Iron Deficiency Chlorosis… Old Frustrations and New Products

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- First, the old frustrations, with IDC and soybeans….
- We all know the primary control measures…
  - Plant a resistant variety
  - Use an effective in-furrow iron fertilizer
- ….and that there are other control measures
  - Wider rows, heavier seeding rates
  - Companion crops
  - Foliar sprays

- We know so much more about IDC than we did 20 years ago
- Why are scenes like this STILL SO COMMON?

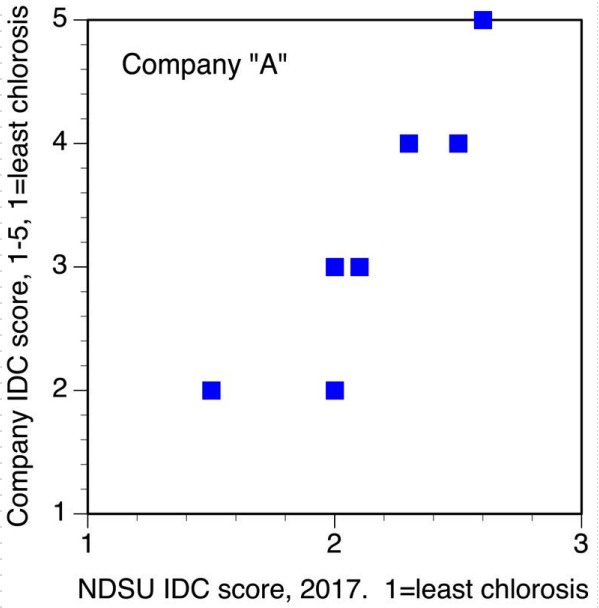
- “IDC is as bad as it ever was….because the varieties are as bad as they ever were.”

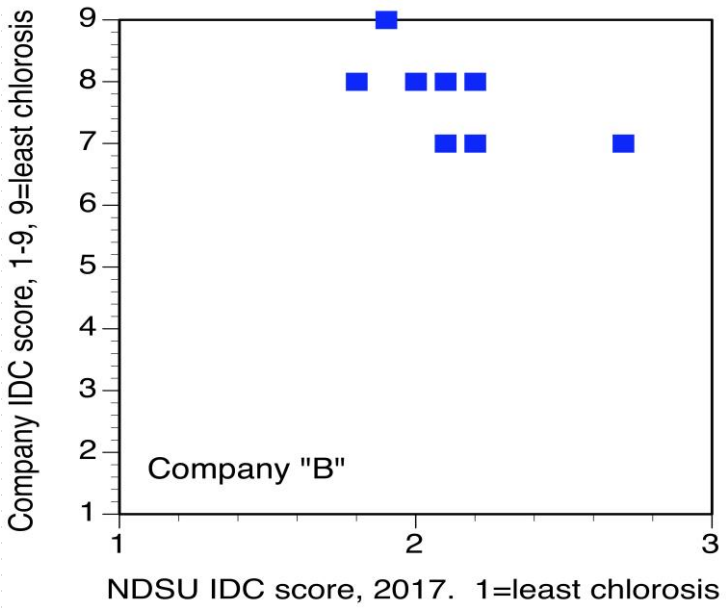
- “IDC is as bad as it ever was….because the varieties are as bad as they ever were.” Me

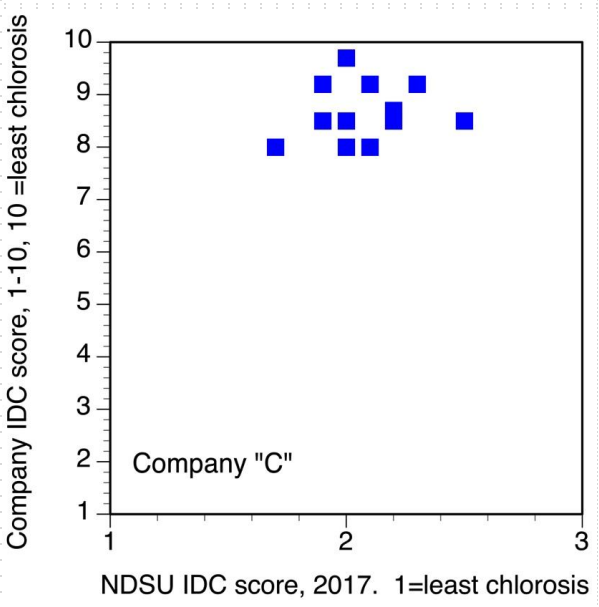
- Genes ***do*** exist for higher levels of IDC resistance….

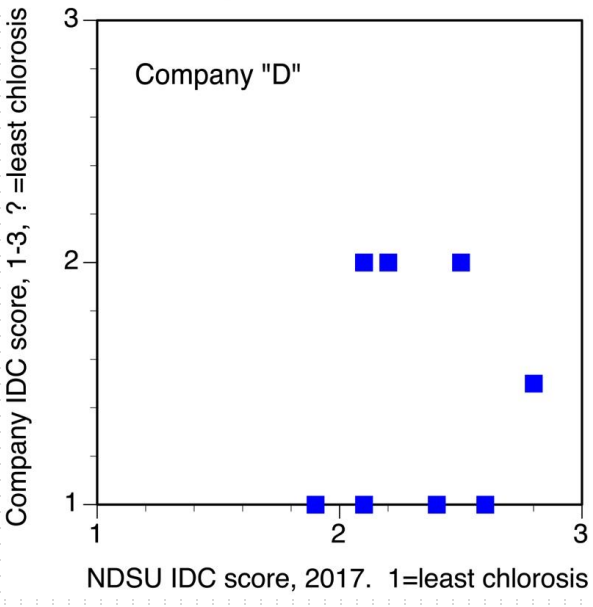
- OK!! Problem solved!! We can trust the seed companies to produce varieties with high levels of IDC resistance, and give us accurate information on the IDC resistance of their varieties, right?????

- Seed company ratings, vs NDSU ratings…









- So, please, please, take the IDC ratings given by seed companies with a grain of salt:

- But, to be fair, inheritance of IDC resistance is complicated, so Dr. Miranda has agreed to discuss at the beginning of her talk…

PLOS ONE

PUBLISH ABOUT BROWSE

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Genome-Wide Association Studies Identifies Seven Major Regions Responsible for Iron Deficiency Chlorosis in Soybean (*Glycine max*)

Sujan Mamidi, Rian K. Lee, Jay R. Goos, Phillip E. McClean

Published: September 16, 2014 • https://doi.org/10.1371/journal.pone.0107469

- So, with regards to variety selection, do the best you can, but know that “marketing” is more important than agronomy when it comes to many seed companies’ IDC ratings

- Look at NDSU’s ratings, ask a neighbor
- For chlorosis-prone soils, go with a variety with a track record, not a new variety. Example:


This new variety was rated as ”very good” by the seed company, and literally died without FeEDDHA
3#/A FeEDDHA at planting
No FeEDDHA at planting

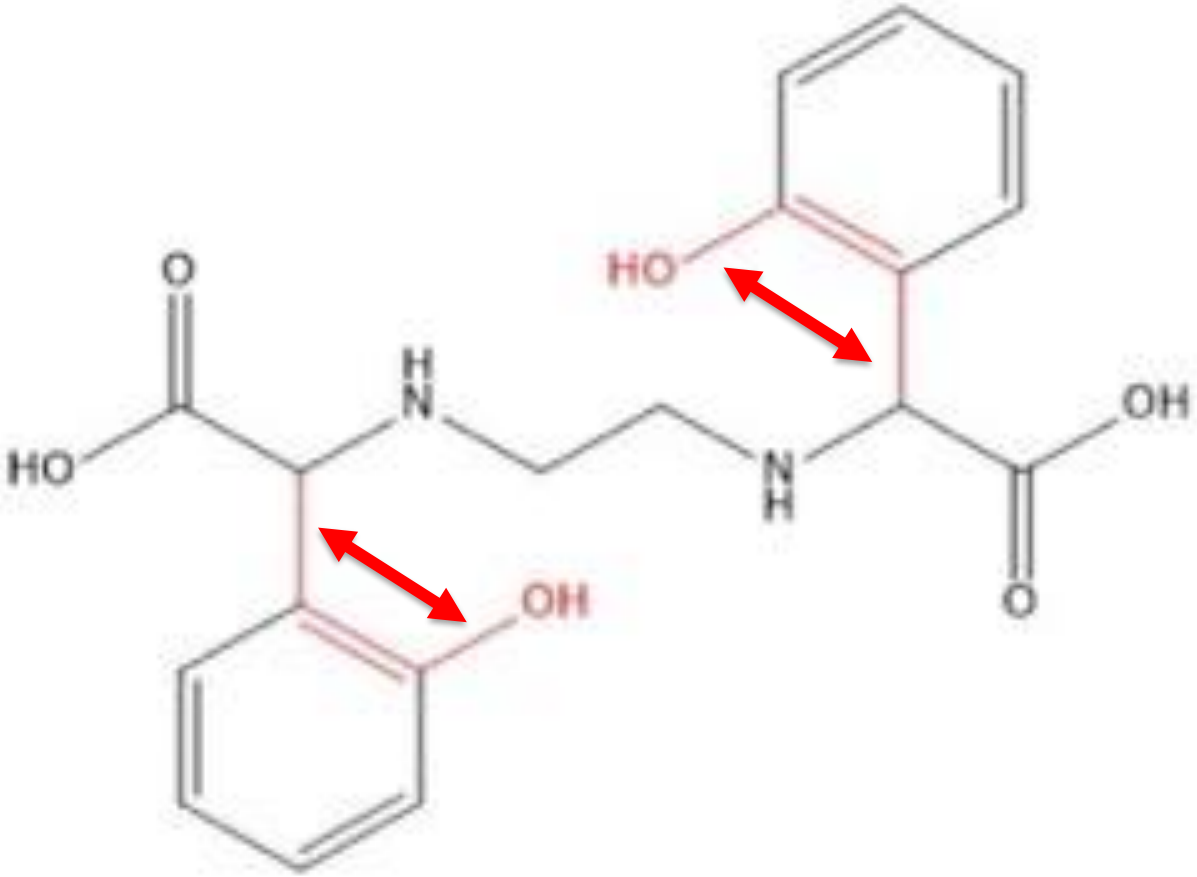

And, remember, 3 lb/A of chelate at planting, doesn't completely solve the problem, if the variety is low in IDC resistance
3#/A FeEDDHA at planting
No FeEDDHA at planting

- But enough complaining about seed companies…
- What is new with regards to control measures?
- A new chelate arrives!!
- The search for “rescue treatments” continues….and continues….and continues…..

- A new chelate arrives, FeHBED
- About FeHBED
  - Has entered the market
  - “Iron Laiden”
  - “Rexolin”;
  - “Felcon”
    - Any others???
  - It is also a “red” chelate, like FeEDDHA and FeEDDHSA

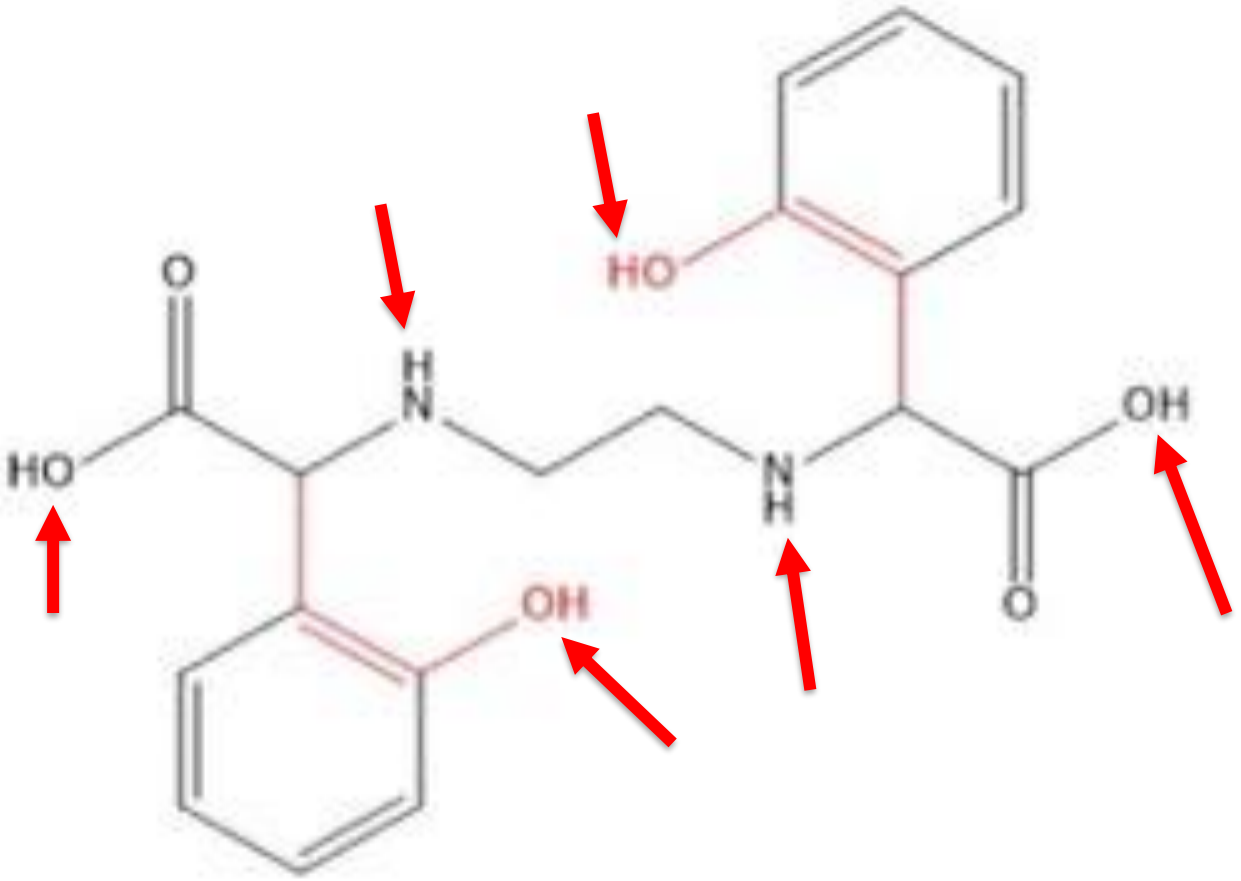
- The “red” chelates are the best for correcting IDC, but not all products are the same
- There are some differences due to “stability constant”
- There are some differences in quality of each product
  - All commercial products contain some degree of ineffective isomers and condensates

- The “red” chelates have many similarities, let’s look first at ortho-ortho EDDHA:



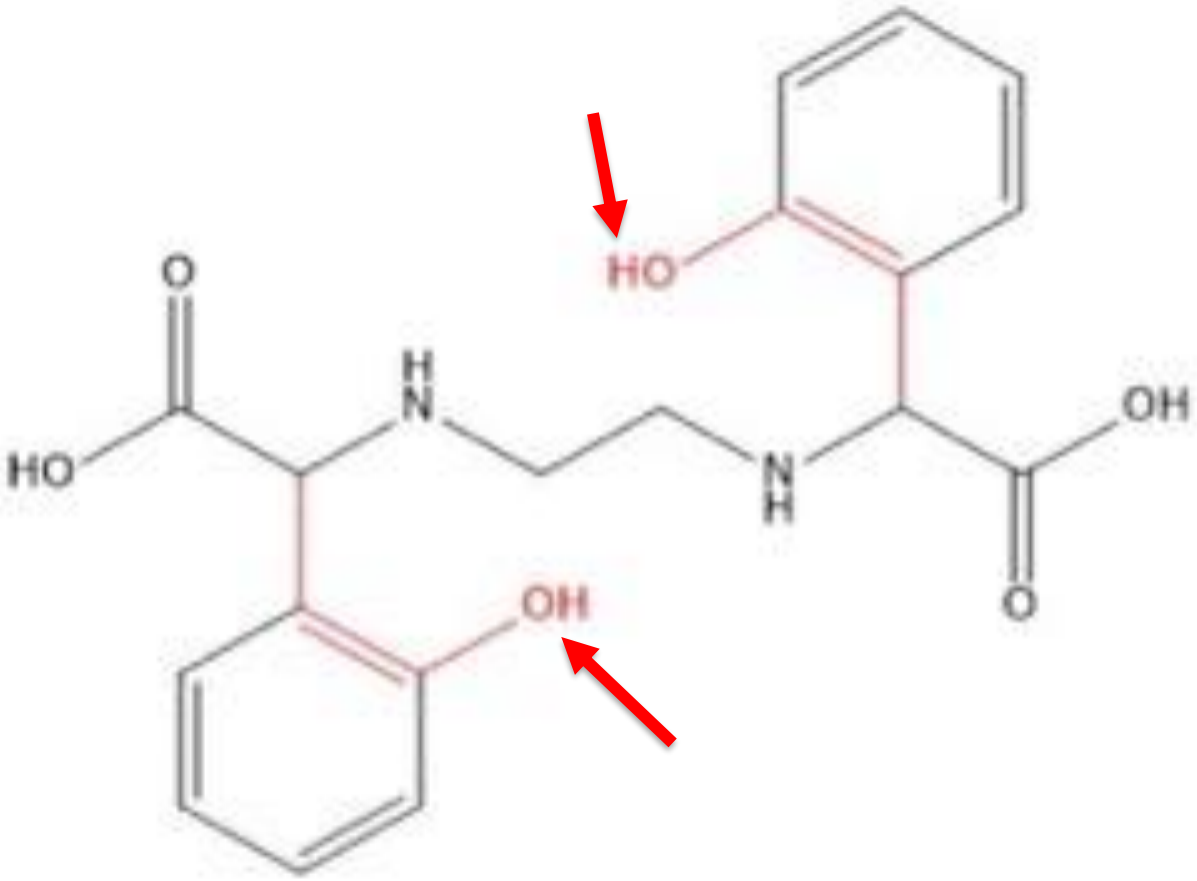
ortho-ortho EDDHA, 35.09

- Ortho-ortho EDDHA ”grabs” iron at six locations:



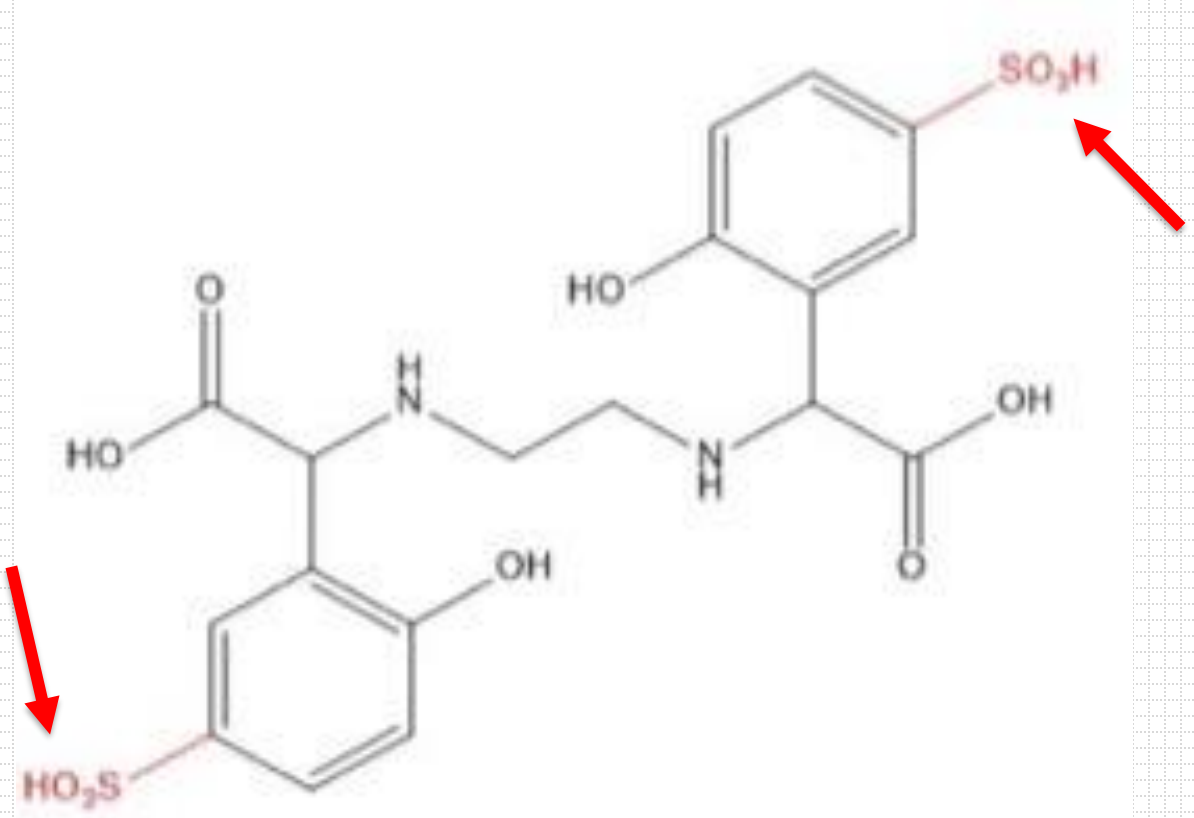
ortho-ortho EDDHA, 35.09

- It’s the Fe-phenyl group bonds that make the chelate “red”



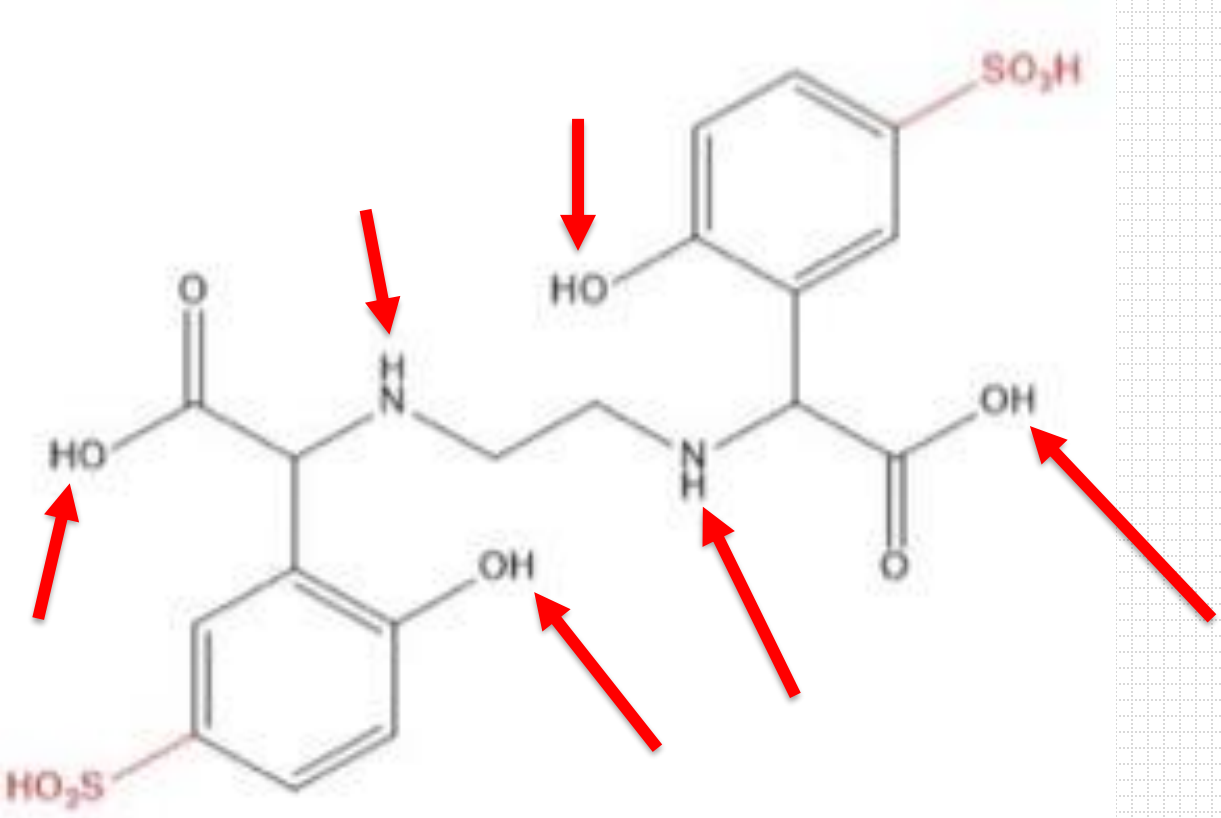
ortho-ortho EDDHA, 35.09

- EDDHSA is very similar to EDDHA, except it has two $-SO_3$ groups, that make it easier to dissolve in water



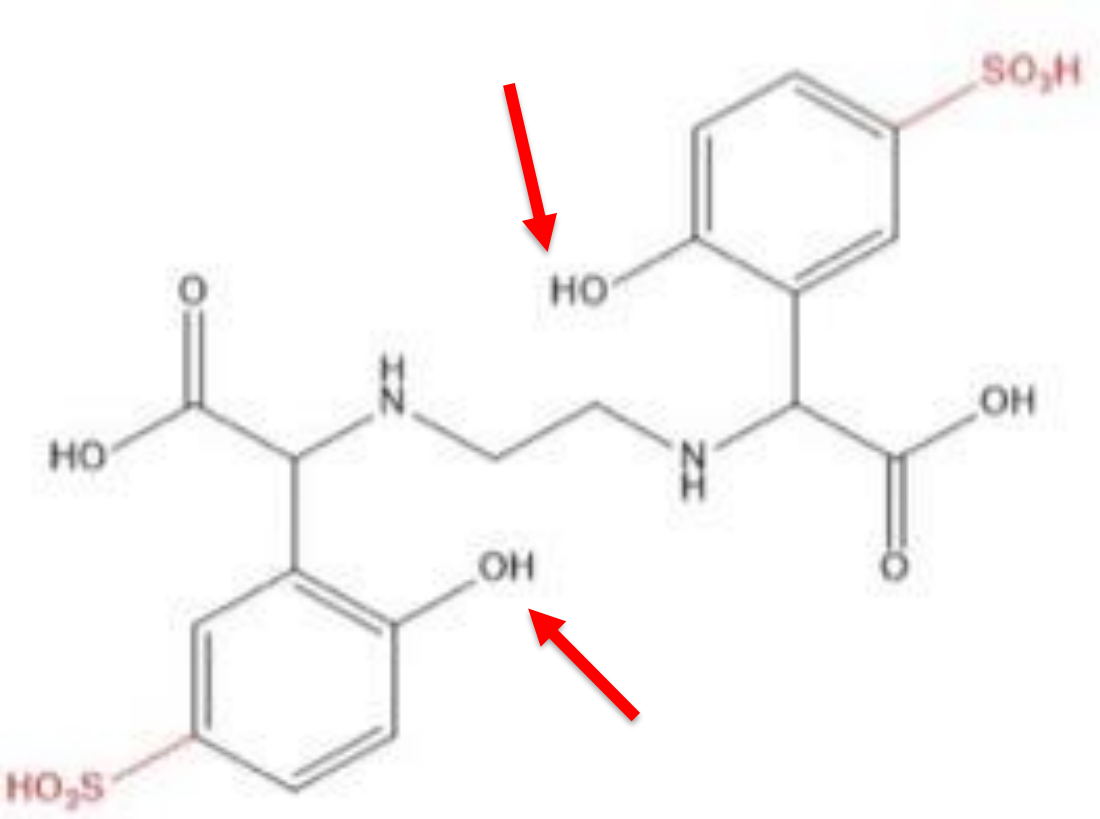
ortho-ortho EDDHSA, 32.79

- EDDHSA also grabs iron at six different locations, but somewhat less strongly than FeEDDHA



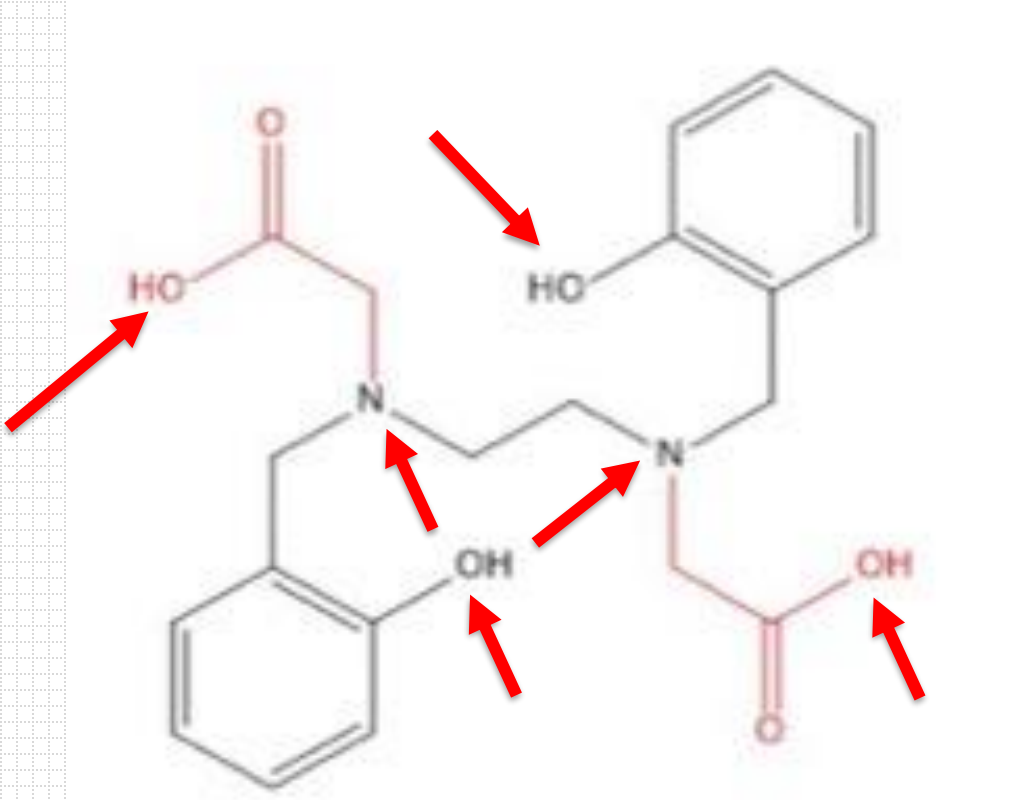
ortho-ortho EDDHSA, 32.79

- Again, with the same Fe-phenyl group bonds that makes the chelate “red”



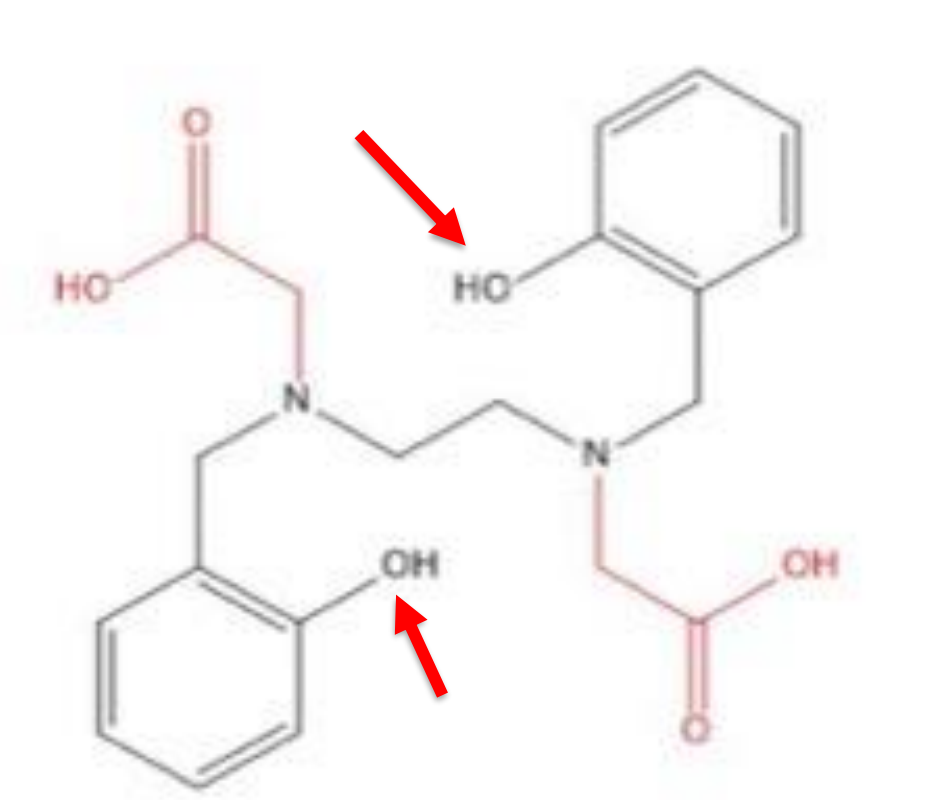
ortho-ortho EDDHSA, 32.79

- HBED also “grabs” iron six ways,



HBED, 39.01

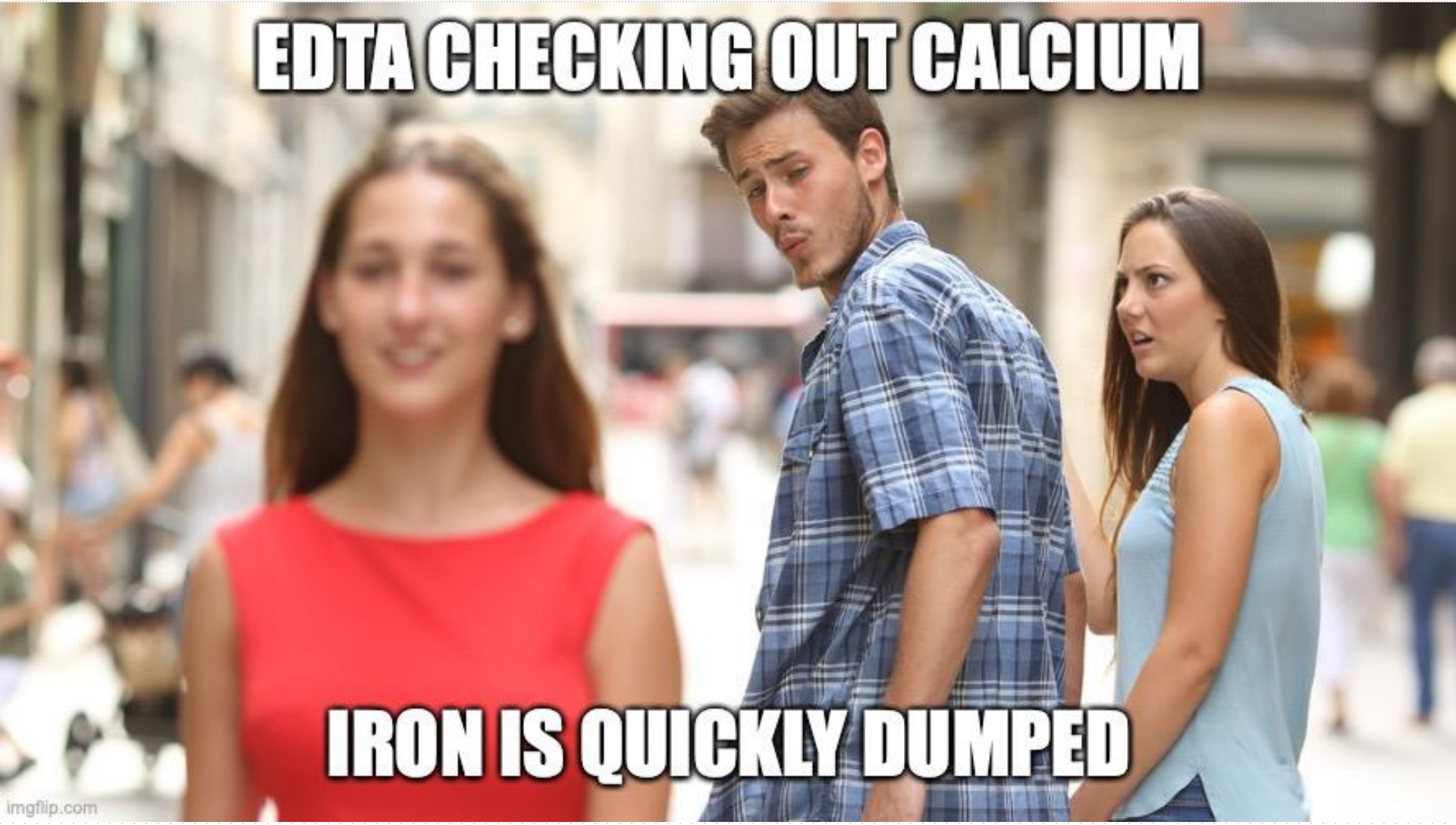
- Again, it's the Fe-phenyl group bonds that makes FeHBED a "red" chelate



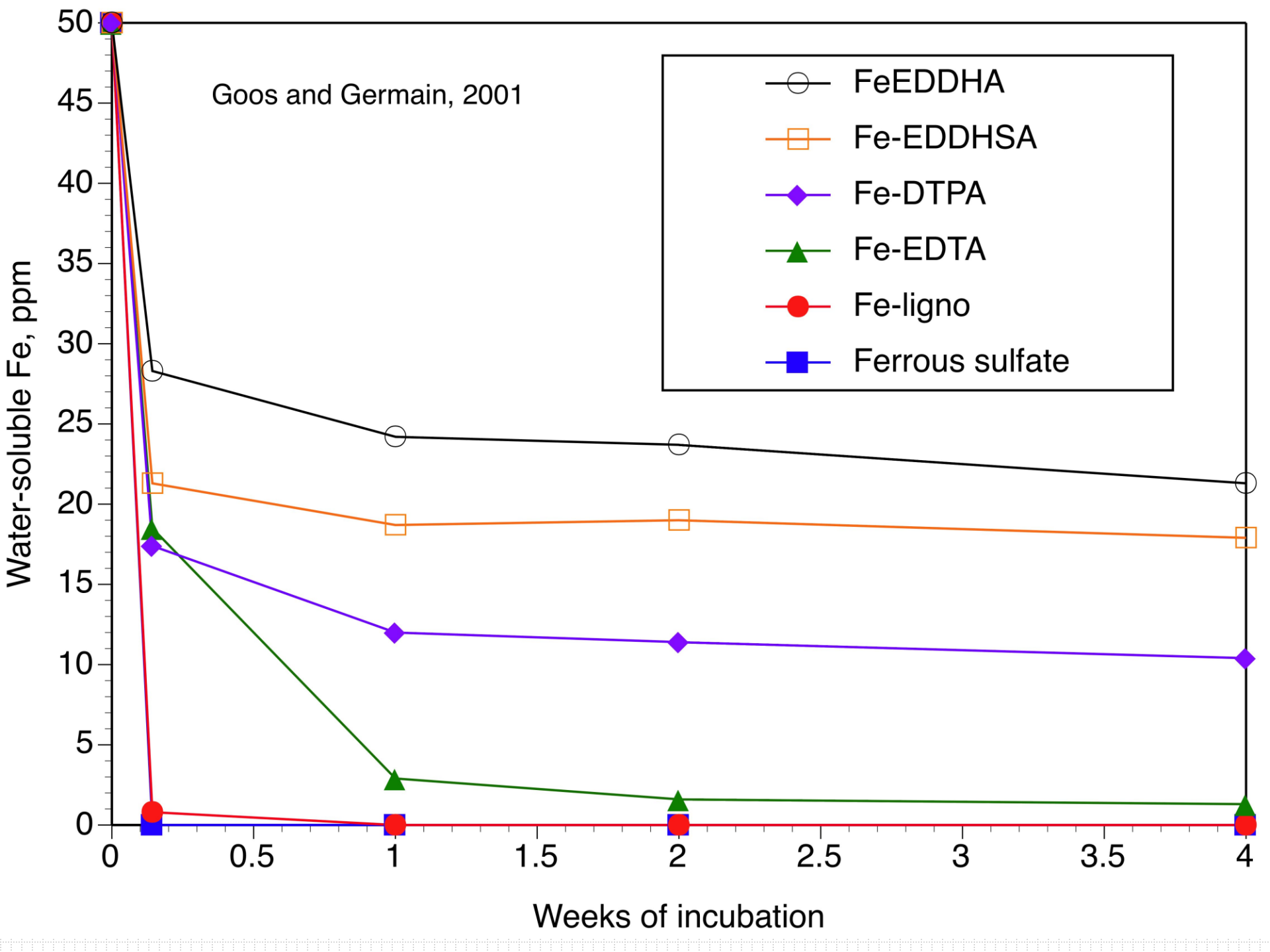
HBED, 39.01

- HBED has a greater *stability constant* for Fe^{3+} than EDDHA
- What is a "stability constant for Fe^{3+}"
- A ratio of chelated Fe^{3+} to non-chelated Fe^{3+} under a standardized set of conditions
- And, stability constants are BIG numbers, so much so, that we use the $\log_{10}$ versions
- Fe^{3+} would prefer to be bound by EDDHA over free Fe^{3+} by a factor of more than
- 1,000,000,000,000,000,000,000,000,000,000,000

- Approximate $\log_{10}$ stability constants
- FeHBED, 39.7
- ortho-ortho FeEDDHA, 35.1
- FeEDDHSA, 32.8
- DTPA, 27.5 (not a red chelate)
- EDTA, 25.1 (not a red chelate)
- Stability constant is important, but also selectivity for iron, for example, EDTA LOVES calcium, too, so this is what happens to Fe-EDTA in the soil….


EDTA CHECKING OUT CALCIUM
IRON IS QUICKLY DUMPED
imgflip.com

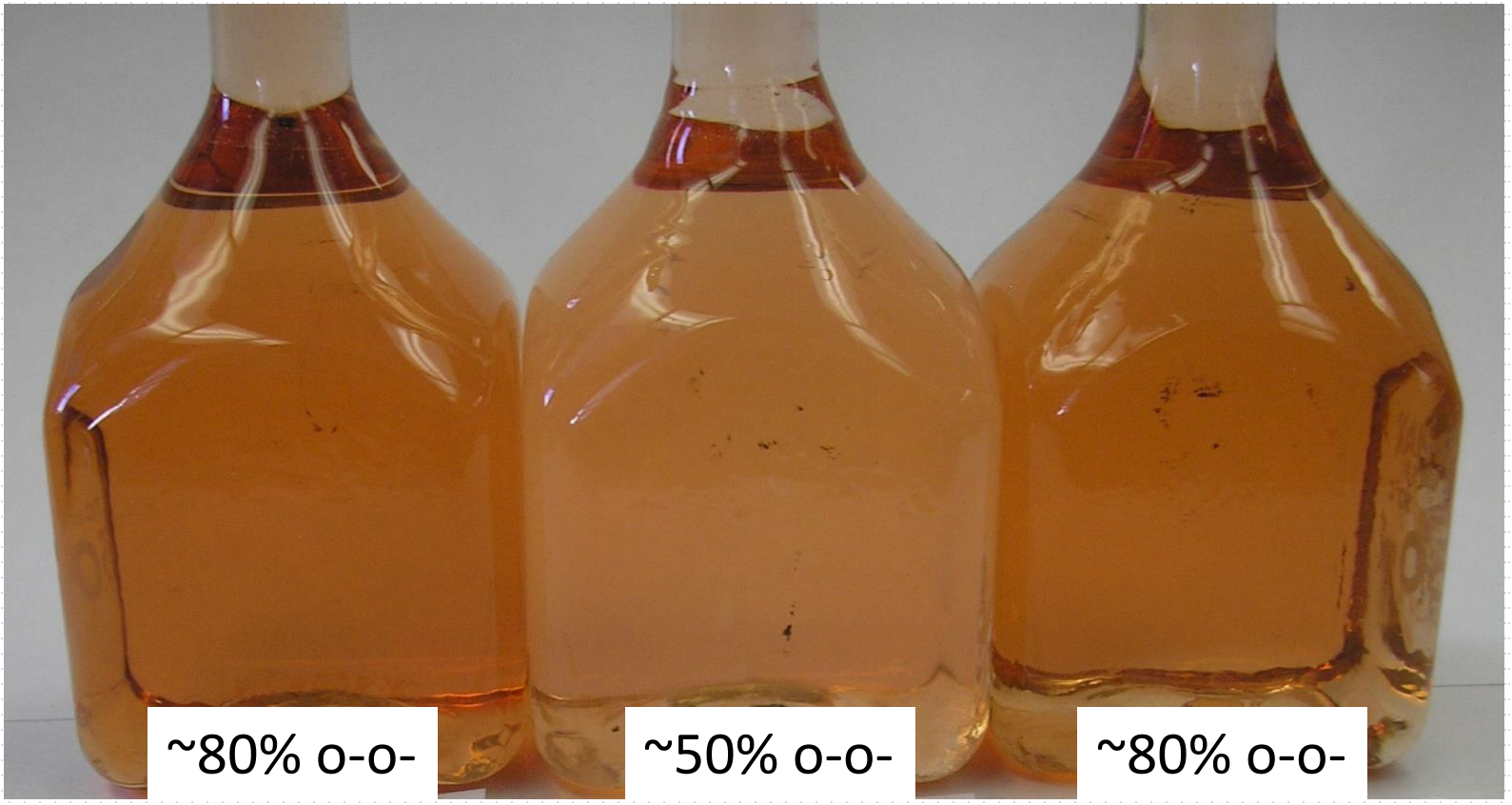
- An early experiment with iron, 20+ years ago
- Different sources added to soil at 50 ppm
- Water-soluble Fe determined at 1 day, and periodically afterwards
- Included inorganic ferrous sulfate
- Included Fe-lignosulfonate, a complex
- Included chelates
- Fe-EDTA
- Fe-DTPA
- Fe-EDDHSA, FeEDDHA


Goos and Germain, 2001
FeEDDHA
Fe-EDDHSA
Fe-DTPA
Fe-EDTA
Fe-ligno
Ferrous sulfate
Water-soluble Fe, ppm
Weeks of incubation
0
5
10
15
20
25
30
35
40
45
50
0
0.5
1
1.5
2
2.5
3
3.5
4

- The stability constant for FeHBED is about 10,000 times higher than for FeEDDHA
- It should be better than FeEDDHA, but is it??
- One of my last experiments at NDSU, before I retired

- Objective of the experiment
- Evaluate four iron fertilizers under both lab and greenhouse conditions
  - FeEDDHA-1, ~80% ortho-ortho
  - FeEDDHA-2, ~50% ortho-ortho
  - FeEDDHSA
  - FeHBED

- Laboratory test…
- Incubate the soil with 12 ppm of Fe, and see how much remains soluble after 1 week
- “Soil-stable” Fe

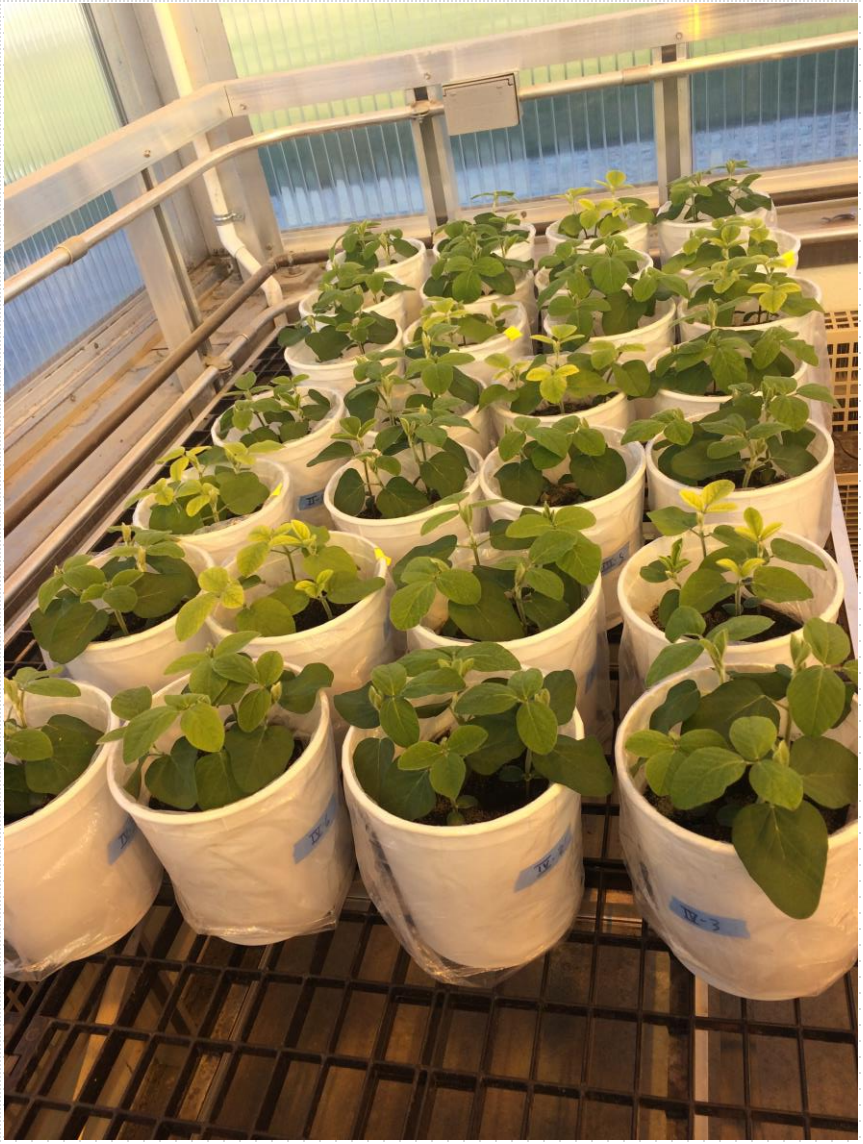


Product	% Fe on label	% water-soluble Fe	% soil-stable Fe	% of water soluble soil-stable
FeEDDHA-1	6	6.4	5.3	83
FeEDDHA-2	6	6.3	3.0	48
FeEDDHSA	6	6.0	2.1	35
FeHBED	3	3.3	2.8	85

- Greenhouse study
- 2 ”crops” grown to full 3rd trifoliolate stage
- 0.5 mg Fe/pot, according to % Fe on label
- Chlorophyll, dry matter, Fe uptake measured
- Four replicates

- Why we test in the greenhouse…

- Overview of the first “crop” in progress



- Control, crop 1

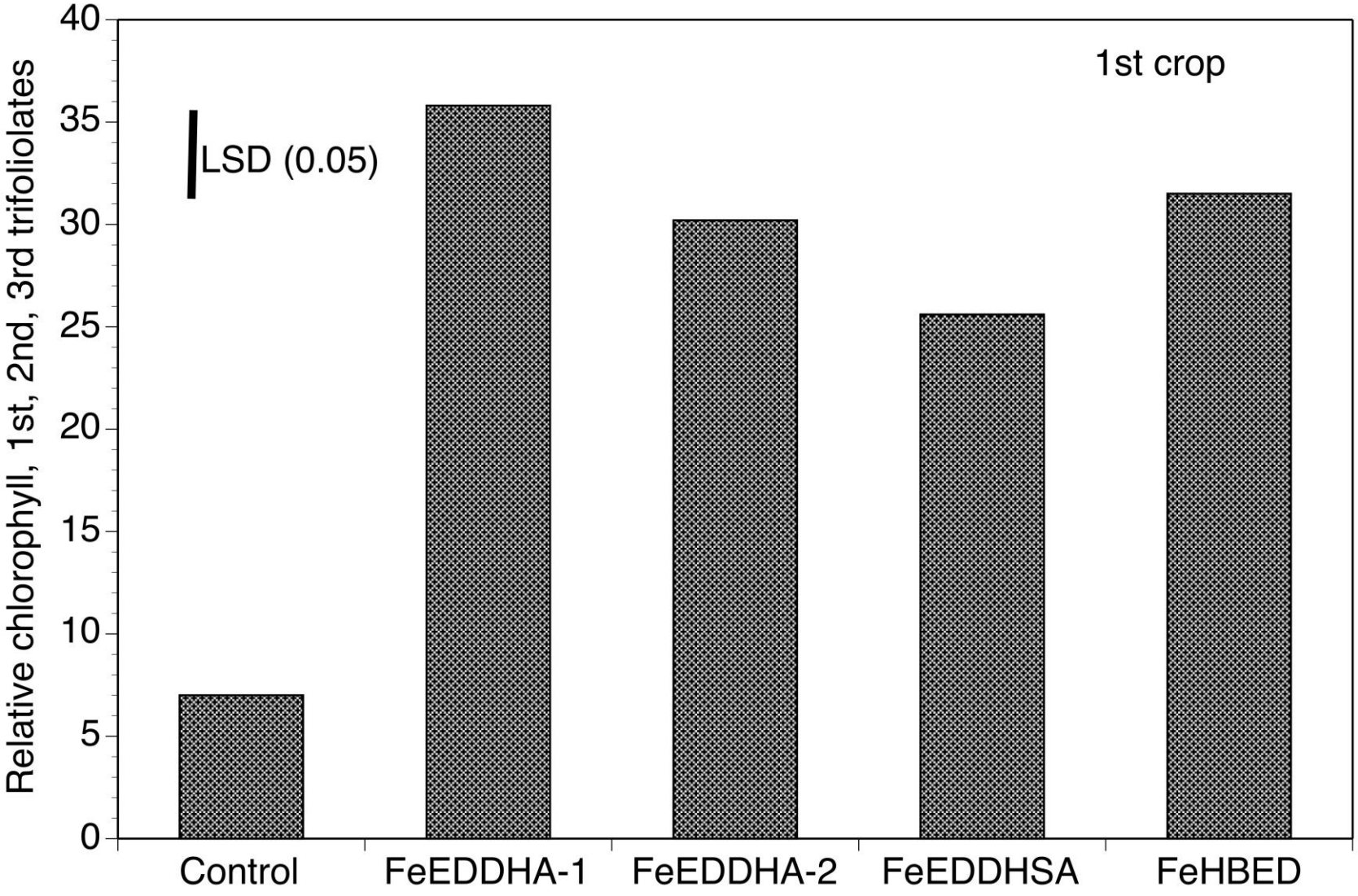
- FeEDDHA-1

- FeEDDHA-2

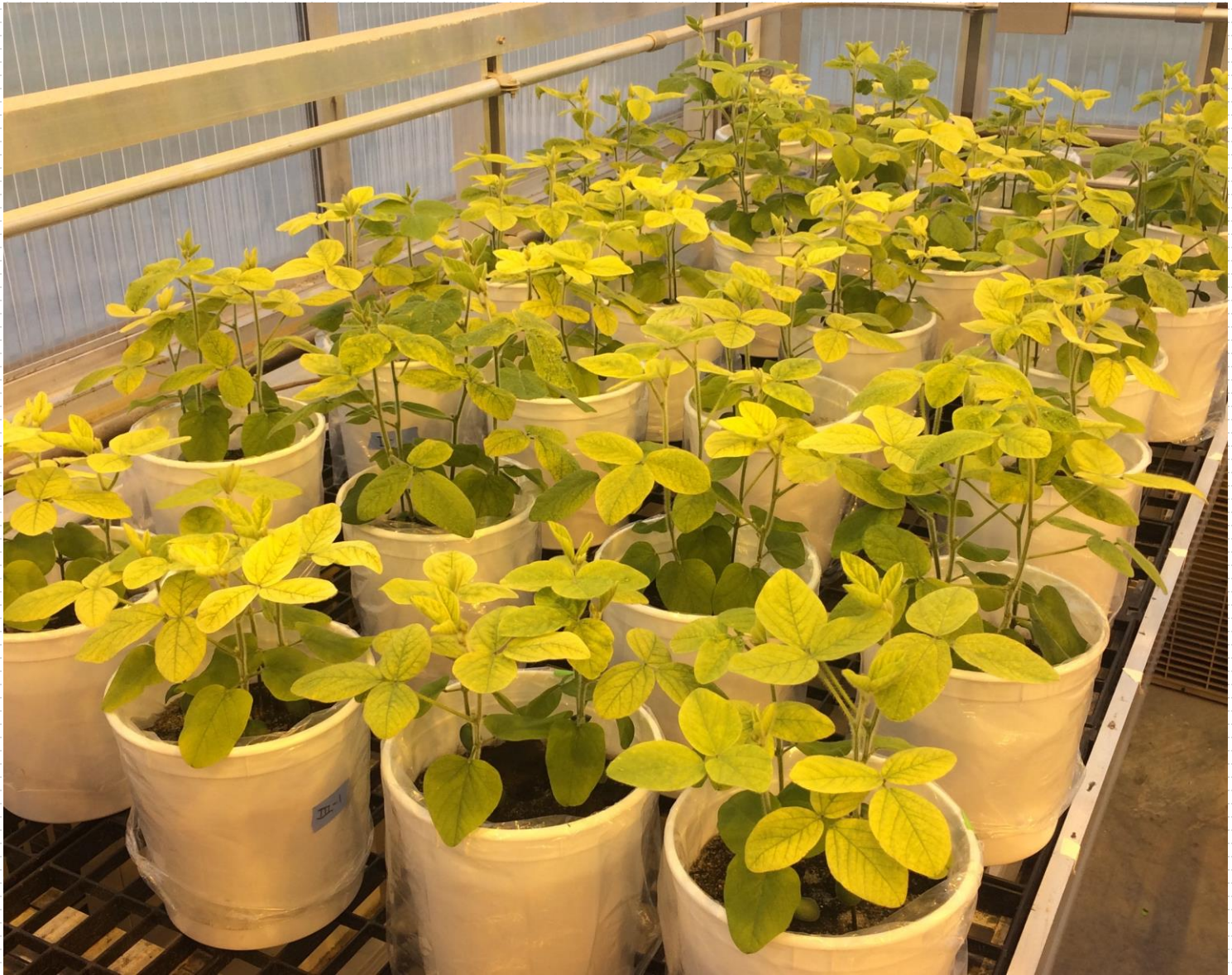
- FeEDDHSA

- FeHBED

- Relative chlorophyll values, 1st, 2nd, 3rd trifoliolate leaflets, by Minolta SPAD meter

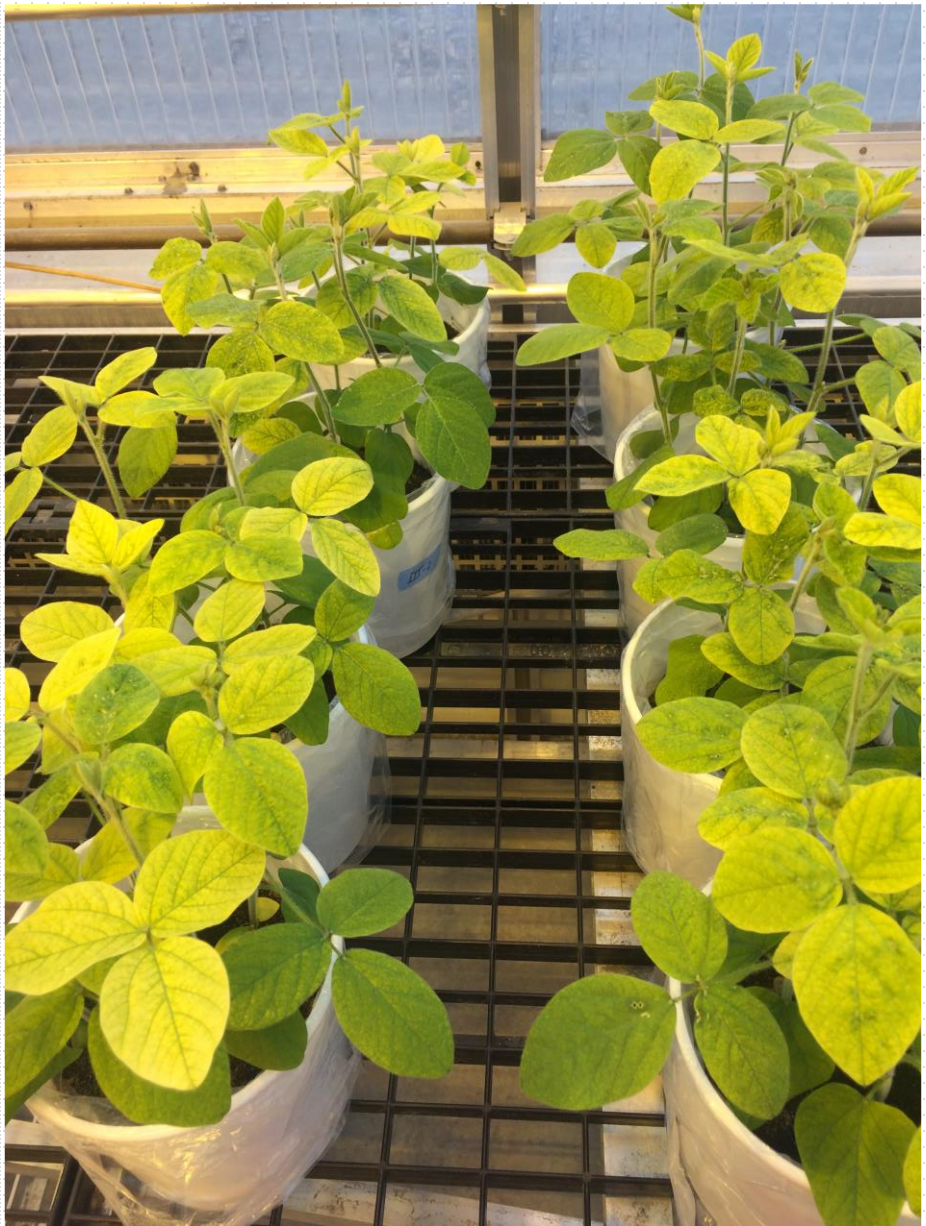


- Overview, 2nd crop

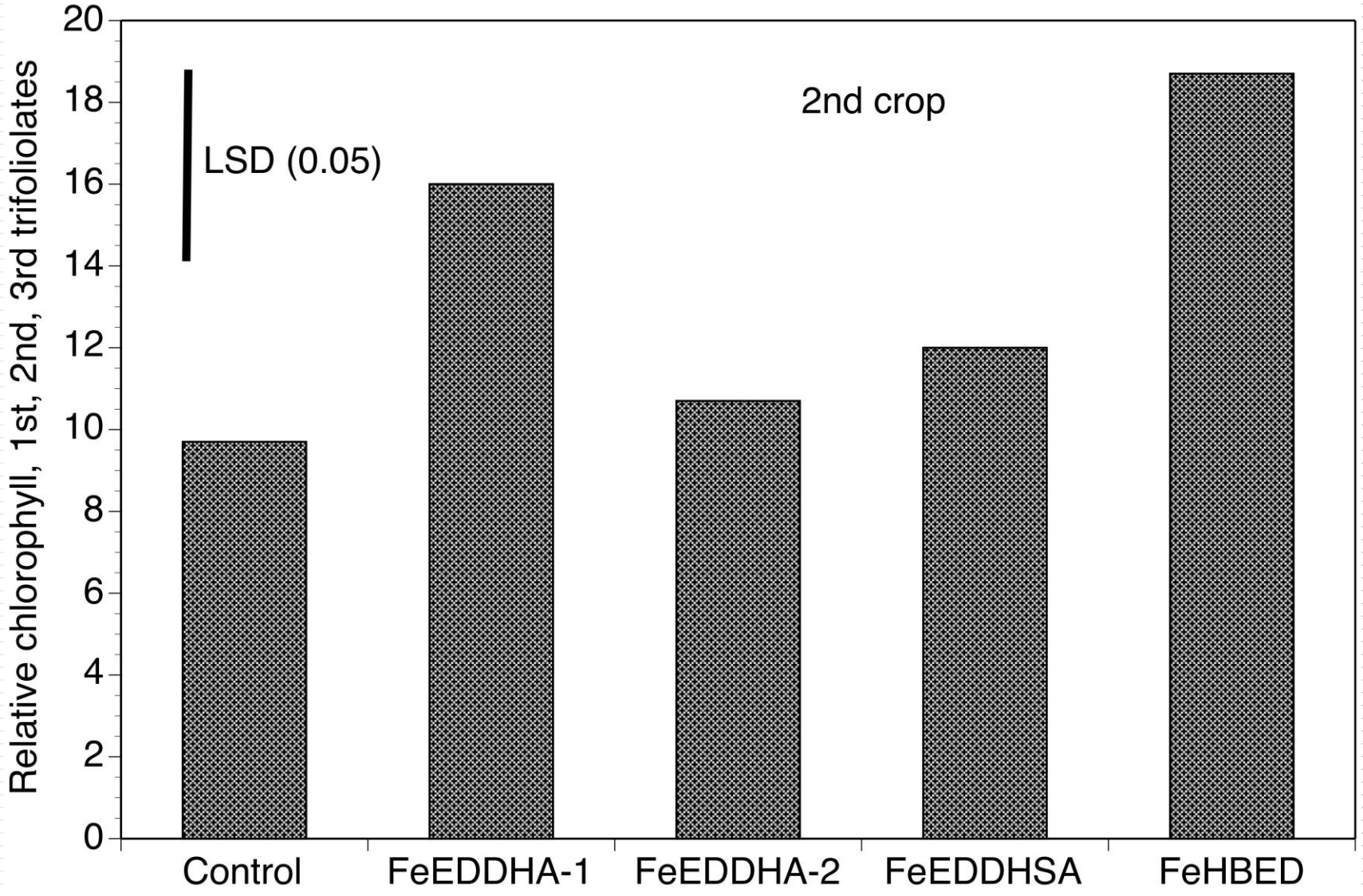


- Control (left) vs. FeEDDHA-1 (right)

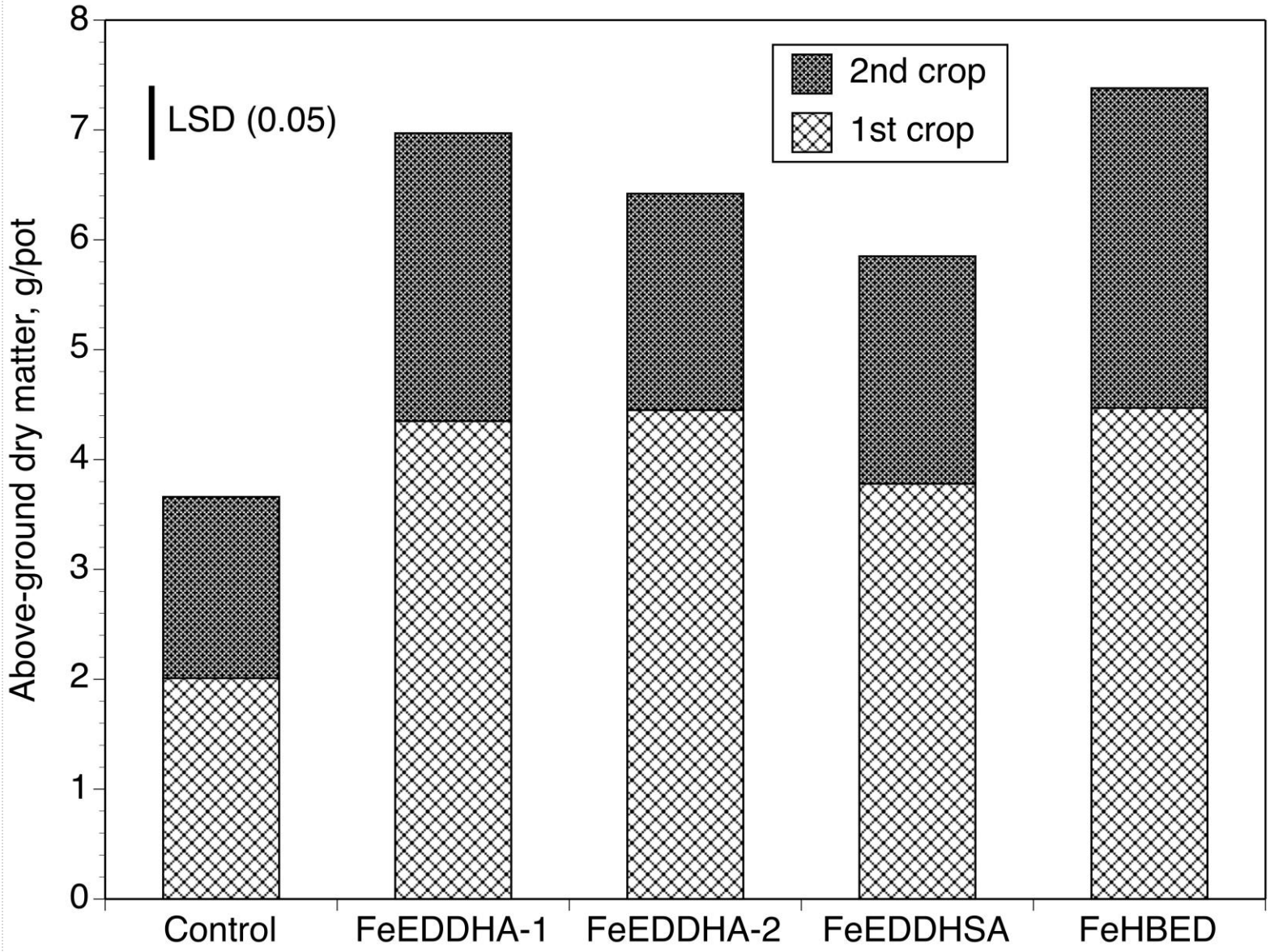
- FeEDDHA-1 (left) vs. FeHBED (right)



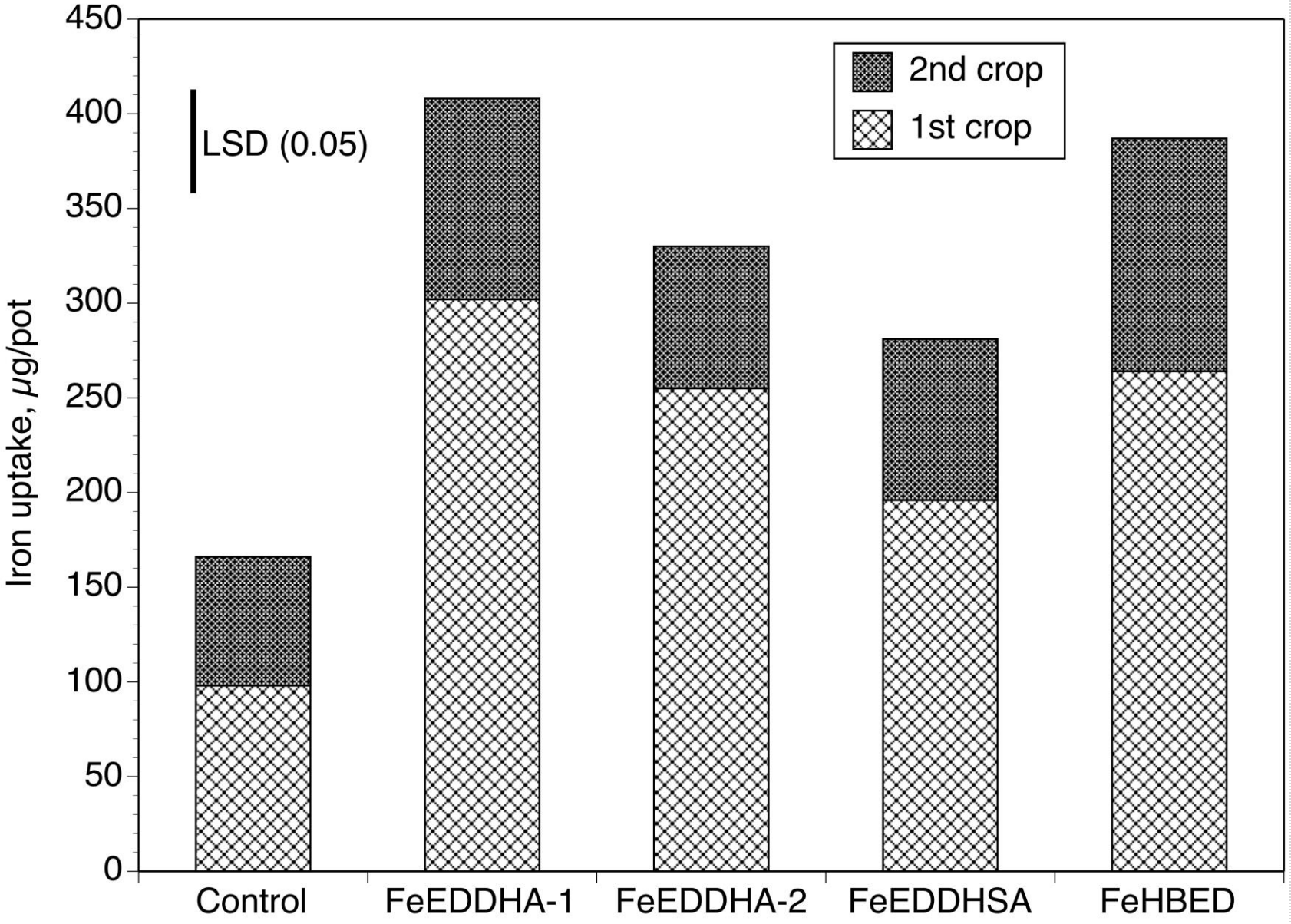
- Relative chlorophyll values, 1st, 2nd, 3rd trifoliolate leaflets, by Minolta SPAD meter



- Dry matter production, 1st and 2nd crop



- Iron uptake 1st plus 2nd crops



- So, the FeHBED product we tested was, overall, equal to a high-quality FeEDDHA product
  - FeEDDHA a little better, first crop
  - FeHBED a little better, second crop
- FeHBED marketing saying it is better than a high-quality FeEDDHA…..I didn't observe that
- Conclusion…it's all good
  - With regards to FeEDDHSA and lower o-o-FeEDDHA, just use a higher rate

- So…what do you do if you thought you had selected a variety with good IDC resistance, and you get chlorosis anyway
- What about “rescue treatments?”
- My hypothesis
  - Treat the foundational problem, AND the secondary effects
  - Medical analogy…

- Study in 2022, 1 lb/A FeEDDHA rescue treatment, centered on row
- With and without 3 lb/A FeEDDHA at planting
- With and without ”recovery additives”
- Applied at 2-3 vs 4-5 trifoliolate stage
- Site with severe IDC by Glyndon, MN
- No sponsor, just my own work

- What are “recovery additives?”
- Compounds that help treat the secondary effects of Fe deficiency

- Results where FeEDDHA not applied at planting
- Effect of FeEDDHA very apparent, to the row, at ~2 trifoliolate stage

- The soybeans without FeEDDHA at planting, mostly died

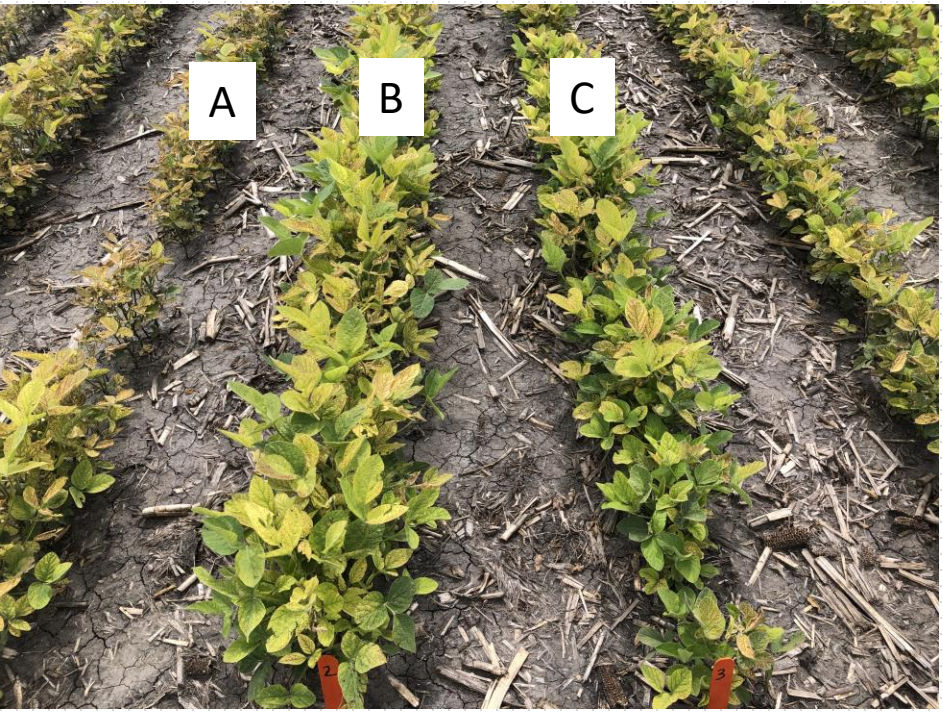
- The effect of FeEDDHA at planting faded, but there was some recovery later

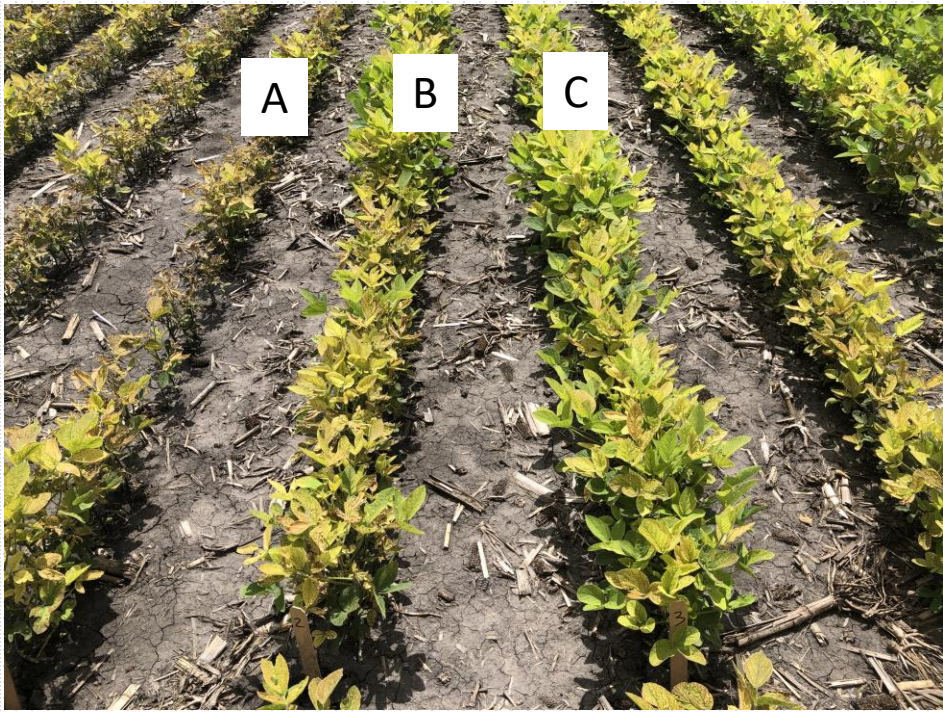
- Results where no FeEDDHA was applied at planting
- Plants already showing necrosis at ~2-3 trifoliolate stage

- #2. Results where no FeEDDHA was applied at planting
- 1 spray at ~2 trifoliolate stage
- 2 lb/A of a Fe-complex, Control, 1 lb/A of FeEDDHA

- Results where FeEDDHA was applied at planting
- Plants had some chlorosis, but not necrosis at 2-3 trifoliolate stage

- 4 weeks after spraying at ~2-3 trifoliolate stage
- Control, FeEDDHA, FeEDDHA + Additive 1
- With 3 lb/A of FeEDDHA at planting





- But….did a spray at the ~4-5 trifoliolate stage work better?
- A=No spray
- B=1 lb/A FeEDDHA + Additive-2
- C=1 lb/A FeEDDHA
- D=1 lb/A FeEDDHA + Additive-3
- Just a strip trial
- Will continue to study Additive-2

- Conclusions (?) after 2022
- Variety was very weak
- Soybeans died without FeEDDHA at planting, spray didn’t help much
- With FeEDDHA at planting, a foliar spray at 4-5 trifoliolate seemed to work better than at 2-3 trifoliolate
- The search for “recovery additives” continues

- So, what about me?
- I retired from NDSU on 1 September 2021
- I am doing some consulting work and public speaking
- Continuing to look for answers with regards to IDC