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Spotting and Preventing Iron Deficiency Chlorosis in Soybeans

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KEY POINTS

- Iron deficiency chlorosis (IDC) is a challenge for soybean farmers in several regions of North America, particularly in poorly drained calcareous soils in Minnesota, the Dakotas, Nebraska, and Iowa.
- Soil properties can influence the severity of IDC in a field, including carbonate levels, salts, and drainage.
- Environmental conditions such as soil moisture, temperature, and compaction can also influence IDC, resulting in variability of symptoms from year to year.
- Selecting soybean varieties with good iron chlorosis tolerance is the most important management strategy.
- Corteva Agriscience soybean breeders are continually implementing new methods for understanding and evaluating soybean response to IDC.

Figure 1. Interveinal chlorosis pattern characteristic of iron chlorosis of soybeans.

IRON DEFICIENCY CHLOROSIS IN SOYBEANS

Soybean iron deficiency chlorosis (IDC) is a nutrient deficiency with general symptoms of chlorosis (yellowing) of the soybean foliage and stunting of the plant. IDC most frequently develops in high pH soils and soils containing soluble salts, where chemical conditions reduce the availability of iron. This condition can limit soybean yields in the northern and western Corn Belt including western Minnesota, the Dakotas, Nebraska, Iowa and other states.

Iron Deficiency Symptoms

You can typically spot soybeans affected by IDC by leaves that turn yellow while the veins of the leaves stay green (known as interveinal chlorosis). Iron is an important constituent of enzymes essential for producing chlorophyll. An iron deficiency will limit chlorophyll production, resulting in yellowing of plant tissue. If conditions are severe, the entire leaf may turn yellow and the leaf margins may turn brown, a condition known as necrosis.

Symptoms will not be visible until soybeans begin to develop trifoliate leaves. Cotyledons and unifoliate leaves do not exhibit IDC symptomology. Symptoms may increase or decrease in intensity during the season depending on growing conditions. Iron is not mobile within the plant, so symptoms will appear on the youngest leaves first. Iron chlorosis in a soybean field typically appears in spots, often with no apparent pattern, due to differences in chemical and physical properties of the soil.

3 FACTORS CONTRIBUTING TO IDC

Soils typically have abundant levels of iron, so IDC is not caused by a lack of iron but rather by conditions that limit the availability of iron for plant uptake. The factors that may cause chlorosis are complex and interact with each other to intensify the level of chlorosis. The most dominant factors affecting IDC occurrence are carbonate levels, salts, and depressional field areas with poor drainage. IDC severity can vary from year to year within the same field depending on the environmental conditions of the growing season.

1. Soil Properties

Soybean IDC frequently occurs in calcareous (lime-containing) soils. These soils are often referred to as alkaline soils and have high pH values (>7.5). At high soil pH, iron is less soluble, making it less available for uptake by plant roots.

However, chlorosis of soybeans does not occur on all high-pH soils. The pH of surface soils in areas where IDC symptoms occur and areas where they do not are often the same but there can be differences in both chemical and physical properties of subsoil. The subsoil in a chlorotic soybean area is generally poorly drained, higher in pH, contains soluble salts and excess lime (carbonates), and may have a higher concentration of sodium.

2. Weather Conditions

The interaction of weather conditions with soil properties causes differences in IDC severity from year to year and field to field.

Growing seasons with excess rainfall and cool soils typically result in higher incidence of IDC. Soils with high calcium carbonate levels near the soil surface can often have significant symptoms of IDC. Biological activity in the soil converts calcium carbonate into carbon dioxide and bicarbonate (HCO_3^-). Wet conditions limit air exchange between the soil and the atmosphere, causing bicarbonate ions to accumulate in the water in the topsoil. Bicarbonate interferes with both uptake of iron and mobility of iron within the plant.

Continual rainfall and saturated soils also reduce oxygen in the root zone. Oxygen is need for plant uptake of iron. Soil compaction along with excess rainfall can be contributing factors in the reduction of iron uptake. Cool springs with lower soil temperatures reduce microbial activity within the soil. The reduction of microbial activity leads to less iron uptake and increased severity of IDC.

3. Nitrate Levels

Higher nitrate levels in the soil are also a contributing factor to IDC, according to field and greenhouse studies by University of Minnesota researchers (Kaiser et al., 2011). Differences in IDC driven by soil nitrate levels are commonly seen when wheel tracks through a chlorotic area of the field remain green (Figure 2). The soil under the wheels is slightly more compacted, creating a lower oxygen environment which increases denitrification. The compacted soils under the wheels are not excessively compacted, just enough to account for differences in nitrate in the soil.

The fact that lower oxygen levels in the soil can both reduce IDC severity due to a reduction in nitrates in the soil and increase IDC severity in saturated soils by limiting iron uptake exemplifies the complexity of factors and interactions that contribute to IDC occurrence.

Figure 2. A field with reduced IDC symptoms in areas where soil was compacted by wheel traffic.

HOW TO ASSESS SOIL FOR IDC RISK

The table below was developed by AGVISE Laboratories, a soil testing firm with labs in Minnesota and North Dakota where IDC is often a perennial issue (Table 1). The index is a tool to help producers differentially target certain fields or parts of fields for IDC management strategies. Soil sample fields for carbonates and soluble salts to help make these decisions.

- Fields with a low level of carbonate and low level of salts have a low risk of developing IDC symptoms.
- Fields that test high in carbonates (CCE, calcium carbonate equivalent) and high in soluble salts have a higher risk of developing IDC symptoms and may be severe.
- All soils that have a pH > 7.3 should be tested for CCE and salts to determine actual level in the soil. Two different soils with the same pH of 7.5 may have different CCE values and therefore different risk of IDC.

Table 1. Soybean IDC severity risk (AGVISE Laboratories).

Calcium Carbonate Equivalent	Soluble Salts Electrical Conductivity (EC) mmhos/cm (1:1)			
	< 0.25	0.26 - 0.5	0.51 - 1	> 1
< 2.5%	Low	Low	Moderate	Very High
2.6 - 5%	Low	Moderate	High	Very High
> 5%	Moderate	High	Very High	Extreme

Risk	Management Considerations
Low	IDC not likely to be in this portion of field based on low EC and salt levels.
Moderate	IDC may develop in some areas of this field in wet, cool conditions based on EC and salt levels. Plant an IDC-tolerant variety.
High	IDC is likely to develop in some areas of the field under wet, cool conditions based on EC and salt levels. Plant an IDC-tolerant variety.
Very High	IDC may be severe in this field under wet, cool conditions based on EC and salt levels. Planting an IDC tolerant variety is strongly advised.
Extreme	IDC may be severe in this field under wet, cool conditions based on EC and salt levels. Potential for substantial reductions in yield. Soybeans are not recommended for this field.

6 MANAGEMENT OPTIONS FOR GROWING SOYBEANS IN AREAS WITH IRON CHLOROSIS

A survey of soybean producers in areas affected by soybean IDC found that selection of IDC-tolerant soybean varieties was the most common management tactic (employed by 70% or respondents), followed by planting practices (42%), field drainage (33%), tillage (16%), fertility practices (11%), and herbicide selection (6%) (Hansen et al., 2003).

1. Select a Tolerant Variety

Soybean varieties vary widely in their tolerance to IDC, making variety selection the most important step in managing this problem. Corteva Agriscience has a significant research effort to characterize soybean germplasm for IDC tolerance and select for tolerant varieties. The use of genetic prediction models and multi-year field testing allows for a high degree of confidence in the IDC ratings assigned to Pioneer® brand soybean varieties. Varieties are rated on a 1 to 9 scale where 1 indicates poor tolerance and 9 indicates excellent tolerance. If growers are planting into an area with a history of IDC, they should select varieties with an IDC score of 6, 7 or 8.

Additionally, Pioneer agronomists routinely establish observation plots of soybean varieties in soils prone to IDC. Symptoms are assessed throughout the growing season to help further understand variety tolerance to IDC and optimize IDC management at the local level.

Figure 3. Pioneer soybean variety trial showing differences in IDC symptoms between a more susceptible variety (left) and a more tolerant variety (right).

2. Increase Seeding Density

University and Pioneer research studies have shown that higher seeding rates can reduce iron chlorosis symptoms and increase yield in areas of fields with a history of iron chlorosis (Goos and Johnson, 2001; Naeve, 2006). Soybean roots excrete acids as they are growing that increase the availability of iron. Higher plant density increases the amount of this acid in the root zone.

In a Pioneer study in Minnesota in a field with high soluble salt levels, chlorosis effects were more severe when plant density was low (seeding rate < 140,000 seeds/acre). Soybeans yielded from 10-15 bu/acre more at 200,000 vs. 100,000 seeds/acre. Growers should seed soybeans at densities of 200,000 seeds/acre or above for maximum protection against iron chlorosis.

Variable rate seeding allows farmers to increase seeding density in areas of the field with a history of iron chlorosis and reduce in areas that are not prone to iron chlorosis. Reducing seeding rate in areas of the field that do not exhibit iron chlorosis can help reduce pressure from white mold.

3. Improve Soil Drainage

Soils with poor drainage often have higher accumulations of soluble salts and carbonates that reduce the solubility of iron in the soil. Wet soils also lead to lower oxygen levels in the soil and reduced root growth and health. The reduction in root health and the lower solubility of iron in wet soils are major contributors to IDC symptoms. Practices that improve soil structure and water infiltration can reduce issues with IDC. Field tile drainage is also important to consider where applicable to help with soil moisture levels.

Figure 4. Soybeans showing differences in IDC symptoms at different plant densities. Soybeans on the left were planted at 200,000 seeds/acre and those on the right were planted at 140,000 seeds/acre.

4. Consider Your Herbicide Selection

Foliar and soil applied herbicides may increase plant stress which can accentuate symptomology of IDC. Research has shown increased potential for greater yield loss when applying some post-emergence herbicides to soybeans under chlorotic stress. Reduce stress from herbicides by following manufacturer recommendations for weather and application conditions.

5. Use a Companion Crop

In fields with high levels of nitrates, a companion crop of oats may reduce iron chlorosis symptomology. This companion crop needs to be terminated by the time it is 10 to 12 inches tall.

6. Iron Chelate

Pioneer Agronomists have studied the use of an iron chelate (Fe-EDDHA chelate) fertilizer to help reduce IDC symptoms and increase yields. Iron chelate products have been evaluated as seed treatments, foliar treatments, and in-furrow treatments. Benefits of seed-applied and foliar-applied treatments have been inconsistent. Research by both University and Pioneer agronomists has shown a more consistent yield response to in-furrow applications of iron chelate.

Soygreen® is a commonly used in-furrow iron chelate fertilizer that entered the market in 2006. New formulations have been added since then including a liquid formulation that is less likely to be leached out of the root zone following rainfall.

A Pioneer Agronomy study conducted in 2012 across 11 locations in Nebraska and Kansas with a history of IDC found an average yield response of 2.3 bu/acre with a 3 lbs/acre in-furrow application of Soygreen (Mueller, 2012) (Figure 5). Yield differences were minimal at some locations; however, visual differences were noted, as the varieties treated with an in-furrow application of Soygreen were greener and more robust. A similar study conducted in 2008-2009 found an average yield advantage of 3.9 bu/acre with Soygreen.

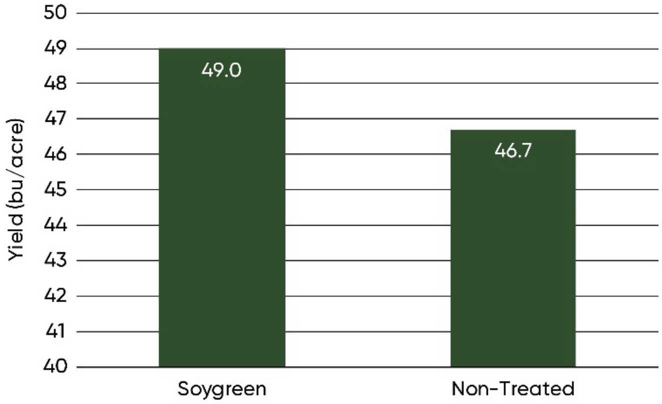

Figure 5. Average soybean yield with and without Soygreen® in-furrow treatment across 11 locations with a history of IDC.

CORTEVA AGRISCIENCE IDC CHARACTERIZATION STRATEGY

Soybean breeders at Corteva Agriscience characterize genetic tolerance of soybean varieties to IDC in multiple ways through the course of the product development pipeline.

Genetic Prediction Models

Genetic prediction models give soybean breeders the ability to predict the probable IDC tolerance of a soybean line and leverage that information in variety selection prior to any in-field testing. Observations captured from multiple soybean lines over multiple years and locations, coupled with molecular marker and genotypic data, are used to create these models. Soybean lines predicted to have high levels of IDC tolerance can be selected and advanced into field screening trials for further characterization.

Figure 6. Corteva Agriscience single-row observation plots showing varietal differences in tolerance to IDC.

Field Screening

Field assessment of soybean varieties for IDC tolerance is crucial for refining tolerance ratings for soybean lines as well as improving genetic prediction models. IDC tolerance is assessed in field screening nurseries beginning at the R2 pipeline stage, approximately 3 years before commercial release. Characterization continues through R3 and R4 precommercial stages, providing three years of IDC tolerance data across multiple environments for a soybean variety when the decision is made whether to commercialize it. The combination of genetic prediction models with multi-year, multi-location field screening provides a high level of confidence in the IDC trait scores assigned to Pioneer® soybean varieties.

Field trials for tolerance are conducted at managed screening nurseries located from the Red River Valley of Northwest Minnesota through Central Minnesota and North Central Iowa to Eastern Nebraska. Multiple replications of each genotype are planted in fields identified as having uniform characteristics conducive for IDC manifestation and a history of IDC sensitive observations. Each plot is scored on a scale of 1 through 9, with 1 being the most sensitive to IDC and 9 being the most tolerant. Field screening nurseries often include thousands of plots (Figure 7).

Figure 7. Aerial view of a Corteva Agriscience soybean IDC field screening nursery.

Advancements in Phenotyping and Characterization

Historically, IDC tolerance scores have been determined based on a researcher's visual assessment of a plot at approximately the V3-V5 growth stage. While this has been a successful approach for characterizing and driving IDC improvement for decades, there are inherent limitations and inefficiencies associated with visual phenotyping. Over the last few years, scientists at Corteva Agriscience have deployed new methods using unmanned aerial systems (UAS) to capture IDC data from screening nurseries. This technological advancement has enabled improvements in the quality and consistency of data captured from field screening nurseries and has greatly increased the efficiency and scale of data collection (Figure 8).

Corteva Agriscience researchers continue to explore further enhancements to IDC characterization efforts. An emerging advancement enabled by UAS technology is the capturing of time-series data from field screening nurseries. Assessing IDC symptoms at multiple timings allows soybean breeders to observe how different lines respond for several weeks beyond the initial appearance of IDC symptoms. Two lines with the same traditional IDC tolerance value may respond and recover differently over time; understanding these differences provides an opportunity for additional differentiation in IDC tolerance.

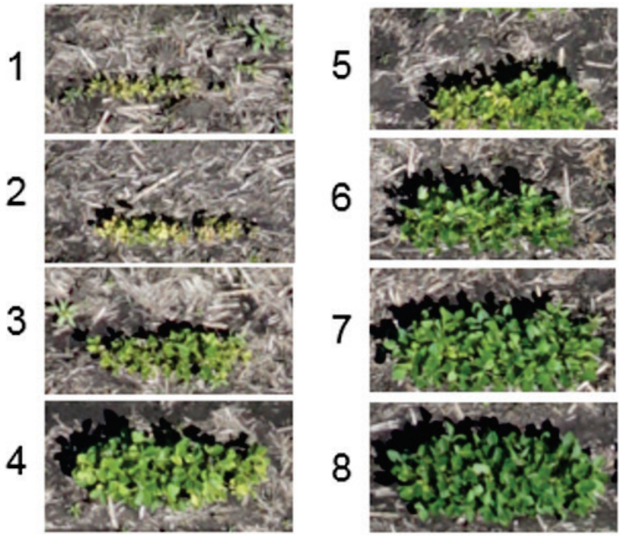

Figure 8. UAS imagery showing differences in IDC tolerance among soybean varieties in a Corteva Agriscience field screening nursery.

SUMMARY

Iron deficiency chlorosis is caused by complex interactions of soil properties and the environment. Understanding the history of fields with iron chlorosis and applying management techniques including variety selection and higher seeding densities, and incorporating the use of in-furrow chelated iron can help reduce the impact from IDC. Corteva Agriscience will continue to lead the way in development and characterization of varieties with greater tolerance to iron chlorosis and other traits.

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