Iron Deficiency Chlorosis (IDC) in high pH soils: A guide for the high plains and beyond

Executive summary

- IDC is a complex issue influenced by various factors, including soil pH, carbonate content, crop type, and management practices.
- Successful IDC management requires combining strategies including variety selection, soil amendments, and the use of specialized iron products.
- Growers can reduce the impact of IDC and produce healthy crops even in high pH soils by understanding the causes and using appropriate strategies.

Iron Deficiency Chlorosis

Iron Deficiency Chlorosis (IDC) is a common nutritional disorder that comes from a plant's inability to absorb iron from the soil. It's characterized by chlorosis, which is the yellowing of leaves between the veins, while the veins still remain green. [1]

IDC is challenging for growing crops in high pH soils, particularly in the high plains region, with related issues also affecting areas of Montana, Minnesota, and California. [2]

The reason it's difficult is because these regions typically have calcareous soils with high pH, which restricts the availability of iron. Iron is of course needed for many plant processes, including chlorophyll synthesis, photosynthesis, and respiration. When a plant is deficient in iron, it limits plant growth and productivity.

Understanding the science behind IDC, the factors contributing to it, and management strategies available can help growers reduce its impact on crop quality and yield.

Science of IDC

Iron availability in soil is heavily influenced by pH. In high pH soils (typically above 7.0), iron is present in insoluble forms unavailable for plant uptake. High carbonate levels, common in these soils, make the problem worse by tying up iron and impacting solubility. [3]

Crops obtain iron through their roots using various methods, including the release of chelating agents and reducing ferric iron into the more soluble ferrous form. However, these methods are usually less effective in high pH environments.

---

[1] Managing iron deficiency chlorosis in soybean, https://extension.umn.edu/crop-specific-needs/managing-iron-deficiency-chlorosis-soybean

[2] Soil pH and organic matter, https://apps.msuextension.org/publications/pub.html?sku=4449-8#

[3] Iron deficiency chlorosis, https://soybeanresearchinfo.com/soybean-disease/iron-deficiency-chlorosis/

Understanding the biochemical processes involved in iron uptake and utilization is helpful when developing strategies for dealing with this issue.

Factors contributing to IDC in high pH soils

Many factors contribute to the development of IDC in high pH soils:

Soil pH: Higher pH leads to lower iron solubility. The pH scale ranges from 0 to 14, with 7 being neutral. Values below 7 are acidic, and values above 7 are basic. In high pH soils (typically above 7.0, and often above 7.5 or even 8.0 in IDC-prone areas), iron exists mostly in forms that are insoluble and unavailable for plant uptake. Specifically, at high pH, iron is often present as iron oxides and hydroxides, which plants struggle to absorb. The higher the pH, the lower the iron solubility and the greater the risk of IDC.

Soil texture and structure: Soil texture refers to the proportion of sand, silt, and clay particles in the soil. Soil structure describes how these particles aggregate to form larger units. Heavy clay soils, due to their small particle size and tight packing, often have poor aeration. This contributes to:

- **Reduced root growth:** Plant roots require oxygen for respiration and growth. Waterlogged or poorly aerated soils restrict root growth, limiting the plant's ability to obtain iron.
- **Impaired iron uptake:** The biochemical processes involved in iron uptake by roots can be negatively affected by low oxygen levels.
- **Increased carbon dioxide levels:** Poor aeration can lead to a buildup of carbon dioxide in the soil, which can reduce iron availability.

Carbonate content: High carbonate levels also reduce the availability of iron. Carbonate ions react with iron, forming insoluble iron carbonates plants can’t absorb. Basically, carbonates tie up the iron, preventing it from being taken up by plant roots. The higher the carbonate content, the worse the iron availability problem. Plants prefer the reduced form of iron (Fe II), and they have adapted to extract iron from the soil. Type I plants (like soybeans) excrete acids and chemical reductants from their roots. These acids make the $Fe(OH)_3$ more soluble. The reductants change insoluble Fe(III) to more soluble Fe(II). Type II plants (like corn and grasses) excrete iron chelators that bind Fe(III) , so the iron can be absorbed by the root.

Moisture and temperature: Waterlogged soils and low temperatures can impact root activity and iron uptake. Waterlogged soils can create oxygen-deficient conditions that impede root function and iron uptake. Fluctuating soil moisture can also stress plants and make them more susceptible to IDC. Low soil temperatures can slow root growth and reduce the activity of enzymes involved in iron uptake. This happens often in early spring when soil is still cool, even if air temperatures are warming up.

Crop susceptibility: Different crops have varying degrees of tolerance to IDC. Soybeans are more susceptible to IDC, while corn, and other grasses are more tolerant. Even within soybeans, there are varieties with varying levels of IDC tolerance. Choosing a resistant variety is helpful in managing IDC.

Nutrient interactions: Imbalances in other nutrients, like phosphorus and zinc, can also influence iron availability. For instance, high phosphorus levels can interfere with iron uptake, even if iron is present in the right amount. Banding phosphorus fertilizer near the seed row, instead of broadcasting it, can help. While less common than phosphorus interactions, high zinc levels can also sometimes make IDC worse.

It's not usually a single factor that causes IDC – it's a combination working together. As a result, a comprehensive approach is usually needed to successfully manage IDC.

IDC management strategies

To manage IDC, growers need to address the specific soil conditions and crop needs.

1. Soil amendments:

Iron chelates

Chelates are synthetic organic compounds that bind to iron, making it more available to plants and protecting it from reactions that would make it insoluble. The choice of chelate depends on the severity of IDC, soil pH, cost considerations, and the crop being grown. Chelates can be applied in many ways, including soil application, foliar sprays, or through fertigation. The most effective method depends on the specific chelate, soil conditions, and crop.

Inorganic iron sources

Ferrous sulfate is a common inorganic iron source, but its effectiveness in high pH soils is limited because it quickly oxidizes and forms insoluble iron compounds. It can be a more economical option for mild IDC or as a supplemental iron source, but it's not a standalone solution.

Organic matter

Organic matter improves soil structure, water-holding capacity, and overall soil health. However, its direct impact on iron availability in high pH soils is limited. While organic matter can contribute to a healthier soil environment that supports root growth and nutrient uptake, it alone doesn’t solve the IDC issue.

Acidifying amendments

Materials like elemental sulfur can be used to lower soil pH over time. This is a slow process, and the effects can be unpredictable. It requires careful monitoring and management to avoid over-acidification, which can create other problems. Acidifying amendments are generally not a practical solution for large-scale crop production, but they might be considered for smaller areas or in long-term soil management plans.

2. Crop management practices:

Variety selection

Choosing IDC-tolerant or resistant varieties is an important step in managing IDC. Different crop varieties have different predispositions to IDC, so growers can talk to local representatives to identify varieties that work well in specific soil conditions.

Planting practices
If possible, early planting can give crops a head start, allowing the plants to establish a strong root system before IDC symptoms become severe. Using recommended plant spacing and seeding rates can promote root development and reduce competition for nutrients, including iron.

Irrigation
Too much water can lead to waterlogged soils, which reduce oxygen availability and worsen IDC. Drainage is needed for soil aeration, which can happen through adding organic matter or installing a drainage system.

Fertilizer
High phosphorus levels can interfere with iron uptake. Banding phosphorus fertilizer near the seed row, instead of broadcasting it, can improve phosphorus availability. Overall, any nutrient deficiencies or imbalances can worsen IDC. Regular soil testing is always helpful for monitoring nutrient levels.

A comprehensive approach to IDC
When making a strategy, regular soil testing helps monitor pH, carbonate levels, and the availability of nutrients. Local agents and crop advisors can give recommendations based on specific regional conditions.

The most useful IDC management strategy is usually combining soil amendments with the appropriate crop management practices. Consider:

Chelates + tolerant variety + irrigation management: Using EDDHA chelates in conjunction with planting an IDC-tolerant variety and managing irrigation can reduce IDC symptoms and improve yields.

Soil testing + balanced fertilization: Regular soil testing to monitor pH and nutrient levels, combined with a fertilization program, can help prevent nutrient imbalances that contribute to IDC.

Organic matter + crop rotation: Building soil organic matter through practices like cover cropping and crop rotation can improve soil health and resilience, making plants less susceptible to IDC.

In conclusion, IDC management is an ongoing process, not a one-time fix. By understanding what contributes to IDC and using a comprehensive management strategy, growers can reduce the impact of IDC and produce healthy crops, even in high pH soil.