# Zinc

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| **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 |

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| **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 |

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| **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 |

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| **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 ZnSO4 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 |

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| **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** | Volume 41, Issue 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 ZnSO4, Zn chelated with EDTA, Zn *lignosulphonate*, and a control were evaluated. Forms of Zn were not found to significantly increase yield (P D 0.828) or grain Zn concentration (P D 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 |
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| Author Name | Noulas Christos, Tziouvalekas Miltiadis & Karyotis Theodore |
| Journal Name | Journal of Trace Elements in Medicine and Biology |
| Year | 2018 |
| Volume and Issue | 49 |
| Page | 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 |

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| **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 |
| **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 |

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| **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** | Volume 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 |

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| **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** | Volume-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 |

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| **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 |

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| **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** | Volume 16, Issue 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 |

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| **Title** | **Understanding the Role of Iron and Zinc in Animals and Crop Plants from Genomics Perspective** |
| **Author Name** | Zargar SajadMajeed*, Mahajan Reetika, Farhat Sufia, Nazir Muslima, Mir Rakeeb Ahmad, Nazir Momina, Salgotra R K, Mallick S A |
| **Journal Name** | Indian Journals |
| **Year** | 2015 |
| **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. |

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| **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** | Volume-17, Issue-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. |