SOYBEAN CHLOROSIS IN NORTH DAKOTA - CAUSES, SEVERITY AND POSSIBLE SOLUTIONS[1]

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Introduction

Soybean acres continue to increase in northwestern Minnesota and North Dakota in spite of severe problems with iron chlorosis in some years. Soybeans often turn yellow within a few weeks of emergence and remain yellow for up to 8 weeks before plants green up and mature. Iron chlorosis tolerant soybeans available today are somewhat effective in reducing chlorotic acreage, but are not tolerant enough to counteract the soil conditions in this area.

Several researchers have found that iron chlorosis is associated with calcareous soils (Anderson, 1982; Clark, 1982; Vose, 1982). Other studies have shown the importance of Fe oxide phase and Mg^{2++} content of the solution (Loeppert and Hallmark, 1985), high soil and plant Mg^{2+} levels, higher soil Na^+ and Cl^-, higher Mg/Ca ratios, over-saturation of calcium carbonate with respect to calcite, higher plant P, higher soil moisture, lower soil temperature and higher bicarbonate levels (Bloom and Inskeep, 1986; Inskeep and Bloom, 1986).

In the Red River Valley of Minnesota and North Dakota, pedogenic carbonates are associated with discharge position soils (discharge is where soil water flows to from groundwater. Recharge is where water moves into the soil from the surface) in a depression focused recharge landscape (Knuteson, et al., 1989). Calcium carbonate equivalent levels may reach 30% or more in the discharge locations. The distance between recharge and discharge in these soil associations may be less than 100 feet. Elevation differences between the recharge and discharge sites are commonly only 6-12 inches. Soils developed in this association are classified as Calciaquolls and non-Calciaquolls. Salts may be more prevalent in Calciaquolls than non-Calciaquolls, but not necessarily. The appearance of salts is an ephemeral feature, while a calcic horizon is associated with much longer term water movement over centuries.

Salts may have a role in increasing iron chlorosis in soybeans. Dahiya and Singh (1979) showed that available soil iron levels decreased with increasing salt levels. Randall (1981) commented that soybean responses to foliar iron amendments were not effective when applied to soybeans growing in high salt soils. The relationship of Mg with Ca referred to as associated with chlorosis in previous studies may be a reflection of not only the nature of carbonate minerals in the soil, but also may have been associated with the presence of significant soluble salts in certain soils.

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Iron deficiency has also been observed to decrease nodulation and N-fixation in soybeans. Nodule initiation was identified as a critical stage for the iron deficiency effect by Tang and Robson, 1992. Salinity was found to decrease nodule activity and subsequent accumulation of N in the four grain legumes (Cordovilla et al., 1995).

The objective of this study was to identify soil factors that affect iron chlorosis symptoms in soybeans in order to better direct breeding selection efforts for reducing or eliminating severe chlorosis problems in this region and identify interactions with herbicide activity on soybean yield.

Materials and Methods

Field studies

Six different locations were selected each year from 1996 through 1998 in the Red River Valley of North Dakota and Minnesota which contained chlorotic and green areas of soybeans. A gradient of six sampling sites from severely chlorotic to green soybeans was established at each site, each representing a visual category from the chlorosis rating of 1 through 6. Gradients of soybean chlorosis were selected using a visual rating of 1 to 6, with 1 being most chlorotic and 6 having a normal green color. Two gradients were established at each location in 1997 and again in 1998. Video of individual plants and soil cores at the 0-6 inch depth were taken at each location along the gradient. Separate 0-2 foot soil cores were obtained from the chlorotic and green ends of the gradient. The deep soil cores were measured for horizon depth in the field, then wrapped with saran wrap, folded and taken back to the lab for more thorough profile description.

At each location, soil cores from the 0-6 inch depth were taken at each of these 6 gradient sites for analysis. Soil samples were dried and analyzed for potassium (K), pH, EC (soluble salts using a 1:1 paste), iron (Fe) and zinc (Zn) by DTPA extraction, calcium (Ca), magnesium (Mg), sodium (Na) and calcium carbonate equivalent (CCE). In 1998, copper (Cu) and manganese (Mn) was also analyzed. Regression analysis was used to determine relationships between the severely chlorotic and green locations and the gradient samples at each field site.

The video recording was used to assign a digital chroma value to the degree of chlorosis. The image analyzer Java (Jandel Scientific, Corte Madera, CA) was used to give a mean value to polygons representing leaf surfaces at each location in the gradient. The mean chroma value was then correlated with soil factors at each location.

In 1998, a study was initiated to examine the interaction of herbicides and soybeans stressed from chlorosis. Ten different postemergence herbicide treatments were imposed on sites selected for iron chlorosis (Table 1). Soil samples were analyzed for calcium carbonate equivalent and soluble salts. If yields were related to soil salt or carbonate levels, yields were adjusted for the effects of the soil factors.

Table 1. Herbicide treatments imposed on chlorotic soybeans, 1998.

Treatment 1, Basagran, 2 pt/acre and 2 pt/acre Herbimax
Treatment 2, Blazer, 1.5 pt/acre and 0.25%v/v Activator 90
Treatment 3, Galaxy, 2 pt/acre and 2 pt/acre Herbimax
Treatment 4, Storm, 1.5 pt/acre and 2 pt/acre Herbimax
Treatment 5, 10 oz Cobra and 1.5 pt/acre Herbimax
Treatment 6, 0.75 pt/acre Flexstar and 2 pt/acre Herbimax
Treatment 7, 0.25 oz/acre Pinnacle and 0.25% v/v Activator 90
Treatment 8, 0.3 oz/acre First Rate and 0.125 %v/v Activator 90 and 2.5% v/v 28%
Treatment 9, 3 oz/acre Pursuit and 2 pt/acre Herbimax and 2.5%v/v 28%
Treatment 10, 4 oz Raptor and 2 pt/acre Herbimax and 2.5%v/v 28%

Results and Discussion

Causes of Chlorosis

Soil taxonomic type and soil series phase were not entirely consistent in separating green and chlorotic soybeans (Table 2). In the three years of the study, soil type was not different between green and chlorotic sites in eleven of thirty comparisons, or 37% of the time. Calciaquolls were chlorotic and non-Calciaquolls were green in twelve of thirty comparisons (40%). Internal drainage as evidenced by soil morphology accounted for differences in three sites (10%) and saline phases accounted for four sites (13%). Undoubtedly, chlorosis is more complex than soil type. There may be several interacting causes at work simultaneously. Some relationship between evaporites and dissolved constituents seems likely, however.

In 1996, calcium carbonate equivalent was correlated with iron chlorosis rating at r>0.4 at five of six locations, while soluble salts (EC) had a correlation r>0.4 at four of five locations (Table 3). At the two sites not highly correlated with salt levels, CCE was very highly correlated. At the site with lower CCE correlation, salt levels were highly correlated. Soil pH was correlated higher than 0.4 at three of six locations, iron at one of six, with sodium highly correlated at five of six locations.

In 1997 (Table 4), both EC and CCE were significantly correlated (P>0.1) at seven of twelve comparisons. EC had a correlation r>0.4 at eleven of twelve locations, while CCE has a correlation >0.4 at nine of twelve locations. At Wang east, 1997, chlorotic soybeans associated with the Colvin soil type, compared to Bearden in the green soybean area. Although both soils are classified as a calciaquoll, the Colvin soil has poor internal drainage (Typic Calciaquoll compared to Aeric Calciaquoll in the Bearden), so the difference may have been the increased moisture status of the Colvin soil. In the other two comparisons not correlated with EC or CCE, soil pH and extractable iron were correlated with chlorosis.

In 1998, EC was significantly correlated with chlorosis at two of twelve locations and r>0.4 at eight of twelve locations (Table 4). CCE was significantly correlated with chlorosis at three of twelve locations and r>0.4 at nine of twelve locations. Over all years, EC was significantly and positively correlated with chlorosis at ten of thirty locations, and r>0.4 at twenty-four of thirty locations. CCE was significantly correlated with chlorosis at twelve of thirty locations and r>0.4 at twenty-three locations. Soil pH was significantly correlated only six times, with r>0.4 at twenty locations. Soil iron was significantly correlated ten times, with r>0.4 at nineteen locations.

Over all years, calcium carbonate equivalent, a representation of the free lime content of the soil and EC, a measure of soil salt activity were most consistently related to soybean chlorosis.

Herbicide interaction- presentation of a summary of first year results

One of the ironies of soybean production is that postemergence herbicides must be applied at the time when soybeans are under stress from chlorosis. There were significant differences in yield due to herbicide treatment at four of six locations. Differences from highest to lowest yielding treatments were as large as 20 bu/acre. Galaxy was generally ranked higher in yield than other treatments. First Rate was rated highly in the heavier textured sites, but was lower on the coarser textures. This is consistent with other observations from other studies not necessarily on chlorotic soybeans. First Rate was the only treatment not affected by differences in salt and carbonate levels.

Yields with Pursuit and Raptor treatments were generally higher on lower salt sites, however, when salt levels were high (0.5 mmhos/cm on sands, 0.8 mmhos/cm on heavier soils) they were near or at the lowest in yield. Generally, the three treatments most consistently low in yield were Pinnacle, Cobra and Blazer. Storm, Flexstar and Basagran were consistently in the middle yielding treatments. This work is being repeated in 1999 to determine whether the results are consistent between years and fields.

Conclusions

Soybean chlorosis was most related to high soil carbonate and soluble salt levels. Clearly, there are affects of chlorosis on soybean production in North Dakota. The chlorosis seen in North Dakota is different and more intense than that encountered in the more traditional soybean growing areas of the United States. In order to improve the chlorosis tolerance of varieties in this stressful environment, soybean breeders should consider selecting sites in North Dakota or Northwest Minnesota with high carbonate and salt levels that would encourage selection towards tolerance to these common soil conditions. Simply introducing soybeans into the area in the proper maturity class with chlorosis tolerance adequate for southern Minnesota or northern Iowa conditions is clearly not enough.

Herbicide treatments applied to soybeans stressed with chlorosis resulted in yield differences. Although weeds need to be controlled, selection of herbicide options that are less stressful to soybeans may result in higher yields if the safer herbicide also controls the weeds present in a given field.

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Table 2. Comparison of soil series descriptions at chlorotic and green locations.

Site	Soil Series	
	Green	**Chlorotic**
Zimmerman, 1996	Bearden sil	Bearden sil
Wang 1996	Bearden sil	Bearden sil
Nordick 1, 1996	Glyndon sil	Glyndon sil
Nordick 2, 1996	Perella sicl	Colvin sicl
Strand 1, 1996	Wyard l	Wyard l
Strand 2, 1996	Embden l	Wyndmere l
Wang east 1, 1997	Bearden sil	Colvin sicl
Wang east 2, 1997	Bearden sil	Colvin sicl
Wang west 1, 1997	Colvin sicl	Colvin sicl
Wang west 2, 1997	Colvin sicl	Colvin sicl
Fixen 1, 1997	Gardena l	Arveson l
Fixen 2, 1997	Gardena l	Arveson l
Gylland 1, 1997	Perella sicl	Colvin sicl
Gylland 2, 1997	Perella sicl	Colvin sicl
Nordick east 1, 1997	Tiffany sl	Arveson sl
Nordick east 2, 1997	Tiffany sl	Arveson sl
Nordick west 1, 1997	Embden sl	Arveson sl
Nordick west 2, 1997	Embden sl	Arveson sl
Nordick 1, 1998	Bearden sil	Bearden l
Nordick 2, 1998	Arveson l	Arveson l
Rydell 1, 1998	Colvin sicl	Colvin sicl saline
Rydell 2,1998	Colvin sicl	Colvin sicl, saline
Wang 1, 1998	Colvin sicl	Colvin sicl, saline
Wang 2, 1998	Colvin sicl	Colvin sicl, saline
Gebecke 1, 1998	Glyndon fsl	Arveson l
Gebecke 2, 1998	Glyndon fsl	Borup l
Kummer 1, 1998	Tiffany sl	Arveson sl
Kummer 2, 1998	Tiffany sl	Tiffany sl
Brodshaug 1, 1998	Perella sicl	Bearden sicl
Brodshaug 2, 1998	Bearden sicl	Bearden sicl

Arveson- Coarse loamy, frigid Typic Calciaquolls
Bearden- Fine-loamy, frigid Aeric Calciaquolls
Borup-Coarse-silty, frigid Typic Calciaquolls
Colvin- Fine-silty, frigid Typic Calciaquolls
Embden- Coarse-loamy, mixed Pachic Udic Hapludolls
Gardena-Coarse-silty, mixed Pachic Udic Hapludolls
Glyndon- Fine-silty, frigid Aeric Calciaquolls
Perella- Fine-silty, mixed, frigid Typic Haplaquolls
Tiffany-Coarse-loamy, mixed, frigid Typic Haplaquolls
Wyard- Fine-loamy, mixed frigid Typic Haplaquolls
Wyndmere-Coarse-loamy, frigid Aeric Calciaquolls

Table 3. Correlation (r) of 1996 soil fertility factors within gradients of chlorotic to green soybeans at each location.

Site	pH	EC	Fe	Na	Mg/Ca	CCE
Zimmerman	0.46	0.28	0.16	0.88‡	0.96‡	0.95‡
Wang	0.39	0.84‡	0.17	0.97‡	0.92‡	0.87‡
Nordick 1	0.24	0.53	0.25	0.44	0.58	0.33
Nordick 2	0.43	0.62	0.34	0.47	0.52	0.55
Strand 1	0.90‡	0.68	0.88‡	0.61	0.18	0.60
Strand 2	0.21	0.28	0.00	0.01	0.27	0.71†

† Significant at P>0.10
‡ Significant at P>0.05

Table 4. Correlation (r) of 1997 soil fertility factors within gradients of chlorotic to green soybeans at each location.

Site	pH	EC	Fe	Na	Mg/Ca	CCE
Wang east 1	0.62	0.02	0.55	0.22	0.52	0.02
Wang east 2	0.95‡	0.68	0.15	0.40	0.11	0.12
Wang west 1	0.71	0.75†	0.62	0.50	0.82‡	0.94‡
Wang west 2	0.69	0.53	0.93‡	0.16	0.68	0.55
Fixen 1	0.67	0.93‡	0.73†	0.92‡	0.63	0.43
Fixen 2	0.43	0.55	0.85‡	0.49	0.76‡	0.86‡
Gylland 1	0.72†	0.43	0.66	0.20	0.93‡	0.91‡
Gylland 2	0.32	0.85†	0.91‡	0.65	0.97‡	0.73†
Nordick East 1	0.68	0.88‡	0.53	0.39	0.94‡	0.91‡
Nordick East 2	0.56	0.75†	0.68	0.69	0.95‡	0.82‡
Nordick West 1	0.20	0.73†	0.43	0.82‡	0.36	0.88‡
Nordick West 2	0.00	0.87†	0.43	0.42	0.51	0.25

† Significant at P>0.10
‡ Significant at P>0.05

Table 5. Correlation (r) of 1998 soil fertility factors within gradients of chlorotic to green soybeans at each location.

Site	pH	EC	Fe	Na	Mg/Ca	CCE
Nordick 1	0.90‡	0.71	0.89‡	0.43	0.94‡	0.88‡
Nordick 2	0.00	0.70	0.26	0.52	0.03	0.81†
Rydell 1	0.25	0.01	0.00	0.01	0.58	0.38
Rydell 2	0.25	0.03	0.36	0.08	0.24	0.74
Wang 1	0.96‡	0.89‡	0.91‡	0.98‡	0.95‡	0.41
Wang 2	0.57	0.64	0.62	0.65	0.24	0.65
Gebecke 1	0.61	0.20	0.15	0.11	0.64	0.86†
Gebecke 2	0.18	0.53	0.00	0.41	0.41	0.32
Kummer 1	0.72	0.71	0.81†	0.10	0.75	0.73
Kummer 2	0.74	0.97‡	0.89‡	0.69	0.96‡	0.34
Brodshaug 1	0.87†	0.23	0.85†	0.20	0.09	0.58
Brodshaug 2	0.61	0.40	0.66	0.20	0.21	0.42

† Significant at P>0.10

‡ Significant at P>0.05

Table 6. Ranking of responsive sites to herbicide treatment in order of yield.

Kent, MN		**Fairmount, ND**		**Arthur, ND**		**Galchutt, ND**	
medium texture		heavy texture		sandy texture		sandy texture	
low salt		high salt		medium salt		high salt	
medium carbonate		medium carbonate		low carbonate		medium carbonate	
		Yield, bu/acre					
Pursuit	43.4	Galaxy	37.9	Galaxy	38.5	Galaxy	33.0
First Rate	40.1	FirstRate	35.5	Raptor	35.6	Storm	32.8
Flexstar	38.3	Flexstar	30.8	Pinnacle	34.9	Flexstar	31.0
Basagran	35.3	Cobra	29.7	Storm	34.3	Blazer	29.7
Cobra	35.0	Storm	28.9	Pursuit	33.6	Basagran	29.1
Galaxy	33.3	Basagran	28.7	Basagran	32.7	FirstRate	28.2
Raptor	31.3	Pursuit	27.4	Flexstar	31.0	Raptor	28.1
Pinnacle	29.1	Blazer	24.3	Blazer	29.7	Cobra	27.7
Storm	26.9	Pinnacle	23.6	FirstRate	29.1	Pinnacle	25.0
Blazer	24.9	Raptor	20.3	Cobra	20.9	Pursuit	24.0
LSD 5%	6.4		6.2		6.1		1.0

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