IRON DEFICIENCY CHLOROSIS

Introduction

The element iron (Fe) is required to form chlorophyll, the green pigment in plants. When iron uptake from the soil is limiting to plants, plants become iron-deficient. The most common symptom is interveinal chlorosis in newly developed leaves, where the leaf tissue turns yellow while the veins remain green. This deficiency, termed iron deficiency chlorosis or IDC, can cause moderate to severe yield reductions in soybeans (NCSRP–SRII; Pioneer, 2009).

IDC occurs to some extent in soybeans that are grown on the high-pH soils in the Black Belt region of east Mississippi (MSU Info. Sheet 873, 2011).

IDC is not caused by iron deficiency in the soil, but rather by the plant's inability to extract it from the soil. Soybean plants obtain iron from the soil by releasing acids that solubilize the iron in soil to a form that is readily taken up by the roots. In high pH soils with high levels of bicarbonates and soluble salts, this process can be limited by the chemical reactions between these materials and the iron (NCSRP–SRII). In other words, iron becomes less soluble at higher soil pH, especially when the soil contains large amounts of calcium carbonate.

Soil pH is not a good indicator of where IDC will occur and does not correlate well with IDC. However, there is a direct correlation between IDC and high concentrations of calcium carbonate and soluble salts in soil. Thus it is important to determine the levels of these materials in soil on sites planned for soybean production (Asgrow, 2013; Pioneer, 2009), and take remedial action if those levels suggest the potential occurrence of IDC.

An excellent source of issues related to and remedies for soybean production on sites that have known IDC-inducing conditions can be viewed on the PMN webcast presented by Dr. Daniel Kaiser.

In the March-April 2012 issue of Crops & Soils Magazine, Mr. John Morgan developed an article from Dr. Kaiser's PMN webcast that includes a pictorial presentation of IDC ratings of soybeans. Dr. Kaiser also discusses in great detail the soil chemistry aspects associated with and that contribute to IDC. From that article, the following points are pertinent.

- The problem of IDC is an absence of enough iron to grow a healthy plant.
- IDC is not caused by an iron deficiency in the soil.
- In many cases, digging into the soil will reveal a carbonate layer at a shallow depth in many soils where IDC is present.
- The crux of the IDC problem is due to an overabundance of bicarbonate in the soil and not a dearth of iron. This can be exacerbated by wet soils with limited air exchange, decaying organic matter that adds to the amount of carbon dioxide in the soil, and high levels of soil nitrate.

Management Strategies

The best strategy for managing IDC is to select a soybean variety with tolerance (Helm et al., Agronomy Journal, Vol. 102, 2010; Asgrow, 2013; NDSU, 2012; NCSRP–SRII). Ratings for some varieties that are grown in Mississippi appear at the end of this article. **Ratings of private varieties against IDC made**

by the originating company are likely the best source for selecting varieties with IDC tolerance (e.g. Asgrow, Pioneer); however rating for IDC is not available for all varieties.

Iron chelate fertilizer placed close to the seed at planting can be effective for getting iron into the plant, but its cost should be considered (see below research results). Results from research or recommendations for applying iron chelate to the seed are mixed (Liesch et al., "Agronomy Journal", Vol. 103, 2011; NCSRP–SRII). Applying iron as a foliar fertilizer is unpredictable in its effect or will not correct the problem (Liesch et al., "Agronomy Journal", Vol. 103, 2011; NDSU, 2012; NCSRP–SRII).

Wiersma, in an article published in "Crop Science" (Vol. 52, 2012), presents evidence that iron-efficient and iron-inefficient soybean varieties have seed iron contents that are distinctly different from each other, and the maximum iron contents in seed of each of the variety classes are seldom exceeded. Thus, soybean plants tend to maintain iron in the seed within genetically controlled limits.

Furthermore, he concludes that:

- Seed iron content is useful for identifying soybean genotypes that have resistance to iron deficiency
- Using iron content of soybean seed is equivalent or superior to using visual chlorosis score as an indicator of resistance to iron deficiency
- Conventional plant breeding can be used to increase seed iron content in order to improve resistance to iron deficiency
- Iron content of soybean seed that are to be planted can be used to successfully predict IDC
- It should be possible to measure iron content in seed from a chlorosis nursery and relate this trait to genotypic resistance to iron deficiency. Soybean breeders should explore this methodology to ascertain its usefulness as a selection criterion for developing varieties with resistance to IDC.

A summary of results from two recent studies provide additional insight into mitigation of IDC.

Results from a 2010-2012 study (Vol. 106, Issue 4, Agronomy Journal) that was conducted in the Blackbelt region of Alabama shed new light on how IDC can be managed in affected fields in the southeastern US. The study was conducted on high-pH soils at two sites–one a Sumter soil series with an average pH of 8.2, and the other a Leeper soil series with an average pH of 7.9. Treatments were various iron chelate materials applied either in-furrow at planting, as a foliar spray at the V3 growth stage, or a combination of both. Major findings are:

- Visual chlorosis scores (VCS–range of 1 = no chlorosis to 10 = necrotic and stunted or dead plants) ranged from 3.8 to 6.6 at the higher pH site, and 2.8 to 4.6 at the lower pH site.
- VCS ratings were not lowered enough by any treatment to reduce chlorosis level to that of a non-chlorotic plant.
- Fe-EDDHA (6% iron) applied at 4 lb/acre

either in-furrow at planting or as a split application between in-furrow and a foliar spray at V3 was effective in improving yield when a variety with moderate sensitivity to IDC was used. Average yield increase for the best treatment was 3.25 bu/acre above the average 16.7 bu/acre yield for the untreated control.

- Soybean prices used in this study were \$11.17, \$11.99, and \$14.71 per bushel in 2010, 2011, and 2012, respectively. Fe-EDDHA price was \$6.82/lb, or \$27.28 for the 4 lb/acre rate. Thus, returns were increased by about \$9 to \$20.50/acre across the 3 years using the 3.25 bu/acre best yield increase measured in this study.

- Using the yield increase of 3.25 bu/acre and the Fe-EDDHA cost of \$27.28/acre for the 4 lb/acre rate used in this study, soybean price will have to be above about \$8.40/bu for this to be a profitable treatment to alleviate IDC in soybeans.

- The magnitude of the yield effect measured in this study should be determined in a higher yielding environment than used in this study, where yields were in the 16.5 to 20 bu/acre range. In other words, will the yield effect be greater as yields increase, or will it remain the same regardless of the yield level?

- The findings from this study should be confirmed on several varieties that are known to be IDC-sensitive, and/or that are known to have varying degrees of IDC sensitivity among them. This can be done on a known IDC site with varieties that have a confirmed history of IDC sensitivity.

In the realm of agricultural research, affirmation of prior results and statements is a valuable tool in the quest to provide accurate information about pertinent subjects to producers.

Such is the case with the second article entitled "Comparison of Field Management Strategies for Preventing Iron Deficiency Chlorosis in Soybean" that was published in the September 2014 (Vol. 106, Issue 6) issue of Agronomy Journal and authored by Kaiser, Lamb, Bloom, and Hernandez. The study was conducted from 2010 to 2012 in Minnesota. A summary of their findings and conclusions follow.

- Fe-EDDHA (6% iron) applied in-furrow at 3 lb/acre was effective in improving yield when an IDC-susceptible soybean variety was grown on sites that promoted moderate to severe IDC.

- An IDC-tolerant soybean variety without IDC management produced yields similar to those of the susceptible variety that received the in-furrow Fe treatment when both were grown on sites that promoted IDC.

- Yields of the IDC-sensitive variety that received the Fe treatment were no better than those of the tolerant variety with or without the Fe treatment.

- On sites that promoted severe IDC, yields of both the IDC-susceptible and tolerant varieties with no IDC management were reduced, but the yield from the susceptible variety was 39% less than that from the tolerant variety.

- At the time of this research, the Fe-EDDHA cost for the rate used was \$8/lb or \$24/acre. Thus, a yield increase of about 2.5 bu/acre would cover its cost when soybean commodity price is $10/bu.

- Since the susceptible variety with IDC management did not result in greater yield than the tolerant variety when both were grown under moderate to severe IDC conditions, growing an IDC-tolerant soybean variety is the best management strategy on sites that promote IDC.

- These results indicate that in-furrow application of Fe-EDDHA is a relatively cheap solution to mitigate the effects of moderate to severe IDC in susceptible soybean varieties.

There are two reports that provide impetus for investigating the use of cover crops to aid in IDC mitigation.

The first is Managing Iron Deficiency Chlorosis in Soybean by Kaiser, Lamb, and Bloom, which reports results from studies in Minnesota. Points from that article follow.

- Using a companion crop such as oat that is planted at or before soybean planting can use excess soil nitrate and also dry a wet soil to reduce bicarbonate buildup.

- Oat must be killed at the proper growth height to realize this benefit. This ensures that oat did in fact reduce the level of soil nitrate.

The second is Growing Productivity with Innovative Research from Pioneer. Data from a one-year study on a high pH site in the Black Belt region of Alabama provided the following results.

- Using a wheat cover crop increased yield of all soybean varieties in the test, but the increase from the IDC-sensitive variety was by far the greatest.

- Yields of all varieties in the test were similar when a cover crop was used.

- The findings suggest that using a wheat cover crop before soybean planting can reduce the severity of IDC on high pH soils. This may be tied to the reduction of soil nitrate as mentioned above.

Assessment of Results

The conclusions that can be inferred from these studies follows.

- Fe-EDDHA applied in-furrow at planting can improve yield when IDC-sensitive soybean varieties are grown on soils that promote moderate to severe IDC, and this yield increase likely will be profitable.

- The best strategy for managing IDC is to select a soybean variety with tolerance.

- The problem with the second conclusion is this: there is no information about IDC tolerance in many currently used varieties.

- The use of cover crops to mitigate problems on IDC-inducing soils planted to soybean should be further investigated on those sites.

- Fields that promote IDC in soybeans should be well-drained, and depressional areas in those fields should be remedied by minimum to moderate land-forming.

This, then, leads to the conclusion that variety trials in states that have soils that promote IDC in soybeans should have a variety trial on a site with a known history of soybeans with IDC. This trial could be a limited version of the larger variety trials that are conducted throughout the state; i.e., a trial on such a site should at least contain the known top yielders among the larger group of variety trial entries to determine their susceptibility/tolerance to IDC.

An experiment of the above type could also incorporate a cover crop variable to determine the repeatability of results from the studies cited above.

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In 2012, Charlie Stokes and David Roberts rated several soybean varieties grown in East Mississippi for IDC tolerance. Their data appear in the following table.

Iron Deficiency Chlorosis Ratings–East Miss.–2012			
	County & growth stage at rating time		
Variety	**Lowndes–R1**	**Monroe–V4**	**Prentiss–V2**
Hornbeck 5525	1	2	2
Progeny 5610	2	3	2
Progeny 5711	4	4	2
Northrup King 57-K3	3	3.5	2
Northrup King 56-G6	2	3	3
Northrup King 54-V4	2	---	---
Asgrow 5532	2	2	---
Asgrow 5632	---	3.5	4
Asgrow 5831	2	2	2
Asgrow 5332	2	3	4
Asgrow 5633	2	---	---
Terral 51R53	--	2	---
Terral 56R63	--	2	---
Tolerance ratings: 1 = excellent; 2 = above average; 3 = average; 4 = below average; 5 = poor.			

In 2014, Dr. Trent Irby, Mr. Charlie Stokes, and Dr. Dennis Reginelli rated soybean varieties in Monroe and Lowndes Counties for IDC tolerance. Their ratings appear in the below table.

2014 MSU-ES Soybean Variety Screening for Tolerance to Iron Chlorosis

		Monroe County, Planting Date: 5/21				Lowndes County, Planting Date: 7/7			
		Rating date				Rating date			
Brand	**Variety**	**7/8**	**7/14**	**7/24**	**Avg.**	**7/24**	**8/5**	**9/16**	**Avg.**
Asgrow	AG4934	1.0	4.0	3.0	**2.7**	2.5	4.5	5.0	**4.0**
Asgrow	AG5233	3.0	4.0	3.0	**3.3**	5.0	5.0	5.0	**5.0**
Asgrow	AG5332	2.0	3.0	2.0	**2.3**	5.0	4.5	5.0	**4.8**
Asgrow	AG5533	1.0	3.0	2.0	**2.0**	5.0	4.0	5.0	**4.7**
Asgrow	AG5632	3.0	4.0	4.0	**3.7**	5.0	5.0	5.0	**5.0**
Credenz	HBK RY5221	1.0	3.0	2.0	**2.0**	4.0	3.0	2.8	**3.3**
Croplan	R2C5081	1.0	3.0	2.0	**2.0**	2.5	3.5	3.0	**3.0**
Dyna-Gro	32RY55	1.0	3.0	2.0	**2.0**	2.5	2.0	2.5	**2.3**
Dyna-Gro	39RY57	2.0	3.0	2.0	**2.3**	4.5	3.5	3.0	**3.7**
NK	S52-Y2	1.0	2.0	2.0	**1.7**	2.0	2.5	3.0	**2.5**
Pioneer	53T73RS	0.0	1.0	1.0	**0.7**	2.5	3.0	2.3	**2.6**
Pioneer	54T94R	1.0	3.0	2.0	**2.0**	4.0	5.0	5.0	**4.7**
Progeny	P 5333 RY	1.0	3.0	2.0	**2.0**	1.0	1.0	2.0	**1.3**
Progeny	P 5555 RY	3.0	4.0	3.0	**3.3**	5.0	4.5	5.0	**4.8**
Terral	REV 55R53	2.0	3.0	2.0	**2.3**	3.5	3.0	5.0	**3.8**
Terral	REV 56R63	1.0	2.0	2.0	**1.7**	1.0	2.5	5.0	**2.8**

Plots were rated by Dr. Trent Irby, Mr. Charlie Stokes, and Dr. Dennis Reginelli using a scale of 0 = completely tolerant to 5 = completely susceptible. Work supported by MSPB Project No. 57-2014.