

# **Influence of Phosphorus and Potassium in a Multi-year Spring Wheat-Soybean Crop Rotation**

**Nutrient Management Conference**

**February 8<sup>th</sup>, 2022**

**Mankato, MN**



**UNIVERSITY OF MINNESOTA**

# Presentation Overview

- **What we know about soils of NW MN**
- **Laws of the minimum and maximum**
- **Project objective and methods**
- **Review of weather conditions in 2020 and 2021**
- **Small plot results in 2020 and 2021**
- **Large On-Farm trial results in 2020 and 2021**
- **Summary**
- **Contact information**

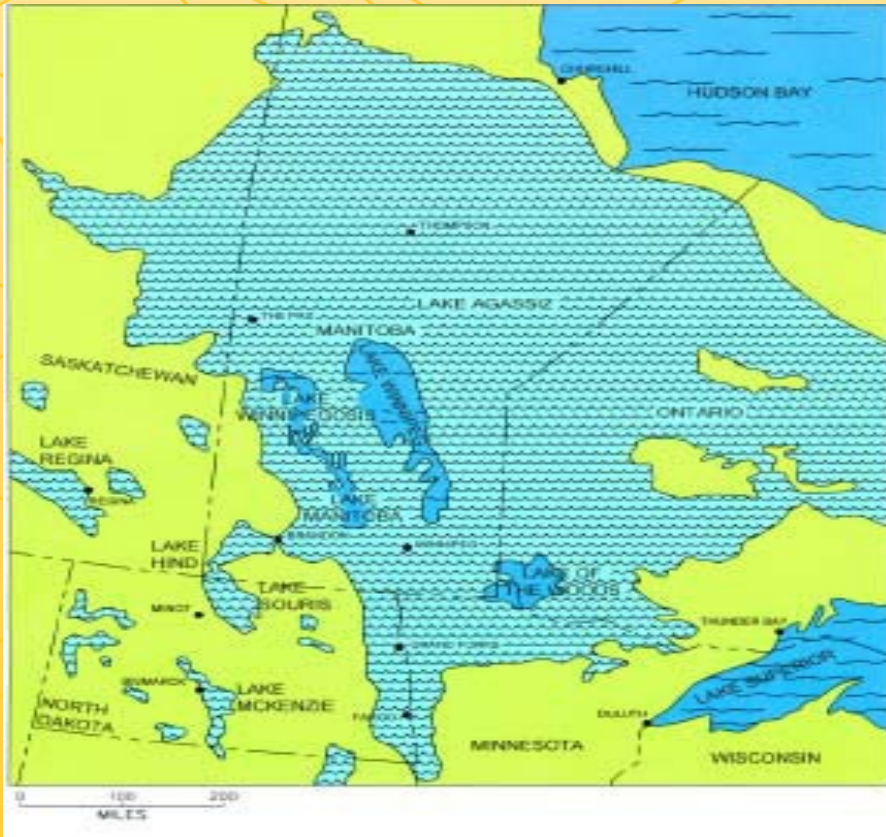
# NW MN Soils: What We Know?

- **Glacial Lake Agassiz is the origin of area soils**
- **Cold soils reduce nutrient uptake**
- **High pH soils can limit nutrient uptake**
- **A 50 bu bean crop removes: 40# P<sub>205</sub> & 70# K<sub>20</sub>**
- **An 80 bu wheat removes: 50# P and 30# K**
- **A 7-30-30 will not supply needed P&K, so plants will have to 'mine' soil to obtain P&K for high yield goals**



# Glacial Lake Agassiz was a Major Influence on Soils of NW MN

## Glacial Lake Agassiz



## Lake Agassiz Statistics

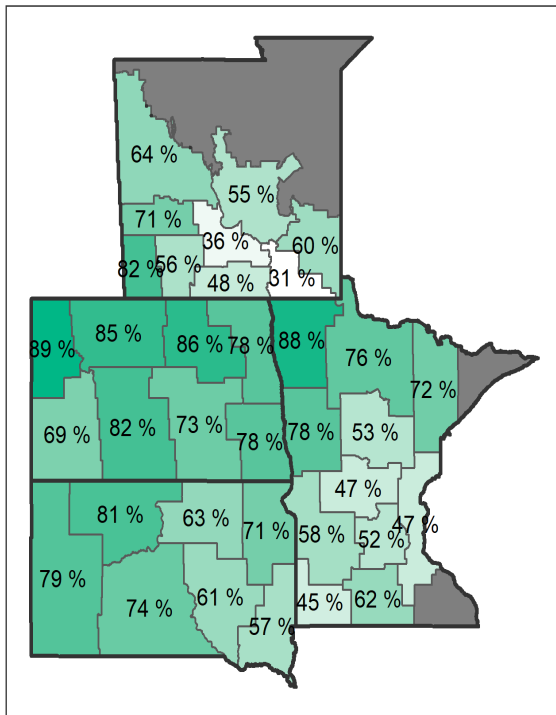
- Area of 365,000 square miles
- 5 times the size of North Dakota
- 11,700 to 7,5000 years ago
- Several lakes of today are remnants of Lake Agassiz
- Glacial river Warren cut the MN River valley
- Lake bed (lacustrine soil) fine textured soils - e.g. Fargo clay
- Beach ridges & outwash plains



# Phosphorus and Potassium Levels in Soils

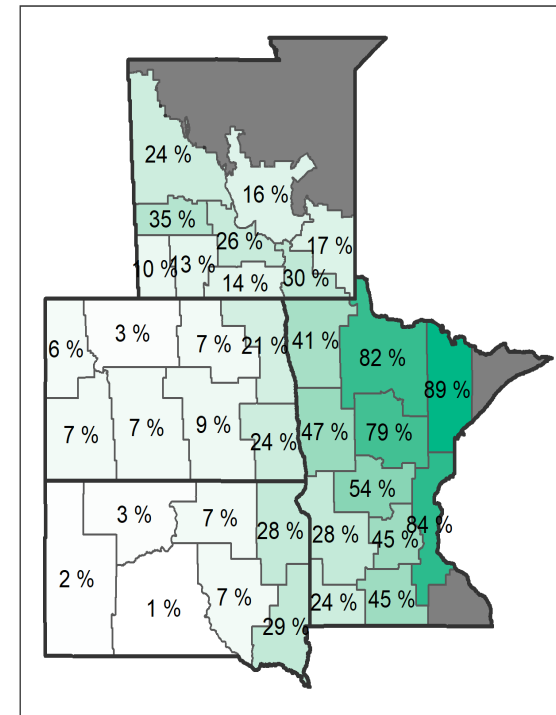
## AGVISE Survey - 2020

Soil samples with soil test phosphorus below 15 ppm (Olsen P) in 2020



Data not shown where n < 100  
AGVISE Laboratories, Northwood, ND

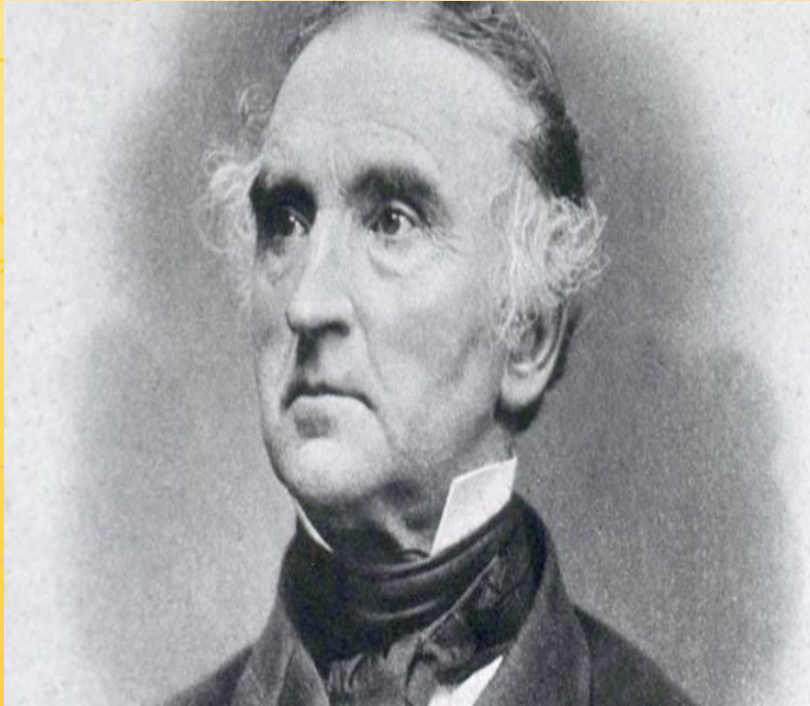
Soil samples with soil test potassium below 150 ppm in 2020



Data not shown where n < 100  
AGVISE Laboratories, Northwood, ND

# Law of Minimum and Law of Maximum

Justus Von Liebig

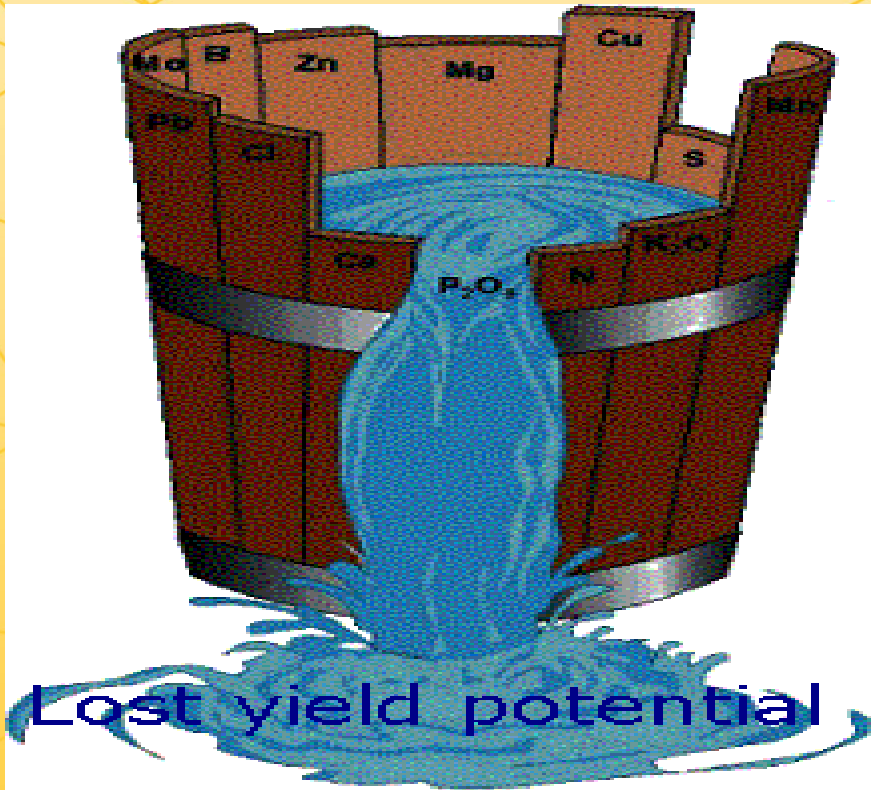


Arthur Wallace





# Plant Growth & Yield - Law of the Minimum



- Barrel stave concept
- Justus Von Liebig
- Plant growth and yield limited by the nutrient most scarce
- Goal is to provide nutrients (Macro & Micros) in quantity needed to maximize plant growth and yield

# Plant Growth & Yield - Law of the Maximum

## Law of the Maximum

- The Law of Maximum is a principle developed by Arthur Wallace states that total growth of a crop or a plant is proportional to about 70 growth factors.

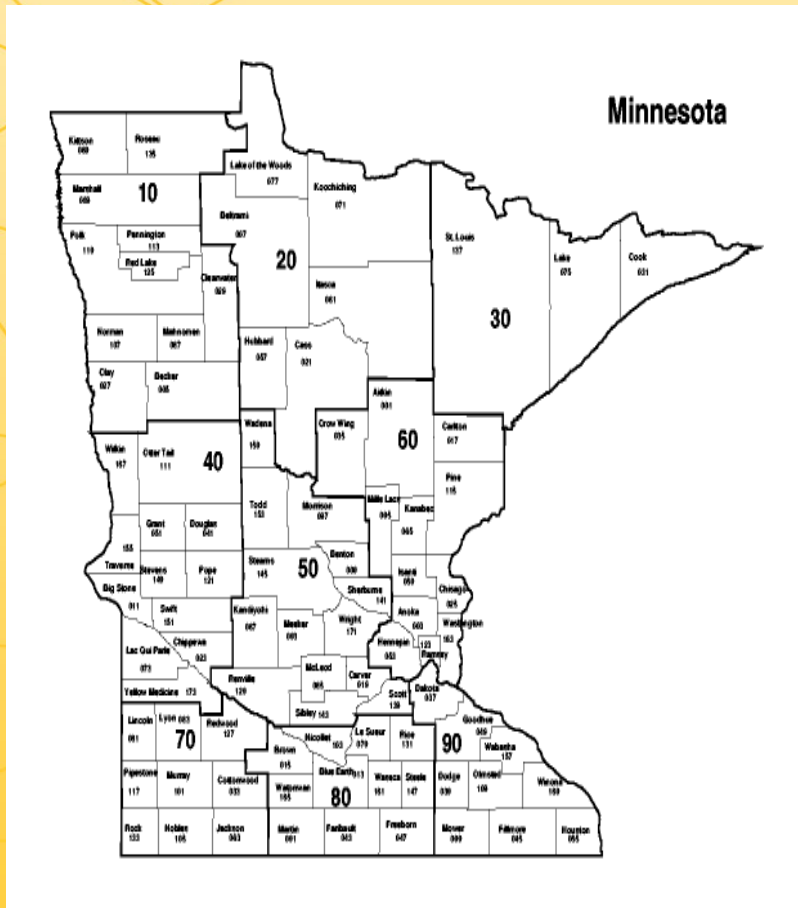
## Growth Factors

- Adequate nutrition
- Nutrient excesses (toxicity & stress)
- Interaction of nutrients
- Soil conditions and physical processes
- Soil biology
- Weather
- Management





# Project Scope: USDA District 10 - NW MN



- 11 Counties area in NW MN
- Soybean acres
  - 2007 = 1,106,000
  - 2017 = 1,813,000
- Soybean Yields (bu/ac)
  - 2007 = 35.7
  - 2017 = 34.1
- Wheat Yields (bu/ac)
  - 2007 = 50.4
  - 2017 = 65.8

# Project to Incorporate Both Small Replicated and Large On-Farm Trials

## Small Plot Replicated Research



## Large On-Farm Trials



# Research Objectives

- **To establish long term crop rotation trials (4 year minimum) in wheat and soybeans**
- **Conduct small plot replicated research and large on-farm trials to determine the influence of elevated levels of P and K on wheat & soybean growth, development, yield and seed quality**
- **Project partners: AFREC, MN Wheat Growers, MN Soybean Growers, U of MN and farmer cooperators**





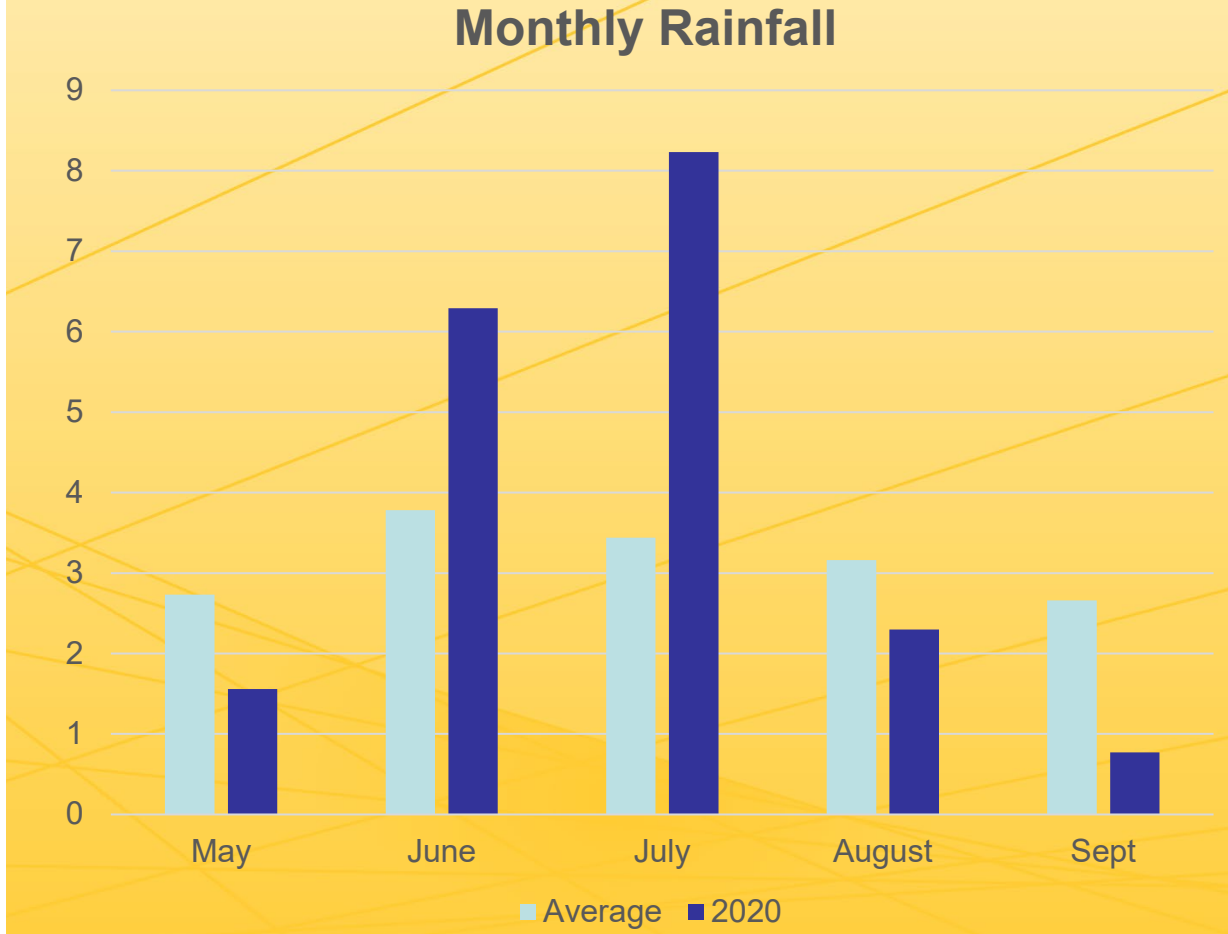
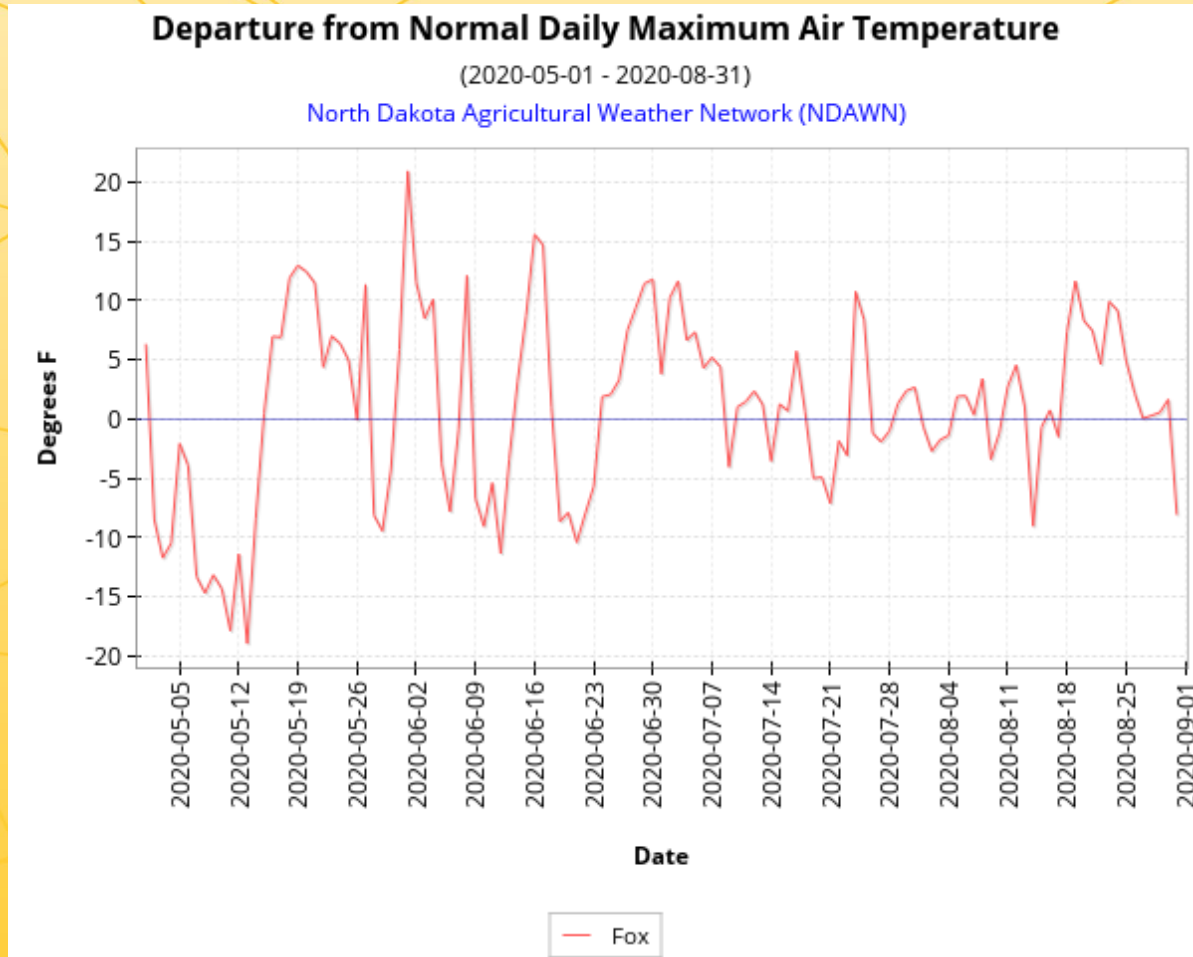
# Project Specifics

- **Crop rotation: wheat-soybean-wheat-soybean**
- **Manage wheat for 80 and soybeans for 50 bu/ac**
- **Trial design: RCB with 4 replications**
- **Soil samples collected post harvest**
- **Tissue samples collected at early tillering in wheat and in early flowering in soybeans**
- **Data collection: Early season crop vigor, tissue tests, yield & grain quality and post harvest soil samples**

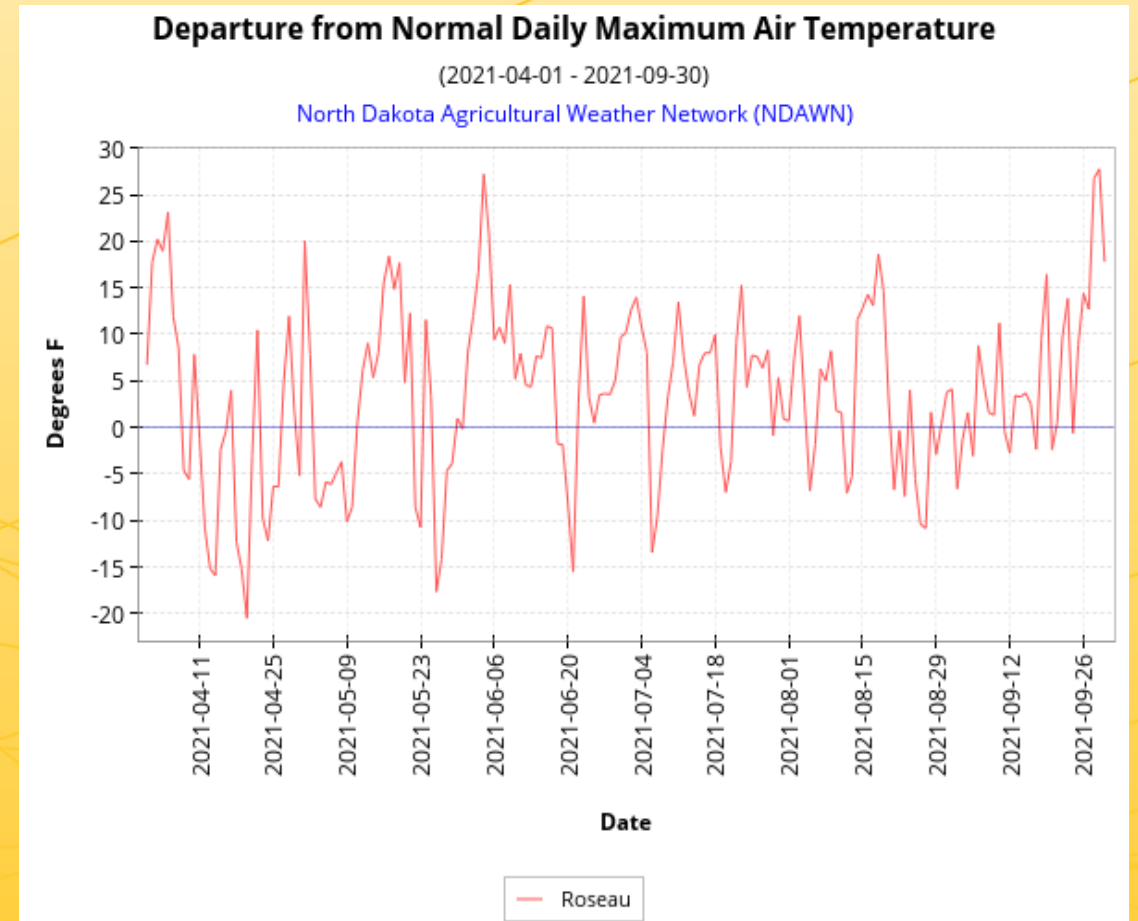




# Temperature and Rainfall in 2020

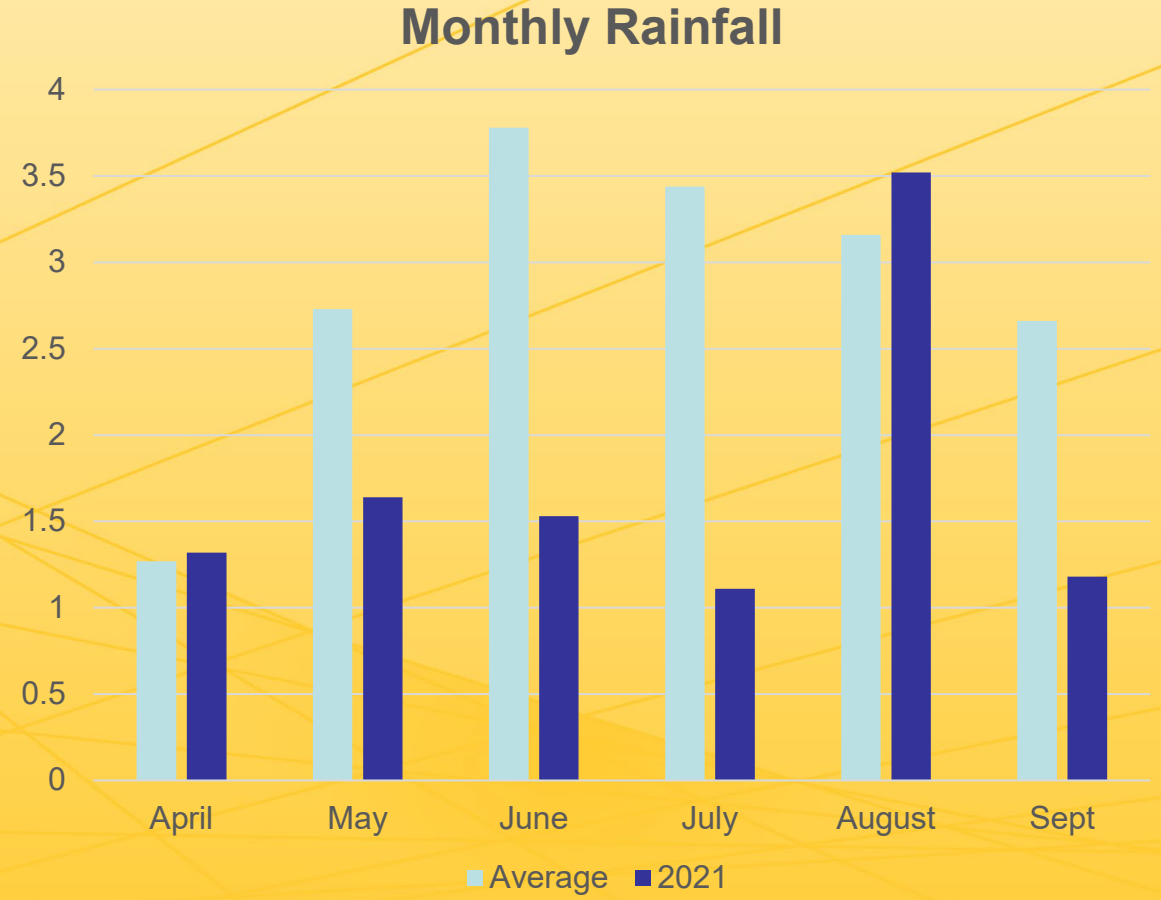


# 2021 Growing Season Was Hot





# 2021 Growing Season Was Dry

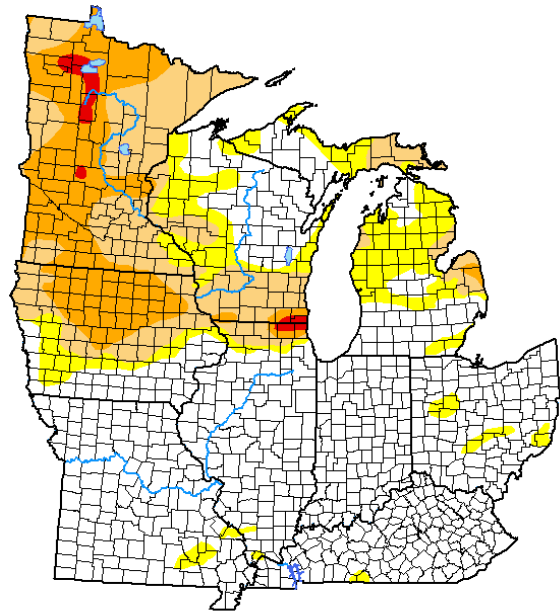


# Palmer Drought Index – Midwest 2021

## Mid - July

## End of August

### U.S. Drought Monitor Midwest



July 13, 2021

(Released Thursday, Jul. 15, 2021)  
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	59.60	40.40	28.79	13.19	0.87	0.00
Last Week 07-06-2021	54.47	45.53	30.89	12.06	0.20	0.00
3 Months Ago 04-13-2021	69.00	31.00	7.00	1.02	0.00	0.00
Start of Calendar Year 12-29-2020	56.05	43.95	12.36	2.26	0.45	0.00
Start of Water Year 09-29-2020	58.19	41.81	11.09	3.01	0.00	0.00
One Year Ago 07-14-2020	62.99	37.01	7.68	1.41	0.00	0.00

Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

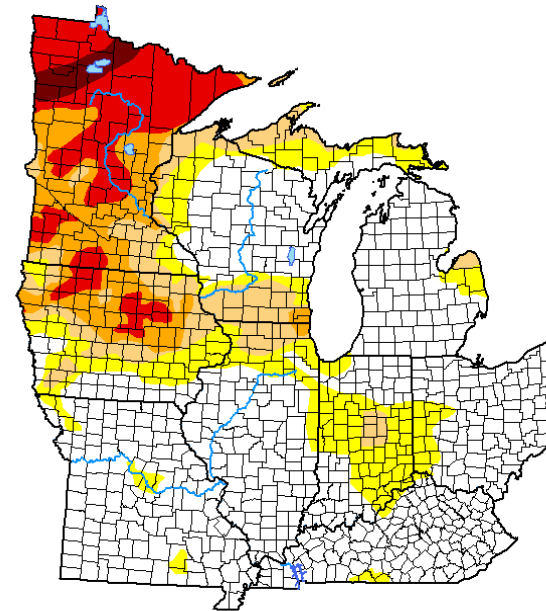
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to <https://droughtmonitor.unl.edu/About.aspx>

Author:  
Adam Hartman  
NOAA/NWS/NCEP/CPC



droughtmonitor.unl.edu

### U.S. Drought Monitor Midwest



August 24, 2021

(Released Thursday, Aug. 26, 2021)  
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	57.91	42.09	27.84	18.95	10.89	1.37
Last Week 08-17-2021	61.03	38.97	25.72	19.23	9.60	1.37
3 Months Ago 05-25-2021	57.72	42.28	17.82	1.95	0.00	0.00
Start of Calendar Year 12-29-2020	56.05	43.95	12.36	2.26	0.45	0.00
Start of Water Year 09-29-2020	58.19	41.81	11.09	3.01	0.00	0.00
One Year Ago 08-25-2020	60.68	39.32	12.58	3.41	0.74	0.00

Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to <https://droughtmonitor.unl.edu/About.aspx>

Author:  
Curtis Riganti  
National Drought Mitigation Center



droughtmonitor.unl.edu



# Small Plot Replicated Research

## Research Team

- **Dr. Nancy Ehlke - PI**
- **Donn Vellekson - Manager of U of MN Magnusson Research Farm**
- **Dave Grafstrom - Research agronomist**
- **Val Laidley - Summer Intern**

## U of MN Magnusson Research Farm



# Small Plot Research - Methods

- **2 sites: one wheat and one soybean**
- **15 treatments + Untreated = 16 total treatments**
- **P source: 0-46-0**
- **K source: 0-0-60**
- **Rates: 20, 40, 60, 80 & 100 units of each product and combinations**
- **P&K spring applied and incorporated prior to planting**

# Project Methods - Continued

- **Soil samples taken at two depths (0-6 & 6-24) in years 1&4, and one depth (0-6) in years 2&3**
- **Complete analysis in year 1&4 and P and K only in years 2&3**
- **Soil and plant tissue analysis will help determine if elevated P&K levels are causing an interaction with other plant nutrients (e.g. P & Zn, K & Ca)**



# Small Plot Trial - Specifics

## Wheat Trial

- Nitrogen (urea) applied PPI, a total of 160 #/ac for all plots
- P&K treatments were applied by hand to the entire 6'x15' plot
- Linkert wheat seeded @ 120 #/ac on 5/6/21 and 5/21/20
- Tissue samples taken late-tillering
- BMP used for weed, disease and insect control
- Plots harvested on 7/31/21 and 8/19/20 with soil samples taken post harvest

## Soybean Trial

- P&K treatments were applied by hand to the entire 6'x15' plot
- AG005X1 seeded on 5/13/21 and 5/21/20 at 1.4 units/ac (172,000) final plant population
- Tissue samples taken early flowering
- BMP used for weed, disease and insect control
- Plots harvested on 9/13/21 and 9/26/20, soil samples taken post harvest





# Background Soil Test Information

## Spring of 2019

### Site 1: Mag Farm, F-7 SW

- Soil test 0-6 inch
- Borup silt loam
- OM - 2.8%
- PH - 8.2
- P (Olsen) - 6 ppm
- K - 154 ppm
- S - 14 #/ac
- Soluble salts 0.23

### Site 2: Mag Farm, F-7 NW

- Soil test 0-6 inch
- Zippel very fine sandy loam
- OM - 2.8%
- PH - 7.8
- P (Olsen) - 23 ppm
- K - 166 ppm
- S - 34 #/ac
- Soluble salts 0.4



# Small Plot P&K Trial - Field Layout

Wheat Trial - June 2



Soybean Trial - June 8





# Small Plot Fertility Trial

Treatments Weighted and Labeled



Fertility Treatments Hand Spread





# Small Plot Fertility Trials

P&K Soybean Trial - Late Season



Plot Harvest -Small Plot Combine





# All Plots Soil Sampled After Harvest

WD-40 Used in Sticky Soil



0-6 Inch Soil Cores/plot (eight)



# Small Plot Replicated Wheat Results- 2020

Wheat-2020					Soil Test Results		Tissue Test Results	
Trt#	Added <sup>1</sup>	Yield <sup>2</sup>	Test	Protein <sup>3</sup>	P	K	P	K
	P & K	Bu/Acre	Wt./Bu		ppm	ppm	%	%
1	0-20-0	73.0	63.0	14.7	16.5	123	0.28	1.6
2	0-40-0	75.8	62.3	14.6	16.3	118	0.28	1.6
3	0-60-0	72.8	62.3	14.5	24.5	121	0.28	1.6
4	0-80-0	69.8	62.7	14.3	27.0	123	0.28	1.6
5	0-100-0	67.8	62.7	14.0	32.3	122	0.28	1.5
6	0-0-20	70.5	62.1	14.4	12.8	135	0.28	1.7
7	0-0-40	69.3	62.9	14.6	14.5	135	0.27	1.8
8	0-0-60	69.5	63.1	14.5	12.8	130	0.27	1.8
9	0-0-80	70.3	62.4	14.9	14.0	139	0.28	1.9
10	0-0-100	71.3	63.1	14.5	14.5	135	0.26	1.8
11	0-20-20	70.5	63.0	14.5	17.5	126	0.25	1.6
12	0-40-40	74.8	62.1	14.2	20.5	129	0.27	1.7
13	0-60-60	73.3	61.7	14.4	24.8	135	0.27	1.6
14	0-80-80	76.0	62.8	14.6	25.0	126	0.28	1.7
15	0-100-100	74.0	62.6	14.4	37.0	138	0.29	1.8
16	0-0-0	67.0	62.6	14.7	16.3	116	0.26	1.5
LSD @5%level		7.4	1.3	0.7	8.1	16	0.03	0.2
LSD @10%level		6.2	1.1	0.5	6.7	13	0.02	0.1
CV(%)		7.2	1.5	3.2	28	8	5	4

- Yields ranged from 67 to 76 bu/a
- Yields higher from the combination of 40, 60, 80, & 100 of P&K vs untreated
- K alone flat response in wheat yield
- No Trt. difference in test wt. & protein vs untreated
- P applied alone or in combination at 60, 80 & 100 increased soil test P
- K soil test levels tended to or increased with all K rates
- No Trt. effect in P tissue test levels vs untreated
- All K rates tended to or increased K tissue test levels



# Small Plot Replicated Soybean Results - 2020

Soybeans-2020	Yield <sup>2</sup>	Test				Soil Test Results		Tissue Test Results	
						P	K	P	K
Trt#	Bu/Acre	Wt./Bu	Protein <sup>3</sup>	Oil <sup>3</sup>	ppm	ppm	%	%	
1	0-20-0	64.8	57.7	38.7	20.9	4.5	120	0.54	2.4
2	0-40-0	69.0	57.7	38.9	20.7	4.5	113	0.55	2.2
3	0-60-0	65.0	57.8	38.8	20.9	8.0	117	0.59	2.6
4	0-80-0	65.5	57.8	38.2	21.2	10.3	123	0.58	2.4
5	0-100-0	69.0	57.8	38.6	20.9	13.8	113	0.62	2.5
6	0-0-20	61.0	57.7	38.5	20.9	4.5	111	0.57	2.6
7	0-0-40	69.0	57.7	38.5	20.9	3.3	114	0.53	2.3
8	0-0-60	63.2	57.8	38.5	21	2.5	125	0.59	2.5
9	0-0-80	66.3	57.7	38.3	21.0	3.0	134	0.52	2.3
10	0-0-100	66.5	57.6	38.6	20.9	2.8	131	0.62	2.7
11	0-20-20	69.8	57.6	38.6	20.9	4.0	126	0.57	2.5
12	0-40-40	68.3	57.9	38.5	20.9	6.3	118	0.59	2.5
13	0-60-60	69.3	57.8	38.6	21.0	7.0	123	0.59	2.5
14	0-80-80	63.5	57.7	38.5	21.0	9.5	126	0.60	2.5
15	0-100-100	63.8	57.6	39.0	21.0	9.0	132	0.61	2.5
16	0-0-0	61.0	57.7	39.1	20.7	3.3	109	0.60	2.5
LSD @5%level	8.3	NS	0.4	0.4	3.2	17	0.07	0.32	
LSD @10%level	6.5	0.3	0.4	0.3	2.6	14	0.06	0.26	
CV(%)	7.8	0.4	0.8	1.3	37	10	6	6	

- Yields ranged from 61 to 69.8 bu/a
- Yields higher from the combination of 20, 40, & 60 of P&K vs untreated
- No Trt. difference in test wt. & protein vs untreated
- P applied alone or in combination at 60, 80 & 100 increased soil test P
- P soil test levels increased with rate
- K soil test levels tended to or increased with all K rates
- No Trt. effect in P or K tissue test levels vs untreated



# Small Plot Replicated Wheat Results- 2021

Wheat-2021				Soil Test Results <sup>4</sup>		Tissue Test Results <sup>5</sup>		
Trt#	Added <sup>1</sup> P & K	Yield <sup>2</sup> Bu/Acre	Test Wt./Bu	Protein <sup>3</sup>	P ppm	K ppm	P %	K %
1	0-20-0	72.6	61.9	16.9	5.5	130	0.36	2.9
2	0-40-0	79.6	62.0	16.8	8.5	125	0.39	3.1
3	0-60-0	78.6	62.0	17.0	9.5	125	0.41	2.8
4	0-80-0	80.0	62.0	16.6	12.5	128	0.45	3
5	0-100-0	79.0	61.4	17.0	16.8	119	0.45	2.7
6	0-0-20	64.3	62.2	17.0	4.0	121	0.33	3
7	0-0-40	63.2	61.9	17.3	5.0	127	0.32	3.3
8	0-0-60	60.3	62.1	17.3	4.5	132	0.32	3.6
9	0-0-80	60.7	62.3	17.4	4.8	147	0.3	3.7
10	0-0-100	59.0	62.2	17.1	3.8	136	0.32	4
11	0-20-20	75.9	62.2	17.1	6.0	126	0.35	3.2
12	0-40-40	80.5	61.8	16.8	10.8	135	0.39	3.3
13	0-60-60	82.4	62.2	17.1	12.5	125	0.43	3.5
14	0-80-80	82.8	62.3	17.1	19.5	130	0.43	3.4
15	0-100-100	84.8	62.0	17.1	19.8	139	0.44	3.5
16	0-0-0	60.0	61.7	17.0	3.7	120	0.33	3
LSD @5%level		7	0.6	0.7	3.8	12	0.05	0.3
LSD @10%level		5.8	0.5	0.6	3.1	10	0.04	0.2
CV(%)		6.7	0.6	3.0	28	6	9	7

- Yields ranged from 60 - 84.8 bu/ac
- Low P rate (20) > 12.6, all other P rates > 19.6 bu/ac or more than untreated
- K alone similar yields as untreated
- No differences in test weight or protein vs untreated
- P at 40,60,80 & 100 alone or with K increased soil test P
- K > 80 increased soil test K
- P at 40,60,80 & 100 alone or with K increased tissue test P
- K > 60 increased tissue test K

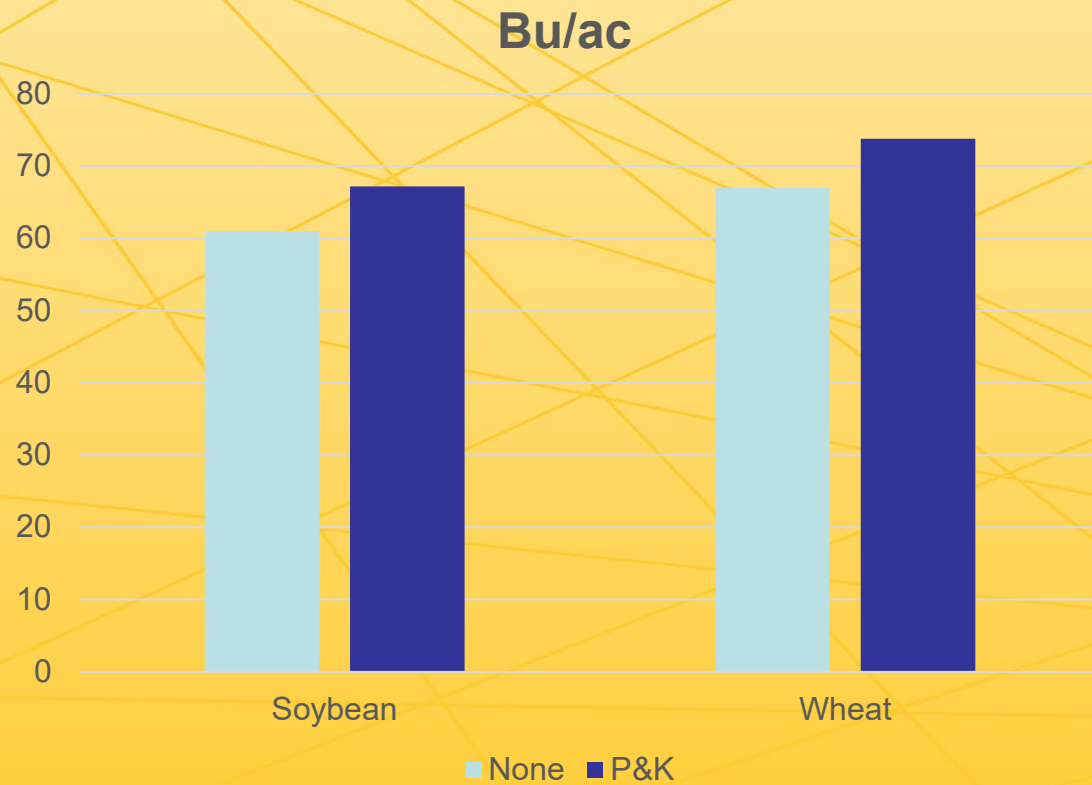
# Small Plot Replicated Soybean Results - 2021

Soybean-2021					Soil Test Results <sup>4</sup>		Tissue Test Results <sup>5</sup>		
Trt#	Added <sup>1</sup> P & K	Yield <sup>2</sup> Bu/Acre	Test Wt./Bu	Protein <sup>3</sup>	Oil <sup>3</sup>	P ppm	K ppm	P %	K %
1	0-20-0	46.0	59.7	37.7	20.6	17.0	117	0.48	1.9
2	0-40-0	44.3	59.4	37.9	20.9	17.0	112	0.48	1.7
3	0-60-0	46.3	59.4	37.6	20.8	17.2	120	0.5	1.9
4	0-80-0	48.3	59.5	36.5	21.3	20.5	115	0.5	1.9
5	0-100-0	50.9	59.5	38.5	20.6	27.8	129	0.47	2
6	0-0-20	48.3	59.5	37.3	20.2	10.5	113	0.47	1.9
7	0-0-40	50.7	59.3	36.9	20.9	11.5	137	0.45	2.1
8	0-0-60	54.1	59.4	35.5	21.1	10.8	133	0.48	2.3
9	0-0-80	47.2	59.4	37.4	21.1	12.7	129	0.48	2.2
10	0-0-100	51.7	59.2	37.9	20.7	10.0	125	0.49	2.3
11	0-20-20	48.0	59.3	36.4	21.0	13.0	108	0.49	2.1
12	0-40-40	46.4	59.5	38.6	20.9	14.5	118	0.5	2.1
13	0-60-60	48.2	59.3	35.8	21.1	22.2	131	0.5	2.1
14	0-80-80	51.1	59.5	37.6	20.9	20.5	126	0.47	2.1
15	0-100-100	48.2	59.2	36.9	21.3	27.3	124	0.5	2.2
16	0-0-0	46.0	59.4	38.0	21.2	12.5	110	0.49	1.9
LSD @5%level		7.5	0.4	1.4	0.8	6.0	11	0.03	0.2
LSD @10%level		6.2	0.3	2.0	0.6	5.0	9	0.02	0.1
CV(%)		10.8	0.5	3.5	2.6	26	6	5	6

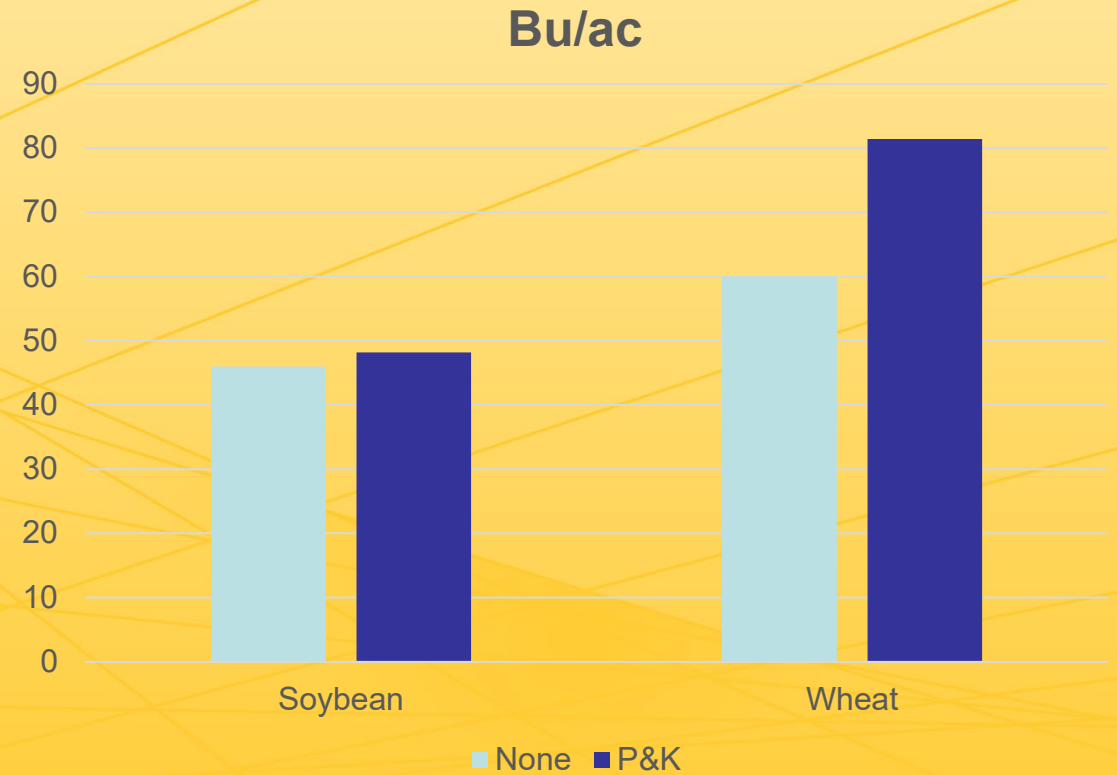
- Yields ranged from 46-54.1 bu/ac
- Soybean yields flat from all treatments
- No treatment differences in test wt., protein and oil vs untreated
- Soil test P generally higher and from all trts vs untreated
- Soil test levels from K > 40 higher vs untreated
- No Trt effect in P tissue tests
- Tissue levels of K at > 60 were higher than untreated

# Soybean and Wheat Yields From Untreated and Averaged Over P&K Rates in 2020 & 2021

## Yields (bu/ac) in 2020



## Yields (bu/ac) in 2021





# Post Harvest P & K Soil Test Results (ppm) in Untreated Plots from 2019 - 2021

## Location 1 (Low P)

	<u>2019*</u>	<u>2019</u>	<u>2020</u>	<u>2021</u>
<b>P</b>	6	4	3.3	3.7
<b>K</b>	154	124	109	120

\* Soil samples taken in the spring prior to trial initiation

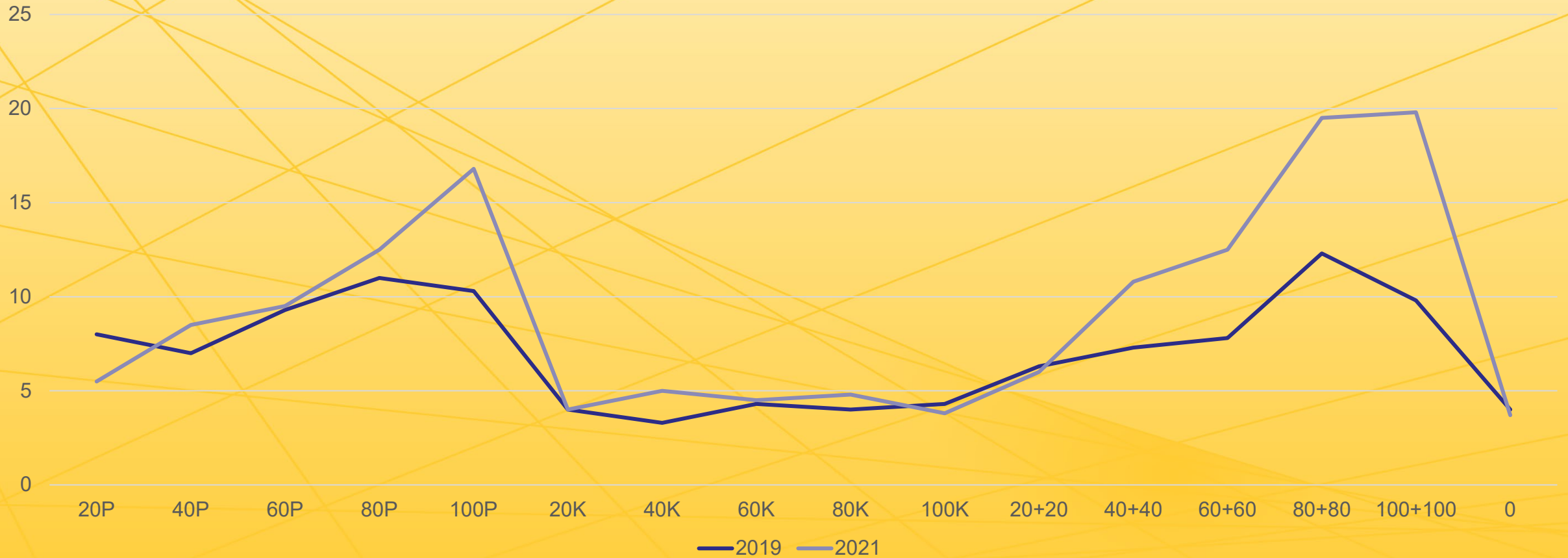
## Location 2 (High P)

	<u>2019*</u>	<u>2019</u>	<u>2020</u>	<u>2021</u>
<b>P</b>	23	17.5	16.3	12.5
<b>K</b>	166	121	116	110

\* Soil samples taken in the spring prior to trial initiation

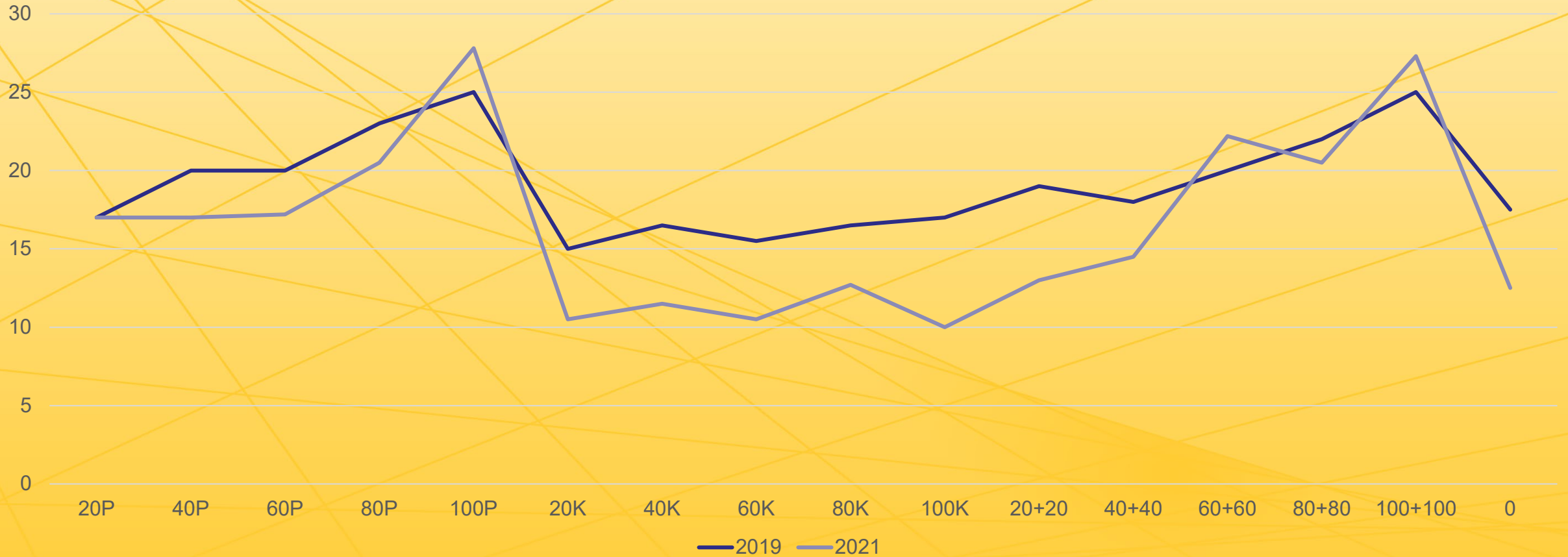
# Location One (low P) - Soil Phosphorus Levels (ppm) in 2019 vs 2021

P in ppm 2019 vs 2021



# Location Two (high P) - Soil Phosphorus Levels (ppm) in 2019 vs 2021

P in ppm 2019 vs 2021





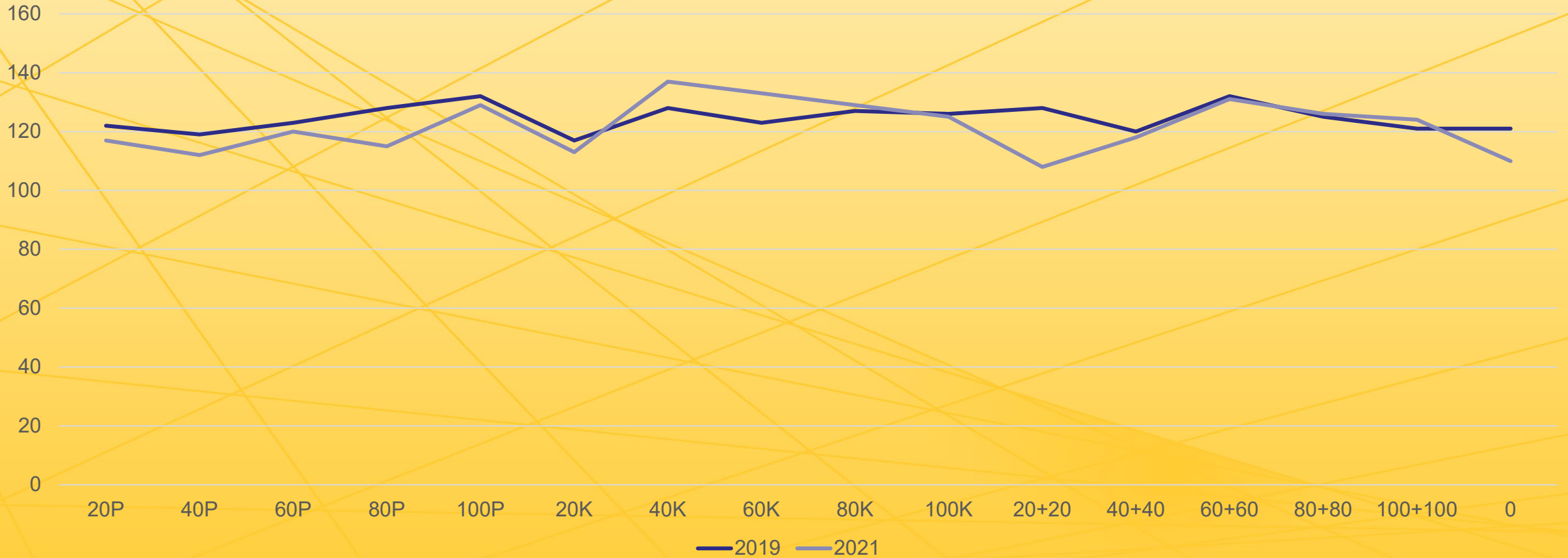
# Location One - Soil Potassium Levels (ppm) in 2019 vs 2021

K in ppm 2019 vs 2021



# Location Two - Soil Potassium Levels (ppm) in 2019 vs 2021

K in ppm 2019 vs 2021



# Large On-Farm Trials





# Large On-Farm Trial - Research Team

- **Missy Carlson - MN Wheat**
- **Donn Vellekson - U of MN**
- **Dave Grafstrom - U of MN**
- **Val Laidley - Summer Intern**





# Field Scale Equipment in Large Trials

Terragator Applied Fertilizer



Air Seeder Planting Trials





# Large Plot On-Farm P&K Trials



- At harvest, headlands were harvested before individual treatments
- Each strip had a full combine header width taken the entire length of the field
- Each strip was weighted and yield calculated

# Field Scale Equipment in Large Plots

Full Header Width in Each Plot



Grain Cart and Scale Weighted Plots





# Plot Harvest and Post Harvest Soil samples

JD Gator for Soil Sampling Plots



Full Combine Header Width





# 2021 Growing Season - Hot and Dry

Gravel Streaks in Wheat Field



Cracks in Soil



# Summary Large On-Farm Trials in 2020

- **One wheat and four soybean sites harvested in 2020**
- **Wheat site had herbicide drift that influenced results**
- **FP+50 increased soybean yields at one site and produced similar yields at three sites compared to FP**
- **P&K tissue levels generally were higher in FP+50 compared to FP**
- **Fall soil tests indicate that FP+50 was building P and K levels compared to FP**



# Large Plot On-Farm P&K Trials in 2020



- Soybean yields ranged from 30.7 to 50 bu/acre
- In one of the four sites (25%) FP + 50 gave a higher soybean yield than FP
- The range in harvested soybean yield difference across the field was 29.7 to 55.2 bu/ac
- Yield monitor 10 to 80+ bu/ac



# On-Farm P&K Trials - 2021

- **Five locations in 2021: Wheat, 4; Soybeans, 1**
- **Moderate to extreme drought in all locations**
- **Wheat yields ranged from 42 to 79 bu/ac**
- **A one wheat location a 5.5 bu/ac advantage from FP+50 vs FP. No differences in test weight or protein**
- **Soybean yield ranged from 46 to 47.7 bu/ac and was not different at (0.05) confidence level. No differences in test weight or protein**

# Wheat Yield Results in 2021

- In one of four sites, a 5.5 bu/ac yield advantage from the FP + 50 compared FP. The soil P at this location was 6.5 (low).
- In 2021, one of four wheat sites (25%) gave a positive response to additional P&K.
- In the combined analysis FP wheat yields = 57.7 and FP + 50 = 59.4 bu/ac. The combined analysis did not show significant differences between treatments at the (0.10) confidence level.

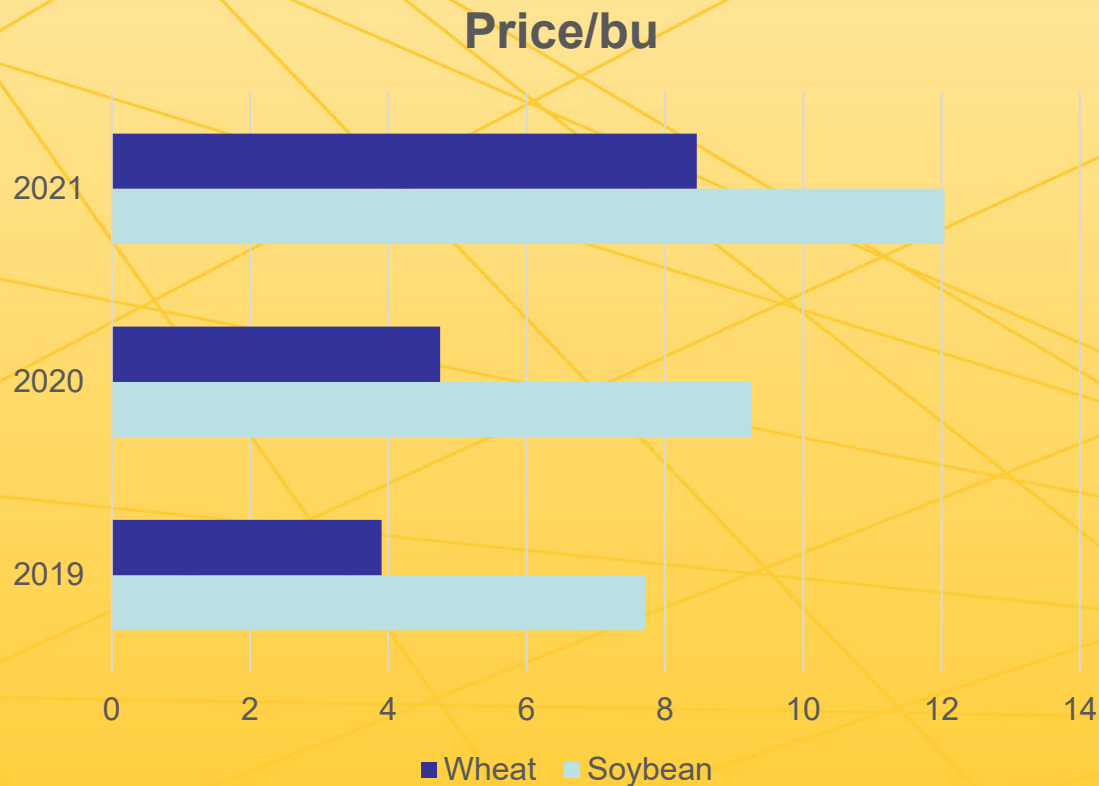


# Economics of FP + 50 Units of P&K

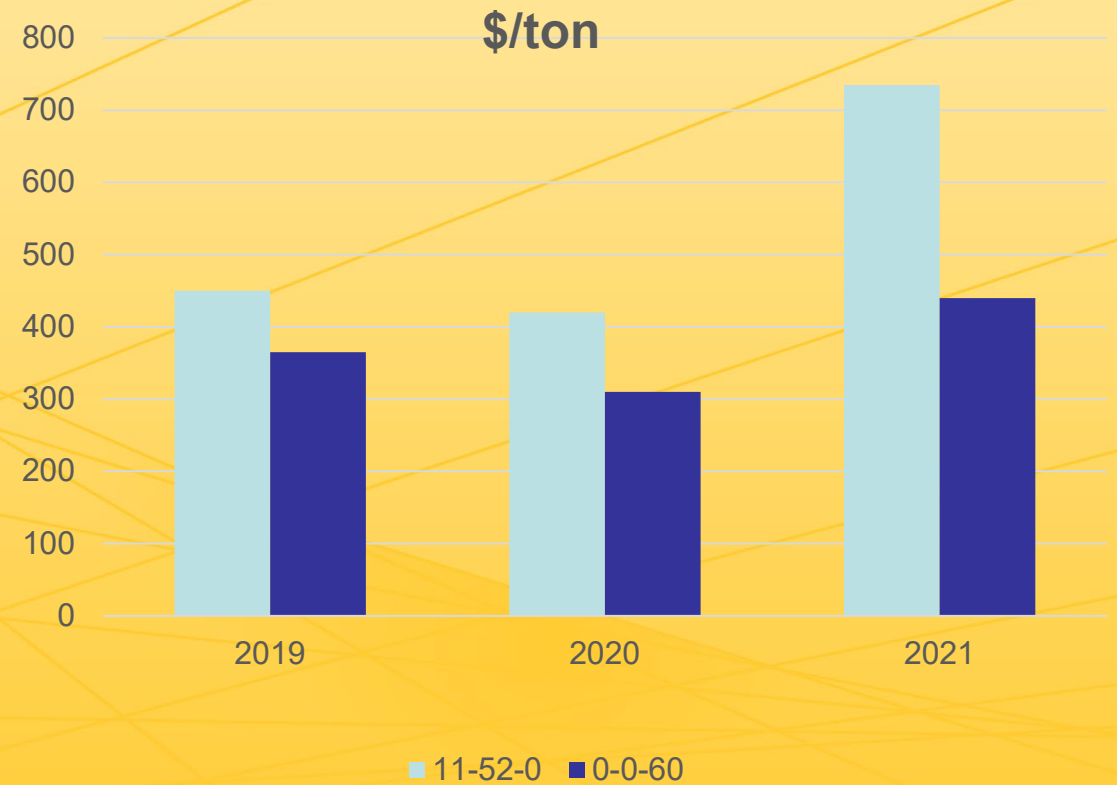


# Average Price of Soybeans, Wheat and P & K in Roseau County (2019-2021)

## Soybean and Wheat Price (\$/bu)



## Fertilizer Price (\$/ton)

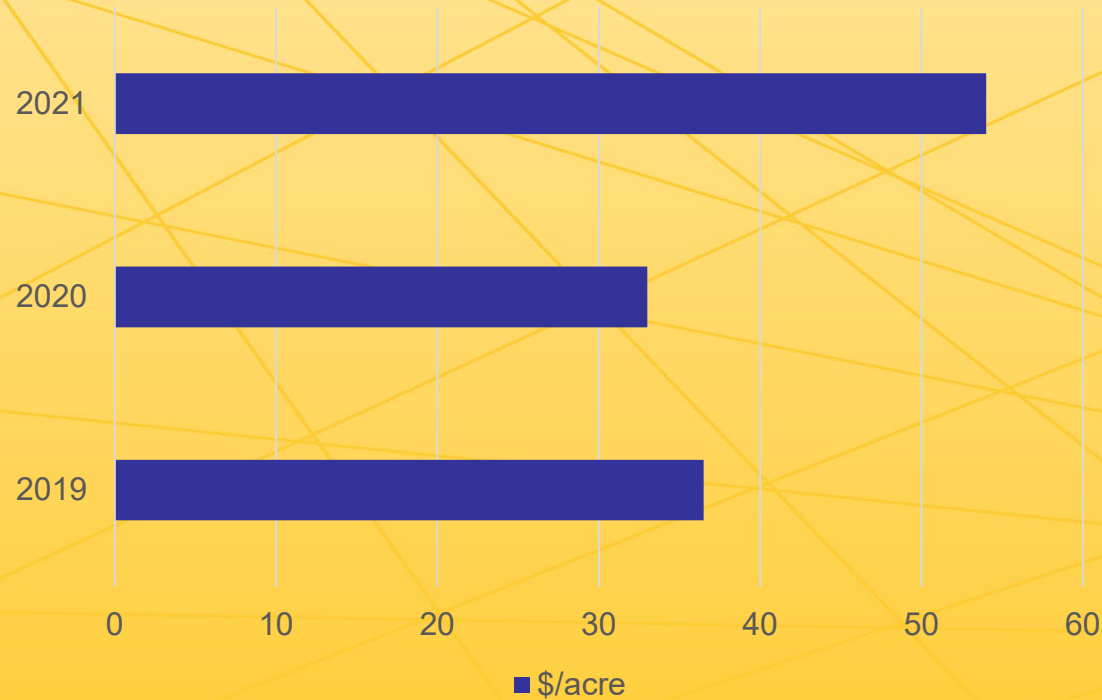




# Cost of 50 Units of P&K and Number of Bushels to Breakeven in 2019-2021

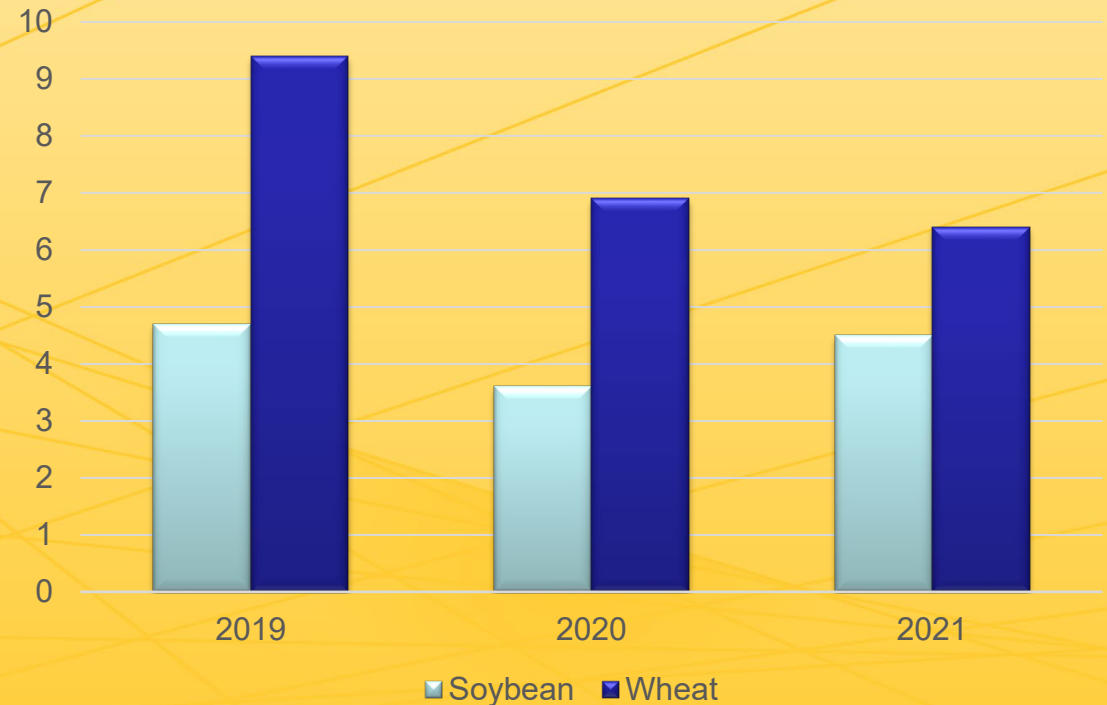
## Cost of 50 Units of P&K

\$/acre

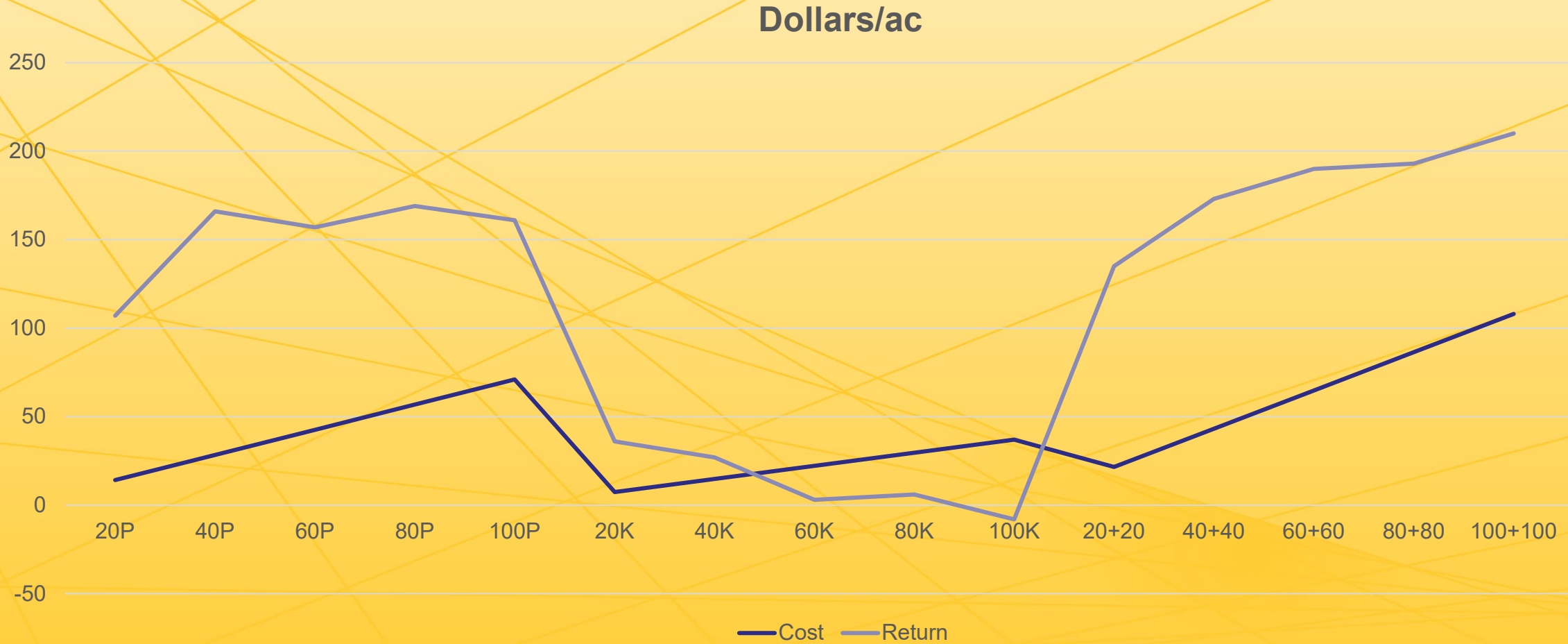


## Bushels Needed to Breakeven

Bu/acre



# Fertilizer Price vs Wheat Return (\$/ac) Over the Untreated in 2021

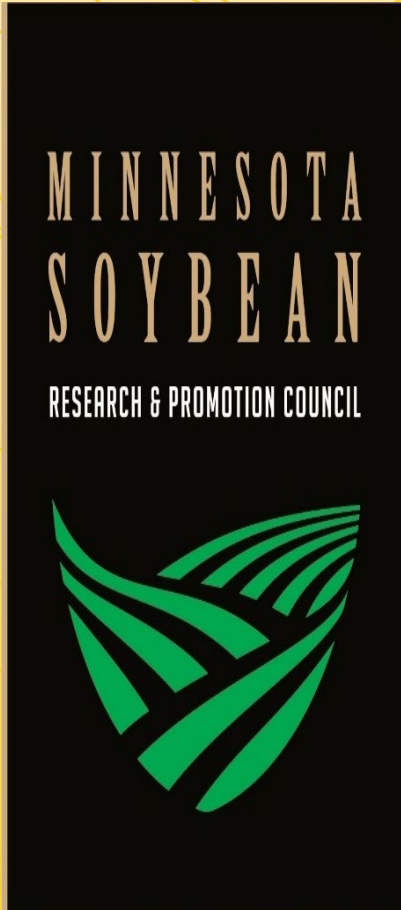




# **Long Term P&K Rotation Trial in Wheat and Soybeans - Summary**

- **The 2021 season was year three of a four year project**
- **Project has both a small plot replicated and large on-farm component**
- **Project area experienced a moderate to severe drought in 2021**
- **Plot locations are in place for 2022**
- **Project has had great cooperation with AFREC, MN Wheat, MN Soybean and the U of MN**

# Questions





# Contact Information

- **Dave Grafstrom**
- **Email: [Grafts010@umn.edu](mailto:Grafts010@umn.edu)**
- **Cell: 320-293-8722**
  
- **MN Wheat Growers Website:**
  - **Mnwheat.org**
- **U of MN Turfgrass Science Website:**
  - **Turf.um.edu/seed-production-research-reports**