameters (net photosynthetic rate, stomatal conductance, transpiration rate, except for Ci); meanwhile, spraying high Zn concentration (80 and 100 mg L^{-1}) exerted opposite effects. The optimal growth of millet was achieved when the Zn concentration was 40 mg L^{-1}. At this concentration, CA activity increased and β-CA family expression was upregulated, which exerted little or no effect on other CA families. Compared to Zhangzagu 10 (zinc-resistant variety), Jingu 21 (zinc-sensitive variety) showed a more signifcant change. This study may serve as a reference for further research on the function of CA and physiological processes, such as photosynthesis in millet, and a theoretical basis for the effective use of Zn fertilizer in millet.
Keywords	carbonic anhydrase gene family; peroxidase; photosynthetic pigment; superoxide dismutase

Title	**Phytotoxicity of nano-zinc oxide to tomato plant (*Solanum lycopersicum L.*): Zn uptake, stress enzymes response and influence on non-enzymatic antioxidants in fruits**
Author Name	Mariam Abiola Akanbi-Gada, Clement O.Ogunkunle, Vinita Vishwakarma, Kanagasabai Viswanathan & Paul O. Fatoba
Journal Name	Environmental Technology & Innovation
Year	2019
Volume and Issue	14, 100325
Pages	--
Abstracts	The production of metallic nanoparticles is greatly increasing due to its wide range of applications in agricultural formulations. The present pot experiment investigated the uptake of Zn from nano-zinc oxide (n-ZnO)-amended soil at 300, 600 and 1000 mg n-ZnO/kg concentrations, and its effects on the enzymatic and non-enzymatic antioxidants in tomato tissues and fruits respectively. Results showed that root uptake of Zn increased with increasing n-ZnO concentrations. The enzyme activity showed that n-ZnO, through the generation of H2O2 and induction of oxidative stress, significantly reduced the activity of stress-controlling enzymes (APX and SOD) in the root. Conversely in leaves, despite alteration in chlorophyllsin the early growing stage, APX activity was only significant at 1000 mg n-ZnO/kg) while SOD activity was enhanced at all treatments. CAT activity was significantly reduced, unlike in the roots where CAT activity was significantly enhanced. Contents of total phenols, flavonoids, β-carotene and lycopene in fruits were significantly reduced by at least 4.8% while ascorbic acid was promoted at low n-ZnO treatments. In conclusion, the toxic effect of n-ZnO on stress enzymes was prominent in tomato roots, and there was also inhibitory effect on induction of non-enzymatic antioxidants in the tomato fruits.
Keywords	Nano-zinc oxide; Oxidative stress; Stress enzymes; Zinc; Solanum lycopersicum; Antioxidants

Title	**Biochemical, molecular, and elemental profiling of *Withania somnifera L.* with response to zinc stress**
Author Name	Jyoti Ranjan Rout, Rout George Kerry, Debasna Panigrahi, Santi Lata Sahoo, Chinmay Pradhan, Shidharth Sankar Ram, Anindita Chakraborty & Mathummal Sudarshan
Journal Name	Environmental Science and Pollution Research
Year	2019
Volume and Issue	26, 4
Pages	4116–4129
Abstracts	Zn stress seriously induces various toxic responses in *Withania somnifera L.*, when accumulated above the threshold level which was confirmed by investigating the responses of protein, expression of antioxidant enzymes, and elemental profiling on accumulation of Zn. Zn was supplemented in the form of $ZnSO_4$ (0, 25, 50, 100, and 200 μM) through MS liquid medium and allowed to grow the in vitro germinated plants for 7 and 14 days. The study revealed that when the application of Zn increased, a significant reduction of growth characteristics was noticed with alterations of proteins (both disappearance and de novosynthesis). The activity of CAT, SOD, and GPX were increased up to certain concentrations and then declined, which confirmed through in-gel activity under different treatments. RT-PCR was conducted by taking three sets of genes from CAT (RsCat, Catalase1, Cat1) and SOD (SodCp, TaSOD1.2, MnSOD) and found that gene RsCat from CAT and MnSOD from SOD have shown maximum expression of desired genes under Zn stress, which indicate plant's stress tolerance mechanisms. The proton-induced X-ray emission study confirmed an increasing order of uptake of Zn in plants by suppressing and expressing other elemental constituents which cause metal homeostasis. This study provides insights into molecular mechanisms associated with Zn causing toxicity to plants; however, cellular and subcellular studies are essential to explore molecule-molecule interaction during Zn stress in plants.
Keywords	Antioxidant enzymes; Ashwagandha; Gene expression; Phytotoxicity; PIXE & Zinc excess

Title	**The mycorrhizal pathway of zinc uptake contributes to zinc accumulation in barley and wheat grain**
Author Name	Antonio Coccina , Timothy R. Cavagnaro , Elisa Pellegrino , Laura Ercoli , Michael J. McLaughlin and Stephanie J. Watts-Williams
Journal Name	BMC Plant Biology
Year	2019
Volume and Issue	19(133)
Pages	1 - 14
Abstracts	Increasing zinc (Zn) concentrations in crops is important for alleviation of human Zn deficiency. Arbuscular mycorrhizal fungi (AMF) contribute to plant Zn uptake, but their contribution to Zn in the edible portion of crops has not yet been investigated. This study aimed to quantify the mycorrhizal pathway of Zn uptake into grain of wheat and barley under varying soil Zn availabilities. Bread wheat (Triticum aestivum) and barley (Hordeum vulgare) were grown in pots with a hyphal compartment containing 65Zn. Plants were inoculated with Rhizophagus irregularis and grown at three soil Zn concentrations. Radioactive Zn in grain and straw was measured and the contribution of AMF to Zn uptake was calculated.
Keywords	Arbuscular mycorrhizal fungi; Barley (Hordeum vulgare); Radioisotope tracing; Wheat (Triticum aestivum); Yield; Zinc nutrition

Title	**Comparison study of zinc nanoparticles and zinc sulphate on wheat growth: From toxicity and zinc biofortification**
Author Name	Wei Du, Jingya Yang, Qingqing Peng, Xiaoping Liang & Hui Mao
Journal Name	Chemosphere
Year	2019
Volume and Issue	227
Pages	109-116
Abstracts	ZnO nanoparticles (NPs) are studied as a potential solution to alleviate Zn deficiency in human diet due to their special physicochemical properties. However, information for food quality and safety in NP-treated crops is limited. The effects of ZnO NPs and $ZnSO_4$ on germination and growth of wheat (*Triticum aestivum L.*) were studied in germination and pot experiments. Zn content increased significantly, ZnO NPs were more effective than $ZnSO_4$ at increasing grain Zn content, but less effective at increasing leaf Zn, and no ZnO NPs were detected in the wheat tissues by NP-treatments, indicated by XRD. Both ZnO NPs and $ZnSO_4$ at moderate doses increased grain yield and biomass. Compared with control, the maximum grain yield and biomass of wheat treated with ZnO NPs and $ZnSO_4$ were increased by 56%, 63% and 55%, 72%, respectively. $ZnSO_4$ was more toxic than ZnO NPs at high doses as measured by the inhibitory effects in seed germination, root length, shoot length and dry biomass of seedlings. Structural damage in roots and variation in enzyme activities were greater with $ZnSO_4$ than with ZnO NPs. ZnO NPs did not cause toxicity different from that of $ZnSO_4$, which indicates that ZnO NPs used under the current experimental conditions did not cause Nano specific risks.
Keywords	ZnO nanoparticles; $ZnSO_4$; Wheat; Germination; Yield

Title	Effects of zinc fertilizer amendments on yield and grain zinc concentration under controlled environment conditions
Author Name	Sarah Anderson, Jeff Schoenau & Albert Vandenberg
Journal Name	Journal of Plant Nutrition
Year	2018
Volume and Issue	41 (14)
Pages	1842-1850
Abstracts	The application of zinc (Zn) fertilizer to lentil is an agronomic strategy that has the potential to improve yield and enhance grain Zn concentration. A pot study was conducted to determine if Zn fertilizer applied to three popular Saskatchewan lentil cultivars could increase yield and concentration of Zn in the grain. The effects of soil and foliar applied Zn forms, including $ZnSO_4$, Zn chelated with EDTA, Zn lignosulphonate, and a control were evaluated. Forms of Zn were not found to significantly increase yield ($P = 0.828$) or grain Zn concentration ($P = 0.708$) in any of the lentil cultivars tested. Fertilization with soil applied ZnSO4 resulted in significantly ($P < 0.0001$) higher amounts of residual available Zn in the soil relative to other Zn treatments. Soil fertilized with ZnSO4 had 1.13 mg kg−1 diethylenetriaminepentaacetic acid (DTPA)-extractable Zn compared to 0.84 mg Zn kg−1 and 0.77 mg Zn kg−1 in the soil and foliar applied chelated Zn, respectively.
Keywords	Cultivar; fertilizer; lentil; uptake; zinc

Title	Zinc in soils, water and food crops
Author Name	Noulas Christos, Tziouvalekas Miltiadis & Karyotis Theodore
Journal Name	Journal of Trace Elements in Medicine and Biology
Year	2018
Volume and Issue	49
Pages	252-260
Abstracts	A basic knowledge of the dynamics of zinc (Zn) in soils, water and plants are important steps in achieving sustainable solutions to the problem of Zn deficiency in crops and humans. This paper aims at reviewing and discussing the relevant aspects of the role of Zn in the soil–water–plant agro biological system: from the origins of Zn in soils and water to soil Zn deficiency distribution and the factors affecting soil Zn availability to plants, therefore to elucidate the strategies potentially help combating Zn deficiency problems in soil-planthuman continuum. This necessitates identifying the main areas of Zn-deficient soils and food crops and treating them with Zn amendments, mainly fertilizers in order to increase Zn uptake and Zn use efficiency to crops. In surface and groundwater, Zn enters the environment from various sources but predominately from the erosion of soil particles containing Zn. In plants is involved in several key physiological functions (membrane structure, photosynthesis, protein synthesis, and drought and disease tolerance) and is required in small but nevertheless critical contents. Several high revenue food crops such as beans, citrus, corn, rice etc are highly susceptible to Zn deficiency and *biofortification* is considered as a promising method to accumulate high content of Zn especially in grains. With the world population continuing to rise and the problems of producing extra food rich in Zn to provide an adequate standard of nutrition to increase, it is very important that any losses in production easily corrected so as Zn deficiencies are prevented.
Keywords	Zn content; Soil; Water; Food crops; Zn deficiency; Biofortification

Title	**Zinc oxide nanoparticles alter the wheat physiological response and reduce the cadmium uptake by plants**
Author Name	AfzalHussain, ShafaqatAli, MuhammadRizwan, MuhammadZia urRehman, Muhammad RizwanJaved, Muhammad Imran, Shahzad Ali ShahidChatha & RashidNazirf
Journal Name	Environmental Pollution
Year	2018
Volume and Issue	--
Pages	Pages 1518-1526
Abstracts	An experiment was performed to explore the interactive impacts of zinc oxide nanoparticles (ZnO NPs) and cadmium (Cd) on growth, yield, antioxidant enzymes, Cd and zinc (Zn) concentrations in wheat (Triticumaestivum). The ZnO NPs were applied both in Cd-contaminated soil and foliar spray (in separate studies) on wheat at different intervals and plants were harvested after physiological maturity. Results depicted that ZnO NPs enhanced the growth, photosynthesis, and grain yield, whereas Cd and Zn concentrations decreased and increased respectively in wheat shoots, roots and grains. The Cd concentrations in the grains were decreased by 30–77%, and 16–78% with foliar and soil application of NPs as compared to the control, respectively. The ZnO NPs reduced the electrolyte leakage while increased SOD and POD activities in leaves of wheat. It can be concluded that ZnO NPs (levels used in the study) could effectively reduce the toxicity and concentration of Cd in wheat whereas increase the Zn concentration in wheat. Thus, ZnO NPs might be helpful in decreasing Cd and increasing Zn biofortification in cereals which might be effective to reduce the hidden hunger in humans owing the deficiency of Zn in cereals.
Keywords	Zinc biofortification; Cadmium; Antioxidants; Wheat; Grain yield

Title	**Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mungbeans plant (Vignaradiata)**
Author Name	Tayyeba Samreen, Humaira, Hamid Ullah Shah, Saleem Ullah and Muhammad Javid
Journal Name	Arabian Journal of Chemistry
Year	2017
Volume and Issue	10
Pages	S1802-S1807
Abstracts	Four varieties of *mungbeans* (Ramazan, Swat mungI, NM92 and KMI) from different research stations of KPK (Khyber Pukhtunkhwa) in Pakistan were grown hydroponically in pots containing sand giving nutrient solutions with and without Zn. Each variety was applied with Zn solutions at three levels i.e. 0, 1 and 2 μM concentrations. Plant samples were taken 2 months after transplant and the effect of Zn supply was observed on plant growth rate, protein, minerals and chlorophyll contents of *mungbean* leaves. Plant growth, chlorophyll contents, crude proteins and Zn contents were noted to be higher when greater supply of zinc doses was applied. Plant phosphorous contents declined with supply of Zn from 1 μM to 2 μM compared to the control signifying a Zn/P complex foundation possibly in roots of plant, preventing the movement of P to plant. Plant copper and Mg contents increased whereas Fe showed competitive behavior with Zinc while K, Na and Mn plant contents were non-significantly depressive with Zn increase from control to 2 μM. Zinc application at 2 μM concentrations in solution culture turned out to be the best treatment for improving the growth and quality parameters of mungbean.
Keywords	Mungbean; Hydrophonic; Protein; Chlorophyll; Zn; Micronutrients

Title	**Zinc biofortification of wheat through preceding crop residue incorporation into the soil**
Author Name	Amir Hossein Khoshgoftarmanesh, Mojtaba Norouzi, Majid Afyuni and Rainer Schulin
Journal Name	European Journal of Agronomy
Year	2017
Volume and Issue	89
Pages	131 - 139
Abstracts	We conducted a two-year field experiment to investigate the potential benefit of preceding crop residue incorporation into the soil as a strategy to enhance the density of bioavailable grain zinc (Zn) in a subsequent wheat (*Triticumaestivum L.*) crop. Sunflower (*Heilianthusannuus L. cv. Allstar*), sorghum (Sorghum bicolor L. cv. Speed Feed), clover (*Trifoliumpratense L.*) and safflower (*Carthamustinctorius L. cv. Koseh-e-Isfahan*) were grown as preceding crop (precrop) on a Zn-deficient calcareous soil in central Iran, followed by a culture of two wheat cultivars i.e., Kavir and Back Cross Rushan. The harvested aboveground plant matter was air-dried, crushed into pieces of 0.5–2 cm size, mixed, and after taking a sample for analysis, incorporated manually into the upper 15 cm of the soil of one half of the same plot from which it had been harvested, while the other half received no residues. The aboveground residues of precrops were incorporated into soil or removed. A treatment with no preceding crop (fallow) and no residue incorporation, but with the same management otherwise, was implemented as control treatment. For both wheat cultivars studied, higher grain yield was obtained after clover (between 14 and 25.6%) and sunflower (between 11.3 and 19.5%) than that after safflower, sorghum and the fallow. All precrop treatments significantly increased the accumulation of grain Zn and N and decreased the phytic-acid-to-Zn (PA:Zn) molar ratio (by 5–41% in Kavir and by 11–48% in Back Cross), most effectively the clover treatment. The treatment effects on grain Zn were closely correlated with soil pH and dissolved soil organic carbon (DOC). The results show that the cultivation of appropriate precrops, especially legumes, can be an effective strategy to biofortify wheat grains with Zn without compromising yields.
Keywords	Biofortification;Crop residue; Green manure; Precrop culture; Wheat; Zinc

Title	Silicon addition to soybean (Glycine max L.) plants alleviate zinc
Author Name	Pascual MB, Echevarria V, Gonzalo MJ & Hernández-Apaolaza L.
Journal Name	Plant Physiology and Biochemistry
Year	2016
Volume and Issue	108
Pages	132-138
Abstracts	It is well established the beneficial role of silicon (Si) in alleviating abiotic stress. However, it remains poorly understood the mechanisms of the Si-mediated protection against metal deficiency, especially the zinc (Zn) one. Recently, it has been proposed that Si may act by an interaction with this biometal in the root apoplast contributing to its movement through the plant, as in the case of Fe deficiency. In the present work, the effect of initial or continuous Si doses in soybean Zn deficient plants has been studied. For that purpose, plants grown in hydroponic culture were treated with different Si doses (0.0, 0.5 and 1.0 mM) under Zn limiting conditions. SPAD index in leaves, several growth parameters, mineral content in the whole plant and the formation of Zn pools in roots were determined. An initial addition of 0.5 mM of Si to the nutrient solution led to an enhancement of plants growth, Zn and Si content in leaves, and a higher storage of Zn in the root apoplast. The results suggest that this treatment enhanced Zn accumulation on roots and its movement to shoots when needed, mitigating Zn deficiency symptoms.
Keywords	Apoplast; Silicon; Soybean; Zinc deficiency; Zn; Si interaction

Title	**Effect of crop residue and residual zinc on zinc fractions and their contribution to zinc uptake under rice-wheat cropping system in calciorthents.**
Author Name	Kumari, kamini; prasad, j.; kumar, vipin; solanki, i. S.
Journal Name	Research on Crops
Year	2015
Volume and Issue	16 (2)
Pages	205-212
Abstracts	The long term effect of crop residue and residual zinc on Zn fractions in soil and their contribution to Zn uptake in rice-wheat system was studied in calciorthents of the Rajendra Agricultural University, Pusa, Samastipur (Bihar) during 2010-11 and 2011-12. Application of zinc and crop residue increased the water soluble+exchangeable, complexed, organically bound, carbonate and amorphous oxide, crystalline oxide, residual and total Zn in the soil. The order of dominance of different fractions in soil was total Zn (164.35 mg/kg) “residual-Zn (156.41 mg/kg)” Zn bound to crystalline oxide (3.06 mg/kg) ”complexed Zn (2.27 mg/kg)“ organically bound “Zn (1.14 mg/kg)” water soluble plus exchangeable Zn (0.84 mg/kg) and Zn bound carbonate and amorphous oxide (0.73 mg/kg). All the soil Zn fractions were significantly correlated among themselves indicating existence of a dynamic equilibrium with each other. Zinc uptake by rice-wheat was improved with zinc along with crop residue plus compost. Among different Zn fractions, Zn bound to crystalline oxide, followed by Zn bound to carbonate and amorphous oxide played a key role in explaining the variation in yield and nutrient uptake by rice and wheat. The highest zinc uptake by rice and wheat was reported with the conjoint use of 100% crop residue and 10 kg Zn/ha.
Keywords	Zn fractions; zinc; calciorthents; carbonate

Title	**Understanding the Role of Iron and Zinc in Animals and Crop Plants from Genomics Perspective**
Author Name	Zargar Sajad Majeed, Mahajan Reetika, Farhat Sufia, Nazir Muslima, Mir Rakeeb Ahmad, Nazir Momina, Salgotra R K, Mallick S A
Journal Name	Indian Journals
Year	2015
Volume and Issue	---
Pages	182-196
Abstracts	The micronutrients iron (Fe) and zinc (Zn) play an important role in the metabolism of both animals and plants. The deficiency of these micronutrients, therefore, has a direct effect on their growth and metabolism. In order to enhance the level of micronutrients in crop plants, it is necessary to understand the genetic makeup and regulation of their transporter genes. The genetic improvement of crop plants is an option to attain nutritional security along with food security. In this review, we have described the impact of Fe and Zn on animal and crop plants, the need to improve the mineral contents (Fe and Zn) in crops with a special focus on common bean as a model for understanding the mineral uptake and the approaches towards deciphering the micronutrient contributing genes.
Keywords	Iron; Zinc; Common bean; Transporters; Genomics.

Title	**Inhibitory Effect of Pre-harvest Foliar Application of Zinc Sulphate on Sucrose Inversion in the Harvested Sugarcane**
Author Name	R. Banerji, S. Solomon, Rajesh Kumar, Ram Kishor, P. Singh, A. Chandra
Journal Name	Sugar Research & Promotion
Year	2015
Volume and Issue	17(3)
Pages	322–324
Abstracts	Sugar recovery in sub-tropical India is low during late milling season despite improved cane varieties and management practices. For maximizing sugar recovery, post-harvest sucrose loss could be minimized by either reducing the time lag between harvest and milling or minimizing sucrose inversion by using some invertase inhibitors. Keeping above facts in view, field experiments were conducted during the year 2007 and 2008 for studying the effect of pre-harvest foliar application of divalent cation zinc as zinc sulphate (an invertase inhibitor) on post-harvest sucrose loss and internodal acid invertase activity during staling of cane. Results showed the deterioration of zinc sulphate treated cane was less in comparison todeterioration of untreated cane as revealed by significant higher commercial cane sugar (CCS %) in zinc sulphate treated trash covered cane after 1 week of staling in comparison to CCS % of control trash covered cane. Higher CCS % in zinc sulphate treated cane was due to lower enzymic inversion of sucrose because of inhibition of internodal acid invertase by zinc sulphate.
Keywords	Pre-harvest; Foliar application; Zinc sulphate; Sucrose inversion Harvested sugarcane.