

# Evaluating the Effectiveness of Iron Chelates in Managing Iron Deficiency Chlorosis in Grain Sorghum

*A. Obour, A. Schlegel, R. Perumal, and D. Ruiz Diaz*

## Summary

Grain sorghum production in alkaline or calcareous soils is frequently affected by iron (Fe) chlorosis. Soil conditions such as high pH, high free calcium carbonate (lime), and low organic matter favor development of Fe deficiency chlorosis (IDC), which can delay crop maturity and reduce yields. Field experiments were conducted in the summer of 2014 and 2015 to determine the effectiveness of Fe chelate application in alleviating IDC in grain sorghum. Treatments were four Fe chelate application rates (0, 3, 6, and 9 lb product/a) applied either in-furrow with the seed at the time of planting or 2 weeks after planting in 2014. A split treatment of 3 lb/a applied at planting and another 3 lb/a applied 2 weeks after planting was included. The study in 2015 had four Fe chelate rates (0, 3, and 6 lb product/a, and split treatment of 3 lb/a applied at planting and another 3 lb/a applied 2 weeks after planting) as main plots and five commercial sorghum hybrids as sub-plots. Results in 2014 showed IDC scores among the treatments were significant only in the early stages of growth. Iron chelate application did improve sorghum yield, with the highest yield occurring when Fe chelate was split-applied at 6 lb product/a. Grain sorghum hybrids differed in their response to IDC in 2015. Application of Fe chelates suppressed IDC and increased grain yield, particularly in susceptible hybrids in both dryland and irrigated sites. Our findings indicate that sorghum hybrids 86G32 and 87P06 showed promise for tolerance to IDC and that Fe chelate application to reduce IDC is economically feasible at current grain prices.

## Introduction

Grain sorghum is susceptible to iron (Fe) deficiency chlorosis (IDC) when grown on high-pH soils in the Great Plains. High pH and free calcium carbonate associated with calcareous soils reduce the availability of Fe to the sorghum plant. This results in IDC with delayed crop maturity and reduced yields. The general approach to alleviating Fe deficiency in sorghum has been the application of foliar or soil amendments; however, these amendments have not been economically feasible on the field scale. Available Fe chelate products that are reported to correct Fe deficiency are too expensive to use on low-value field crops like grain sorghum.

Several studies have attempted to develop alternative, cheaper strategies for managing IDC in sorghum. These include breeding and selecting for Fe-efficient sorghum cultivars and application of Fe-containing fertilizer products.

Managing IDC is complicated by the temporal and spatial heterogeneity of IDC in sorghum fields. Heterogeneity in soil chemical composition within sorghum fields causes spatial development of IDC in sorghum fields, which creates a major challenge to managing IDC on a field scale. An effective management strategy for preventing IDC in grain sorghum should be a comprehensive approach that considers soil heterogeneity, application of chelated Fe products, and selection of IDC-tolerant sorghum cultivars. Previous research has documented that in-furrow application of ortho-ortho-EDDHA Fe can reduce IDC in soybean and dry edible beans. Research extending this technology to managing IDC in grain sorghum has been limited. The objectives of this study were to 1) determine the effectiveness of ortho-ortho Fe-EDDHA in alleviating IDC in grain sorghum, and 2) screen grain sorghum hybrids for their tolerance to IDC.

## Procedures

A field experiment was conducted in the summer of 2014 on a producer's field near Holcomb, KS, to evaluate the effectiveness of iron chelate in alleviating IDC in grain sorghum. Treatments were four ortho-ortho-EDDHA Fe chelate application rates (0, 3, 6, and 9 lb product/a) applied either in-furrow with the seed at the time of planting or two weeks after planting as foliar treatment. A split application treatment of 3 lb product/a applied at planting and another 3 lb product/a applied 2 weeks after planting was included. The study was expanded in 2015 to include sites at Southwest Kansas Agricultural Research Centers (SWREC) in Garden City and Tribune, and at a producer's field near Garden City, KS. The study in Tribune was under irrigated conditions. Treatments were four application rates of ortho-ortho Fe-EDDHA (0, 3, and 6 lb product/a, and split treatment of 3 lb/a applied at planting and another 3 lb/a applied 2 weeks after planting) as main plots and five commercial sorghum hybrids (Pioneer hybrids 86G32, 87P06, 85Y40, Golden Acres hybrid GA5613, and Northrup King hybrid NK5418) as sub-plots. The Fe chelate was applied in-furrow at planting except the split treatment where the chelate was applied at planting plus additional Fe chelate application 2 weeks after planting.

All plots received equal amounts of nitrogen (N) and phosphorus (P) applied at 100 and 30 lb/a, respectively. Before planting, three soil core samples were taken from 0- to 15-cm depths from individual plots (individual plots were 10 ft × 30 ft), combined to form a composite sample for each block, and analyzed for soil chemical properties.

SPAD (chlorophyll meter) readings, IDC scores (a score of 1 means non-chlorotic leaves, 5 means plants with complete leaf chlorosis), and plant height information were taken 30 and 60 days after planting. The plots were harvested in mid-November in 2014 to determine grain yield. Harvesting in 2015 was done in October in Garden City, and mid-November in Tribune.

## Results

Results in 2014 showed IDC scores among the treatments were significant only in the early stages of growth. Split application of Fe chelate at 6 lb product/a did better at suppressing IDC compared to the other chelate treatments (Table 1). At 60 days after planting, IDC was similar among the Fe chelate treatments. In general, severity of IDC tends to decrease over the growing season, confirming the ability of sorghum hybrids to grow out of IDC under favorable environmental conditions. Similarly, relative leaf

chlorophyll content (SPAD readings) and plant height at 30 days after planting were greatest when 6 lb/a Fe chelate was split applied. As the growing season progressed, no differences in SPAD readings and plant height were observed among the treatments. Iron chelate application did improve sorghum yield compared to the control. The highest yield occurred when Fe chelate was split applied at 6 lb product/a. SPAD readings, IDC, and grain yield were not affected by Fe-EDDHA application method.

Results in 2015 showed that IDC differed among the sorghum hybrids studied. Iron chelate application suppressed IDC, particularly in the highly susceptible hybrids (85Y40 and NK5418) at both the dryland (Table 2) and irrigated locations (Figure 1). Severity of IDC decreased as the growing season progressed at SWREC (Table 2) in Garden City and in Tribune (data not shown) but not in the producer's field (Table 2). Greater severity of IDC at the producer's farm may be due to high carbonate concentrations in the soil and the drought experienced in July. Although Fe concentrations in the soil at the two dryland locations were similar (2.5 mg/kg at SWREC in Garden City, and 2.3 mg/kg at producer's field), calcium carbonate equivalence (CCE) in the soil at the producer's field was 82 g/kg and that in the soil at SWREC was 25 g/kg. In general, sorghum hybrids 87P06, 86G32, and GA5613 were more tolerant to IDC than NK5418 and 85Y40. Similar to IDC scores, SPAD readings were greater with hybrids that showed tolerance to IDC (data not shown).

Grain yields were different among the sorghum hybrids at both dryland and irrigated sites. At the dryland sites, yields averaged across Fe treatments were generally greater at SWREC than the producer's field (Figure 2). This may be due to reduced incidence of IDC observed in the later part of the growing season at SWREC. Sorghum hybrid 86G32 produced the greatest yield among the hybrids evaluated at SWREC. However, 87P06 had the highest grain yield at the producer's field (Figure 2). This is due to relatively lower IDC scores observed in 87P06 at the producer's field, particularly in treatments where Fe chelate was split applied at 6 lb/a. Similarly, grain yield of 86G32 was greatest among the hybrids under irrigation in Tribune when averaged across Fe chelate application rates (Figure 3).

Averaged across Fe treatments, grain yields with GA5613 and NK5418 were similar to 86G32 under irrigation compared to the dryland sites. When moisture was not limited, grain yields in NK5418 were not significantly affected by Fe chelate (Figure 4). This suggests that in good growing conditions when water is not limited, these hybrids (NK5418 and GA5613) will grow out of IDC and produce decent grain yields. However, 85Y40 consistently produced the lowest grain yield at all sites, confirming greater susceptibility to IDC.

Applying Fe chelate to grain sorghum increased grain yield compared to the control at both dryland sites near Garden City and the irrigated site at Tribune (Figure 5 and 6). At Tribune, there was a significant chelate  $\times$  hybrid ( $P = 0.08$ ) effect on grain yield. This interaction occurred because of the substantial increase in grain yield when Fe chelate was applied to GA5613 and 85Y40. The increase in grain yield due to Fe chelate application was nominal in other sorghum hybrids (Figure 4). Averaged across sorghum hybrids, application of 3 lb/a Fe chelate caused a 2-fold increase in grain yield above the control at the dryland site. At \$3.22/bu current grain sorghum sale price, the increase in

gross revenue generated with 3 lb/a Fe-EDDHA application is \$86.94/a ( $\$3.22/\text{bu} \times 27 \text{ bu/a}$ ) for dryland and \$54.74/a ( $\$3.22/\text{bu} \times 17 \text{ bu/a}$ ) for the irrigated site. The cost of 3 lb/a Fe-EDDHA at a retail price of \$8 product/lb is \$24. It is therefore economically feasible to apply Fe-EDDHA to grain sorghum at current grain prices.

**Table 1. Grain sorghum yield, iron (Fe) deficiency chlorosis (IDC) scores, and relative leaf chlorophyll content (SPAD) as affected by Fe chelate application**

Fe chelate treatment	IDC score		SPAD readings		Grain yield, bu/a
	30 DAP <sup>1</sup>	60 DAP	30 DAP	60 DAP	
Check	1.9	1.2	29.1	32.1	88.8
3 lb/a in-furrow	1.6	1.2	29.8	33.7	101.2
6 lb/a in-furrow	1.5	1.2	29.7	30.3	104.5
9 lb/a in-furrow	1.4	1.2	30.3	32.1	91.5
3 lb/a postemergence	1.6	1.2	31.0	34.6	106.5
6 lb/a postemergence	1.5	1.1	32.1	33.2	101.8
9 lb/a postemergence	1.6	1.2	31.5	33.4	109.5
6 lb/a split	1.1	1.1	37.4	33.9	109.8
Standard error	0.1	0.1	1.9	2.1	6.5

<sup>1</sup> Days after planting.

**Table 2. Iron chelate application and grain sorghum hybrid effects on iron (Fe) deficiency chlorosis (IDC) scores in grain sorghum at 30 and 60 days after planting at SWREC and a producer's field, Garden City, KS in 2015**

Fe chelate rate, lb/a	IDC scores at 30 DAP <sup>1</sup>										
	SWREC-Garden City					Producer's field-Garden City					
	GA5613	NK5418	85Y40	86G32	87P06	GA5613	NK5418	85Y40	86G32	87P06	
Check	2.9	3.8	4.1	2.5	2.8	2.2	2.8	2.7	1.6	1.9	
3	2.5	2.6	2.3	1.8	2.0	1.3	1.6	2.3	1.8	1.4	
6	2.2	2.9	2.7	1.5	1.9	2.2	2.0	1.4	1.0	1.1	
6 split	3.0	2.7	2.8	2.3	2.5	1.1	1.0	1.5	1.0	1.2	
Standard error	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
	IDC <sup>2</sup> scores at 60 DAP										
	Check	3.2	3.8	4.5	1.4	2.2	3.5	3.5	3.8	3.2	3.2
	3	1.8	2.0	2.2	1.1	1.7	3.3	3.8	3.9	3.3	3.2
	6	2.4	2.7	2.6	1.4	1.6	3.3	3.3	3.3	3.0	2.8
	6 split	2.6	2.0	3.0	1.2	1.3	2.5	2.5	3.5	2.7	2.3
	Standard error	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

<sup>1</sup> Days after planting.

<sup>2</sup> Iron deficiency chlorosis score (IDC), a score of 1 means non-chlorotic leaves and 5 means plants with complete leaf chlorosis.



**Figure 1. Application of Fe chelate suppressed IDC in susceptible hybrids (e.g. Pioneer 85Y40). The control treatment (top) and a plot that received 3 lb/a Fe chelate (bottom) show the difference between treatments. Photos were taken on August 4, 2015 (60 days after planting at Tribune, KS).**

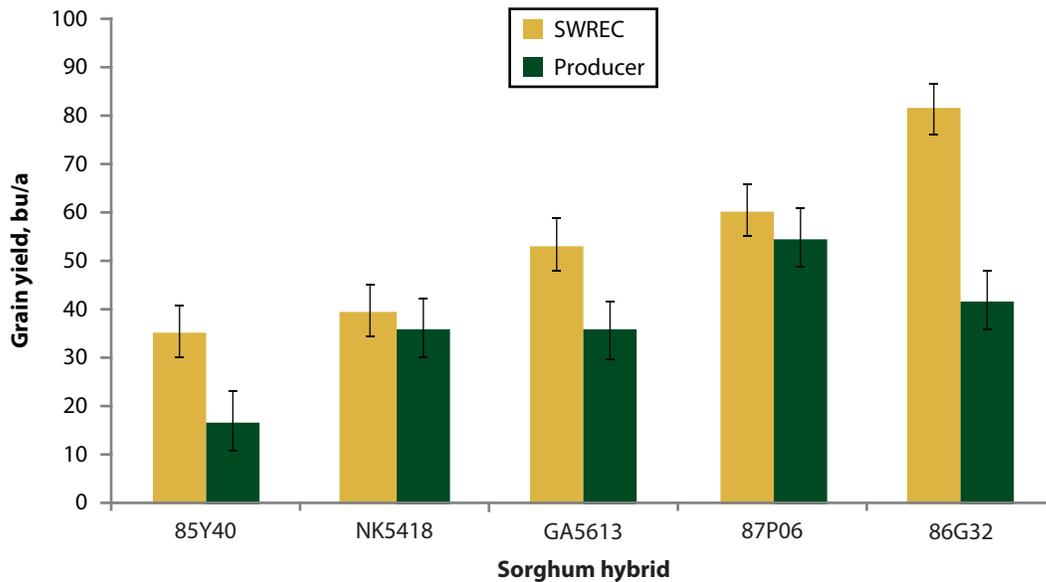


Figure 2. Grain yield of sorghum hybrids at the two dryland sites at SWREC and a producer’s field in Garden City, KS. Means are averaged across Fe chelate.

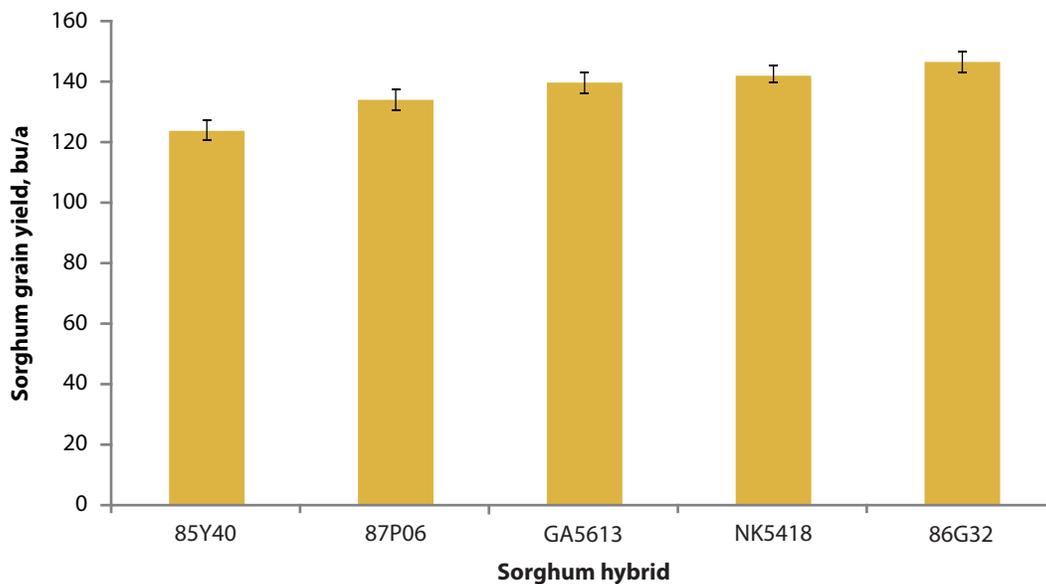


Figure 3. Grain yield of sorghum hybrids under irrigation at SWREC in Tribune, KS. Means are averaged across Fe chelate treatments.

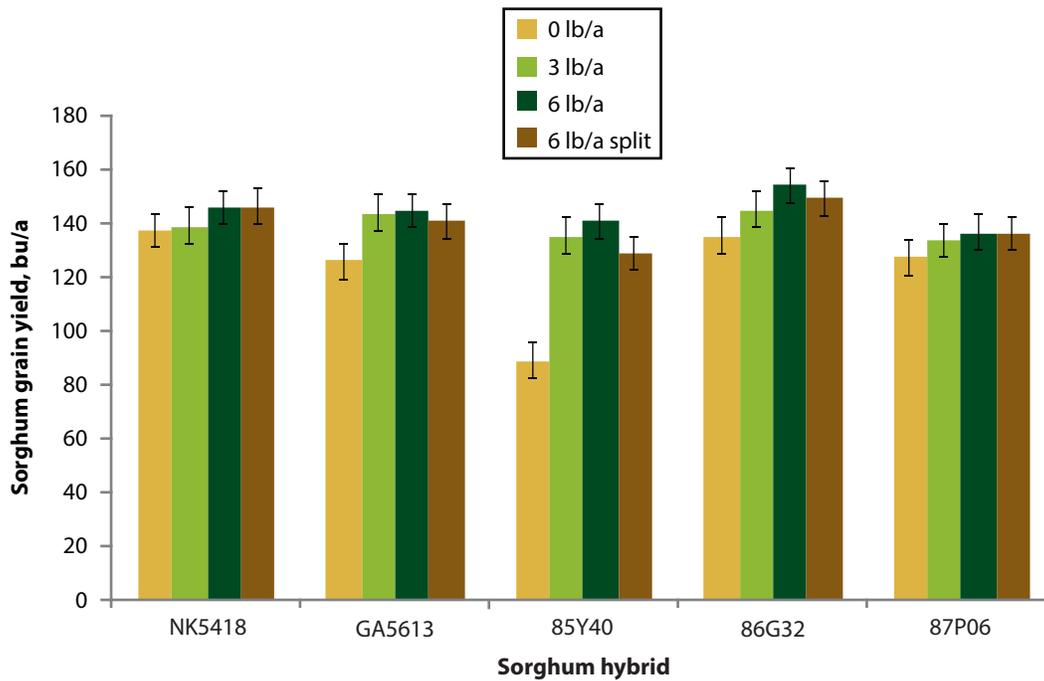


Figure 4. Sorghum grain yield as affected by iron chelate application and sorghum genotype under irrigation at Tribune, KS.

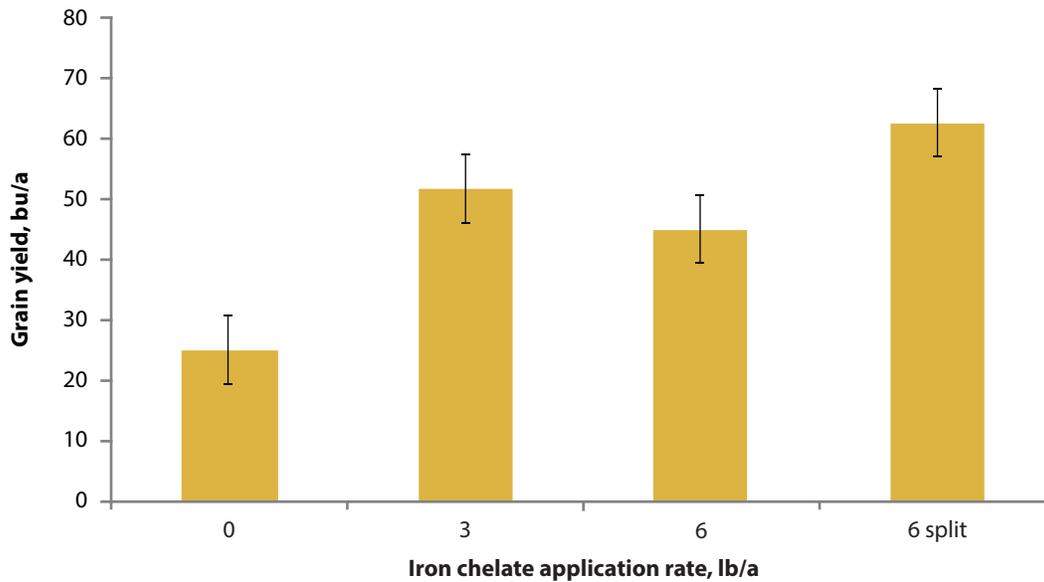


Figure 5. Sorghum grain yield as affected by iron chelate application across the two-dry-land locations in Garden City, KS.

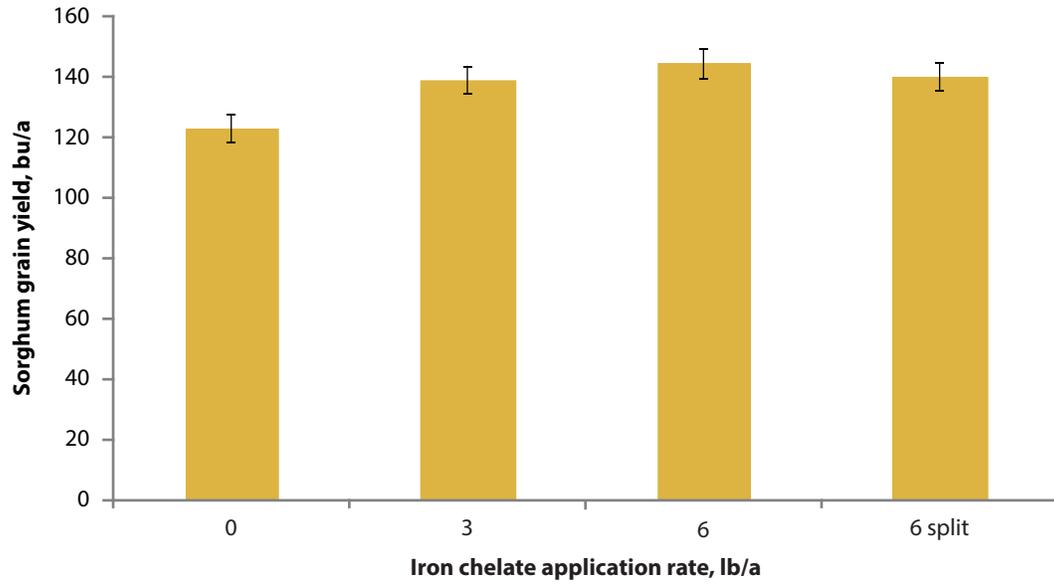


Figure 6. Sorghum grain yield as affected by iron chelate application under irrigated conditions in Tribune, KS.