Mn Deficiency: Causes, Diagnosing, and Correcting (Plus, Phosphorus, Sulfur, and Zinc)

David Moseley, Kylie Miller, Randy Price, Rasel Parvej

Diagnosing Symptoms

- **Deficiency symptoms**
  - Manganese (Mn): Interveinal chlorosis first in younger leaves
  - Zinc (Zn): Stunted plants; smaller leaves; short internodes; interveinal chlorosis first in younger leaves
  - Sulfur (S): Overall yellowing of leaves
  - Phosphorus (P): Stunted plant; distorted leaf shapes
- **Soil-test for the on-farm trial:**
  - Collected from 0 – 6-inch depth
  - Be careful that recommendations are valid (soil lab and interpretations)
    - Dr. Rasel Parvej (LSU AgCenter State Soil Fertility Specialist)

Phosphorus (P) Recommendations

Based on Mehlich-3 Soil-Test P Concentration

	Soil-Test Level	Mehlich-3 Soil-P Conc. (ppm)	Number of Sites (#)	Range of Yield Increase from P Fertilization		Yield Increase Probability (%)	Recommended P Rate (lb P_2O_5 $acre^{-1}$)
				(bu/A)	(%)		
≤ 20 lb/A	Very Low	≤ 10	1	10	17	100	90
22-40 lb/A	Low	11 – 20	20	1 – 20	2 – 32	80	60
	Medium	21 – 30	21	1 – 11	1 – 17	19	40
	Optimum	30 – 50	14	0 – 8	0 – 14	7	0
	Very High	> 50	5	1 – 5	2 – 5	0	0

Dr. Rasel Parvej, LSU AgCenter State Soil Fertility Specialist

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Sulfur and Zinc Recommendations

- **Sulfur**
  - Application recommended if below **24 lbs/acre** (Apply 20 lbs S as sulfate per acre)
  - Products
    - Gypsum (16% S)
    - Ammonium sulfate (21-0-0-24 S)
    - Some soil applied S sources (K thiosulfate; Mg thiosulfate)
- **Zinc**
  - Applications recommended according to soil-test Zn concentration
  - (Soil concentration : Recommendation)
    - **2 lbs Zn/acre** : apply 10 lbs Zn per acre
    - **2-5 lbs Zn/acre** : apply 5 lbs Zn per acre
    - >5 lbs Zn/acre : No application of Zn fertilizer

Parvej, R. (2021). Fertilizer Recommendations for Soybean. LSU AgCenter.

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Causes of Mn Deficiency

- Causes:
  - Low Mn soil content (<50 lbs/acre – suggested threshold – Dr. Parvej)
    - No actual threshold established
  - High pH (soil pH is above 6.6 or 6.8) (Use variable rates when applying lime)
  - Droughty soil conditions (Causes 'yellow flash')
    - Plant can recover quickly after a rain

Vyn, T. (2009). Manganese Deficiency in Soybeans? Experts Advise Foliar Application. Purdue University.

Causes of Mn Deficiency

- Most common nutrient deficiency seen in soybeans in Michigan
- Soil conditions that favor deficiency:
  - Muck or dark-colored sands with pH > 5.8
  - Lakebed or out-washed soils with pH > 6.5
  - Coarse-textured soils with low organic matter pH> 6.5

Staton, M. (2023). Identifying and correcting manganese deficiency in soybeans. Michigan State University Extension

Glyphosate-induced Nutrient Deficiency

Glyphosate can reduce the root uptake and translocation of iron (Fe), manganese (Mn), and zinc (Zn)

Huber, D. (2007). What About Glyphosate-Induced Manganese Deficiency. Fluid Journal.

Addressing Multiple Nutrient Deficiencies: An On-Farm Case Study

- Farm on the Louisiana Delta Plantation
- Collaborators: Steve Crawford, Lawrence Perritt, Allen Perritt, Charlie Riggs
- Began as a manganese deficiency demonstration
- Low soil content:
  - P, S, Zn
  - Mn (suggested)
- Wanted to apply foliar products
  - In-furrow at planting
  - In-season

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Soil Texture

FieldID	Plot #	SoilType	% Sand	% Clay	% Silt	% Silt + Clay
121	5	CLAY	7.92	74.36	17.72	92.08
121	17	CLAY	8	72.28	19.72	92
121	29	CLAY	11.92	78.28	9.8	88.08
122	2	CLAY	12.08	70.24	17.68	87.92
122	15	CLAY	7.72	84.6	7.68	92.28
122	29	CLAY	8.16	72.24	19.6	91.84

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Soil Test Results

Field	Plot	Treatment	pH (Soil)	pH (Buffer)	P	S	Zn	Mn	K	Mg	B	Fe	Cu	Na	OM
									lbs/A						%
121	5	Control	6.6	7.15	8	11	3.2	30	543	2925	1.6	408	7.3	254	2.79
121	17	Control	7	6.95	6	12	2.5	26	494	3065	1.4	339	6.6	250	3.07
121	29	Control	6.5	7	13	14	3.1	18	583	3626	1.8	384	7.4	305	3.42
122	2	Control	6.1	6.65	26	11	4.5	16	575	2587	1.5	478	6.7	162	3.7
122	15	Control	6.2	6.85	30	10	6	13	570	2849	1.8	551	8.2	222	3.86
122	29	Control	6.8	6.9	16	11	3.4	8	534	2539	1.6	460	6.4	171	3.47

Very Low
Low
Optimum

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On-Farm Nutrient Deficiency Demonstration

- **Farmer's Original Questions**
  - What product(s) and application timings can mitigate manganese (Mn) deficiency?
  - Does spraying glyphosate induce additional Mn deficiency?
  - Can we mitigate yield loss from Mn deficiency and maintain profits?
- **Are there more yield limiting factors than Mn?**

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Treatments With Mn, S, Zn, and/or P_2O_5 from Four Companies (Application Timings: Planting, V4, and R5.5)

Trt	Mn Trts	Total Mn	S Trts	Total S	Zn Trts	Total Zn	P trts	Total P	Timing
	Fertilizer Applications (lb/A)								
1	Control (All plots had a seed treatment with trace Mn)								
2	0.06	**0.17**	0.03	**0.09**	0.001	**0.0011**	0	**1.56**	Planting
	0.06		0.03		0		0		V4
	0.06		0.03		0		1.56		R5.5
3	0.02	**0.04**	0.04	**0.12**	0.048	**0.142**	0	**1.56**	Planting
	0.01		0.04		0.047		0		V4
	0.01		0.04		0.047		1.56		R5.5
4	0.06	**0.18**	0.04	**0.11**	0.0012	**0.0012**	0	**1.56**	Planting
	0.06		0.04		0		0		V4
	0.06		0.04		0		1.56		R5.5
5	0.5	**1**	0.3	**0.58**	0	**0**	0	**0**	Planting
	0.5		0.3		0		0		V4
6	1	**3**	0.6	**1.74**	0	**0**	0	**0**	Planting
	1		0.6		0		0		V4
	1		0.6		0		0		R5.5
7	0.08	**0.08**	0	**0**	0	**0**	0	**0**	Planting

Trt	Mn Trts	Total Mn	S Trts	Total S	Zn Trts	Total Zn	P trts	Total P	Timing
	Fertilizer Applications (lb/A)								
8	0.3	**0.42**	0	**0**	0	**0**	0	**0**	Planting
	0.08		0		0		0		V4
	0.08		0		0		0		R5.5
9	0.1	**0.28**	0	**0**	0.071	**0.143**	0	**0**	Planting
	0.1		0		0.036		0		V4
	0.1		0		0.036		0		R5.5
10	0.1	**0.32**	0	**0**	0.071	**0.123**	0	**0.21**	Planting
	0.11		0		0.026		0.11		V4
	0.11		0		0.026		0.11		R5.5
11	0.59	**1.1**	0	**0**	0	**0.0013**	0	**0.203**	Planting
	0.52		0		0.0013		0.2		V4
12	0.52	**1.04**	0	**0**	0	**0.0013**	0	**0.203**	Planting
	0.52		0		0.001		0.2		V4
13	0.14	**0.7**	0.08	**0.41**	0.003	**0.0155**	0.11	**0.525**	Planting
	0.28		0.16		0.006		0.21		V4
	0.28		0.16		0.006		0.21		R5.5

On-Farm Nutrient Deficiency Demonstration

- Catahoula Parish (Louisiana Delta Plantation)
  - Field 121: No glyphosate; furrow irrigated; soybean after corn
  - Field 122: Glyphosate; pivot irrigation; soybean after soybean
- Planted: (May 1 and May 2) at 130,000 seeds/acre
  - MG 4.6 XF variety
- 13 fertilizer treatments
  - 10 g/acre volume
  - In furrow at planting
  - Foliar at V3-V4 (May 31)
  - Foliar at R5.5 (July 25)

On-Farm Nutrient Deficiency Demonstration

2540 Feet	11	9	10	2	1	13	7	8	4	6	3	12	5	4	3	5	1	2	10	11	13	12	7	9	6	8	4	7	1	6	12	11	8	3	2	13	10	9	5
Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Rep	Rep 1													Rep 2													Rep 3												

Field 121

Each Strip = One Rep; Twelve 38" Rows = 38' Strips (Reps)

Furrow irrigated with a glyphosate application

2600 Feet	3	1	13	2	11	7	10	6	8	4	5	9	12	2	1	12	11	13	9	3	4	6	8	7	10	5	11	12	1	3	6	13	2	5	10	8	7	4	9
Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Rep	Rep 1													Rep 2													Rep 3												

Field 122

Each Strip = One Rep; Twelve 38" Rows = 38' Strips (Reps)

Overhead irrigation with no glyphosate application

On-Farm Nutrient Deficiency Demonstration

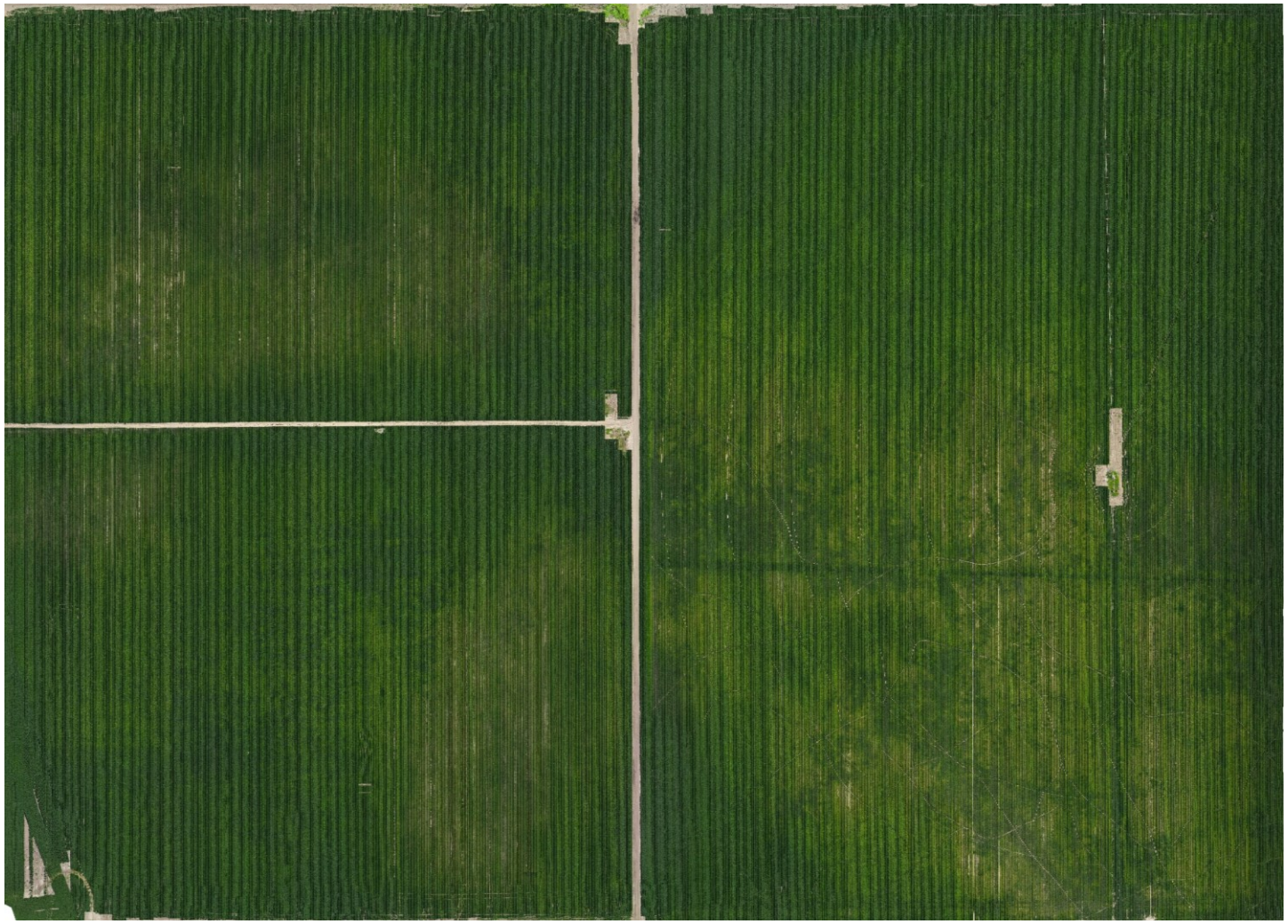
UAV images taken by Dr. Randy Price on July 8

Lower Yield **Higher Yield**

Higher Yield
Field 121 (No glyphosate)

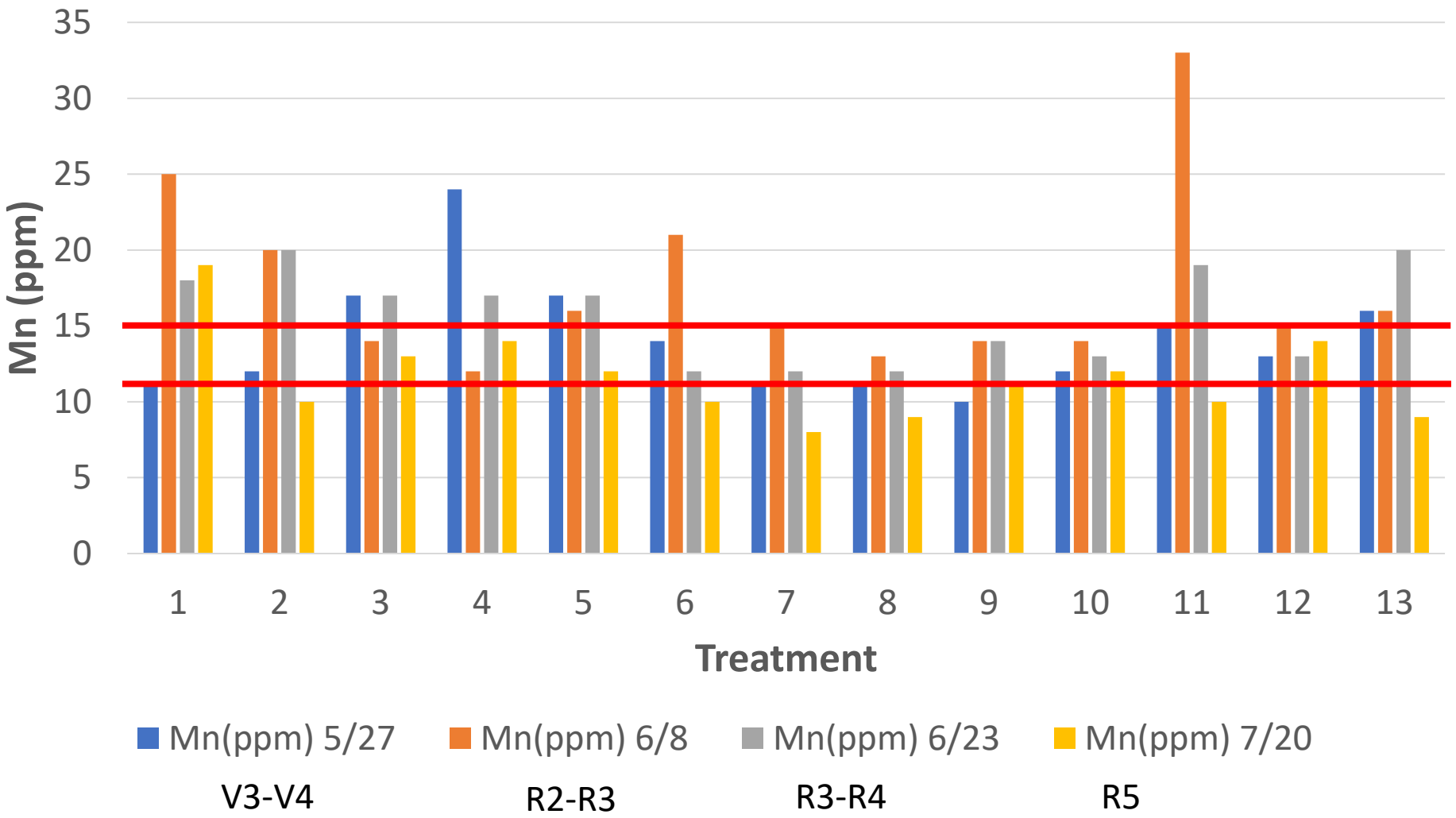
Lower Yield
Field 122 (glyphosate)

On-farm Demonstration Field on July 21, 2023



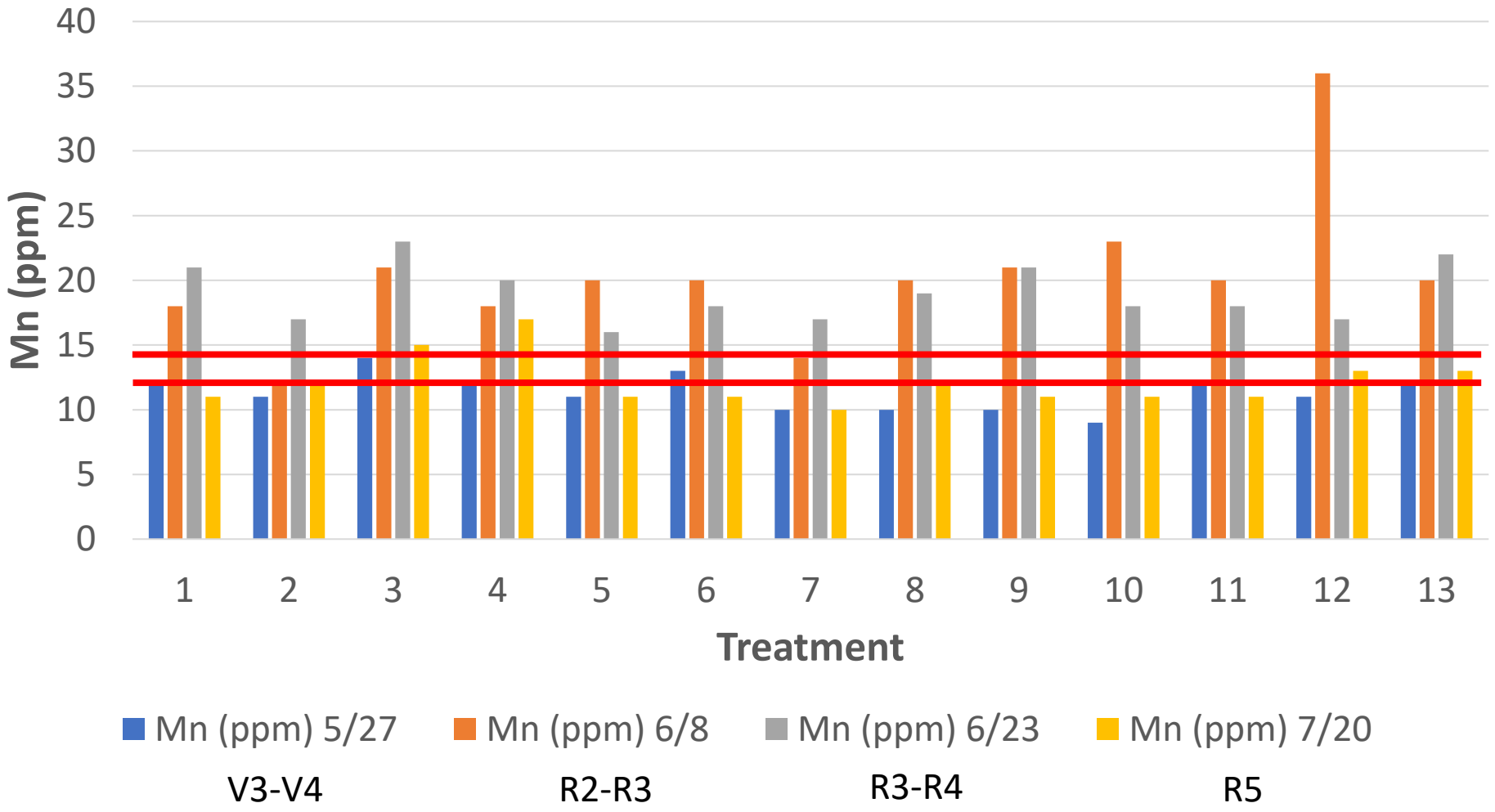
Mn Leaf Content Across the Growing Season (Field 121 – no glyphosate)

Applications Dates
May 1 – At Planting
May 31 – V3-V4
July 25 – R5



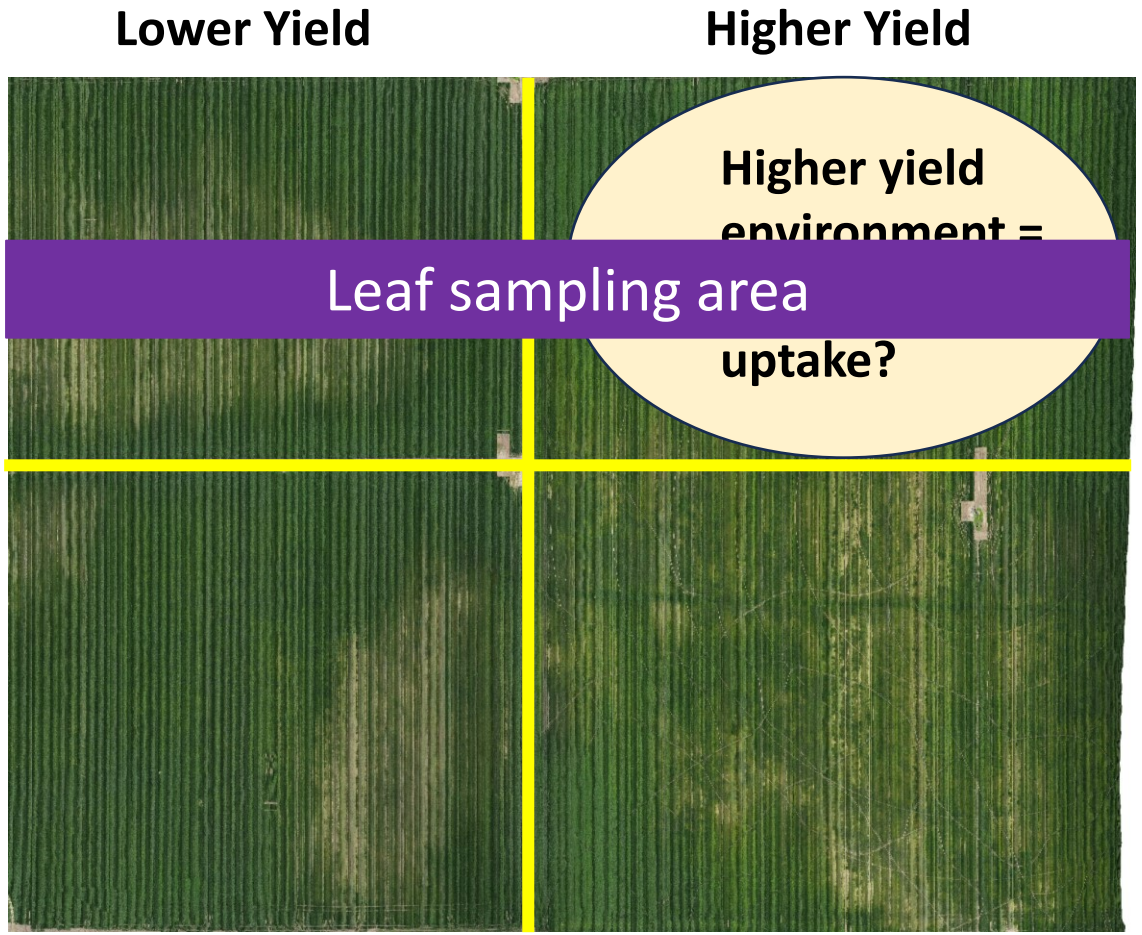
Mn Leaf Content Across the Growing Season (Field 122 – glyphosate application)

Applications Dates
May 1 – At Planting
May 31 – V3-V4
July 25 – R5



On-Farm Nutrient Deficiency Demonstration

UAV images taken by Dr. Randy Price on July 8



Samples from field 122 (glyphosate) were in a higher yield environment than from 121 (no glyphosate).

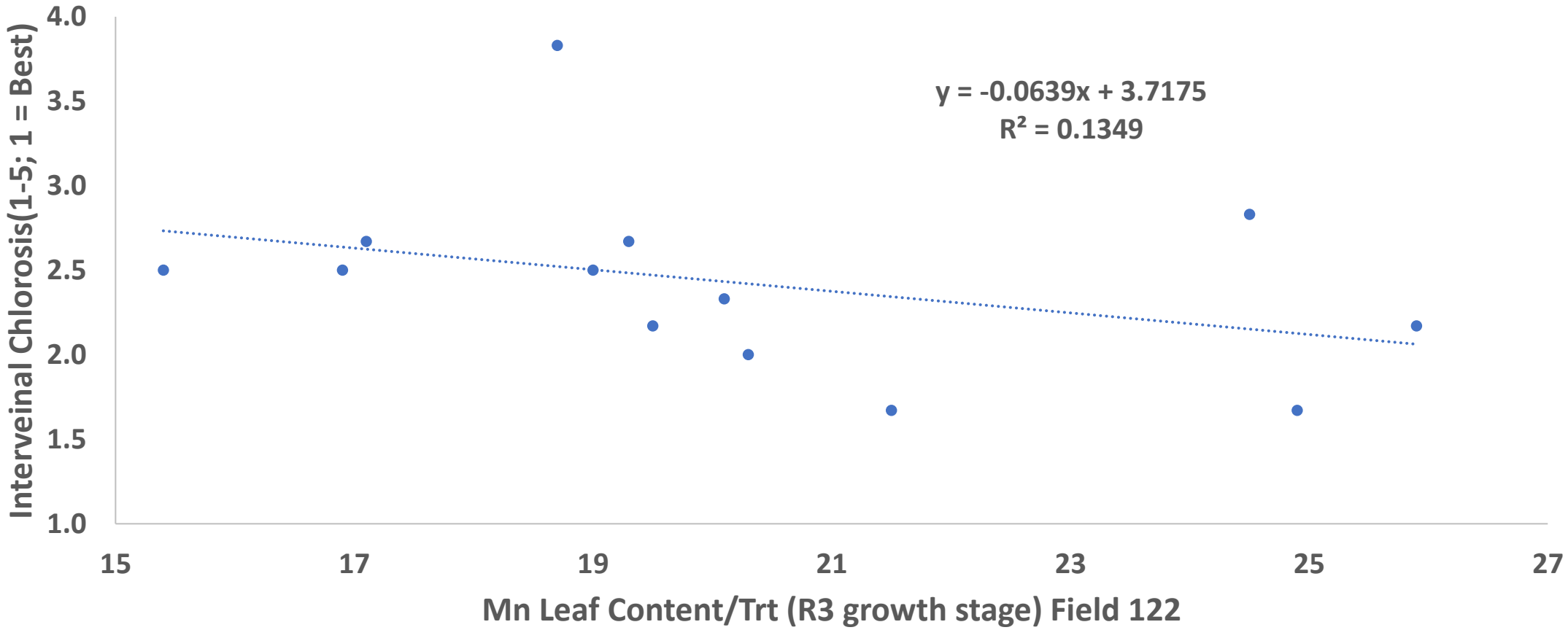
We need to analyze our UAV data. Leaf sampling is limited to the area sampled. UAV images can analyze the entire field.

Field 122 (glyphosate) Mn Deficiency Ratings

Trt	Interveinal Chlorosis Ratings (1-5; 1 = best) V1 Rating 16-May	V3-V4 Rating 26-May	R3 Rating 8-Jun	R3-R4 Rating 27-Jun	Mn (ppm) 8-Jun	Field 122 Yield (bu/a)
6	1	1.8	2.3	2.7	20.1	35.7
13	1	1.8	1.7	3.0	21.5	34.5
2	1	2.2	2.2	2.8	19.5	34.1
3	1	2.3	2.0	3.0	20.3	33.8
4	1	2.5	2.7	2.7	19.3	33.7
5	1	2.3	2.5	2.8	15.4	33.2
11	1	2.5	2.2	3.2	25.9	31.8
10	1	2.8	1.7	3.2	24.9	31.2
8	1	2.8	2.5	3.2	19	31.2
12	1	2.3	2.8	3.3	24.5	30.8
1	1	1.8	2.5	3.3	16.9	30.6
9	1	3.0	2.7	3.0	17.1	30.0
7	1	2.7	3.8	3.3	18.7	28.7
Average	**1**	**2.4**	**2.4**	**3.0**	**20.2**	**32.3**

V3-V4 had significant differences between treatments: LSD = 0.752 at P=.05

Field 122 (glyphosate) Mn Leaf Content at R3 and Interveinal Chlorosis Rating



1 lb Mn and 0.6 lb S each at planting, V4, and R5.5 (Source: MnSO4 powder)

Treatment	Yield (bu/a)
6	34.3
3	34.3
4	34.1
2	34.0
13	33.8
5	33.7
11	32.2
12	31.6
10	31.6
8	31.0
1	31.0
9	30.8
7	29.9

Control (Trace Mn seed trt)

0.08 lbs EDTA Mn at planting

Treatment Yield Average

Across both fields

6 Strips

Approximately 13 acres for each treatment

Mn, S, Zn, and P_2O_5 Applications (At Planting, V4, and R5.5)

Trt	Mn Trts	Total Mn	S Trts	Total S	Zn Trts	Total Zn	P trts	Total P	Timing
	Fertilizer Applications (lb/A)								
1	Control (All plots had a seed treatment with trace Mn)								
2	0.06	**0.17**	0.03	**0.09**	0.001	**0.0011**	0	**1.56**	Planting
	0.06		0.03		0		0		V4
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3	0.02	**0.04**	0.04	**0.12**	0.048	**0.142**	0	**1.56**	Planting
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	0.06		0.04		0		0		V4
	0.06		0.04		0		1.56		R5.5
5	0.5	**1**	0.3	**0.58**	0	**0**	0	**0**	Planting
	0.5		0.3		0		0		V4
6	1	**3**	0.6	**1.74**	0	**0**	0	**0**	Planting
	1		0.6		0		0		V4
	1		0.6		0		0		R5.5
7	0.08	**0.08**	0	**0**	0	**0**	0	**0**	Planting

Trt	Mn Trts	Total Mn	S Trts	Total S	Zn Trts	Total Zn	P trts	Total P	Timing
	Fertilizer Applications (lb/A)								
8	0.3	**0.42**	0	**0**	0	**0**	0	**0**	Planting
	0.08		0		0		0		V4
	0.08		0		0		0		R5.5
9	0.1	**0.28**	0	**0**	0.071	**0.143**	0	**0**	Planting
	0.1		0		0.036		0		V4
	0.1		0		0.036		0		R5.5
10	0.1	**0.32**	0	**0**	0.071	**0.123**	0	**0.21**	Planting
	0.11		0		0.026		0.11		V4
	0.11		0		0.026		0.11		R5.5
11	0.59	**1.1**	0	**0**	0	**0.0013**	0	**0.203**	Planting
	0.52		0		0.0013		0.2		V4
12	0.52	**1.04**	0	**0**	0	**0.0013**	0	**0.203**	Planting
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13	0.14	**0.7**	0.08	**0.41**	0.003	**0.0155**	0.11	**0.525**	Planting
	0.28		0.16		0.006		0.21		V4
	0.28		0.16		0.006		0.21		R5.5

Final Thoughts

- Use variable rates when applying lime (Do not exceed 6.5)
- Difficult to increase the availability of Mn in the soil
- Broadcasted Mn fertilizer can be rapidly fixed in the soil or expensive (chelated Mn)
- Did not see much yield response from Mn only (Sulfur seemed to create a bigger response.)
- Apply Mn sulfate unless tank mixing with glyphosate (use chelated Mn if mixing)
  - Glyphosate application first – wait 3 days or more – Apply Mn Sulfate
  - If applying Mn sulfate first – wait at least seven days before applying glyphosate
- If caused by drought, the plant can quickly recover without an application
- Additional research is needed to examine the response of Mn (versus sulfur and phosphorus)
  - Need to correct the most limiting factor first

Staton, M. (2023). Identifying and correcting manganese deficiency in soybeans. Michigan State University Extension.

Future Research Plans

- Examine results from four different yield environments
- Apply new treatments according to previous results
  - Include P, S, and Zn treatments to examine other limiting factors
  - Begin foliar treatments at V2 and make two additional applications
  - Apply different rates and formulations of Mn
- Analyze RGB data to better understand possible precision applications
- Evaluate the economics of the treatments

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Questions

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