Iron

Title	**Acquisition and Homeostasis of Iron in Higher Plants and Their Probable Role in Abiotic Stress Tolerance**
Author Name	Durgesh K. Tripathi1, Shweta Singh, Shweta Gaur, Swati Singh, Vaishali Yadav, Shiliang Liu, Vijay P. Singh, Shivesh Sharma, Prateek Srivastava, Sheo M. Prasad, Nawal K. Dubey, Devendra K. Chauhan & Shivendra Sahi
Journal Name	Frontiers of Environmental Science
Year	2018
Volume and Issue	Volume 05
Abstracts	Iron (Fe) is a micronutrient that plays an important role in agriculture worldwide because plants require a small amount of iron for its growth and development. All major functions in a plant's life from chlorophyll biosynthesis to energy transfer are performed by Fe (*Brumbarova et al., 2008; Gill and Tuteja, 2011*). Iron also acts as a major constituent of many plant proteins and enzymes. The acquisition of Fe in plants occurs through two strategies, i.e., strategy I and strategy II (*Marschner and Römheld, 1994*). Under various stress conditions, Nramp and the YSL gene families help in translocation of Fe, which further acts as a mineral regulatory element and defends plants against stresses. Iron plays an irreplaceable role in alleviating stress imposed by salinity, drought, and heavy metal stress. This is because it activates plant enzymatic antioxidants like *catalase* (CAT), *peroxidase, and an isoform of superoxide dismutase (SOD)* that act as a scavenger of reactive oxygen species (ROS) *(Hellin et al., 1995)*. In addition to this, their deficiency as well as their excess amount can disturb the homeostasis of a plant's cell and result in declining of photosynthetic rate, respiration, and increased accumulation of Na+ and Ca− ions which culminate in an excessive formation of ROS. The short-range order hydrated Fe oxides and organic functional groups show affinities for metal ions. Iron plaque biofilm matrices could sequester a large amount of metals at the soil–root interface. Hence, it has attracted the attention of plant physiologists and agricultural scientists who are discovering more exciting and hidden applications of Fe and its potential in the development of bio-factories. This review looks into the recent progress made in putting forward the role of Fe in plant growth, development, and acclimation under major abiotic stresses, i.e., salinity, drought, and heavy metals.
Keywords	Trace elements, iron (Fe); abiotic stress, plants; reactive oxygen species (ROS); enzymatic antioxidants; proteins; gene families

Title	**Physiological and transcriptomic analysis of responses to different levels of iron excess stress in various rice tissues**
Author Name	May Sann Aung, Hiroshi Masuda, Takanori Kobayashi & Naoko K. Nishizawa
Journal Name	Soil Science and Plant Nutrition
Year	2018
Volume and Issue	64, 3
Page	370 – 385
Abstracts	Iron (Fe) toxicity is a major nutritional disorder of plants and affects rice yield and production in rainfed and irrigated lowland rice grown in acid soils. Rice plants are reported to have exclusion and inclusion adaptation strategies for preventing damage from excess Fe. However, the molecular mechanisms behind the Fe toxicity response and the identities of the genes involved remain largely unknown. To reveal these mechanisms, we exposed rice plants to different levels of ferrous (Fe2+) excess treatment for 14 days and analyzed their growth, bronzing score, and mineral concentrations. Then, gene expression patterns in various tissues (roots, discrimination center [DC], stems, old leaves [OLs], and newest leaves [NLs]) in response to different levels of Fe excess (×1, ×10, ×20, ×50, and ×70 Fe) were examined using microarray analysis. Our results showed that the higher levels of Fe excess led to more Fe being preferentially translocated to OLs, thus avoiding Fe excess damage in the NL. We proposed three zones of Fe excess levels: the non-affected, affected, and dead zones. As an exclusion strategy, Fe uptake- and transport-related genes were suppressed in roots since in the non-affected zone. Roots are important for preventing Fe uptake to the plant body under Fe excess stress. As inclusion strategies, first, some genes highly induced in various tissues under Fe excess, such as OsNAS3, OsVIT2, and rice ferritin genes (OsFers), may be important for detoxification or isolation of excess Fe within the plant body. OsZIPs may contribute to the maintenance of zinc homeostasis. Second, the plant induces the expression of oxygen and electron transfer genes, cytochrome P450 family proteins, or some NAC-type transcription factors to avoid reactive oxygen species and abiotic stress caused by Fe excess in the affected zone. The plant may use similar Fe homeostasis mechanisms in the non-affected and affected zones in the NL and roots but employ different mechanisms in the OL, DC, and stem tissues. Our results will contribute to current screening and breeding efforts, which aim to develop Fe excess tolerance in diverse rice cultivars, thus increasing rice production in lowland fields.
Keywords	Iron toxicity; rice; microarray; stress responses; transcriptome

Title	**Alleviation of iron toxicity in Schinus terebinthifolius Raddi (Anacardiaceae) by humic substances**
Author Name	Leonardo Barros Dobbss, Tamires Cruz dos Santos, Marco Pittarello, SávioBastos de Souza, Alessandro Coutinho Ramos&Jader Galba Busato
Journal Name	Environmental Science and Pollution Research
Year	2018
Volume and Issue	25
Pages	Pages 9416–9425
Abstracts	One of the industrial pillars of Espírito Santo state, South East of Brazil, is iron-mining products processing. This activity brings to a high level of coastal pollution due to deposition of iron particulate on fragile ecosystems as mangroves and restinga. *Schinustherebinthifolius (aroeira)* is a widespread restinga species. This work tested iron toxicity alleviation by *vermicompost humic substances (HS)* added to aroeira seedlings in hydroponic conditions. Catalase, peroxidase, and ascorbate peroxidase are antioxidant enzymes that work as reactive oxygen species (ROS) scavengers: they increase their activity as an answer to ROS concentration rise that is the consequence of metal accumulation or humic substance stimulation. *S. terebinthifolius* seedlings treated with HS and Fe augmented their antioxidant enzyme activities significantly less than seedlings treated separately with HS and Fe; their significantly lower Fe accumulation and the slight increase of root and leaf area confirm the *biostimulating* effect of HS and their role in blocking Fe excess outside the roots. The use of HS can be useful for the recovery of areas contaminated by heavy metals.
Keywords	Iron contamination ; Antioxidative enzymatic function ; Reactive oxygen species ; Catalase ; Peroxidase ; Aroeira

Title	**Shoot tolerance mechanisms to iron toxicity in rice (Oryzasativa L.)**
Author Name	Lin-Bo Wu, Yoshiaki Ueda, Shang-Kun Lai & Michael Frei
Journal Name	Plant, Cell and Environment
Year	2017
Volume and Issue	Volume 40
Pages	570–584
Abstracts	Iron toxicity frequently affects lowland rice and leads to oxidative stress via the Fenton reaction. Tolerance mechanisms were investigated in contrasting genotypes: the intolerant IR29 and the tolerant recombinant inbred line FL483. Seedlings were exposed to 1000 mg L-1 ferrous iron, and the regulation of genes involved in three hypothetical tolerance mechanisms was investigated (I) Iron uptake, partitioning and storage. The iron concentration and speciation in different plant tissues did not differ significantly between genotypes. Sub-cellular iron partitioning genes such as vacuolar iron transporters or ferritin showed no genotypic difference s. (II) Antioxidant biosynthesis. Only one gene involved in carotenoid biosynthesis showed genotypic differences, but carotenoids are unlikely to scavenge the reactive oxygen species (ROS) involved in Fe toxicity, i.e. H2O2 and hydroxyl radicals. (III) Enzymatic activities for ROS scavenging and antioxidants turnover. In shoots, glutathione-S-transferase and ascorbate oxidase genes showed genotypic differences, and consistently, the tolerant FL483 had lower *dehydroascorbatereductase* and higher *ascorbate oxidase* activity, suggesting that high rates *ascorbate* reduction confer sensitivity. This hypothesis was confirmed by application of exogenous reduced ascorbate or L-galactono-1,4-lactone, which increased lipid peroxidation under iron toxic conditions. Our results demonstrate in *planta pro-oxidant* activity of reduced *ascorbate* in the presence of iron.
Keywords	antioxidant; ascorbic acid; Fenton reaction; iron toxicity; microarray; pro-oxidant; rice

Title	Role of Iron in Alleviating Heavy Metal Stress
Author Name	Zaid ul Hassan, Shafaqat Ali, Muhammad Rizwan, Qasim Ali, Muhammad Zulqarnain Haider, Muhammad Adrees & Afzal Hussain
Journal Name	Essential Plant Nutrients
Year	2017
Volume and Issue	Volume-54 Issue-4
Pages	356-366
Abstracts	Heavy metals naturally present in soils usually result from human activities such as agricultural practices, mining, automobile, sewage processing, and metal industries. Higher concentrations of these metals in surrounding environment showed toxic effects on plants and animals. Heavy metals entered in soil-plant environment through various anthropogenic activities are taken up and accumulated in various plant parts. Higher concentrations of these metals showed toxic symptoms in plants. Heavy metals at higher dosage negatively affect plants physiological, morphological, and biochemical traits. On the other hand, plants used different strategies to cope with damaging effects induced by metal toxicity. There are some metals such as macro and micro nutrients, which are essentially required by plants for their growth and development processes. Micronutrient such as iron plays a key role in minimizing toxic effects of heavy metals and limits their entry in food chain. It has been thoroughly documented by many researchers that Fe has potential to alleviate metal toxicity by limiting metals uptake in different plants. Reports suggested that Fe improves plant physiological, morphological, and biochemical parameters by neutralizing metals toxicity. However, Fe deficiency resulted in malnutrition that affects human population worldwide. Various strategies have been used to enhance food quality, improve Fe uptake from soil and increased Fe shortage through a process known as *biofortification*. Fe uptake can be enhanced by *overexpressing genes.* Micronutrients level in plants could also be enhanced through agricultural practices, plant breeding, and biotechnology techniques.
Keywords	Heavy metals; Fe; Anthropogenic activities; Physiological; Morphological; Biochemical; Micronutrient; Biofortification

Title	Responses of rice to chronic and acute iron toxicity: genotypic differences and biofortification aspects
Author Name	Michael Frei, Richmond Narh Tetteh, Ando Lalaina Razafindrazaka, Michael Apolonius Fuh, Lin-Bo Wu & Mathias Becker
Journal Name	Plant Soil
Year	2016
Volume and Issue	408, 1–2
Pages	149–161
Abstracts	Iron (Fe) toxicity is a wide spread stress in low land rice production. The aim of this study was to differentiate between responses to acute Fe stress during the vegetative stage and chronic Fe stress throughout the growing period. *Methods* Six rice genotypes were tested in a semi artificial greenhouse setup, in which acute (almost 1500 mg L−1 Fe in soil solution during the vegetative stage) and chronic (200to300mgL−1 Fe throughout the season) Fe toxicity were simulated. *Results* Acute Fe stress induced early development of heavy leaf bronzing, whereas moderate symptoms occurred in the chronic treatment throughout the season. Grain yields were only reduced in the chronic stress treatment (−23 %) due to reductions in spikelet fertility, grain number and grain weight. Symptom formation during the early growth stages did not reflect yield responses in all genotypes. Only one genotype showed increases in grain Fe concentrations (24 % in the acute stress and 44 % in the chronic stress) compared to the control. *Conclusions* contrasting genotypes responded differently to acute and chronic Fe toxicity, and one genotype showed consistent tolerance and the ability to translocate excess Fe into grains. These traits can be useful in the adaptive breeding of rice for Fe toxic environments.
Keywords	Breeding; Cereals; Food security; Iron deficiency anemia; Metal homeostasis; Flooded soils

Title	**Mapping Seed Phytic Acid Concentration and Iron Bioavailability in a Pea Recombinant Inbred Line Population**
Author Name	A. S. K. Shunmugam, X. Liu, R. Stonehouse, B. Tar'an, K. E. Betta,A. G. Sharpeb and T.D. Warkentin
Journal Name	Alliance of crop, soil and environmental science societies
Year	2015
Volume and Issue	Volume 55, Issue 2
Pages	828-836
Abstracts	Phytate, the storage form of P in seeds, is not well digested by monogastrics, thereby contributing to micronutrient deficiency, decreased feed efficiency, and environmental pollution. This research was aimed at developing a single nucleotide polymorphism (SNP) based genetic linkage map and mapping genomic regions associated with phytic acid- phosphorus (PA-P) concentration using a recombinant inbred line (RIL) population (PR-15) derived from a cross between a low phytate (low phytic acid [lpa]) mutant pea *(Pisum sativum L.)* genotype, 1-2347-144, and a normal phytate cultivar CDC Meadow. A total of 163 RILs were genotyped using a 1536-SNP *Illumina GoldenGate* array. Three hundred and sixty-seven polymorphic SNP markers ordered into seven linkage groups (LGs) were used to generate a linkage map with a total length of 437.2 cM. PR-15 lines were grown in replicated field trails in *Saskatoon and Rosthern,* SK, in 2012 and 2013. Chi-square statistics confirmed the single gene inheritance of PA-P concentration in these *RILs. Phytic acid-phosphorus (PA-P)* phenotype was mapped to LG5. Iron bioavailability (FEBIO) of PR-15 lines estimated using the Caco-2 cell culture bioassay was negatively correlated with PA-P concentration. A quantitative trait locus (QTL) for FEBIO was mapped on to the same location on LG5 as phytic acid concentration. The QTL with a maximum LOD score of 15.1 explained 60.5% of the phenotypic variation in FEBIO. The markers flanking this QTL region can be employed in marker-assisted selection to select pea lines with low phytate and greater Fe bioavailability.
Keywords	Seeds; micronutrient; environmental pollution; acid-phosphorus

Title	**Assessment of Iron Bioavailability and Iron Biofortification of Staple Food Crops: Guiding the Breeding Approach with in vitro and in vivo Screening Tools**
Author Name	Raymond Glahn and Elad Tako
Journal Name	European Journal of Nutrition & Food Safety
Year	2015
Volume and Issue	Volume-5, Issue-5
Pages	477-478
Abstracts	The objective of this presentation will be to demonstrate how the combination of invitro screening and an animal model can be extremely useful to develop and monitor *Fe-biofortified* crops, and evaluate meal plans in advance of human studies to determine if the crop is adequately *biofortified* with Fe prior to expensive human testing. Methods: In recent years much has been learned about how to properly screen varieties of staple food crops to improve the Fe content and bioavailability. Research has shown that simply measuring Fe content and levels of known inhibitors such as *phytic acid* and total *polyphenols* is not adequate to guide crop breeding efforts, as it leads to misdirection because of inability to assess all of the genetic, environmental, and environment by genotype interactions that play a role in Fe bioavailability from staple foods. Moreover, once *Fe-biofortified* crops are developed and released, there needs to be cost effective methodology in place to monitor and maintain the nutritional quality of successive harvests. Results: This presentation reports on a decade of applications of a high throughput bioassay (in vitro digestion/Caco-2 model) and a poultry feeding model that have been developed and applied to a variety of staple food crops (eg. beans, lentils, maize, sorghum and pearl millet). Recent comparisons to human efficacy trials involving black beans, pearl millet and red mottled beans.
Keywords	biofortified crops; bioavailability; staple foods

Title	**Pre-Roman Iron Age settlement continuity and cereal cultivation in coastal Finland as shown by multiproxy evidence at Bäljars 2 site in SW Finland**
Author Name	Santeri Vanhanen, Satu Koivisto
Journal Name	Journal of Archaeological Science: Reports
Year	2015
Volume and Issue	01
Pages	38–52
Abstracts	Pre-Roman Iron Age (ca. 500–1 BC) occupation was revealed at the site of *Bäljars* 2 in SW Finland. *Archaeobotany*, charcoal analysis, and geochemistry were applied to the samples gathered at the site. The results suggest habitation, storage, agriculture, fire- keeping, and plant gathering at the site during the Pre-Roman Iron Age. By that time, the *Lepinjärvi* basin was surrounded by rich local flora and served as an excellent node of communication with both overseas regions and the interior of Finland. Eight new sites were discovered around the lake, thus disproving the previously suggested hiatus of habitation around the lake. The light soils were suitable for early cultivation methods. The results point towards cultivation of ard-ploughed, fire-managed, and manured fields, where summer-annual barley, *speltoid wheats*, and possibly oat were grown. Other contemporary sites in Finland reveal that barley was the most *importantcereal* during the first millennium BC.
Keywords	Pre-Roman Iron Age; Coastal Finland, Settlement archaeology; Cereal cultivation; Geochemistry; Archaeobotany; Charcoal analysis