EVALUATION OF FOUR IRON SOURCES FOR THE CONTROL OF IRON DEFICIENCY CHLOROSIS IN SOYBEAN

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ABSTRACT

Iron deficiency chlorosis (IDC) is a destructive disorder of soybeans grown on calcareous soils in the North Central region. Certain chelates are effective at preventing IDC, but the quality of commercial-grade materials varies. The objective of this greenhouse study was to compare the ability of four commercial iron fertilizers to prevent IDC in soybeans. The four sources were a high-quality FeEDDHA product (FeEDDHA-1), an FeEDDHA product of lower quality (FeEDDHA-2), FeEDDHSA, and FeHBED. The iron sources were applied at 0, 0.5, 1.0, and 1.5 mg Fe per pot, based on the % Fe on the label. Four plants of an iron-inefficient cultivar were grown on 2 kg of a calcareous soil-sand mixture. Two crops to the 4th trifoliolate stage were grown. For the first crop, all four sources were effective in alleviating IDC. With the second crop, significant differences between sources were observed. The ability of the sources to alleviate IDC in the second crop was in the order: FeEDDHA-1 = FeHBED > FeEDDHSA > FeEDDHA-2. It was concluded that all sources were effective for a short-term response, but that the higher-quality materials gave a longer-lasting effect in the prevention of IDC. A simple "soil stability" test correctly predicted which sources were of higher quality (FeEDDHA-1, FeHBED) and lower quality (FeEDDHA-2, FeEDDHSA).

INTRODUCTION

Iron deficiency chlorosis (IDC) is common on the poorly-drained, calcareous soils of the North Central region. Possible control measures include variety selection, foliar sprays, higher seeding rates, companion crops, and planting blends of cultivars (Bloom et al., 2011; Goos and Johnson, 2000; Goos and Johnson, 2001; Trimble and Fehr, 1982). Seed treatment with FeEDDHA or an in-furrow application FeEDDHA can also give partial control (Kaiser et al., 2013; Karkosh et al., 1988).

Regarding iron chelates, FeEDDHA is the industry standard. Unfortunately, commercial-grade FeEDDHA varies considerably in quality from manufacturer to manufacturer. Commercial-grade FeEDDHA products typically contain varying concentrations of the effective *ortho-ortho* isomer (consisting of both *racemic*- and *meso*- forms), the ineffective *ortho-para* isomer, and condensates with partial effectiveness (Schenkeveld et al., 2007). Other chelates in the marketplace include FeEDDHSA and FeHBED. Incubations using calcareous soils demonstrated that FeEDDHSA maintained a portion of its iron in a water-soluble form (Goos and Germain 2001). The product FeEDDHSA does not have as high of a stability constant for ferric iron as FeEDDHA, but it has a practical advantage over FeEDDHA in that it is more easily solubilized to make a liquid fertilizer. The product FeHBED has a greater ability to chelate ferric iron than EDDHA (Chaney, 1988), but few studies evaluating its effectiveness have been found. Structural differences between *ortho-ortho* EDDHA, *ortho-para* EDDHA, EDDHSA, and HBED, and their stability constants with respect to ferric iron, are shown in Figure 1.

The objective of this study was to measure the response of soybeans to four commercially-available iron fertilizers.

MATERIALS AND METHODS

A study was performed with six replicates in a randomized-complete block design, with daily rotation of pots on the greenhouse bench. Each experimental unit was 1 kg of calcareous soil mixed with 1 kg of white sand. The soil was a Glyndon loam (Aeric Calciaquoll) with a 1:1 pH, EC, $CaCO_3$ content and DTPA-Fe of of 8.2, 0.18 mmho/cm 4.0%, and 4 ppm respectively. Before mixing the sand and soil, the sand was amended with solutions of the four iron fertilizers, and basal nutrient solutions providing 66.7 mg N, 100 mg P, 252 mg K, 5 mg Zn, 5 mg Cu, and 5 mg Mn as ammonium nitrate, potassium phosphate dibasic, and sulfates of potassium, zinc, copper, and manganese, respectively. The iron treatments consisted of 0, 0.5, 1.0, and 1.5 mg Fe/pot, as a high-quality FeEDDHA product (FeEDDHA-1), a lower-quality FeEDDHA product (FeEDDHA-2), a FeEDDHSA solution, and FeHBED. The rates of iron were based on the percent Fe on the label. Properties of these materials are given in Table 1. The basal nutrient solutions and iron treatment solutions were mixed with the sand before mixing with the soil. The soil:sand mixture was then placed in closed-bottom pots, moistened to 12% water content, and allowed to react for a week before planting 12 seeds of a susceptible soybean cultivar, Stine 0480.

After emergence, the pots were thinned to five plants, and an additional 66.7 mg of N added to each pot as ammonium nitrate. A week later, the pots were thinned to four plants per pot, and 66.7 mg of N as ammonium nitrate added. The pots were weighed daily, and brought to 12% water content by addition of distilled water. The relative chlorophyll content of the 1st, 2nd, 3rd, and 4th trifoliolate leaves was determined after full development with a Minolta SPAD meter. At the 4th trifoliolate stage, the plant tops were excised just above the coleoptilar node. The tops were dried, weighed and ground. The plant samples were analyzed for total iron, by HNO_3-H_2O_2 digestion and determination by ICP by Agvise Laboratory, Northwood, ND.

After the first harvest, the soil in each pot was mixed, a small (10 g) sample taken, and analyzed for nitrate-nitrogen. Negligible nitrate was found in the iron-fertilized pots, but about 60 mg nitrate-N/pot was found in the controls without added iron. The pots were replanted and a second crop was grown in the same manner as the first crop. No additional iron or basal fertilizer was added, but the rates of nitrogen application were adjusted so that the controls received 140 mg N/pot, and the other pots received 200 mg N/pot as ammonium nitrate, to equalize the available mineral N.

The fertilizers were characterized as follows. The iron fertilizers were dissolved in water, centrifuged, and analyzed by AA for percent water-soluble iron. Fertilizers FeEDDHA-1 and FeEDDHA-2 were analyzed by HPLC for percent iron as *ortho-ortho* FeEDDHA. The fertilizers were also analyzed by a simple “soil stability” test developed in our laboratory. The soil stability test consisted of a 1-week aerobic incubation, at field capacity, of 10 g of the Glyndon soil with 120 micrograms of added Fe, followed by extraction with 0.01 M $CaCl_2$, centifugation, filtration, and analysis by AA.

RESULTS, FIRST CROP

The average relative chlorophyll levels in the 1st, 2nd, 3rd, and 4th trifoliolate leaflets as affected by iron fertilization are shown in Figure 2. All four products provided a dramatic alleviation of IDC. The higher-quality FeEDDHA-1 product gave a slightly greater chlorophyll level at the lowest rate, 0.5 mg Fe/pot, but at higher rates, the four sources gave a similar response. The above-ground dry matter results for the first crop are shown in Figure 3. All sources substantially increased the dry matter yield. The higher-quality FeEDDHA-1 gave the highest yield at the lowest rate of iron, but all sources gave a similar yield at the two highest rates. Above ground iron uptake for the first crop is shown in Figure 4. All sources substantially increased iron uptake. The higher-quality FeEDDHA-1 consistently gave the greatest iron uptake.

RESULTS, SECOND CROP

The effect of the residual value of four iron fertilizers on the second crop of soybeans is shown in Figures 5-7. Relative chlorophyll levels were increased by all four fertilizers, but the effectiveness was in the general order: FeEDDHA-1 = FeHBED > FeEDDHSA > FeEDDHA-2. It was expected that FeEDDHA-1 and FeHBED would out-perform the other two sources, based on the “soil stability” test (Table 1).

The results for the dry matter production (Figure 6) and iron uptake (Figure 7) mirrored the results found for leaflet chlorophyll content. The two higher-quality iron sources (FeEDDHA-1, FeHBED) provided greater growth and iron uptake than the two lower-quality sources (FeEDDHA-2, FeEDDHSA).

CONCLUSION

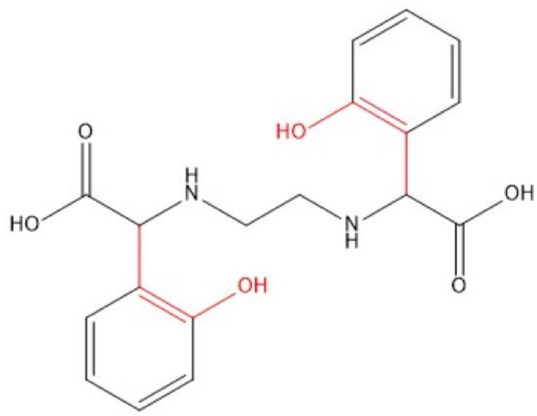
Iron chelates differ in quality and effectiveness. All four of the products tested were effective in giving a short-term response (first crop), but higher-quality products excelled with regards to a longer-term response (second crop). Higher-quality iron fertilizers could be differentiated from lower-quality iron fertilizers by a simple soil stability test.

Table 1. Properties of the fertilizers tested.

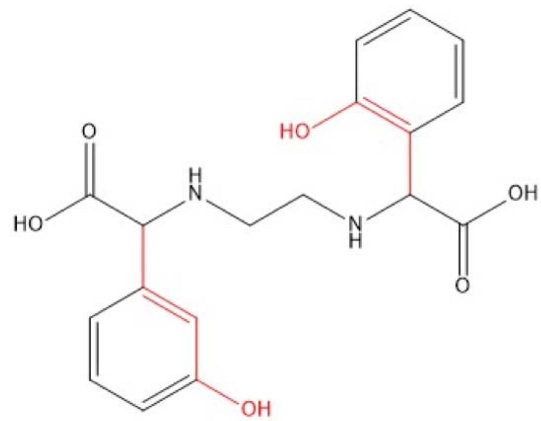
Product	% Fe on label	% water-soluble Fe	% Fe as *ortho-ortho*	% Fe "soil stable"	% of water-soluble Fe "soil stable"
FeEDDHA-1	6	6.59	5.41	5.27	80
FeEDDHA-2	6	6.51	2.92	3.08	47
FeEDDHSA	1.8	1.85	--	0.77	42
FeHBED	9	8.02	--	6.17	77

FeEDDHA-1 from Laboratorio JAER, the other materials from Deretil Group, both of Barcelona, Spain. The *ortho-ortho* analyses of the two FeEDDHA products were performed by FITOSOIL Laboratories, San Ginés, Spain, the other analyses at NDSU.

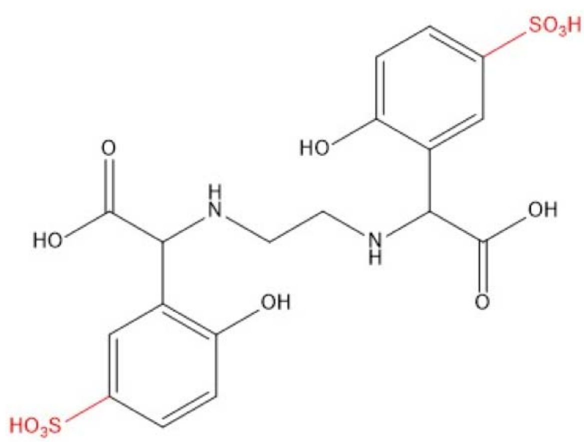
Figure 1. The free-acid structures of four chelates, and the log of the stability constant for chelation of ferric iron (Chaney, 1988; Yunta, et al., 2003)



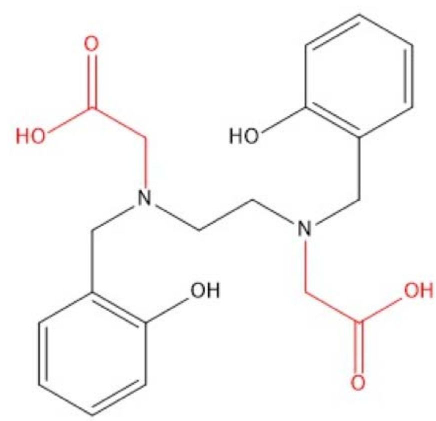
ortho-ortho EDDHA, 33.91



ortho-para EDDHA, 28.72



ortho-ortho EDDHSA, 32.79



HBED, 39.68

Figure 2. Average chlorophyll level of the 1st, 2nd, 3rd, and 4th trifoliolate leaves of soybeans, as affected by differing rates of four iron fertilizers. First crop.

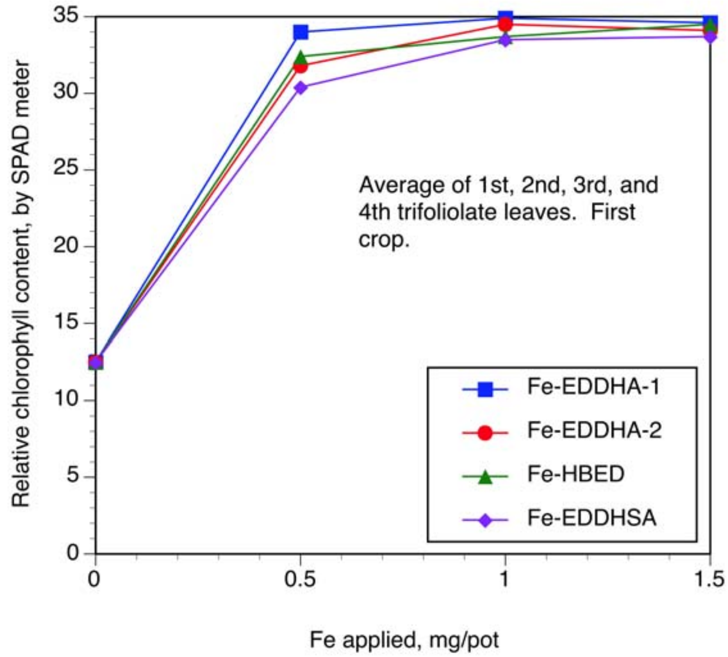


Figure 3. Above ground dry matter production for the first crop, as affected by rate and source of iron. First crop.

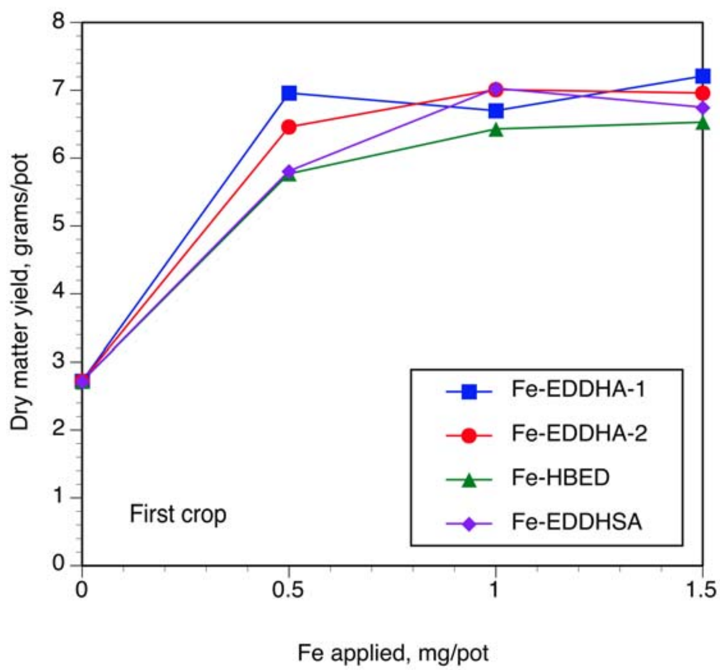


Figure 4. Above-ground Fe uptake by soybean plants, as affected by rate and source of iron. First crop.

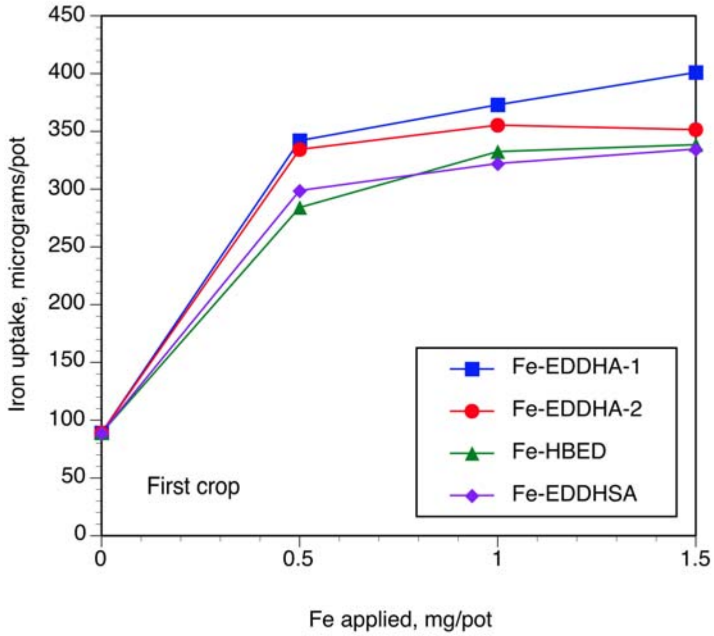


Figure 5. Average chlorophyll level of the 1st, 2nd, 3rd, and 4th trifoliolate leaves of soybeans, as affected by differing rates of four iron fertilizers. Second crop.

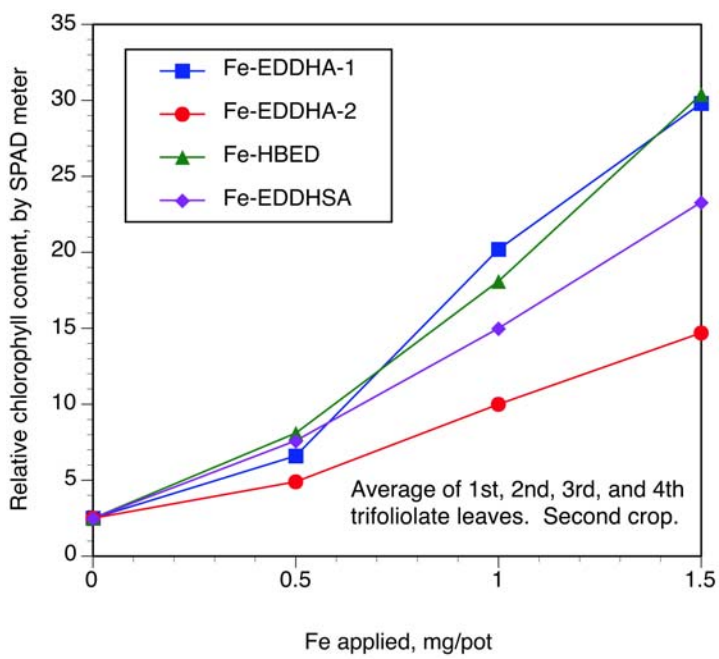


Figure 6. Above ground dry matter production for the first crop, as affected by rate and source of iron. Second crop.

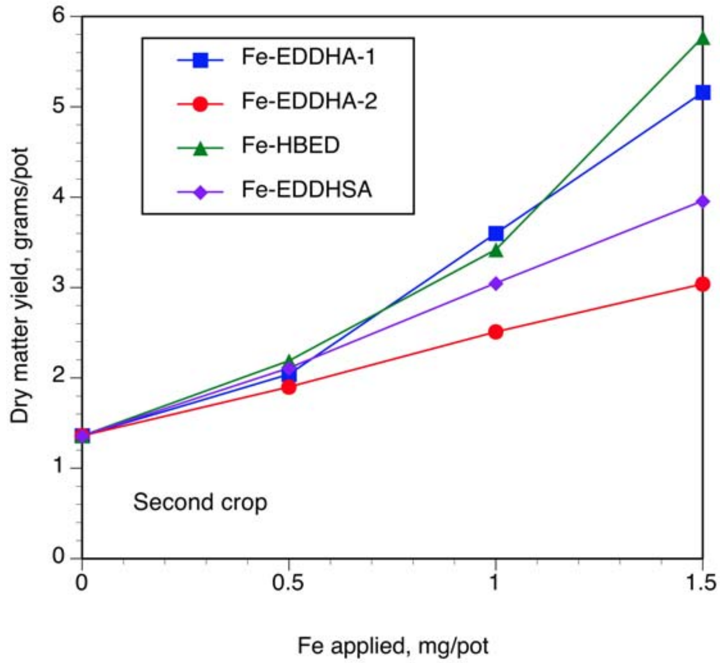
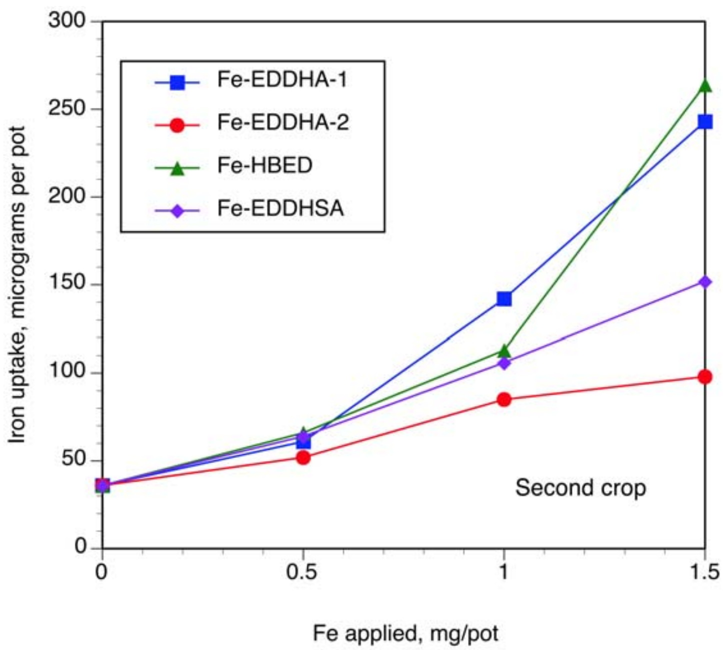


Figure 7. Above-ground Fe uptake by soybean plants, as affected by rate and source of iron. Second crop.



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