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Review Article

Iron Toxicity in Plants: A Review

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Abstract: Iron (Fe) is an essential micronutrient for plant growth and development. However, increased absorption of iron leads to iron toxicity. This leads to damage to plant cell membranes, decreased growth, productivity, and thus general health. The presence of free iron in cells can lead to an imbalance Redox in cells Pro-oxidant state, thus generating oxidative stress. In plants, iron is involved in chlorophyll synthesis, and is therefore essential for maintaining the structure and function of chloroplasts. Micronutrients in the soil can limit plant growth, even if all other nutrients are available in sufficient quantities. Micronutrient deficiencies are widespread due to the nature of the soil, high pH, low organic matter, salt stress, and persistent drought. High levels of bicarbonate in irrigation water, as well as unbalanced use of fertilizers. Iron (Fe) toxicity is a widespread nutritional disorder. It grows in acidic, sulphurous soils, as well as low sandy soils (i.e. iron is easily reducible) that contain a high percentage of organic matter. Iron toxicity can be reduced by using rice that is tolerant to high levels of iron.

Keywords: Iron, Plant, Toxicity, Redox.

INTRODUCTION

Essential micronutrients when absorbed in excess These elements produce toxic effects on plants [1]. These elements are present in trace or very trace amounts (1 µg/kg-1 or µg L-1) in environmental matrices [2]. Iron (Fe) is considered one of the essential micronutrients for plant growth and development, and it plays a major role in various physiological processes, such as photosynthesis and respiration, in addition to nitrogen metabolism [3]. Plants need iron (Fe) at a concentration of 10-4 to 10-9 M for optimal growth [4]. Any increase in iron absorption leads to iron poisoning, which in turn leads to damage to plant cell membranes, thus affecting growth and production and affecting health [5]. The general symptoms of the plant [6]. The most important symptoms that appear due to iron toxicity are: The color of the lower leaves changes to reddish brown, purple bronzing, yellow, or orange [7]. Symptoms of iron toxicity generally appear in the form of small brown spots that start from the tips of the leaves and spread to the bases of the leaves [8]. Bottom. These spots collect on the entrances of the leaves as the toxicity of the iron increases [9]. Therefore, as the increase in iron concentration continues, the entire leaf appears purple-brown, as well as dryness in the leaves, as the plant appears burned. Soils that have a low pH, or are Low iron levels are not usually associated with iron poisoning [10]. These conditions likely lead to iron deficiency rather than iron toxicity in plants [11]. Waterlogging may increase Fe2+ in the soil, thus leading to iron toxicity in dry crops such as wheat [12]. There are reports of varying degrees of reduced wheat productivity [13]. This is due to iron toxicity that occurs worldwide [14]. There are predictions in future climate conditions that extreme weather events will become more common [15]. Heavy rains in major areas of West Africa are expected to grow by 10-25% [16], and the risk of iron toxicity resulting from waterlogging in such areas will increase significantly [17]. If floods occur in acidic soil environments in wheat growing areas, wheat will be at risk of iron toxicity [18]. It is possible for iron toxicity to occur in different types of soil, that is, those that contain a high pH, or high levels of high organic matter, or high levels of available iron [15].

Iron toxicity occurs in acidic ultisols and oxisols, as well as in acidic sulphurous soils saturated with reducible iron [19]. In 1955, [4] iron toxicity was detected in many countries including India, Indonesia, Thailand, Malaysia, Sri Lanka, Vietnam, Brazil and other countries. The nutritional disorder known as akajari rice is due to iron toxicity [20]. Likewise, the eating disorder known as Akyouchi in Korea [21] is associated with iron toxicity. These conditions lead to an increase in the concentration of free iron ions, which can bind to

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cellular components [22]. This leads to disruption of cellular function and thus to plant stress. This problem is common in many parts of the world, as it affects agricultural crops such as rice, soybeans, wheat, and corn, as well as vegetables. Areas with high iron toxicity in plants are Southeast Asia, Brazil, Africa, Australia, and the United States [20]. United Iron toxicity can occur in both soil and hydroponic systems, and is particularly common in calcareous soils, which have high pH levels [23]. Plants adopt different strategies to reduce the uptake of free iron into the cell from reaction with O2 [24]. Iron toxicity can result from environmental disasters promoted by human activities associated with iron processing as excess iron is an environmental proble [25].

Standard iron in growth media

The level of iron concentration in the culture solution that causes poisoning ranges from 10 mg Fe L1 to 500 mg Fe L1 or may be higher [15]. This poisoning occurs due to differences in the shape and origin of iron, cultivar allowancer, nutrient concentration, temperature, and solar radiation. [16] Bremen and Moorman [9] pointed out that the Fe(II) of ferric hydroxides is insoluble, and the actual concentration of Fe(II) may be less than the stated percentage. Iron source such as iron chelates [Fe(III) EDTA]. Which works to preserve the iron in the solution against the radical action of iron precipitation by affecting possible changes in pH and oxidation and reduction [20]. Symptoms of iron toxicity may be caused by decreased concentrations compared to non-chelated iron sources (ferrous sulfate and ferrous bicarbonate). One problem that may occur in pot experiments on flooded soil is that the iron (Il) concentration may not be uniformly covered. The concentration of iron (II) is low in the upper surface, as most of the roots are generally concentrated in narrow vessels.[9] When using the same soil, the toxicity of iron in rice species will decrease, that is, it will be less in warm pots compared to field conditions. [16] The increase in the proportion of iron (II) in the soil components, which causes symptoms of iron poisoning in rice, will vary depending on the pH of the soil solution.

The effect of iron deficiency on plant growth and development

Iron toxicity in plants is related to the regulation of iron absorption and transport [24]. Iron is absorbed into plants by specific transporters, and these transporters are regulated by the concentration of iron in the soil [25]. This negatively affects plants because it affects their growth and development and can lead to the cessation of plant growth [26]. This, in turn, will lead to a reduction in the absorption of water and elements and a decrease in photosynthesis activity [27].This may also lead to a decrease in chlorophyll content, and this will negatively affect the plant’s ability to complete the photosynthesis process, leading to decreased growth and thus reducing the productivity rate [28]. In severe cases, holes may occur in the leaves, leading to the death of the plant [25]. Yellowing of the leaves is a common symptom of iron toxicity. In addition, iron toxicity can cause seed drop [29].

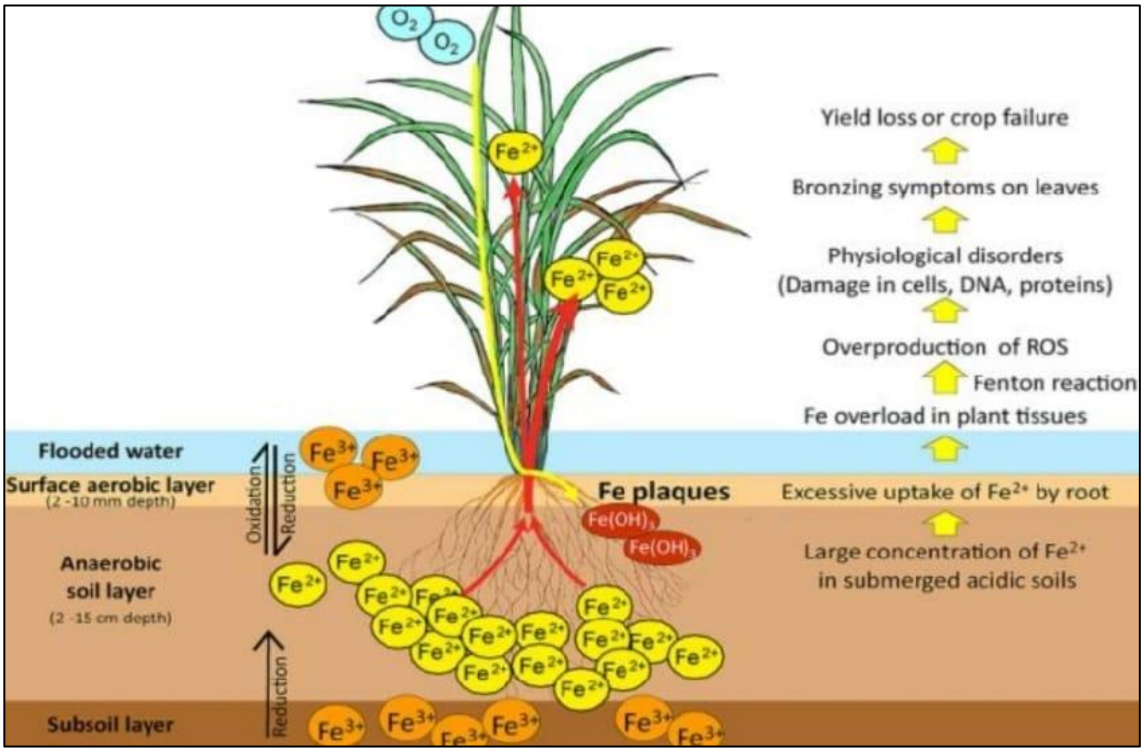

Figure 1: Reducing the concentration of iron in flooded soil. The pH in this type of soil is low. In this type of soil with anaerobic conditions and low PH, the ferric ion (Fe3+) is reduced to more soluble ferrous ion (Fe2+)

SOIL Depletion AND IRON TOXICITY

The soil in which rice is grown can undergo a variety of (reduction +oxidation) processes [30]. Soil subsidence is a process in flooded soils that has a significant impact on the toxicity of iron in marshes rice [31]. Soil subsidence mass iron (II) in the soil solution [32]. The increase in the percentage of iron (ll) is negligible in non-reducing soils [30]. Some reduction products, such as melted sulphides, increase the capability of rice plants to iron toxicity [33]. When the concentration of reduced organic matter productivity increases with iron toxicity, an interaction occurs between the organic matter and the element Iron, and this in turn affects the growth of rice plant roots[34].One of the effects of floods is that the soil decreases and the production of iron (II) occurs on a large scale.[35] Together, these factors work to reduce soil stress, which affects the occurrence of iron toxicity through its effect on soil mobility[30].

Mechanism for alleviating iron toxicity

When the concentration of iron in the soil solution increases, the stage of iron toxicity begins due to the plant's inability to tolerate this percentage and its inability to absorb the iron present in the soil solution and thus its inability to transfer it to the roots [36]. The iron that plants absorb is in the form of Fe2+ (ferrous iron) [67]. As for Fe3+ (ferric iron), it is the most common form of iron in soil types that are aerobic, but this form of iron cannot be easily absorbed by plant roots because it works to form deposits that are insoluble [38]. As for soils that are anaerobic, Fe2+ It is more widespread because it is formed through the reduction of Fe3+ by microorganisms, and thus this type of iron can be absorbed easily through the roots of plants [34]. Plants have mechanisms through which they are able to absorb iron, and among those mechanisms that enable iron to be absorbed are transport proteins [39]. Responsible for transporting Fe2 through the plasma membrane located in root cells [32]. Plants secrete compounds called siderophores, which in turn bind to Fe3+ and help dissolve it, thus absorbing iron through the plant roots [40]. When iron enters the plant, it is used in many processes, including the formation of chlorophyll, which is used for photosynthesis, as well as the production of enzymes that are used in respiration and nitrogen fixation [37]. Excess iron ions cause damage to the root cells and the plasma membrane, which leads to damage to the root cells through stress [41]. Oxidative stress and increased production of reactive oxygen species (ROS) [42]. Reactive oxygen species cause damage to cellular components, such as lipids, proteins, and nucleic acids, and this leads to the death of root cells [22].

Increasing the percentage of iron also affects the absorption of other essential elements, such as phosphorus and zinc, through their competition with transporters that facilitate their absorption through the roots [29]. This intervention can lead to an imbalance of nutrients, as well as a decrease in plant growth, and thus overall plant health [18]. Recent studies have shown that iron overload can lead to changes in the expression of genes involved in iron absorption and transport [31]. These changes in gene expression lead to an increase in physiological and biochemical changes that are associated with iron toxicity [39].

STRATEGIES FOR MITIGATING IRON TOXICITY

Mechanism for alleviating iron toxicity. Iron toxicity in plants is a major problem, especially in areas where iron levels are high in the soil [41]. To reduce this problem, the soil can be mitigated, thus lowering the soil pH and reducing iron absorption [21]. Raising the soil pH by reducing the concentration of free hydrogen ions, it binds iron ions to negative sites in the soil, and this reduces free iron and thus reduces its bioavailability to plants [39]. One of the methods used to reduce iron toxicity is to choose types of plants that tolerate an increase in the percentage of iron [37]. Some types of plants are It has the ability to withstand iron toxicity and can be used in areas where iron levels are high in the soil [29]. Chelation can also be used to reduce the toxicity of excess iron [40]. Chelation is the process that binds metal ions to chelating agents, an example of which are organic molecules[19].Which are called chelators or chelating agents [22]. The complex formed between the chelate and the metal ion is called the chelator [42]. In biological systems, chelation is involved in the transport and storage of metal ions, such as iron, copper and zinc, which are essential for the proper functioning of enzymes and other proteins that require these metals to act as cofactors [40]. In addition, it is possible to use chelation to remove excess metal ions [23].

CONCLUSION

Increased iron concentration is a extensive problem that seriously affects the growth and development of plants in soil that contains a high percentage of iron. This condition reduces the productivity of plants and increases their susceptibility to diseases. Many studies have shown the harmful effects of iron toxicity, especially on the photosynthesis process. And the antioxidant defense systems that contain chlorophyll, and the absorption of nutrients as well as balance in plants. To reduce or mitigate iron toxicity, work has been done to reduce this toxicity by modifying soil conditions by adjusting the pH as well as adding organic matter, such as natural fertilizer to Soil. The process of adding organic matter and adjusting pH depends on the bioavailability of iron to the conditions as well as the biogeochemical compounds present in the soil. Several factors, such as soil composition, iron forms, and nutrient interactions, must be considered when implementing pH adjustments or incorporating these organic materials to control Iron toxicity. One of the important factors is testing the soil and evaluating its specific conditions, which is important to work on determining appropriate remedial measures to mitigate iron toxicity. There are other ways to reduce iron toxicity, which is to use iron-tolerant plant species, which have developed mechanisms to tolerate these high levels. Of iron in its environment. These methods include the process of removing heavy metals, preventing them from being saturated with water, and also using effective types of iron. In addition to these factors, it is possible to conduct more research to find the best ways to reduce iron toxicity in plants and to devise new and more effective methods to reduce high iron concentrations and eliminate the negative effects resulting from high iron concentrations.

REFERENCES

1. Marschner, H. (Ed.). (2011). *Marschner's mineral nutrition of higher plants*. Academic press.
2. Woolhouse, H. W. (1983). Toxicity and tolerance in the responses of plants to metals. In *Physiological plant ecology III: Responses to the chemical and biological environment* (pp. 245-300). Berlin, Heidelberg: Springer Berlin Heidelberg.
3. Kumar, V., Sinha, A. K., Makkar, H. P., & Becker, K. (2010). Dietary roles of phytate and phytase in human nutrition: A review. *Food chemistry*, *120*(4), 945-959.
4. Zou, N., Li, B., Dong, G., Kronzucker, H. J., & Shi, W. (2012). Ammonium-induced loss of root gravitropism is related to auxin distribution and TRH1 function, and is uncoupled from the inhibition of root elongation in Arabidopsis. *Journal of experimental botany*, *63*(10), 3777-3788.
5. Chen, S. X., & Schopfer, P. (1999). Hydroxyl-radical production in physiological reactions: a novel function of peroxidase. *European journal of biochemistry*, *260*(3), 726-735.
6. Alloway, B. J. (2008). Zinc in soils and crop nutrition.
7. Gogorcena, Y., Gordon, A. J., Escuredo, P. R., Minchin, F. R., Witty, J. F., Moran, J. F., & Becana, M. (1997). N2 fixation, carbon metabolism, and oxidative damage in nodules of dark-stressed common bean plants. *Plant Physiology*, *113*(4), 1193-1201.
8. Morrissey, J., & Guerinot, M. L. (2009). Iron uptake and transport in plants: the good, the bad, and the ionome. *Chemical reviews*, *109*(10), 4553-4567.
9. Gogorcena, Y., Gordon, A. J., Escuredo, P. R., Minchin, F. R., Witty, J. F., Moran, J. F., & Becana, M. (1997). N2 fixation, carbon metabolism, and oxidative damage in nodules of dark-stressed common bean plants. *Plant Physiology*, *113*(4), 1193-1201.
10. Aung, M. S., & Masuda, H. (2020). How does rice defend against excess iron?: Physiological and molecular mechanisms. *Frontiers in Plant Science*, *11*, 1102.
11. Wheeler, B. D., & Giller, K. E. (1984). The use of dialysis cells for investigating pore water composition in wetland substrata, with particular reference to dissolved iron and sulphide. *Communications in soil science and plant analysis*, *15*(6), 707-716.
12. Sultana, B., & Anwar, F. (2008). Flavonols (kaempeferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants. *Food chemistry*, *108*(3), 879-884.
13. Lozano, L. C., & Dussán, J. (2013). Metal tolerance and larvicidal activity of Lysinibacillus sphaericus. *World Journal of Microbiology and Biotechnology*, *29*, 1383-1389.
14. Conte, S. S., & Walker, E. L. (2011). Transporters contributing to iron trafficking in plants. *Molecular Plant*, *4*(3), 464-476.
15. Wiseman, H., & Halliwell, B. (1996). Damage to DNA by reactive oxygen and nitrogen species: role in inflammatory disease and progression to cancer. *Biochemical Journal*, *313*(Pt 1), 17.
16. Li, B., Sun, L., Huang, J., Göschl, C., Shi, W., Chory, J., & Busch, W. (2019). GSNOR provides plant tolerance to iron toxicity via preventing iron-dependent nitrosative and oxidative cytotoxicity. *Nature communications*, *10*(1), 3896.
17. Bode, K., Döring, O., Lüthje, S., Neue, H. U., & Böttger, M. (1995). The role of active oxygen in iron tolerance of rice (Oryza sauva L.). *Protoplasma*, *184*, 249-255.
18. Suppan, S. (2017). Applying Nanotechnology to Fertilizer.
19. Athukorala, A. S. N. (2021). Solubilization of micronutrients using indigenous microorganisms. *Microbial technology for sustainable environment*, 365-417.
20. Mirlahiji, S. G., & Eisazadeh, K. (2014). Bioremediation of Uranium via Geobacter spp. *Journal of Research and Development*, *1*(12), 52-58.
21. Xu, D., Xu, J., He, Y., & Huang, P. M. (2009). Effect of iron plaque formation on phosphorus accumulation and availability in the rhizosphere of wetland plants. *Water, Air, and Soil Pollution*, *200*, 79-87.
22. Xu, S., Lin, D., Sun, H., Yang, X., & Zhang, X. (2015). Excess iron alters the fatty acid composition of chloroplast membrane and decreases the photosynthesis rate: a study in hydroponic pea seedlings. *Acta Physiologiae Plantarum*, *37*, 1-9.
23. Keshavarzi, M. H. B., Nooralvandi, T., & Omidnia, P. (2014). Consideration of allelopathic effects of Artemisia annua L. on morphological characteristics of Lactura sativa L.
24. de Araújo, T. O., de Freitas-Silva, L., Santana, B. V. N., Kuki, K. N., Pereira, E. G., Azevedo, A. A., & da Silva, L. C. (2015). Morphoanatomical responses induced by excess iron in roots of two tolerant grass species. *Environmental Science and Pollution Research*, *22*, 2187-2195.
25. Asch, F., Dingkuhn, M., Dörffling, K., & Miezan, K. (2000). Leaf K/Na ratio predicts salinity induced yield loss in irrigated rice. *Euphytica*, *113*, 109-118.
26. Audebert, A., & Sahrawat, K. L. (2000). Mechanisms for iron toxicity tolerance in lowland

rice. *Journal of Plant Nutrition*, *23*(11-12), 1877-1885.
27. Chérif, M., Audebert, A., Fofana, M., & Zouzou, M. (2009). Evaluation of iron toxicity on lowland irrigated rice in West Africa.
28. Couée, I., Sulmon, C., Gouesbet, G., & El Amrani, A. (2006). Involvement of soluble sugars in reactive oxygen species balance and responses to oxidative stress in plants. *Journal of experimental botany*, *57*(3), 449-459.
29. Alscher, R. G., Erturk, N., & Heath, L. S. (2002). Role of superoxide dismutases (SODs) in controlling oxidative stress in plants. *Journal of experimental botany*, *53*(372), 1331-1341.
30. Audebert, A., & Sahrawat, K. L. (2000). Mechanisms for iron toxicity tolerance in lowland rice. *Journal of Plant Nutrition*, *23*(11-12), 1877-1885.
31. AZAMBUJA, I. H. V. (2004). Aspectos socioeconômicos da produção do arroz. *Arroz irrigado*.
32. Dufey, I., Hakizimana, P., Draye, X., Lutts, S., & Bertin, P. (2009). QTL mapping for biomass and physiological parameters linked to resistance mechanisms to ferrous iron toxicity in rice. *Euphytica*, *167*, 143-160.
33. Becker, M., & Asch, F. (2005). Iron toxicity in rice—conditions and management concepts. *Journal of Plant Nutrition and Soil Science*, *168*(4), 558-573.
34. Ishimaru, Y., Suzuki, M., Tsukamoto, T., Suzuki, K., Nakazono, M., Kobayashi, T., ... & Nishizawa, N. K. (2006). Rice plants take up iron as an Fe3+-phytosiderophore and as Fe2+. *The Plant Journal*, *45*(3), 335-346.
35. Cakmak, I. (2008). Enrichment of cereal grains with zinc: agronomic or genetic biofortification?. *Plant and soil*, *302*, 1-17.
36. Durrett, T. P., Gassmann, W., & Rogers, E. E. (2007). The FRD3-mediated efflux of citrate into the root vasculature is necessary for efficient iron translocation. *Plant physiology*, *144*(1), 197-205.
37. Nikolic, M., & Römheld, V. (2002). Does high bicarbonate supply to roots change availability of iron in the leaf apoplast?. *Plant and Soil*, *241*, 67-74.
38. Hermans, C., Chen, J., Coppens, F., Inzé, D., & Verbruggen, N. (2011). Low magnesium status in plants enhances tolerance to cadmium exposure. *New phytologist*, *192*(2), 428-436.
39. Xiong, Y., Contento, A. L., Nguyen, P. Q., & Bassham, D. C. (2007). Degradation of oxidized proteins by autophagy during oxidative stress in Arabidopsis. *Plant physiology*, *143*(1), 291-299.
40. Pereira, E. G., Oliva, M. A., Rosado-Souza, L., Mendes, G. C., Colares, D. S., Stopato, C. H., & Almeida, A. M. (2013). Iron excess affects rice photosynthesis through stomatal and non-stomatal limitations. *Plant Science*, *201*, 81-92.
41. Frei, M., Tanaka, J. P., & Wissuwa, M. (2008). Genotypic variation in tolerance to elevated ozone in rice: dissection of distinct genetic factors linked to tolerance mechanisms. *Journal of experimental botany*, *59*(13), 3741-3752.
42. Cakmak, I. (2008). Enrichment of cereal grains with zinc: agronomic or genetic biofortification?. *Plant and soil*, *302*, 1-17.

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