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Etiology and Mitigation of Iron Deficiency in Indian Agricultural Crops

*Sunil
Department of Biochemistry, CCSHAU, Hisar-125004, Haryana, India
*Corresponding Author's email: suniltaak23@gmail.com

The majority of Indian soils have enough micronutrients overall, but many of them lack the concentrations needed for crop growth. Iron is an essential micronutrient that limits plant growth. It is the fourth most abundant element in the geosphere. The frequent changes in its form (Fe^{2+}, Fe^{3+}), particularly in rice-wheat cropping sequences, significantly reduce its availability to plants. Iron can be found in soil in a variety of forms, including the pool of iron that is immediately available, the pool of iron that is made available through decomposition, and potential medium to long-term sources of available iron. The availability of iron in soil is influenced by several elements, such as organic matter, texture, $CaCO_3$ content, and the amount of iron in solid form that is equal to that in the soil solution. The soils of Karnataka and Himachal Pradesh were found to have the greatest levels of iron deficiency. The soils of numerous Indian states contain large levels of iron. The concentration of total iron in Indian soils is high, ranging from 0.36 to 174 mg kg^{-1}. Based on the critical limitations noted in different Indian states, the level of micronutrient deficiency was assessed in various soils between 2011 & 2017. An average of 12.8% of soils had shortages in iron, according to an analysis of over 2.0 lakh soil samples conducted between 2011 and 2017. While states like Uttar Pradesh, Telangana, Andhra Pradesh, Bihar, Goa, and Tamil Nadu had deficiencies in 10 to 20% of soils, states like Rajasthan (34.4%), Gujarat (25.9%), Haryana (21.7%), and Maharashtra (23.1%) had Fe deficiencies in more than 20% of soils. According to Shukla et al. (2014), the amount of extractable Fe in the soils of the various states of the India ranges from 0.01 to 1461.70 g kg^{-1}. Although, the analysis results of 97,464 georeferenced soil samples showed that overall, Fe deficiency in India stayed close to 13%, its deficiency is rapidly increasing in some states, such as Gujarat (23.9%), Haryana (21.6%), Maharashtra (21.5%), Telangana (17.0%), and Andhra Pradesh (16.8%).

Factor of Iron Deficiency in Plants

Several circumstances, such as inadequate soil iron, elevated soil pH, and excessive soil moisture, can result in iron shortage in plants. It is essential to comprehend these in order to prevent iron shortage and sustain good plant growth.

1) Soil effect iron deficiency

The absence of iron in the soil is one of the primary causes of iron insufficiency in plants. For plants, iron is a micronutrient that is necessary for several physiological functions. Plants find it difficult to absorb enough iron when soil iron levels are low, which results in signs of a deficiency. Although very few soils have a total iron deficiency, many of them have low levels of accessible iron. It has been estimated that the accessible iron in Madhya Pradesh's shallow black soils ranges from 0.6 to 27.5 parts per million. Some areas of Uttar Pradesh have soils classified as inadequate because their accessible Fe content is less than 2 parts per million. High pH and high $CaCO_3$ in the majority of soils in Fe-deficient areas are the main causes of the decrease in Fe availability in most soils. Dark brown, clayey, and extremely calcareous soils with a thick B horizon are found in several areas of the Coimbatore district where Fe deficiency is currently prevalent. The primary issue with these clay soils is inadequate drainage, and $CaCO_3$ nodules are clearly visible across the soil profile. Several areas of Maharashtra have low levels of accessible iron, according to a recent survey, and iron deficits are particularly apparent in intensive and irrigated agriculture.

2) Availability of other nutrients

The most researched interaction is the one between Mn and Fe. In general, Fe uptake is greatly decreased when Mn toxicity is present. This is explained by the antagonistic relationship between Mn^{2+} and Fe^{2+} for the same absorption sites in plant roots. However, there may be instances where Mn^{2+} has a synergistic effect on Fe^{2+} uptake. Different genotypes of the same plant species can frequently have distinct effects, either antagonistic or synergistic. In addition to Mn, it has been discovered that the following nutrients affect the availability and absorption of Fe: Ca, Cu, Mg, Zn, P etc.

3) High Soil pH Levels

Iron deficiency in plants can also be caused by high soil pH levels. The pH of the soil has a significant impact on iron availability, with acidic soils often having higher iron availability. Iron tends to become less soluble and less accessible for plant absorption when the pH of the soil is too high. Even if iron is present in the soil, this can lead to plants not getting enough of it.

4) Low Organic Matter

Low-organic soils may have trouble sustaining sufficient iron levels. Iron is chelated (bound) by organic matter, increasing its availability for plant absorption. Iron may remain in forms that are difficult for plants to reach if there is not enough organic matter present.

5) Excessive Soil Moisture

Another element that might cause iron shortage in plants is excessive soil moisture. Excessive water saturation of the soil produces oxygen-deficient conditions that prevent plant roots from absorbing iron. This can happen when plants are overwatered or in soils that don't drain well. Even if the soil has a sufficient amount of iron, signs of an iron deficiency may arise from inadequate iron uptake brought on by high soil moisture. A lack of iron in plants can negatively impact their development and general health. It is essential to comprehend the symptoms of iron deficiency in order to recognize it early and effectively.

6) Plant factor effect iron deficiency

Fe is a micronutrient that plants need in trace amounts. However, plant species vary greatly within this narrow range of requirements. Certain crop species, or even cultivars within the same species, may not develop Fe chlorosis because they have a lower need than others. Plant species also vary in how well they absorb or use iron, as well as in how much of it they need at different phases of growth. Early in their growth, certain plants, such as sorghum, may have a shortage in iron; however, this may go away as the adventitious roots expand and establish. Under dry nursery conditions, rice exhibits deficiencies but the chlorosis disappears after transplantation. Maharashtra also produces two more significant crops: soybeans (Slycine max L.) and safflower (Carthamus tinctorius L.). In India, safflower is an oilseed crop that is produced on 5.9 lakh hectares and yields 1.3 lakh tonnes of seeds. Maharashtra (64%), Karnataka (26%), and Andhra Pradesh (8%), together, account for about 98% of the safflower area. In accordance with protocol, four significant safflower cultivars were exposed to Fe-deficiency stress in solution culture. Nevertheless, it was discovered that all of the cultivars A-l, S-4, 628, and Tara were extremely vulnerable to Fe-deficiency stress. Translocation to the stem and leaves was significantly less than the amount taken by the roots, according to studies on Fe uptake.

Correction of Iron Deficiency in Plants

The goal of any treatment for iron insufficiency should be to provide iron in a form that plants can absorb and use. Several methods can be used to treat and prevent iron deficiency in plants. These consist of enhancing soil drainage, adding iron fertilizers, and modifying the pH of the soil.

1) Soil pH Adjustment

Iron availability can be increased by reducing the pH of the soil if a high pH is causing iron insufficiency. Iron can be made more soluble and available to plant roots by lowering the pH of alkaline soils with the addition of organic matter or acidifying chemicals.

2) Iron Fertilizer Application

Applying Fe salts as aqueous sprays to the soil or foliage is the most straightforward and popular technique. In sugarcane, foliar treatment of iron works well. In the dry nurseries, rice seedlings IR-8, Sona, and Jaya displayed significant chlorosis, which may be remedied by applying $FeSO_4$ to the soil. Chelates, which are substances that increase iron availability to plants, can be used as iron fertilizers. For rapid absorption, these fertilizers can be sprayed foliarly onto the leaves or administered straight to the soil.

3) Soil Drainage Improvement

Preventing iron insufficiency brought on by excessive soil moisture requires improving soil drainage. Waterlogged situations can be avoided and a more conducive root environment can be created by ensuring enough drainage through the installation of drainage systems, the use of raised beds, or the addition of organic matter.

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