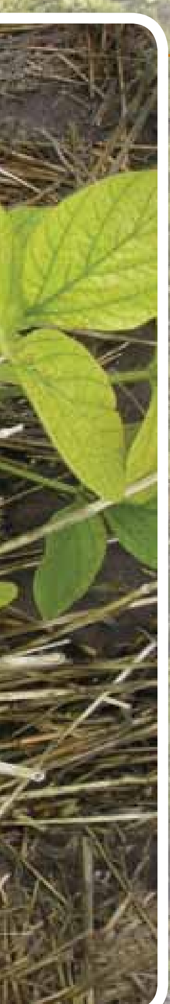
Iron deficiency chlorosis in soybeans

Iron deficiency chlorosis in soybeans is caused by the inability of the plant to utilize iron in the soil. Without enough iron, chlorophyll production is hampered and the plant will suffer and possibly die, with obvious effects on crop yield. This article discusses some of the causes of iron deficiency chlorosis as well as management strategies and recommendations.



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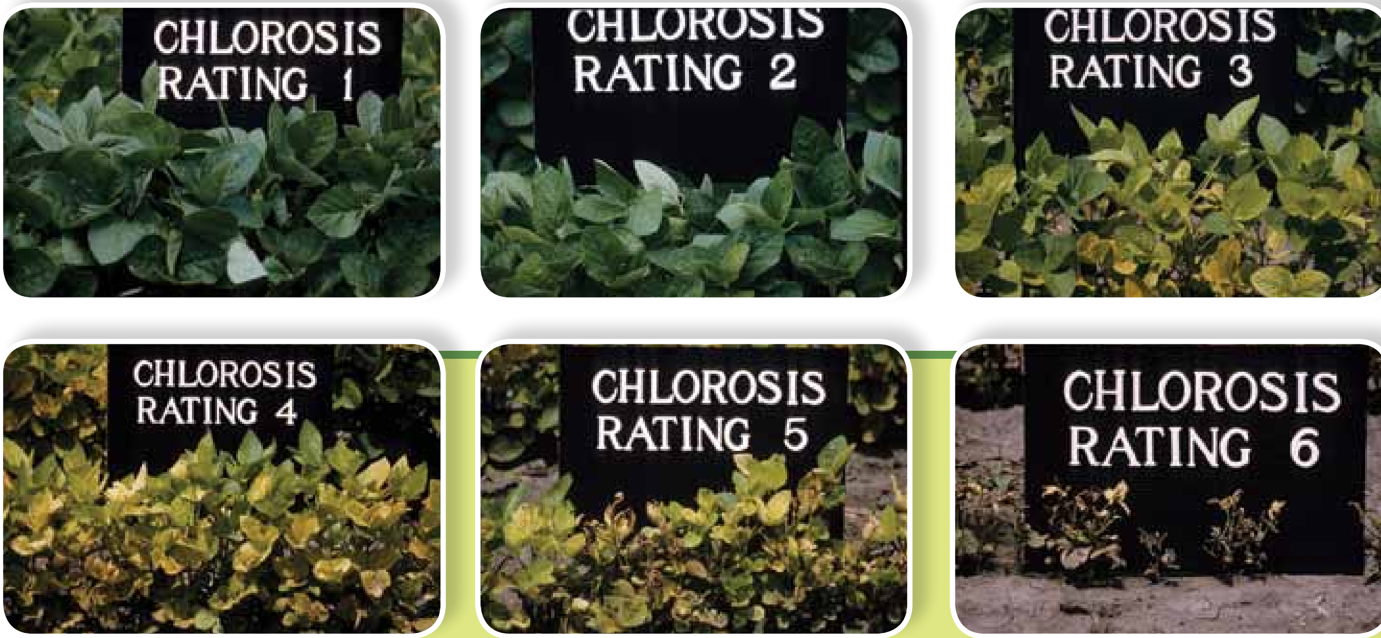
The problem of iron deficiency in crops seems pretty straight forward: there is an absence of enough iron to grow a healthy plant. But it isn't that simple. In the case of iron deficiency chlorosis, or IDC, it's not the availability of iron but the ability for the plant to take up that iron that's the problem, according to Dan Kaiser, an extension nutrient management specialist at the University of Minnesota, who recently presented a webinar on the topic for the Plant Management Network.

"One of the things to note with IDC in soybeans is that it is *not* caused by iron deficiency in the soil," Kaiser said. "This is different from other deficiencies like phosphorus or potassium. With iron, there is plenty in the soil. Iron deficiency chlorosis is caused by the inability of the plant to utilize the iron that's in the soil."

To understand IDC better, it is helpful to look at the role of iron in plant development. First of all, iron is a micronutrient, and thus while it is essential, uptake is relatively smaller than its macronutrient cousins, which plants require in relatively higher concentrations. Yet, without enough iron, chlorophyll production is hampered and the plant will suffer and possibly die, with obvious effects on crop yield.

IDC symptoms are known to be interveinal in their presentation, and so the yellowing occurs between the veins of the leaves, while the veins themselves remain green. The extent of the problem varies depending on the field and the year; plants can even tolerate some degree of yellow-

Background photo courtesy of Jay Goos, North Dakota State University. Inset photo courtesy of IPNI/A. Bianchini photographer.



ing, but if symptoms persist, losses can result.

"In general, when we look at specific areas within a field, small pockets to maybe larger areas of the field will be affected in some areas of the state while whole fields may be affected in others. It really depends on where you are at and what types of soils are present in fields," Kaiser noted.

Thankfully, research has revealed some answers as to what accounts for this variability, and Kaiser and his colleagues who work on IDC throughout the Midwest offer several solutions for counteracting the problem.

Uncovering the causes of IDC

In his research, Kaiser has examined the prairie pothole region of Minnesota. These areas are dotted with small pockets that can remain wet for long periods of time. The reason why IDC occurs more commonly in these areas goes back to how the soils were formed.

"What can happen in these areas is some differentiation between where IDC will and will not occur. In general, this is related to water movement within the soil and also the climatic conditions of where those soils are in relation to how the soils were formed," Kaiser explained.

Picture a pothole area in a field. Water moves to these areas carrying solutes that collect over time. As water sits in the pothole basin, the edges of these areas may remain dry. As water evaporates from the soil, surface solutes can travel with the water out of the pothole area and collect on the rims. This is why the rims of the pothole areas can have more severe IDC present as solutes have collected over time.

"When we look at areas specifically in fields, we look at zones that are high in pH. These are typically zones that have pH levels of 7.4 or higher," Kaiser said. "When we talk about soils of the western Corn Belt and the Great Plains, we have high amounts of pedogenic carbonates, or carbonates that were deposited in the parent material of the soil itself."

While all of this is important, the climate where the soils formed probably has had the bigger impact on where IDC occurs. "In cases where we see many of our IDC-affected soils, the level of evapotranspiration exceeds the amount of water that is leached through the soil," Kaiser explained. "This prevents solutes from leaching, keeping salts or carbonates in the upper surface of the soil. In many cases when you dig into the soil, a carbonate layer can be seen at a shallow depth of many soils where IDC is present."

Chemistry of nutrient uptake in soybeans

In order to understand the proposed management techniques for IDC, it is important to consider three aspects of nutrient uptake in soybeans: bicarbonates in the soil and their relationship to plants, the important distinction of how Strategy 1 plants take up iron, and, finally, the relationship between nitrogen and IDC.

"What it boils down to when we look at this problem is an increase

Left: Chlorosis progression photos show a 1 to 6 rating scale developed by Richard Wiese and Ed Penas in Nebraska. The scale relates linearly to yield with 1 being about 10 to 15% yield and 6 being near 95–100%. Photo courtesy of Gary W. Hergert, University of Nebraska. **Right:** The green wheel tracks in a chlorotic area of a soybean field. Photo by George Rehm.

in concentration of bicarbonates within the soil," Kaiser said. "Typically soils are tested in this region for calcium carbonate equivalent, but this does not necessarily equate back to the bicarbonate content in the soil. In addition, many growers will get a soil test back for soluble salts, which is a measure of the electrical conductivity of the soil. While many field areas with IDC may exhibit high salt contents, soybeans themselves are not sensitive to many of the salt concentrations that we typically see in many soils. Therefore, it is not clear whether salts are a cause of the problem or are more of an indicator of where saturated soil conditions may persist in a field. In the case of a direct soil test for IDC, it isn't really a viable option at this point since there is not a single factor that causes the problem. So we have to look at other factors within the field or look at other environmental factors to gain a better understanding when IDC may be more severe on a year-to-year basis."

Kaiser notes that this means looking at other related factors such as soil moisture and soil temperature in order to make conclusions about whether an area is high in bicarbonates. And when it comes to IDC, bicarbonates are the key, particularly with regard to Strategy 1 plants such as soybeans.

"Strategy 1 plants such as soybean, blueberries, and azaleas must convert iron into an available form in order to allow for uptake. This is accomplished via the release of acids, which make the iron soluble, as well as reductants, or electrons, which reduce the iron present into a form that the plant can use. Strategy 1 plants can significantly differ in what types of pH they adequately grow in. Soybeans can grow in soils with pH levels near neutral or slightly alkaline better than a plant such as blueberries, which survive in very acid soils. When it comes to iron, most soils contain iron oxide or hydroxides. The problem is that in soils with adequate aeration, the form that iron will be in is Fe^{3+}, which is not soluble and the plant cannot take it up. Strategy 1 plants rely on the release of acids and reductants to increase the availability and solubility of Fe in the soil. This is what happens when Fe^{3+} is converted to Fe^{2+}."

So the crux of the IDC problem is truly due to an overabundance of bicarbonate in the soil and not a dearth of iron, and research shows that this most commonly occurs in soils that are saturated or where a lot of carbonates reside thanks to the soil's parent material or a lack of aeration that will trap carbon dioxide in the soil profile. This is important because bicarbonate levels in the soil are proportional to the amount of carbon dioxide. Carbon dioxide is produced through microbial respiration.

One interesting phenomenon related to IDC is the mysterious green wheel tracks (see above). What is found in early spring are green diagonal lines extending though chlorotic areas that exist where the wheels drove during the final tillage pass before planting. Researchers wondered for years what might be causing these tracks.

To understand what was happening, they took both plant and soil samples and examined levels of nitrates, salts and carbonates, potassium, and phosphorus. The only noticeable issue was that the areas within the wheel tracks had lower soil nitrate than the areas outside of them. Several theories have been offered, and there remains some debate regarding the issue, Kaiser acknowledged. But one theory has emerged that the compaction due to the tractor traffic could be causing

Left: Rhizobia, a type of root-colonizing bacteria that supply nitrogen to legumes, reside in protective nodules formed by the plant. The bright red color of the opened nodule is an indication of healthy rhizobia inside. Photo courtesy of pennstatelive's photostream (see www.flickr.com/photos/pennstatelive).

denitrification, which would then lower the nitrate that would be available for uptake by the plant.

"While we know that soybeans with the rhizobium bacteria will produce their own nitrogen, if there is nitrate within the soil, typically soybeans will take that nitrate up and will do that before they actively start colonizing with rhizobium and producing their own nitrogen," Kaiser said. "Plants want to remain neutral. So if they take in an anion, which would include nitrate, they need to let an anion out of the root. They need to exchange one for the other. One of the thoughts about why IDC might worsen because of nitrate is that as [the plants] start to take in nitrate, they'll let out bicarbonate, and over time, we'll see an increase in bicarbonate around the roots due to that nitrate uptake. So, in effect, soybeans can be making things worse for themselves around the roots where maintaining an adequate supply of iron is critical."

The issue gets even more complicated when researchers turn their attention to leaves. Knowing that the plant has to convert nitrate to ammonium, they looked at this conversion in plants with high nitrate levels in their leaves.

"One of the things that is suggested by soil chemists during this conversion is that we see acids and reductants that are needed to convert Fe^{3+} to Fe^{2+} being used to convert nitrate over to ammonia, which the plant can use. What can happen is that iron can accumulate in the leaves and not be utilized. This is the reason that when sampling upper trifoliate leaves from soybeans with IDC, you can see very high levels of iron—the plant has taken it up but cannot utilize it," Kaiser explained.

Management strategy recommendations

Despite the myriad of problems for soybean plants leading to IDC, many management strategies exist. The number one solution for IDC is to first seek out a proven IDC-resistant seed variety and to do your homework when deciding which one is best because, experts warn, not all IDC-resistant varieties are created equal.

"Number one on the list has always been: planting a tolerant variety. When we look at our current recommendations, it still is what we recommend producers to do in case all else fails," Kaiser stressed.

Next on this list—due to the nitrogen/IDC relationship—is simply to strive to minimize nitrate carryover from year to year. Yet, these may not be enough, and other treatments may need to be considered as well.

Because of the nature of IDC, a logical concept might be to counteract the problem by managing the soil itself. But Kaiser explained that while oftentimes nutrient deficiencies can be thwarted via a broadcast fertilizer, it simply won't work in this instance.

"Sometimes we get questions on managing the soil itself and on changing the soil's chemical properties. And in terms of the feasibility, we know that it isn't cost effective to try to change—especially to lower soil pH—because a lot of these soils typically are buffered to a point where you can't really effectively lower the pH enough to be able to lessen the problem. So we start looking at it in terms of managing with some sort of iron fertilizer to try to deal with the problem. Can we use an iron broadcast fertilizer? We know that it isn't really feasible because, again, we know the problem is caused by an inability of the plant

Right: Foliar sprays are a traditional approach to dealing with iron deficiencies and can be successful; however, it is not easy to predict where a positive response may occur, and multiple applications may be needed to correct the problem. A better approach might be to apply iron chelates with the planter, according to Daniel Kaiser. Photo courtesy of the United Soybean Board.

to take up iron and not the fact that there is no iron in the soil."

Kaiser said that foliar sprays, a traditional approach, can be successful, but it is not easy to predict where a positive response may occur, and multiple applications may be needed to correct the problem.

"Most of the past research has shown that we typically need to know where the problem will occur and apply a foliar before the problem occurs to be successful with a foliar. A better approach would be to apply iron chelates with the planter. One approach we have had success with is an application of a 6% EDDHA iron chelate directly on the seed at planting. Unlike other liquid fertilizer sources, the application of EDDHA Fe products alone have not been found in our research to reduce seedling emergence."

Traditionally, the ortho-para form was most commonly used and is seen to be relatively ineffective compared with the ortho-ortho form, which is found in high concentrations for the 6% EDDHA chelates. While there are multiple sources for the EDDHA chelates, it is important to note that the amount in the ortho-ortho form can vary by supplier. This may affect the rate applied, but Kaiser normally suggests applying 1 to 3 lb of these products per acre depending on the potential severity of IDC in an area of the field.

"The biggest difference we see between the ortho-ortho versus the ortho-para is when we start looking at the linkages, especially around the iron molecule itself, is that it's a more complete linkage around the molecule," Kaiser said. "So what this does effectively is it protects the iron longer; it keeps it in a more available, highly soluble form longer than the older ortho-para form. A lot of the older research was done with the ortho-para, but the ortho-ortho form has been around a number of years as well. The ortho-ortho chelate form was simply too expensive to manufacture to be used in soybean production until recently when new manufacturing processes were developed."

Kaiser stresses that the use of the ortho-ortho form, particularly in the heavily chlorotic fields, has been very useful and really rather noteworthy. "The ortho-ortho form has been found to provide more available iron. And this has been one of the biggest success stories in terms of managing IDC with these particular products."

Other management options include planting a cover crop such as oats, which will assist in lowering nitrates and, potentially, for decreasing soil moisture. But the oats will need to be killed at a very specific time (no taller than 10 inches), which can be challenging in the case of wet years. If left for too long, the companion crop may decrease yields. Increasing seeding rates has also been explored but is least understood, and so it barely makes the list of recommendations at this point.

And so while the story of IDC is one wrought with varied causes related to plant–soil interactions that can vary from year to year, field to field, and even within a single field, many strategies exist that are supported by research and which offer effective management.

This article was developed from a webcast produced by the Plant Management Network (PMN). PMN provides content for researchers, crop management professionals, consultants, growers, educators, and students to make better plant management decisions and recommendations. For more information, visit www.plantmanagementnetwork.org.